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Original Article

Risk factors associated with beef cattle losses on intensive fattening farms in Austria, Germany and Italy

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ABSTRACT

The aim of this study was to investigate management and feeding practices associated with on-farm loss rate (mortality) on 63 beef cattle farms in Austria, Germany and Italy with housing systems other than fully slatted pens. Information on mortality and 56 categorised factors relating to the cleanliness of animal facilities, health and feeding management, animal-human interaction, cattle transport and origin were gathered during on-farm visits. Samples of total mixed rations (TMRs) were collected and analysed for chemical composition and particle size distribution. Twenty-eight categorised factors were removed from the initial 56 due to exclusion criteria (missing data $\geq$ 20% and/or monolevel factors with $\geq$ 80% answers in one category). Mortality was the response variable in the risk factor analysis and the remaining 10 continuous covariates from TMR analyses and 28 categorised factors were independent predictors. Mean ($\pm$ standard deviation) mortality, representing the proportion of dead, euthanased and early culled animals over the total number of animals bought in or reared in the previous year, was 2.8 $\pm$ 3.5%. Fourteen factors were significantly associated with mortality in the bivariable analyses; seven factors were not considered further in the multivariable analysis due to collinearity. None of the factors related to TMR were associated with mortality. Four categorical factors, referring to biosecurity measures and management, were retained in the final multivariable model, with country effect. Buying cattle from only one farm, no mixing of animals during transport, presence of a dedicated sick pen and keeping production records were associated with lower percentage mortality.

Introduction

Cattle mortality and culling are important welfare indicators that have a relevant impact on the efficiency of a farm.[1] High on-farm losses are associated with lower financial returns, since each dead or culled animal implies a loss in relation to investments in animals (in the case of purchased bulls), housing, feeding and labour (Mõtus et al., 2017). Additionally, costs arise for carcass pickup, transportation and all disposal-related operations. Moreover, feeding animals that are not used for consumption increases nitrogen excretion and enteric methane emission per kg of meat (Rumor et al., 2015).

Culling is defined by Compton et al. (2017) as removal of a live animal from the farm for immediate slaughter; when applied to intensive beef cattle systems, culling identifies animals with severe health problems from which recovery is unlikely. In this case, beef cattle farmers decide not to treat animals and to cull them at an early stage in order to comply with European legislation on the use

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[1] See: World Organization for Animal Health (Office International des Épizooties, OIE), 2017. Terrestrial Animal Health Code, 21st Ed. OIE, Paris, France. http://www.oie.int/fileadmin/Home/eng/Health_standards/tahc/current/chapitre_aw_beef_-catthe.pdf (accessed 2 July 2018).

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of pharmaceutical treatments, which imposes specific suspension times after drug use before slaughter,[2] and on transportation, which bans the movement of unfit animals.[3] As an example, according to this latter regulation, severely lame animals should be slaughtered on-farm if not treated; otherwise they should be euthanased; animals unfit to travel but judged as healthy at the ante-mortem inspection carried out by the veterinarian, and stunned and bled hygienically on-farm, may enter the food chain after being processed at an abbatoir, while other euthanased animals may not be used for human consumption and are likely to be disposed of as 'fallen stock' for animal by-product production or for rendering.

Several factors are known to affect beef cattle losses on farms. As in North America, the beef production chain in Europe often involves the mixing of young animals from different origins and their subsequent transportation. Crowding and stressful circumstances increase exposure to pathogens and decrease immunity, predisposing animals to disease (Callan and Garry, 2002). Amongst newly purchased beef cattle, losses increase when the management at the receiving fattening unit is poor (Gottardo et al., 2009; Mee et al., 2012). On fattening units in southern Europe, the hot season is a further critical factor for imported young stock (Rumor et al., 2015). Mortality decreases with increasing air volume and space allowance in housing facilities (Béranger, 1986),[4] while exposure to adverse microclimatic conditions has the opposite effect (Callan and Garry, 2002). The risk of early culling is lower for bulls housed on deep litter compared to fully slatted floors (Brscic et al., 2015).

