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UNIVERSITA' DEGLI STUDI DI PARMA

DOTTORATO DI RICERCA IN
SCIENZE DEGLI ALIMENTI

CICLO XXXVII

OCCURRENCE AND REASONS FOR ON-FARM EMERGENCY SLAUGHTER OF CATTLE IN NORTHERN ITALY: HUMAN INTELLIGENCE AND MACHINE LEARNING (ARTIFICIAL INTELLIGENCE) APPROACHES

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Anni Accademici 2021/2022 – 2023/2024

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FREQUENZA E MOTIVAZIONI PER LA MACELLAZIONE SPECIALE D'URGENZA NEI BOVINI DELL'ITALIA SETTENTRIONALE: APPROCCI BASATI SULL'INTELLIGENZA UMANA E SUL MACHINE LEARNING (INTELLIGENZA ARTIFICIALE).

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ABSTRACT

The management and culling of cattle at the end of their productive life raise significant concerns regarding animal welfare. When faced with a suffering, injured, or sick animal, farmers typically have three options: to treat the animal, hoping for its recovery; to humanely euthanise it; or to proceed with an on-farm emergency slaughter (OFES), with the approval of an Official Veterinarian (OV) during an *ante-mortem* inspection.

Regulation (EC) No 853/2004 defines OFES as the emergency slaughter of domestic ungulates outside a slaughterhouse when a healthy animal suffers an "accident" that prevents its transport for welfare reasons. This regulation ensures humane killing and the safety of the meat, upholding high standards of animal welfare and food safety. In April 2022, the Italian Ministry of Health (Circular No. 13895 of April 5, 2022) provided an update regarding the interpretation of the term "accident".

This study aimed to investigate OFES cases recorded in slaughterhouses under the jurisdiction of the Local Competent Authority (LCA) of Brescia, covering animals from four regions and 15 provinces in Northern Italy between 2021 and 2023. It specifically focuses on the motivations and characteristics of cattle subjected to OFES.

Data were sourced from the electronic dataset of the LCA of Brescia, with the OFES motivations provided in free text format by the Official Veterinarians, categorized through both manual analysis and artificial intelligence (AI) techniques, including the Term Frequency-Inverse Document Frequency (TF-IDF) method and a supervised machine learning (ML) model. Additionally, *post-mortem* inspection results were manually categorized.

The analysis revealed a decline in OFES cases delivered to the 20 slaughterhouses located under the jurisdiction of the LCA of Brescia, decreasing from 4,847 in 2021 to 3,367 in 2023, reflecting a 30.5% decrease. This decline was likely a secondary effect of changes in the Italian Ministry of Health guidelines for OFES since April 2022, which redefined the term "accident" and led to stricter evaluations by OVs during *ante-mortem* inspections.

Findings indicated that locomotory issues, such as fractures and acute trauma, were the primary reasons for OFES, accounting for 8,362 cases (69.4%), with increasing rates from 58.1% in 2021 to 78.9% in 2023. In contrast, recumbency cases accounted for 1,597 cases (13.3%), declining from 941 cases (19.4%) in 2021 to 276 cases (8.2%) in 2023. Calving-related problems represented 1,252 cases (10.4%), decreasing from 659 cases (13.6%) in 2021 to 303 cases (9.0%) in 2023.

Artificial intelligence tools, such as TF-IDF analysis and supervised ML, categorized the free-text motivations from OVs, achieving 99.2% consistency with human interpretation, representing a starting point for enhanced data management in veterinary contexts.

Post-mortem inspections at the slaughterhouses revealed that 93.4% of OFES carcasses were fit for human consumption; however, the percentage of condemned carcasses increased from 5.2% in 2021 to 9.1% in 2023, indicating a need for further investigation. When reported, the most commonly condemned carcass parts were the legs and joints, accounting for 39.3% of exclusions, which rose from 37.6% in 2021 to 44.9% in 2023. Additionally, issues related to the liver and hepatic lymph nodes accounted for 18.9% of exclusions, showing a decrease from 21.5% in 2021 to 13.6% in 2023, This trend indicates a reduction in chronic affections, likely attributed to changes in the interpretation of what constitutes an "accident" in case of OFES *ante-mortem* inspections.

In conclusion, this study has contributed to highlight the complexities surrounding the issue of cattle undergoing on-farm emergency slaughter in Northern Italy, particularly in light of recent changes to national guidelines. Other factors such as farmers' management practices, economic considerations, and the willingness of slaughterhouses to accept OFES carcasses can play crucial roles in determining whether these animals die for on-farm emergency slaughter or not. Further research is essential to fully understand the dynamics of these factors, which fall within the broader issue of voluntary and involuntary culling, and particularly regarding the end-of-life of dairy cows. In addition, in the next future, the use of advanced data analysis techniques, such as artificial intelligence tools, within the ClassyFarm system, could facilitate a better categorization of farms, enabling targeted interventions that enhance the overall health, welfare, and quality of life for cattle.

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ABBREVIATIONS

The following is a comprehensive list of abbreviations used throughout this study.

- AI: Artificial Intelligence
- AM: Ante-Mortem
- AW: Animal Welfare
- EC: European Commission
- LCA: Local Competent Authority
- ML: Machine Learning
- MoH: Ministry of Health (Italian)
- OFES: On-Farm Emergency Slaughter
- OV(s): Official Veterinarian(s)
- PM: Post-Mortem
- QoL: Quality of Life
- TF-IDF: Term Frequency – Inverse Document Frequency technique

INTRODUCTION

The management and culling of end-of-career cattle pose significant animal welfare (AW) concerns. Cows may have reached the end of their productive life on a given farm because they are no longer productive, but they are still fertile and healthy (European Commission, 2022).

The owner may decide to remove them from the herd - either by selling them to another farm or a slaughterhouse - based on a planned and rational decision, known as "voluntary culling" (Fetrow et al., 2006; Weigel et al., 2003). Reasons for voluntary culling typically relate to production or economic factors, such as low milk yield, poor milk quality, age, low genetic merit, aggressive behaviour, low milk prices, overstocking, or high feed costs (Hadley et al., 2006; Shahdadi et al. 2018).

Conversely, cows may unexpectedly leave the herd due to illness or injury. They may have suffered an accident or physical injury causing acute pain (e.g., a fractured limb or splits), experienced dystocia, or encountered post-calving complications (e.g., milk fever, palsy, metabolic disorders). They may also be afflicted by chronic conditions such as lameness, arthritis, mastitis, infectious diseases, or internal issues like foreign body ingestion (Dallago et al., 2021). These circumstances lead to an unexpected removal from the herd, a process known as "involuntary culling" which imposes an economic burden on the owner (Weigel et al., 2003; Hadley et al., 2006; Shahdadi et al., 2018).

Cows culled involuntarily may exit the herd either dead or alive (Fetrow et al., 2006). In the case of death, these events are recorded as on-farm mortality, which includes unassisted death, euthanasia, and on-farm emergency slaughter (OFES) (Thomsen and Houe, 2006; Welfare Quality®, 2009; Højlund Nielsen et al., 2014; Fusi et al., 2017; EFSA, 2023). In cases where the cows are still alive but considered "slightly ill or injured" they may be transported (in compliance with Regulation 1/2005) and sold to a slaughterhouse or even to another farm for final fattening (Dahl-Pedersen et al., 2018).

In EU countries, sick or injured animals may also undergo casualty slaughter at the slaughterhouse, depending on the cow's condition and proximity to the nearest slaughter facility (McDermott and McKevitt, 2016; Skúladóttir et al., 2022a). However, as the interpretation and enforcement of Regulation (EC) No 1/2005 concerning the condition of animals before transport are becoming increasingly stricter, with a greater focus on minimizing suffering, casualty slaughter is often no longer considered a viable option (McDermott and McKevitt, 2016; Skúladóttir et al., 2022b).

Alternatively, if an animal becomes ill, injured, or recumbent during transport or upon arrival at the slaughterhouse (e.g., during unloading), it may, for welfare reasons, undergo emergency killing for slaughter, categorized as "emergency slaughter at the slaughterhouse". According to the Italian National Livestock Registry (2023), 10,173 cattle (0.4% of the 2,593,306 slaughtered) underwent emergency slaughter at the slaughterhouse (see also **Table 1**).

Table 1 – Details of the annual cattle population and numbers of animals slaughtered in Italy, Lombardy and province of Brescia respectively, at December 31, 2023. Data from slaughtered animals reflect the total number of cases at the slaughterhouse level.

	Cattle Population[a]	**Known number of cattle slaughtered**[b]	**Number of cattle ordinary slaughtered in a slaughterhouse (% of total slaughtered)** [b]	**Number of cattle emergency slaughtered in a slaughterhouse (% of total slaughtered)** [b]	**Number of cattle emergency slaughtered on-farm (% of total slaughtered)** [b]
Italy	5,420,566	2,593,306	2,569,583 (99.1%)	10,173 (0.4%)	13,550 (0.5%)
Lombardy	1,517,160	610,821	596,555 (97.7%)	4,416 (0.7%)	9,850 (1.6%)
Brescia	456,836	68,901	65,574 (95.2%)	30 (0.0%)	3,297 (4.8%)

Data sources:
[a] Italian National Livestock Registry – Statistics section. https://www.vetinfo.it/j6_statistiche/#/report-pbi/11 (accessed 05 July 2024)
[b] Italian National Livestock Registry – Statistics section. https://www.vetinfo.it/j6_statistiche/#/report-pbi/10 (accessed 05 July 2024)

The issues surrounding "involuntary culling" - such as animal welfare conditions, levels of suffering, decreasing average lifespans, and the ethical implications of cows not living their expected lifespans - raise significant concerns among consumers, the scientific community, and stakeholders regarding the ethical, social, and economic sustainability of dairy cattle production (de Vries et al., 2011; Thomsen and Houe, 2018; Dallago et al., 2021; Schütz et al., 2023). Additionally, these issues can damage the reputation of the cattle industry and weaken the social acceptability of the dairy sector and its products (Skúladóttir et al., 2022a, b; Horgan and Gavinelli, 2006).

A significant debate should emerge regarding the interpretation of "longevity", which should not be limited to the duration of a dairy cow's life. Instead, it should encompass all aspects of the lifespan of high-producing dairy cows, for which there is no standardized definition or metric (Dallago et al., 2021; EFSA, 2023). The focus should shift from merely the length of life to its quality, which can be understood within the framework of quality of life (QoL), emphasizing a "balance of positives over negatives" and ensuring a "life worth living" (Ventura et al., 2021; Lawrence et al., 2019).

1.1 On-farm emergency slaughter

In the case of a suffering, injured, or sick animal, the owner has several options: treat and recover the animal in a sick pen, humanely euthanise it and dispose of the carcass, or conduct an on-farm emergency slaughter (OFES) by requesting approval from the Local Competent Authority (LCA).

According to Regulation (EC) No 853/2004, on-farm emergency slaughter (OFES) refers to the emergency slaughter of domestic ungulates carried out outside the slaughterhouse in case *"an otherwise healthy animal that has suffered an accident that prevented its transport to the slaughterhouse for welfare reasons"* (Regulation (EC) No. 853/2004, Annex III, Section I, Chapter VI). This regulation ensures that emergency killing is conducted humanely, and that the resulting meat is safe for human consumption, upholding high standards of both animal welfare and food safety across the European Union. Transporting an animal in such conditions would, in fact, lead to unnecessary suffering and constitute a violation of Regulation (EC) No 1/2005.

To ensure that each specific request complies with the law, animals supposed eligible for OFES must undergo an on-farm *ante-mortem* (AM) inspection by an Official Veterinarian (OV), in accordance with Article 4 of Regulation (EU) 2019/624.

If the AM inspection yields a favourable outcome (e.g., cow with a fractured limb from a fall in the barn), the animal is slaughtered and bled on-farm. It is then sent to the slaughterhouse, where another OV reviews and assesses the accompanying documentation before conducting the *post-mortem* (PM) inspection of the carcass. Additionally, the OV collects muscle samples for further testing, including the detection of pathogens (e.g., *E. coli* and *Salmonella* spp.) and residues of pharmacologically active substances.

Conversely, in case the AM inspection outcome is unfavourable (e.g., the animal is unhealthy, suffering from a chronic disease, or in a condition not suitable for human consumption), the animal must be euthanised for welfare reasons or, if feasible, given specific therapeutic treatment.

To ensure a consistent application of the European rules related to OFES across the entire Country and provide guidance on how to document the condition of the animals and the execution of slaughter, the Italian Ministry of Health (MoH) delivered also a specific note/circular providing practical guidelines and official documentation (Italian MoH Circular No. 13895 of 05.04.2022). This circular was delivered following a request from the audit conducted in Italy by the European Commission Directorate-General for Health and Food Safety, from January 18 to January 29, 2021. The audit aimed *to evaluate the food safety control systems in place governing the production and*

placing on the market of bovine meat, including Traceability (European Commission, DG(SANTE) 2021-7186). During this audit, the EU Commission inspectors noted that some circulars and procedures/guidelines issued by the Italian MoH and regional Competent Authorities since 2006 were not fully aligned with the provisions of Regulation (EC) No 853/2004: each year, a small number of animals with "metabolic disorders" (and therefore considered unfit for transport) were subjected to OFES despite not meeting the fundamental requirement of having suffered an "accident". As a result, inspectors noted two outcomes: *i)* a low risk of transporting unfit animals to the slaughterhouse (due to the protective measure of accepting more animals than necessary at the AM inspection), and *ii)* a high level of assurance that meat unfit for human consumption did not enter the food chain, thanks to rigorous rules and a long-standing veterinary tradition in food safety controls, including *post-mortem* inspections and sampling for laboratory analyses.

Following this audit, a discussion arose among MoH, Regional Competent Authorities and the National Reference Centre for Animal Welfare (located at the Istituto Zooprofilattico Sperimentale della Lombardia e dell'Emilia Romagna, in Brescia) regarding the proper translation of the English term "accident" (Regulation (EC) No 853/2004), due also to the lack of unequivocal definitions for such a key term, as well as for "slightly ill or injured" (Regulation (EC) No 1/2005) (Dahl-Pedersen et al., 2018; Skúladóttir et al., 2022a). Therefore, it was concluded that an "accident" is an unforeseen "traumatic" event that can cause harm to an animal, resulting in injuries or illnesses, such as fractures, wounds, lesions, and other acute injuries from falls or slips; traumas related to calving or dystocia, without other systemic symptoms, are also included. The animal's health status must not indicate infectious diseases, metabolic syndromes, or neurological disorders. Since April 2022, animals deemed unfit for transport for reasons other than those mentioned are excluded from OFES, likely resulting in changes to the occurrences and reasons for OFES of cattle in Italy.

Currently, very few studies have been published on the reasons and use of OFES. Early studies were conducted in Ireland (McDermott and McKevitt, 2016 and Cullinane et al., 2010 on emergency and casualty slaughter in slaughterhouses), British Columbia, Canada (Koralesky et al., 2018), and Norway (Skúladóttir et al., 2022b). However, no research has been published concerning Mediterranean countries.