Nutrition can have an effect on beef cattle losses. Earlier studies by Béranger (1986) have shown that metabolic disorders due to inappropriate or unbalanced feeding schemes may account for up to 42% of beef cattle mortality. Common diets for finishing beef cattle are rich in concentrates, particularly starch sources, to promote high daily gains (Cozzi et al., 2009). However, a minimum amount of coarse fibrous material must be included in order to ensure adequate rumination (Campbell et al., 1992). Digestive disorders due to ruminal acidosis and feeding of acidogenic diets are responsible for 30–42% of monthly mortality rates in North American feedlots where the total mortality is from 0.17% to 0.42% of animals reared (González et al., 2012). Furthermore, feeding high concentrate diets to beef and dairy cattle has been associated with liver abscessation (Nagaraja and Titgemeyer, 2007) and laminitis (Nocek, 1997).

Although relevant to animal welfare, the environment and farm economics, comprehensive epidemiological analyses of mortality in finishing beef cattle systems under current European farming conditions have not been carried out to date. The aim of the current study was to investigate management and feeding practices associated with mortality rates on 63 beef cattle farms in Austria, Germany and Italy.

Materials and methods

Study design

This study was part of a wider research project investigating the application of the Welfare Quality protocol for beef cattle[5] on commercial beef cattle farms and farmers' attitudes to the implementation of changes intended to improve cattle welfare. Only farms with housing systems other than fully slatted floor pens were included in this study; the rationale behind this choice was to select farmers who were already using flooring considered to provide higher welfare standards. As detailed by Kirchner et al. (2014), a sample of 63 farms (29–31 farms/country) was selected from a pool of 90 commercial farms located in Austria, Germany and Italy that had been recruited according to the following criteria: (1) housing system other than fully slatted floor pens; (2) fattening of intact bulls; (3) at least three pens with finishing bulls > 350 kg live weight.

All farms were visited by three trained assessors (one per country) in spring 2008. During this assessment, each assessor interviewed the farmer, owner or stockperson responsible for the animals using a standardised questionnaire. The farmers were also asked to report, as a single value, the number of dead, euthanased and early culled animals recorded over the last 12 months. This value was used to calculate the percentage of on-farm losses (mortality) by dividing it by the total number of animals bought-in or reared during the previous 12 months. The information gathered from the questionnaire related to: (1) cleanliness of the animal facilities and cattle health management; (2) feeding management; (3) group management and animal-human interaction; and (4) cattle transport and origin (see Appendix: Supplementary material).

Cleanliness of the animal facilities and cattle health management — Questions were related to the frequency of cleaning of the floor and lying area, litter management (frequency of adding bedding material; type and amount of litter used), frequency of cleaning of drinkers and troughs, presence and cleaning of a pen for sick animals, disinfection and maintenance, storage of disinfecting agents, presence of dedicated quarantine areas for newly bought-in animals, veterinary health checks of purchased cattle, number of suckler and dairy herds used as suppliers of the purchased calves, whether calves were purchased or reared on-farm, self-evaluation of the farm health strategy and herd health plan, farm record keeping and subjective evaluation of the mortality in the current year compared to previous years.

Feeding management — Questions were related to the number of different rations, farmer's know-how for ration formulation, routine analysis of feed components, availability of a copy of the last analysis, calculations of exact rations, frequency of analysis of the TMR or other component of the diet, type of feed provision, if feeds were delivered in one place or if special feeds were delivered in special places, the practice and frequency of 'feed push-up' (the action of pushing the feed closer to the animals at the manger between feeding intervals, either mechanically or manually), and expected feed residuals and their management.

Group management and animal-human interaction — Questions were related to access to an outdoor 'loafing area' (an outdoor area where animals are able to rest) and the duration of access (number of days/year and number of h/day), frequency of animal regrouping, ratio between number of animals and stock people (animal keepers) working on a daily basis on the farm, presence of non-regular helpers (not the main animal keepers), presence of malfunctioning equipment assessed in the barn on the day of the farm visit.

Cattle transport and origin — Questions were related to mixing of animals during transport to the farm, calves reared on the farm or transported and the country of origin.