This study aims to address this gap by first examining the reasons and cattle characteristics detailed in veterinary certificates related to OFES in Northern Italy, specifically within the jurisdiction of the Local Competent Authority (LCA), the "Health Protection Agency" (Agenzia di Tutela della Salute, ATS, in Italian), in the province of Brescia.

Secondly, for the first time, to the author's knowledge, artificial intelligence (AI) tools such as "Term Frequency-Inverse Document Frequency" (TF-IDF) analysis were applied to perform a

text-mining process to identify clusters of commonly used terms by OVs. A supervised machine learning algorithm was also employed to classify the OFES motivations, provided in free-text format in the veterinary certificates by the OVs, into specific predefined categories and sub-categories. In addition, a specific analysis was conducted to describe PM findings, collected at the slaughterhouse, in terms of carcasses fit for human consumption, findings on carcass and offal, and their relationship with OFES motivations collected during AM inspection.

MATERIALS AND METHODS

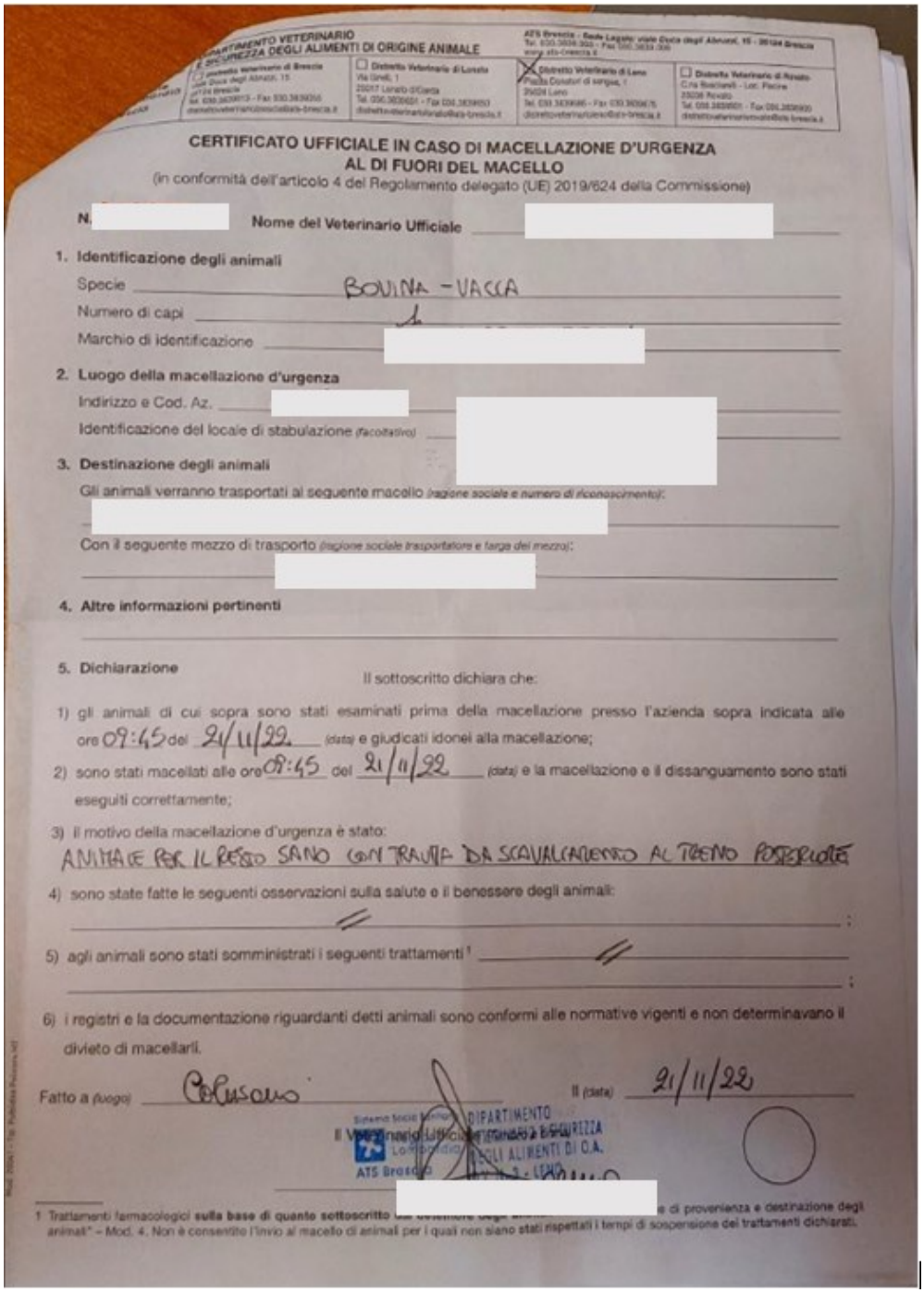
2.1Data sources, collection, and quality control

In this study, all OFES cattle whose carcasses arrived at 20 slaughterhouses located in the jurisdiction of the Veterinary Local Competent Authority (LCA) of the province of Brescia from 2021 to 2023 were considered.

The LCA of Brescia provided access to the entire electronic database for this period, which included: *i)* farm identification information (ID code); *ii)* animal information (ID code, date of birth, sex, absence/presence of drug treatments in the last 90 days); *iii)* date of OFES; *iv)* reason for OFES (recorded in open text format in the veterinary certificate by the OV during AM inspection on-farm and transcribed into the LCA register by the OV at the slaughterhouse) *v)* name of the slaughterhouse; *vi)* results from laboratory analysis (positive/negative) and any findings; *vii)* PM inspection outcome (approval/denial for human consumption); *viii)* any exclusions of carcass parts from human consumption. The data was carefully reviewed, and any transcription errors, such as incorrect ID information or missing birth dates, were rectified when possible, resulting in 596 adjustments.

The farm ID code was utilized to extract secondary data from the Italian National Register such as the predominant production system: farms were therefore classified as "dairy", "beef" or "mixed" (a specific classification applied when both dairy and beef production were significant).

In detail, when a farmer decided to request an OFES, they contacted the LCA office in their area. An OV inspector then visited the animal on-farm for the AM inspection. In case of favourable outcome, the OV inspector completed the veterinary certificate in paper form (according to the Regulation (EU) 2020/2235, Annex IV, Chapter 5 ("*Model animal health certificate in the case of emergency slaughter outside the slaughterhouse in accordance with Article 4 of Commission Delegated Regulation (EU) 2019/624")* and the Italian MoH Circular No. 13895 of 05.04.2022). The certificate (**Figure 1**) included the animal's clinical conditions and the presumed reasons for the OFES in an open text format. The carcass of the animal, after stunning and bleeding, had to be loaded into a clean vehicle that had been thoroughly washed and sanitized in advance. The blood and, if applicable, the viscera had to be transported in closed containers that could be traced back to the corresponding animal. The transportation time of the carcass did not exceed two hours unless the vehicle was refrigerated, provided that climatic conditions made it necessary. In case this condition was not met, the carcass would be rejected from human consumption.



DIPARTIMENTO VETERINARIO E SICUREZZA DEGLI ALIMENTI DI ORIGINE ANIMALE

ATS Brescia

CERTIFICATO UFFICIALE IN CASO DI MACELLAZIONE D'URGENZA AL DI FUORI DEL MACELLO

(in conformità dell'articolo 4 del Regolamento delegato (UE) 2019/624 della Commissione)

N. [redacted] Nome del Veterinario Ufficiale [redacted]

1. Identificazione degli animali

Specie BOVINA - VACCA

Numero di capi 1

Marchio di identificazione [redacted]

2. Luogo della macellazione d'urgenza

Indirizzo e Cod. Az. [redacted]

Identificazione del locale di stabulazione (facoltativo) [redacted]

3. Destinazione degli animali

Gli animali verranno trasportati al seguente macello (ragione sociale e numero di riconoscimento): [redacted]

Con il seguente mezzo di trasporto (ragione sociale trasportatore e targa del mezzo): [redacted]

4. Altre informazioni pertinenti

5. Dichiarazione

Il sottoscritto dichiara che:

1) gli animali di cui sopra sono stati esaminati prima della macellazione presso l'azienda sopra indicata alle ore 09:45 del 21/11/22 (data) e giudicati idonei alla macellazione;

2) sono stati macellati alle ore 09:45 del 21/11/22 (data) e la macellazione e il dissanguamento sono stati eseguiti correttamente;

3) il motivo della macellazione d'urgenza è stato: ANIMALE PER IL RESTO SANO CON TRAUMA DA SCAVALCAMENTO AL TRENO POSTERIORE

4) sono state fatte le seguenti osservazioni sulla salute e il benessere degli animali: //;

5) agli animali sono stati somministrati i seguenti trattamenti[1] //;

6) i registri e la documentazione riguardanti detti animali sono conformi alle normative vigenti e non determinavano il divieto di macellarli.

Fatto a (luogo) Pralboino Il (data) 21/11/22

Il Veterinario Ufficiale DIPARTIMENTO VETERINARIO E SICUREZZA DEGLI ALIMENTI DI O.A. ATS Brescia [redacted]

1 Trattamenti farmacologici sulla base di quanto sottoscritto [illegible] di provenienza e destinazione degli animali" – Mod. 4. Non è consentito l'invio al macello di animali per i quali non siano stati rispettati i tempi di sospensione dei trattamenti dichiarati.

Figure 1 – Example of a hard copy veterinary certificate used during ante-mortem inspection for on-farm emergency slaughter.

Once the carcass arrived at the slaughterhouse, the OV inspector at the slaughterhouse transcribed the reasons for the OFES from the veterinary certificate into the electronic register of the LCA. The information related to the farm and the animal, such as identification data, drug treatments, etc., was electronically available and automatically transmitted to the LCA register, according to module 3 of the of the Italian MoH Circular No. 13895 of 05.04.2022. This module, designed

specifically for OFES cases, serves as the equivalent of the “movement document” for animals, as mandated by Regulation (EU) 2016/429 and its associated delegated and implementing acts.

In addition, a search for statistics on population and slaughter was conducted among the data on the cattle population and the number of animals slaughtered annually in Italy, the Lombardy Region, and within the jurisdiction of the LCA in the province of Brescia (based on 31/12/2023 data). The information was sourced from the Italian National Livestock Registry – Statistics section (https://www.vetinfo.it/j6_statistiche/#/) and used for descriptive comparison.

2.2 Data management and descriptive statistical analysis of cattle characteristics and OFES motivations

Descriptive statistical analysis about cattle and OFES reasons was conducted using Microsoft Excel (Microsoft Corporation, 2019, Microsoft Excel, Version 1808).

The age of each animal, calculated in days by subtracting the birthdate from the slaughter date (and adding 1 day), was used to categorize the animals. According to the Council Directive 2008/119/EC, calves (both male and female) were defined as animals from birth until 180 days old. Heifer is a female from 181 days old until their first calving, which was presumed to occur at 760 days old (Skúladóttir et al., 2022b; Ferrari et al., 2024). Young cow is a female from 761 to 1,460 days of age and old cow is a female older than 1,460 days (Skúladóttir et al., 2022b). The same criteria were applied for male: bull calf (from 181 until 760 days old), young bull (from 761 until 1,460 days old), old bull (older than 1,461 days).

Based on the data actually recorded in the datasheet, the results of the Term Frequency-Inverse Document Frequency (TF-IDF) analysis (described below), and following the methodology of Skúladóttir et al., 2022b and Cullinane et al., 2010, all OFES reasons were manually categorized (through human intelligence) into 4 main categories and 30 sub-categories.

In **Table 2**, categories and sub-categories are shown as well as the inclusion criteria to aggregate them. The inclusion criteria were particularly important in cases where the reasons for OFES were difficult to categorize due to poor descriptions or overlapping information. These criteria helped ensure consistency in identifying the primary reason for OFES, selecting it from the list, and minimizing subjectivity in the interpretation of the reported reasons.

Frequency distributions of the OFES reasons categories were used to analyse categorical data. The reasons for OFES in categories and sub-categories were tabulated by production system, animal type and year of occurrence.

Table 2 – List of categories and sub-categories for OFES reasons, including the corresponding inclusion criteria.

Category	Subcategory and body localization	Inclusion criteria based on motivation reported in the Veterinary Certificate
Locomotion		
	Fracture[1,2]	Cases of fracture or suspected fracture
	- foreleg	
	- hindleg	
	- leg (not specified)	
	- spinal/back	
	- hip/pelvic	
	- shoulder/neck	
	- not specified	
	Lameness[1,2]	Cases of lameness
	- foreleg	
	- hindleg	
	- lame (not specified)	
	Acute Trauma/Injury[1]	Cases of generic trauma or injury to the legs, including acute soft tissue trauma
	- foreleg	
	- hindleg	
	- leg (not specified)	
	- spinal/back	
	- hip/pelvic	
	- shoulder/neck	
	- not specified	
	Hip dislocation & splits[1]	Cases of animals with hip dislocation or splits
	Mounting trauma	Cases of mounting, but no information on the type of injury
	Slip & fall trauma	Cases of slips or falls within the barn, but no information on the type of injury
	Abscess or phlegmon	Cases of abscess or phlegmon to the legs
	Other in locomotion	Cases of reported leg malformation or defects due to other reasons
Recumbency		
	Unable to stand[1]	Cases unable to stand or walk for unknown cause
	Palsy / paralysis[1]	Cases of downer cows (using "palsy" or "paralysis" words) for unknown cause and involving also "hindquarters palsy"
	Metabolic syndrome	Cases of metabolic disorders or collapse for unknown cause
Calving-related problems		
	Stillbirth	Cases of stillbirth or abortion
	Dystocia[1]	Cases of dystocia or calving difficulties, including uterine torsion
	Uterine and obstetrics affections	Cases with a current vaginal or uterine prolapse, including also uterine lacerations or haemorrhages
	Traumatic injuries related to calving	Cases of neuromuscular damage due to compression from trauma occurring during calving, including dislocation of the pelvic bones
	Palsy/paralysis after calving	Cases of downer cows (using "palsy" or "paralysis" words) but reported after calving
	Metabolic syndrome after calving	Cases of metabolic disorders or collapse but reported after calving

Other		
	Generic trauma[1]	Cases of trauma (using only "trauma" word) for unknown cause and unknown localization
	Aggressiveness - public safety[1]	Cases of animals that cannot be caught or loaded on truck, as well as aggressive and uncontrollable individuals
	Cardiac[2]	Cases of cardiovascular disorders
	Digestive[2]	Cases of digestive disorders, such as ruminal bloat, abomasal displacement, intestinal torsion
	Eye[2]	Cases of eye disorders, including blindness
	Foreign body syndrome	Cases of traumatic reticuloperitonitis
	Head[2]	Cases of head injuries, including the horn
	Integument[2]	Cases of skin wounds but unknown body localization
	Mastitis[1]	Cases of mastitis
	Respiratory[2]	Cases of pneumonia or dyspnea
	Udder damage[1]	Cases of trauma or wounds to the udder
	Empty or illogical	Cases where no reason was provided (empty cell) in the dataset or where the information was illogical (e.g., a number or a name)
	Other	Other cases not related to the previous ones, e.g., thorax trauma, or post-operative complications without additional information

[1] In line with Skúladóttir et al., 2022b
[2] In line with Cullinane et. al., 2010

2.3Machine learning (artificial intelligence) approach

To develop a supervised machine learning model for the text mining analysis of OFES reasons, the following steps were undertaken:

A. Data collection and preparation

The original electronic dataset of OFES was pre-processed as follows:

- *Text cleaning*: removal of noise, such as common terms (e.g., articles, prepositions, frequently used words), unnecessary symbols, numbers, and irrelevant words.
- *Text normalization*: conversion to lowercase, removal of stop-words, and application of stemming and lemmatization techniques.
- *Tokenization*: the text was segmented into analysable units (words or phrases).