Dietary analysis

During the same on-farm visit, a sample of the diet provided to the animals (~ 1 kg as fed material) was collected by the assessors from different points of the manger at the time of feed distribution, refrigerated until arrival at the respective research institutions and then frozen at −18 °C. After completion of the farm visits, the samples from Germany and Austria were shipped by carrier to the laboratory of the University of Padova, Italy, for analysis. Samples during shipping were stored in insulated expanded polystyrene boxes provided with dry ice to keep them frozen. Samples from 14 farms were lost due to errors made by the shipping company. After arrival at the laboratory, the samples were thawed and 10 diet samples were discarded since they belonged to farms that did not use a TMR feeding system but provided roughage and concentrates separately.

TMR samples were analysed for dry matter (DM) and crude protein (CP) according to the methods of the Association of Official Analytical Chemists (AOAC, 1990). Neutral detergent fibre (NDF) and acid detergent fibre (ADF) was analysed according to Van Soest et al. (1991). Starch content was determined by liquid chromatography (AOAC, 1990).

[2] See: European Commission Directive 2009/9/EC of 10 February 2009 amending Directive 2001/82/EC of the European Parliament and of the Council on the Community code relating to medicinal products for veterinary use L 44/10 EN Official Journal of the European Union 14.2.2009. https://ec.europa.eu/health/sites/health/files/files/eudralex/vol-5/dir_2009_9/dir_2009_9_en.pdf (accessed 2 July 2018).

[3] See: European Council Regulation No 1/2005 of 22 December 2004 on the protection of animals during transport and related operations and amending Directives 64/432/EEC and 93/119/EC and Regulation (EC) No 1255/97 5.1.2005 EN Official Journal of the European Union L 3/1. http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32005R0001 (accessed 2 July 2018).

[4] See: Scientific Committee on Animal Health and Animal Welfare (SCAHAW), 2001. The Welfare of Cattle kept for Beef Production. SANCO.C.2/AH/R22/2000. https://ec.europa.eu/food/sites/food/files/safety/docs/sci-com_scah_out54_en.pdf (accessed 23 April 2018).

[5] See: Welfare Quality, 2009. Welfare Quality assessment protocol for cattle. Welfare Quality Consortium, Lelystad, Netherlands. http://edepot.wur.nl/233467 (accessed 2 July 2018).

Particle size distribution of the fresh TMR samples from the feed bunk was directly assessed on-farm using the Penn State Forage Particle Separator, Nasco, Fort Atkinson, Wisconsin, USA, consisting of two sieves with 19 and 8 mm apertures, and a bottom pan. Using the procedure of Lammers et al. (1996), samples were separated into three fractions of particles: (1) > 19 mm in length, retained by the top screen; (2) 8–19 mm in length, retained by the middle screen; and (3) < 8 mm in length, settling down on the bottom pan. Each proportion of particles was weighed and divided by total sample weight to obtain the percentages of each of three fractions of particles.

Statistical analysis

Statistical analysis was carried out using SAS/STAT 9.3 (SAS Institute). Mortality served as an outcome variable (response) in the risk factor analysis. Data gathered through the questionnaire relating to country, 56 categorised factors, and TMR chemical and physical analyses (10 continuous covariates) were considered as independent predictors (potential risk factors; see Appendix: Supplementary material). Descriptive statistics (Proc FREQ) were obtained to assess the frequencies of the responses in the data set. Criteria for exclusion of potential risk factors were: (1) factors with ≥ 20% missing data; and (2) factors for which the percentage of answers allocated to one category was ≥ 80% (monolevel factors).

Preselection of potential predictors was conducted by testing all factors (categorical and continuous) individually for an association with the outcome variable mortality ('MORTALITY') using a generalised linear model (Proc GENMOD) with Poisson distribution and logarithm link function (McNutt, 2003; Zou, 2004). Country was always included in the models as a fixed effect to control for its confounding effect with other variables (e.g. herd size, observer, managerial choices, geographical localisation). This statistical approach was considered to be the most appropriate due to the non-normality and substantial skewness of the distribution of mortality. All factors associated with mortality at the level of $P < 0.10$ in the bivariable analysis were considered as candidates for the subsequent analyses. Collinearity between selected factors was assessed using the χ^2 test (Proc FREQ) for categorical factors and Spearman rank correlations (Proc CORR) for continuous factors to avoid bias in the coefficient estimates of the final model. When two or more risk factors were associated/correlated, the risk factor with the highest Wald χ^2 (lower P value) in bivariable analysis was retained. The predictors retained after these steps were included in a multivariable generalised linear model (Proc GENMOD) with Poisson distribution and logarithm link function, including country as fixed effect and using Bonferroni adjustment for pairwise post-hoc comparisons. The minimum threshold for factors to remain in the multivariable model was set to $P \leq 0.05$. Fulfilment of the assumptions for linear models (normality, independency and identical distribution of the residuals) was graphically tested.