B. Feature extraction

To represent the texts numerically and make them interpretable, the Term Frequency-Inverse Document Frequency (TF-IDF) technique was applied.

TF-IDF is widely used in text mining and natural language processing to assess the importance of a word within a document relative to a collection of documents (a corpus). The following definitions apply:

- *Term Frequency (TF):* measures how frequently a term appears in a document, where a higher value indicates that the term appears frequently.

$$TF(t,d) = \frac{f_{t,d}}{\sum_{t' \in d} f_{t',d}}$$

Where:

t = term

d = document

$f_{t,d}$ = frequency of term t in document d

$\sum_{t' \in d} f_{t',d}$ = total number of terms in document d

- *Inverse Document Frequency (IDF):* measures how rare or common a term is across the entire corpus. A term that appears frequently in many documents will have a low IDF, whereas a rare term will have a high IDF.

$$IDF(t, D) = log\left(\frac{N}{1 + |\{d \in D: t \in d\}|}\right)$$

Where:

t = term

D = total collection of documents

N = total number of documents in the collection

$|\{d \in D: t \in d\}|$ = number of documents in which term t appears.

- *The TF-IDF score for each term* is calculated as the product of TF and IDF. This score represents the relevance of a term in a specific row/document relative to the entire corpus.

$$TF - IDF(t, d, D) = TF(t, d) \times IDF(t, D)$$

Where:

TF(t, d) = term frequency of term *t* in document *d*

IDF(t, D) = inverse document frequency of term *t* in the document set *D.*

C. Interpretation of the TF-IDF analysis

The TF-IDF analysis was interpreted as follows:

- *Identification of significant terms:* terms with a high TF-IDF value were identified as significant, as they best differentiated rows or sentences from others in the corpus;
- *Comparison between rows:* by comparing the TF-IDF values of the same term across different rows of the database, it was possible to assess its relative importance.

D. Clustering or classification

TF-IDF scores were used as input for clustering terms used in the OFES certificates, to identify topics, categories, or groups of similar rows. Silhouette scores were also provided to evaluate the quality of the clusters for each motivation.

E. Development and training of the machine learning model

A supervised machine learning model (in Python) was developed for the classification of OFES reasons. The model used a multi-output classification approach with the following components:

- *RandomForestClassifier*: used as the base classification model.
- *MultiOutputClassifier*: a wrapper that allows the model to handle multiple targets simultaneously, enabling multi-label classification.
- *TfidfVectorizer*: used to transform textual features (input) into numerical vectors.

The code also included splitting the dataset into training and testing sets, using a pipeline for transformation and classification to facilitate training and prediction.

The training dataset consisted of data from 2021-2022. The code for performing this part of the model is shown in **Figure 2.**

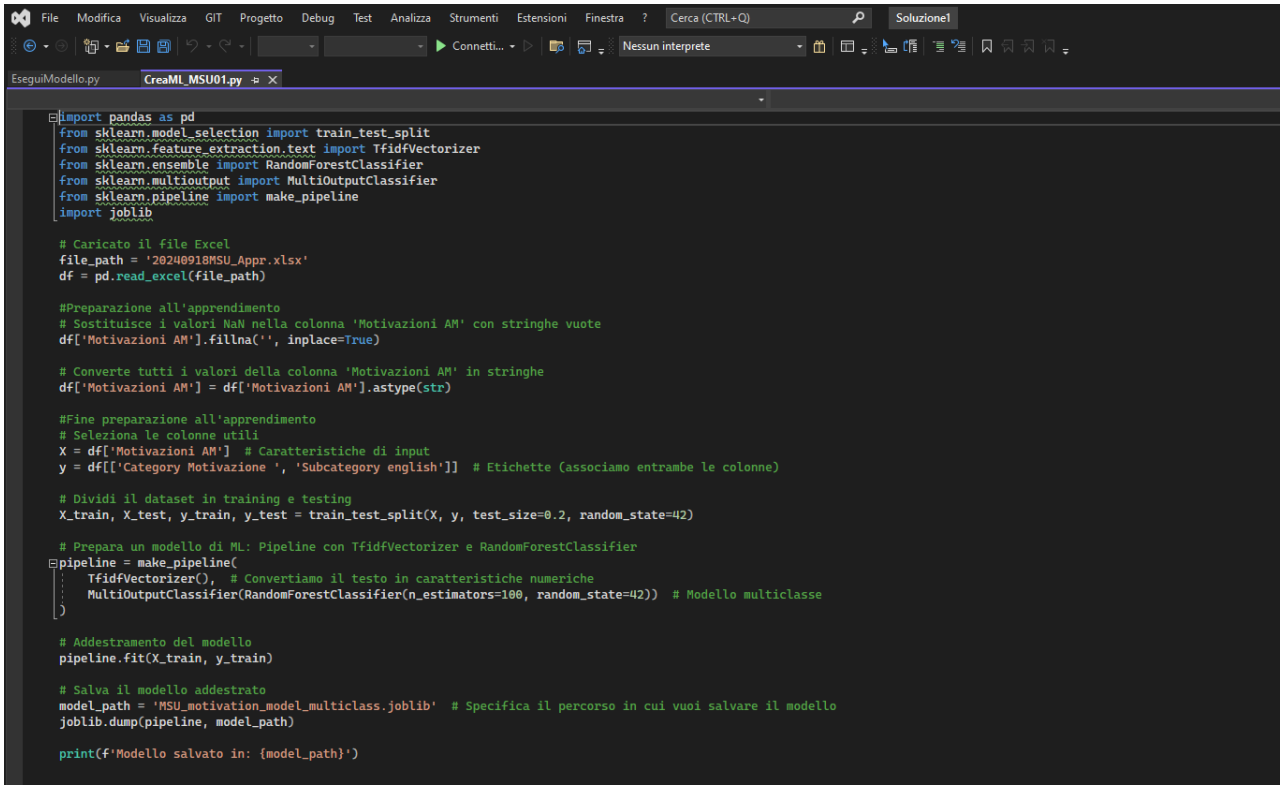


Figure 2 – Examples of code for pre-processing text for supervised machine learning using scikit-learn.

F. Model evaluation

The model's performance was evaluated using the following metrics:

- *Precision, Recall, and F1-score:* to measure the accuracy and ability (performance) of the model in correctly identifying different classes.

- *Confusion Matrix:* to identify types of classification errors and any difficulties or challenges the model faced in distinguishing specific classes of certificates.

G. Final implementation and optimization

After being trained and validated on the 2021-2022 dataset, the final model was integrated into an automated workflow for the analysis of OFES certificates over the 3-year period.

2.4 Data management and descriptive statistical analysis of post-mortem findings in OFES cattle

Post-mortem (PM) findings for OFES cattle included in the LCA dataset were also examined. Veterinary inspectors conducted these PM inspections in accordance with Regulation (EU) 2017/625 and Regulation (EU) 2019/627, assessing carcasses to determine their suitability for human consumption.

As part of the PM inspection, all OFES carcasses are systematically tested for potential microbial contamination in the deep muscle tissues, such as the forearm muscles. The Official Veterinarians conduct systematic sampling of a representative single aliquot for bacteriological examination. The muscle sample must weigh no less than 300 grams, and it is recommended to take a 10 cm^3 (10x10x10cm) piece of meat from a deep portion of skeletal muscle (e.g., forearm). The samples are then sent to official laboratories and subjected, at least, to the following analyses:

i) *Salmonella* spp. (limit: not detectable in 25 g);

ii) *E. coli* beta-glucuronidase positive (limit: <100 cfu/g);

iii) Sulfite-reducing anaerobes (limit: <100 cfu/g).

In cases where specific pathological-anatomical findings are observed by the Official Veterinarians, with lesions attributable to certain pathogenic microorganisms, specific requests can be made to the laboratory.

The muscle sample taken for bacteriological examination is also used to conduct a systematic search for antimicrobial residues through traditional microbiological tests.

Since April 2022, a representative sample of approximately 100 g of muscle taken from the neck must be collected, as a single aliquot distinct from the sample intended for bacteriological examination, for every 10 OFES carcasses (at least 10% of the daily processed OFES carcasses). This sample is essential for detecting residues of antimicrobial substances using high-sensitivity chemical methods, specifically the Multi-Class Liquid Chromatography Tandem Mass Spectrometry (LC–MS/MS) technique.

For the purpose of the study, descriptive statistical analysis was focused on identifying the localization of injuries or anatomopathological lesions and documenting the reasons for exclusion (condemnation) based on information recorded in the veterinary electronic register. Each entry data provided specific details regarding the affected organ or carcass part, the type of injury or anatomopathological lesion, and whether the whole or part of the carcass met the inclusion criteria to be considered fir for human consumption.

Carcass and organ exclusions were categorized first by the affected anatomical region (localization) based on information inserted by the OVs, and then by the reason for exclusion (anatomopathological findings). **Table 3** presents the categories used in this study, along with the criteria used for grouping them, which include key findings such as inflammatory disorders, fractures, hematomas, and parasitic or metabolic lesions.

Table 3 - List of localization and reasons for exclusion for carcasses, including the corresponding inclusion criteria

Localization	**Reasons for exclusion**	**Inclusion criteria based on motivation reported in the Veterinary Certificate**
Legs and joints		
	Hematoma	
	Inflammatory disorders	Cases of phlegmons, abscesses
	Generic trauma	
	Fracture	
Multiorgan		
	Multiorgan impairment	Multiple organs excluded due to being affected by one or more diseases
Liver and hepatic lymph nodes		
	Circulatory and metabolic disorders	Cases of steatosis, telangiectasia, jaundice
	Inflammatory disorders	Cases of hepatitis, hepatic adhesions
	Abscess or phlegmon	
	Parasitic lesions	
	Other	Cases of neoplastic lesions, contaminations and issues during slaughtering
Lower respiratory system		
	Inflammatory disorders	Cases of pneumonias, bronchitis, tracheitis, pleuritis
	Circulatory and metabolic disorders	Cases of telangiectasia, emphysema
	Parasitic lesions	
	Other	Cases of contaminations
Half or whole carcass		
	Hematoma	
	Circulatory and metabolic disorders	Cases of jaundice, pressure ulcers, organoleptic changes, hypostases
	Inflammatory disorders	Cases of abscesses, phlegmons, peritonitis, necrosis
	Other	Cases of decomposing carcasses, generic trauma
Heart and pericardium		
	Inflammatory disorders	Cases of pericarditis, endocarditis
	Circulatory and metabolic disorders	Cases of myxomatous mitral valve diseases
	Parasitic lesions	
Spleen/Kidneys		
	Inflammatory disorders	Cases of renal cysts, splenitis, nephritis
	Circulatory and metabolic disorders	Cases of nephrosis
Gastro-intestinal system and peritoneum		
	Inflammatory disorders	Cases of peritonitis, reticulitis, enteritis
Head and oral cavity		

	Inflammatory disorders	Cases of Abscesses
	Other	Cases of contaminations, neoplastic lesions
Integumentary system and mammary gland		
	Hematoma	
	Inflammatory disorders	Cases of abscesses
Empty or illegible		

The final analysis focused on carcass condemnations and the reasons for the exclusion of the whole or part of the carcass. Data from the veterinary electronic register were aggregated and examined to determine the frequency of exclusions, along with their localization and reason, considering variables such as year, production system, animal category, and OFES classification performed in the first part of the study.

RESULTS

3.1Description of motivations for On-Farm Emergency Slaughter collected during the ante-mortem inspections

For the purpose of the study, a total of 12,052 OFES cases in cattle delivered to 20 slaughterhouses under the jurisdiction of the Local Competent Authority of Brescia were available.

The number of OFES cases is shown in **Figure 3**Errore. L'origine riferimento non è stata trovata.: in 2021, there were 4,847 cases; in 2022, 3,838 (1,009 fewer cases); and in 2023, 3,367 (1,480 fewer cases compared to 2021).

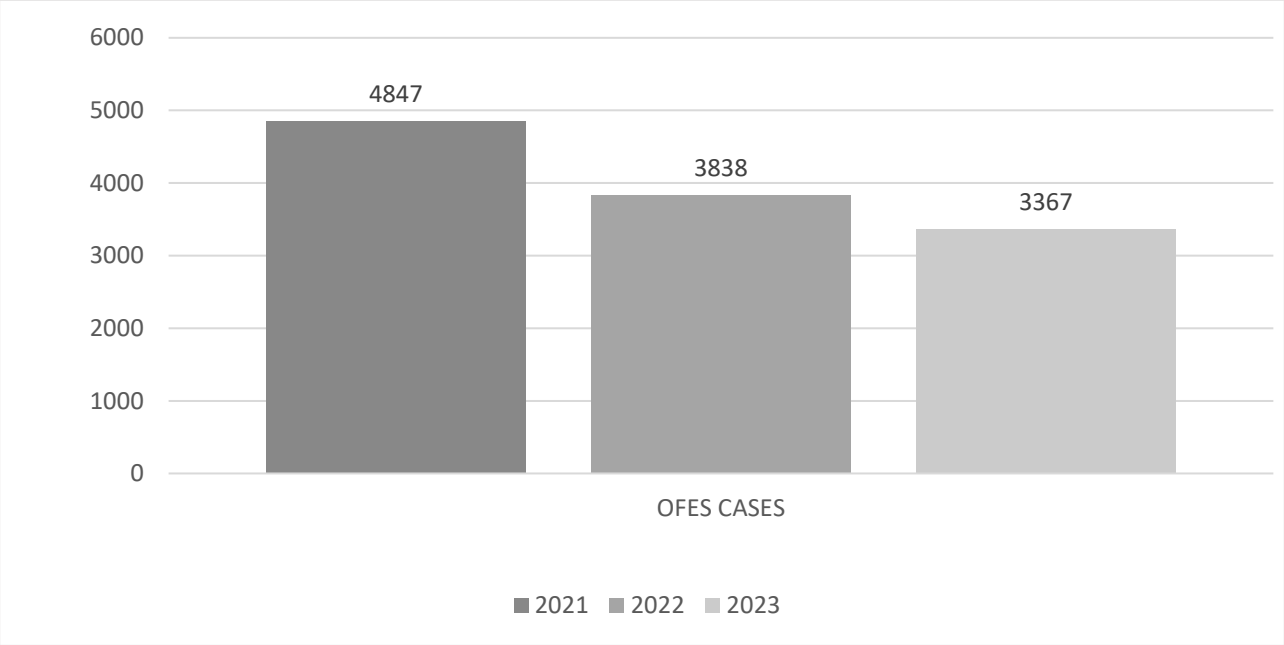


Figure 3 – Distribution of OFES cases among 2021, 2022 and 2023 within the slaughterhouses under the jurisdiction of the Local Competent Authority of Brescia.