Results

The number of animals (mean ± standard deviation, SD) present on each farm during the farm visit ranged from 33 to 1700 animals (Austria: 103.0 ± 54.1; Germany: 249.1 ± 178.0; Italy: 543.2 ± 385.6) with an overall mean ± SD of 298 ± 305 (median 200; lower quartile 97; upper quartile 400). Thirty-nine farms (61.9%) had a sloped floor system (Austria: 13; Germany: 17; Italy: 9) either for the whole pen or as lying area if split from an activity area (dual pen). Thirty-six farms had a deep-bedded straw yard system in the pens (Austria: 10; Germany: 11; Italy: 15) of which the majority (26 farms) had the whole pen deeply littered, whereas 10 offered this only in the lying area of dual pens. Mortality rate on the 63 beef cattle farms ranged from 0% to 18.2% (Fig. 1), with a mean ± SD of 2.9 ± 3.5% (median 1.7%; lower quartile 0.9%; upper quartile 3.6%).

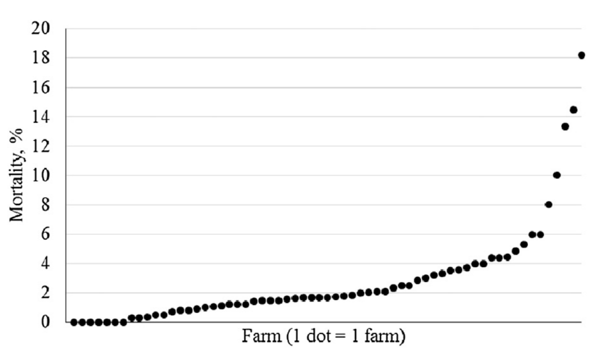

Fig. 1. Mortality values calculated for the 63 farms in Austria, Germany and Italy.

Amongst the 56 categorical factors, 28 were removed due to exclusion criteria; of the remaining 28 potential risk factors, 14 were conspicuously associated with the outcome variable in the bivariable analyses ($P < 0.1$; Table 1). Seven factors were related to farm cleanliness and cattle health management. Buying cattle from a single farm (RESOURCE_buy) and their housing in a dedicated quarantine area (QUARANT_buy) were associated with lower mortality, while mortality was higher when a health check by the veterinarian was performed on animal arrival (HEALTH_buy). The existence of a health plan for metaphylaxis and disease treatment (HHP_exist), a dedicated pen to hold sick animals (SICKPEN), keeping production records (FARMREC_produc) and more frequent cleaning of the lying area (LYAREA_cl) were further significant factors associated with lower mortality.

Four factors related to feeding management were associated with mortality, such that it was lower when ration formulation was based on experience or cattle requirements as compared to the availability of feed ingredients (RATION_base). Mortality was also reduced when farmers applied the calculation of exact rations (RATION_calculate), undertook analytical control of feed components or diets (NUTR_analyse_comp) and delivered feed at least two times per day (FEED_time). Amongst group management and animal-human interaction factors, mortality was associated only with the number of animals per stockman working on a daily basis with the animals (STO_no) and it was the highest when each stockperson was in charge of < 50 animals. Avoiding mixing animals during transport to the farm (TRANSPORT_mixed_binary) and the fattening of animals of national origin (CALF_origin) were also factors associated with lower mortality. Country was significant except in combination with the predictor STO_no.

Descriptive statistics for chemical composition and particle size distribution of TMR samples are reported in Table 2. All chemical and physical variables exhibited high variability, but none were significantly associated with mortality in the bivariable analyses.