Out of all cases were collected in 20 different slaughterhouses located in the province of Brescia, accounting for the 100% of the OFES records in each respective slaughterhouse in 2021-2023. Out of these 20 slaughterhouses, only 5 slaughterhouses accounted more than 98% of all OFES cases throughout the 3 years.

Table 4 shows the distribution of OFES cases among each slaughterhouse, per year and in total.

Table 4 – Distribution of OFES cases (%) among 20 slaughterhouses considered in this study during years 2021-2023.

Slaughterhouse	OFES 2021	OFES 2022	OFES 2023	OFES Total
1	3,250 (67.1%)	2,411 (62.8%)	2,119 (62.9%)	7,780 (64.6%)
2	941 (19.4%)	835 (21.8%)	749 (22.2%)	2,525 (21.0%)
3	386 (8.0%)	320 (8.3%)	272 (8.1%)	978 (8.1%)
4	107 (2.2%)	107 (2.8%)	107 (3.2%)	321 (2.7%)
5	107 (2.2%)	93 (2.4%)	74 (2.2%)	274 (2.3%)
6	25 (0.5%)	36 (0.9%)	19 (0.6%)	80 (0.7%)
7	26 (0.5%)	24 (0.6%)	16 (0.5%)	66 (0.5%)
8	0	3 (0.1%)	2 (0.1%)	5 (0.0%)
9	4 (0.1%)	0	0	4 (0.0%)
10	0	2 (0.1%)	1 (0.0%)	3 (0.0%)
11	0	0	3 (0.1%)	3 (0.0%)
12	0	1 (0.0%)	2 (0.1%)	3 (0.0%)
13	1 (0.0%)	1 (0.0%)	0	2 (0.0%)
14	0	2 (0.1%)	0	2 (0.0%)
15	0	1 (0.0%)	0	1 (0.0%)
16	0	0	1 (0.0%)	1 (0.0%)
17	0	0	1 (0.0%)	1 (0.0%)
18	0	1 (0.0%)	0	1 (0.0%)
19	0	1 (0.0%)	0	1 (0.0%)
20	0	0	1 (0.0%)	1 (0.0%)
Total	4,847 (100%)	3,838 (100%)	3,367 (100%)	12,052 (100.0%)

As shown in **Figure 4**, in 2021, OFES cases occurred especially in March (470), August (468) and September (529); in 2022 especially in January (361), July (360) and August (383); in 2023, especially in June (310), August (327) and November (332); showing a higher prevalence during warm or hot months but not exclusive to them.

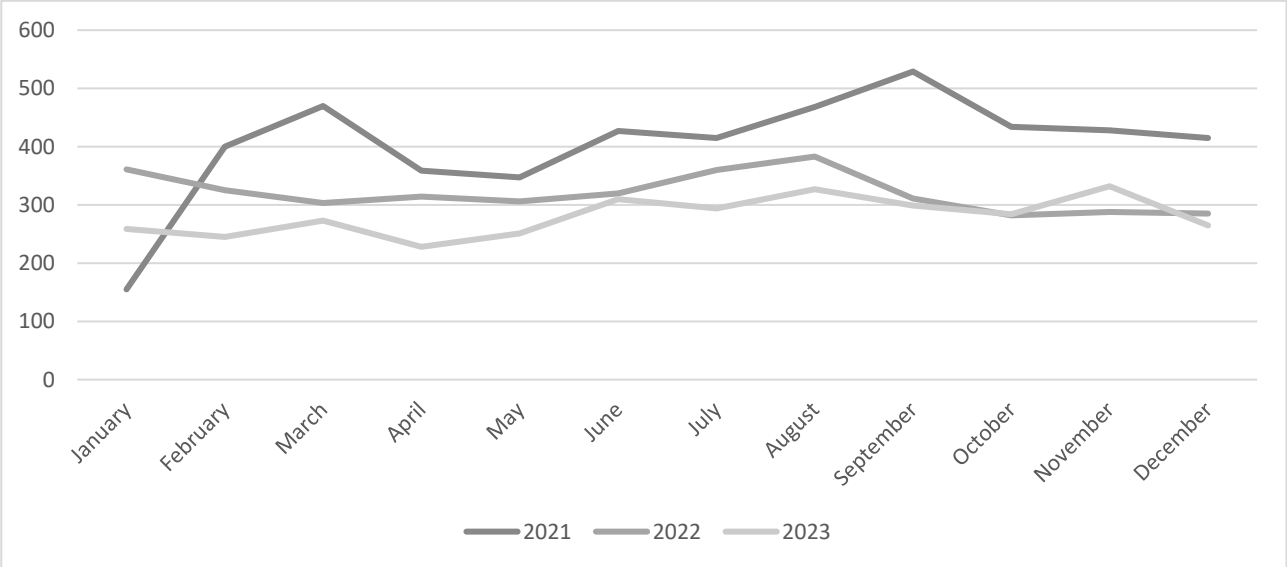


Figure 4 - Distribution of OFES cases throughout months during years 2021-2023, within the jurisdiction of the Local Competent Authority of Brescia.

Regarding days of the week (see **Figure 5**), OFES cases were always more frequent on Mondays in all years (848 on average), followed by Tuesdays (720 on average) and Fridays (716 on average). Saturdays (434 on average) and of course Sundays (4 on average) were the days with fewer OFES cases.

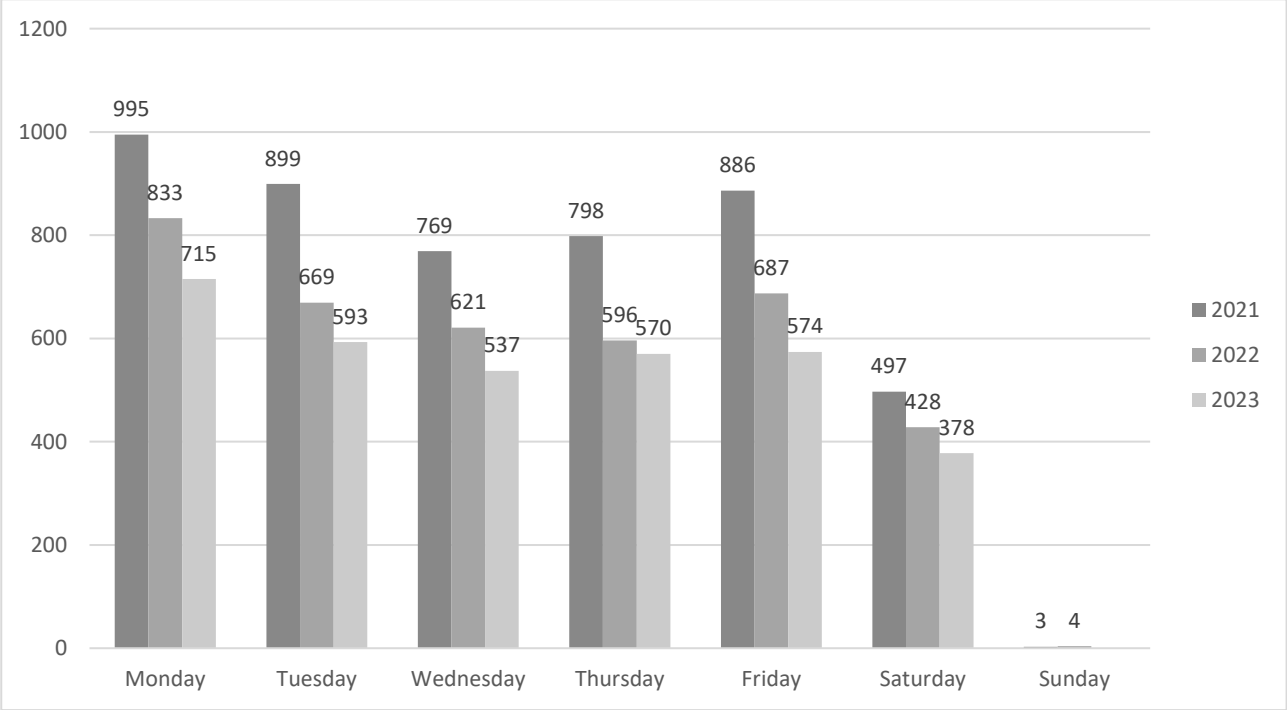


Figure 5 - Distribution of OFES cases throughout day of the week during years 2021-2023, within the jurisdiction of the Local Competent Authority of Brescia.