The multivariable model included country as a fixed effect to correct for differences at the national level, which was the most significant factor in the multivariable model accounting for a great part of the variability ($\chi^2 = 22.8$; $P < 0.001$). Due to collinearity, seven of the pre-selected potential predictors (QUARANT_buy; HHP_exist; NUTR_analyse_comp; RATION_calculate; LYAREA_cl; STO_no and CALF_origin) were not considered further in the multivariable analysis, while the factors HEALTH_buy, RATION_base and FEED_time were not significant. Amongst the factors retained in the multivariable model, TRANSPORT_mixed_binary was significant and RESOURCE_buy, SICKPEN, and FARMREC_produc were close to the significance level of P ≤ 0.05 (Table 3). The outcomes of the multivariable analysis showed that farms mixing animals during transport (TRANSPORT_mixed_binary), as well as buying cattle from several supplying farms (RESOURCE_buy) had an increased risk of mortality compared to farms supplied by a single herd (Table 3). Furthermore, farms with the presence of a dedicated sick pen (SICKPEN) and farms that kept production records (FARMREC_produc) had lower mortality.

Discussion

The mean loss (mortality) recorded in this study (2.9%) falls within the range of animal losses during fattening (1.9–2.9%) reported by Gallo et al. (2014) for 2579 batches of young bulls intensively fattened in the north east of Italy and was the same as that (2.9%) calculated in France by Perrin et al. (2011) for beef cattle 6–24 months of age. In our study, dead, euthanased and early culled animals were included in the loss rate, as is commonly used for other farm animal species, such as broiler

Table 1
Selected potential herd management risk factors for mortality by bivariable analysis using a generalised linear model with Poisson distribution and logarithm link function.

Independent variable (factor)	Definition	Levels	Statistical outcome		Answers (%)
			Estimated mortality Least-squares mean (95% CI)[a]	*P* value	
Farm cleanliness and cattle health management					
RESOURCE_buy	Animals bought from a number of different sources	1: > 5 Herds	2.87 (2.35–3.52)	0.004	93.7
		2: 1–5 Herds	3.54 (2.55–4.90)		
		3: 1 Herd	1.19 (0.64–2.22)		
FARMREC_produc	Keeping production records	0: No	3.73 (2.97–4.68)	0.001	96.8
		1: Yes	2.19 (1.77–2.72)		
SICKPEN	Presence of dedicated sick animal pen	0: No	3.42 (2.78–4.22)	0.003	100.0
		1: Yes	2.14 (1.70–2.69)		
HEALTH_buy	Veterinarian checking health of newly bought animals	0: No	2.07 (1.61–2.67)	0.004	100.0
		1: Yes	3.24 (2.68–3.91)		
LYAREA_cl	Frequency of cleaning of lying area	0: Not done	3.48 (2.62–4.65)	0.073	93.7
		1: < 1 time per month	2.63 (1.83–3.78)		
		2: ≥ 1 time per month	2.01 (1.45–2.78)		
HHP_exist	Existence of a herd health plan	0: No	3.26 (2.57–4.14)	0.031	98.4
		1: Yes	1.94 (1.38–2.74)		
QUARANT_buy	Presence of dedicated quarantine areas for newly bought in animals	0: No	2.21 (1.69–2.88)	0.036	98.4
		1: Yes	3.12 (2.58–3.78)		
Feeding management					
RATION_base	Basis for formulation of ration(s)	1: Own experience	2.45 (1.70–3.52)	0.002	93.6
		2: Available feed ingredients	3.99 (3.18–5.03)		
		3: Cattle requirements	2.22 (1.71–2.87)		
NUTR_analyse_comp	Chemical analyses on different component(s) or entire diet	0: None	3.58 (2.77–4.64)	0.010	100.0
		1: Corn silage, other diet component	2.53 (2.03–3.16)		
		2: Total mixed ration	2.01 (1.40–2.87)		
FEED_time	Feeding time(s)	1: Not regular or once a day	3.00 (2.51–3.59)	0.069	98.4
		2: At least twice per day	2.21 (1.66–2.95)		
RATION_calculate	Calculation of exact rations	0: No	3.39 (2.51–4.58)	0.077	96.8
		1: Yes	2.47 (2.06–2.97)		
Group management and animal-human interaction					
STO_no	Number of animals/stockperson	1: < 50	3.41 (2.42–4.81)	0.006	100.0
		2: 50–99	1.63 (1.06–2.49)		
		3: ≥ 100	2.35 (1.80–3.07)		
Cattle transport and origin					
TRANSPORT_mixed_binary	Animals mixed during transport to the farm	0: No	2.32 (1.91–2.83)	0.008	100.0
		1: Yes or partly	3.57 (2.80–4.55)		
CALF_origin	Origin of the calves	1: Imported	3.64 (2.61–5.06)	0.055	100.0
		2: National	2.33 (1.86–2.92)		

[a] 95% CI, 95% confidence interval.

Table 2
Chemical composition and particle size distribution of 39 samples of total mixed rations (TMR) and their association with mortality by bivariable analysis using a generalised linear model with Poisson distribution and logarithm link function.

	Mean	Standard deviation	Minimum	First quartile	Median	Third quartile	Maximum	*P* value
Chemical composition								
Dry matter (DM, g/kg)	472	124	286	376	431	576	744	0.427
Ash (g/kg DM)	72	11	54	64	70	80	94	0.288
Crude protein (g/kg DM)	124	13	95	116	125	136	150	0.398
Ether extract (g/kg DM)	37	07	27	32	39	43	51	0.145
Starch (g/kg DM)	312	46	175	286	310	337	393	0.959
Neutral detergent fibre (g/kg DM)	369	52	254	329	370	407	473	0.275
Acid detergent fibre (g/kg DM)	193	29	129	171	196	214	256	0.490
Particle size								
Particles retained by 19 mm sieve (%)	7.6	13.7	0.2	1.7	3.7	8.4	82.0	0.764
Particles retained by 8 mm sieve (%)	34.0	13.6	5.1	24.8	30.2	43.2	59.1	0.734
Particles on bottom pan (%)	58.4	14.0	12.9	48.6	60.2	69.7	79.9	0.473

chickens (de Jong et al., 2016; Buijs et al., 2017) and piglets (Baxter et al., 2012). Studies focussing on mortality excluding early culls have reported slightly lower overall means of 1 to almost 2%, with increasing trends over years within and between studies (Loneragan et al., 2001; Cernicchiaro et al., 2012; Rumor et al., 2015).

There would be value in monitoring mortality over several years in order to evaluate the trends over time, as well as to differentiate farms that may have experienced exceptionally high loss rates in particular years due to respiratory virus outbreaks or other diseases.

Table 3
Retained risk factors associated with mortality on 59 intensive beef fattening farms in three European Countries in a multivariable generalised linear model with Poisson distribution and logarithm link function.

Factor[a]	Factor levels	Least square mean (95% CI)[a]	Pairwise comparison between levels	Risk ratio (95% CI)	Adjusted P value for pairwise comparison
TRANSPORT_mixed_binary (P = 0.006)	0: No	2.15 (1.62–2.85)	No vs. Yes	0.60 (0.42–0.87)	*
	1: Yes	3.57 (2.49–5.12)			
RESOURCE_buy (P = 0.057)	1: > 5 herds	2.92 (2.27–3.78)	1 vs. 3	1.68 (0.82–3.44)	0.465
	2: 1–5 herds	4.18 (2.80–6.23)	2 vs. 3	2.40 (1.11–5.20)	0.079
	3: 1 herd	1.74 (0.90–3.35)	–	–	–
SICKPEN (P = 0.056)	0: No	3.29 (2.36–4.60)	No vs. Yes	1.41 (0.99–2.02)	*
	1: Yes	2.33 (1.71–3.18)			
FARMREC_produc (P = 0.059)	0: No	3.28 (2.37–4.53)	No vs. Yes	1.40 (0.99–1.99)	*
	1: Yes	2.34 (1.70–3.21)			

95% CI, 95% confidence interval; TRANSPORT_mixed_binary, animals mixed during transport to the farm; RESOURCE_buy, number of suckler and dairy herds used as suppliers of the purchased calves; SICKPEN, presence of dedicated sick pen; FARMREC_produc, keeping production records.
[a] P value of the factor in the multivariable model.
* Same probability of the main factor for dichotomous variables.

Cattle losses may vary over time under different climate conditions and according to geographical areas. Support for this assumption comes from the significant effect of the country observed in combination with all predictors, except for STO_no, in the bivariable analysis and in the final multivariable model. The significant country effect on mortality might arise from different production environment and management systems. In Italy, beef production is mainly located in the Po valley, a fertile and homogeneous climatic area, and is relatively standardised on specialised farms of large size (Cozzi, 2007). Beef farmers commonly import animals from abroad at the age of 10–14 months and initial live weights of 300–400 kg; they are kept for a finishing period of about 7 months (Gallo et al., 2014). In compliance with the official European Union (EU) regulation on livestock transport (European Council Regulation 1/2005/EC), batches of imported cattle are health checked before leaving the country of origin and diseased animals are not allowed to be transported. In Austria and Germany, beef production is based more on the fattening of domestic animals, often originating from local dairy herds and bought-in at lower weights to family-owned farms of predominantly small size that are variable in duration of the production cycle, environment and management choices. Country was included in all models, but it was not considered as a potential risk factor, since farmers are not likely to change the geographical location of their farm, whereas they could more easily revise their managerial choices and feeding strategies to reduce cattle losses.

The provision of acidogenic rations is considered to be a factor influencing mortality and early culling due to their relation with digestive disorders (Béranger, 1986; González et al., 2012). However, the outcomes of the bivariable analysis in the present study showed no association between loss rates and several chemical and physical variables of the TMRs. This result could arise from the small data set available, as well as from the difficulty in clearly identifying potential critical threshold values for specific chemical constituents and/or physical fractions of the TMR, which may jeopardise beef cattle health. Official recommendations for beef cattle ration formulation, such as the European Food Safety Authority (EFSA),[6] suggest the provision of at least 15% of physically effective roughage to avoid sub-acute ruminal acidosis, bloat and other digestive disorders, but these recommendations are still too general. Future scientific research is needed to address more deeply the relationship between mortality and feeding in beef cattle, with the aim to set thresholds for specific nutritional variables that may be strongly associated with the risk of mortality.

According to the EFSA, adequate biosecurity measures for disease control and prevention are essential in beef cattle fattening units. The risk factors retained in the multivariable analysis in our study identified specific biosecurity measures that should be followed to lower cattle losses. Supported by a broad evidence from previous studies (Martin and Meek, 1986; McConnel et al., 2008), the mixing of animals from different sources is a relevant risk factor for cattle morbidity and mortality. To prevent spread of pathogens and cross-contamination between animals of different origin, beef farmers should try to reduce the number of suppliers of newly bought-in animals by selecting suckler herds of bigger size or specialised calf rearing units, capable of provide an entire batch of cattle that can be transported in a single delivery. On arrival at the farm of destination, animals of the same batch should be kept separated from other incoming groups of cattle during the quarantine period.

Transportation is a necessary component of the beef cattle production chain that is of economic concern to producers because of its association with decreased performance and compromised health of cattle (Earley et al., 2017). Outcomes of the present study support the observation that avoiding the mixing of animals during transport is a way to prevent cattle losses during the subsequent fattening period. Physiological measures indicate that transport of cattle can lead to increased susceptibility to disease and might result in increased pathogen shedding (Swanson and Morrow-Tesch, 2001). As an alternative, beef farmers should also evaluate the feasibility and financial sustainability of rearing their own calves for fattening.

In the present study, separation of sick animals from healthy animals in a dedicated sick pen as a further biosecurity measure was associated with reduced mortality. This may at least partly be due to decreased pathogen flow amongst herd mates, but also because sick animals benefit from being monitored and treated individually (Seppä-Lassila et al., 2016). The association between the herd management practice of keeping farm production records and lower cattle losses suggests that maintaining a detailed and reliable data inventory can be a useful tool to make informed decisions about farm management choices.

Conclusions

Even when accounting for differences amongst countries, the outcomes of the multivariable analysis identified some biosecurity

[6] See: European Food Safety Authority (EFSA), 2012. Scientific opinion on the welfare of cattle kept for beef production and the welfare in intensive calf farming systems. EFSA Journal 10, 2669. https://efsa.onlinelibrary.wiley.com/doi/pdf/10.2903/j.efsa.2012.2669 (accessed 2 July 2018).

measures and herd management practices associated with lower mortality. These beneficial practices should be emphasised when educating farmers, with the aim to improve beef cattle welfare and farm profitability. The lack of significant associations between mortality and chemical and physical parameters of beef cattle diets call for further investigations.

Conflict of interest statement

None of the authors has any financial or personal relationships that could inappropriately influence or bias the content of the paper.

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Appendix: Supplementary material

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.tvjl.2018.08.002.

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