All OFES cases were attributed to 1,858 different farms (min = 1; Q1 = 1; median = 3; Q3 = 8; max = 93), located in 15 provinces across 4 regions in Northern Italy. The provinces with the highest number of OFES cases were: Brescia (961 farms; 7,200 OFES cases); Mantua (433 farms; 2,344 OFES cases); Cremona (142 farms; 1,186 OFES cases); Verona (120 farms; 632 OFES cases), as shown in **Table 5**.

Focusing on these 4 provinces (see **Table 6**), there was a significant decline in both the number of farms delivering OFES cases to the slaughterhouses of Brescia and the number of OFES cases delivered. In particular, the decline in the number of farms ranged from -18.5% for Verona to -23.8% for Cremona, while the decrease in OFES cases delivered varied from -27.8% for Brescia to -33.3% for Cremona.

In **Table 7**, the consistency of cattle farms in these 4 provinces is reported, according to the Italian National Livestock Registry - Statistics section. Considering the variations in the number of

farms over the three years, the farms that delivered at least one OFES case to one of the 20 slaughterhouses of the LCA of Brescia represented 17.5% in 2021 and 14.5% in 2023 for the province of Brescia; 8.2% in 2021 and 6.5% in 2023 for the province of Cremona; 17.1% in 2021 and 14.5% in 2023 for the province of Mantua; and 3.2% in 2021 and 3.7% in 2023 for the province of Verona. However, it should be noticed that the decline in the number of farms and cattle population does not show a similar trend to that of the decline in the farms that delivered OFES cases and the OFES cases delivered to slaughterhouses in Brescia.

Table 5 – Distribution of OFES cases among Regions, Provinces and Farms involved in the study.

Italian Regions	Italian Provinces	No farms	No OFES	Average No OFES per farm
Lombardy	Bergamo	96	369	3.8
	Brescia	961	7200	7.5
	Cremona	142	1186	8.4
	Lodi	2	2	1.0
	Milano	8	16	2.0
	Mantua	433	2344	5.4
Emilia Romagna	Modena	1	1	1.0
	Parma	9	54	6.0
	Reggio Emilia	6	6	1.0
Trentino-Alto Adige	Trento	1	1	1.0
Veneto	Padova	23	57	2.5
	Rovigo	1	1	1.0
	Treviso	1	1	1.0
	Vicenza	54	182	3.4
	Verona	120	632	5.3
Total		**1,858**	**12,052**	**6.5**

Table 6 - Distributions of farms and OFES cases over the three years for the Italian provinces involved in the study. Provinces with fewer than 100 farms delivering at least one OFES case were merged under the "Other Provinces" category. Percentage variations from 2021 are indicated in brackets.

Italian Provinces	No farms with at least 1 OFES case				No OFES		
	2021	**2022**	**2023**		**2021**	**2022**	**2023**
Brescia	728	626 (-14.0%)	588 (-19.2%)		2846	2299 (-19.2%)	2055 (-27.8%)
Cremona	101	91 (-9.9%)	77 (-23.8%)		489	371 (-24.1%)	326 (-33.3%)
Mantua	300	239 (-20.3%)	235 (-21.7%)		937	752 (-19.7%)	655 (-30.1%)
Verona	81	70 (-13.6%)	66 (-18.5%)		242	216 (-10.7%)	174 (-28.1%)
Other provinces	141	91 (-35.5%)	74 (-47.5%)		333	200 (-39.9%)	157 (-52.9%)

Table 7 - Total number of cattle farms and cattle population among the three years for the four Italian provinces with more than 100 farms delivering at least one OFES case in this study. Percentages variations from 2021 are indicated in brackets.

Italian Provinces	Total No cattle farms[a]				Total cattle population[a]		
	2021	2022	2023		2021	2022	2023
Brescia	4,163	4,154 (-0.2%)	4,049 (-2.7%)		470,312	460,079 (-2.2%)	455,686 (-3.1%)
Cremona	1,227	1,221 (-0.5%)	1,189 (-3.1%)		312,730	309,827 (-0.9%)	309,781 (-0.9%)
Mantua	1,751	1,716 (-2.0%)	1,616 (-7.7%)		334,315	330,884 (-1.0%)	325,601 (-2.6%)
Verona	2,557	2,112 (-17.4%)	1,808 (-29.3%)		208,855	201,878 (-3.3%)	198,550 (-4.9%)

Data sources: [a] Italian National Livestock Registry – Statistics section. https://www.vetinfo.it/j6_statistiche/#/report-pbi/1 (accessed 25 October 2024)

Regarding the classification based on the farm production system, as shown in **Table 8** and **Figure 6,** OFES cases were 9,514 (78.9%) from dairy farms; 1,497 (12.4%) from mixed farms and 1,041 (8.6%) from beef farms. Distributions over the 3 years, in percentages within each production system, were similar for OFES cases from the dairy and mixed farms, having 40.2% and 43.0%, respectively, of all cases occurring in 2021; in 2022: 31.6% and 31.3%; and in 2023: 28.2% and 25.7%, respectively. OFES cases from the beef farms, instead, showed a more gradual decline over the years: in 2021 were 383 (36.8%); in 2022 were 362 (34.8%); in 2023 were 296 (28.4%).

Table 8 - Distribution of OFES cases, involved in the study, according to production system, sex and age categories (animal type), throughout 2021, 2022 and 2023.

VARIABLE	OFES 2021	OFES 2022	OFES 2023	OFES Total
PRODUCTION SYSTEM				
DAIRY	3821 (40.2%)	3007 (31.6%)	2686 (28.2%)	9,514 (100.0%)
MIXED	643 (43.0%)	469 (31.3%)	385 (25.7%)	1497 (100.0%)
BEEF	383 (36.8%)	362 (34.8%)	296 (28.4%)	1,041 (100.0%)
SEX				
MALE	266 (38.4%)	250 (36.1%)	177 (25.5%)	693 (100.0%)
FEMALE	4,581 (40.3%)	3,588 (31.6%)	3,190 (28.1%)	11,359 (100.0%)
ANIMAL TYPE				
MALE CALF	3 (30.0%)	4 (40.0%)	3 (30.0%)	10 (100.0%)
BULL CALF	244 (38.1%)	229 (35.7%)	168 (26.2%)	641 (100.0%)
YOUNG BULL	18 (47.4%)	14 (36.8%)	6 (15.8%)	38 (100.0%)
OLD BULL	1 (25.0%)	3 (75.0%)	0 (0.0%)	4 (100.0%)
FEMALE CALF	10 (71.4%)	0 (0.0%)	4 (28.6%)	14 (100.0%)
HEIFER	557 (37.2%)	500 (33.4%)	442 (29.5%)	1499 (100.0%)
YOUNG COW	1787 (39.2%)	1451 (31.8%)	1324 (29.0%)	4562 (100.0%)
OLD COW	2227 (42.1%)	1637 (31%)	1420 (26.9%)	5284 (100.0%)
Total	4847	3838	3367	12052

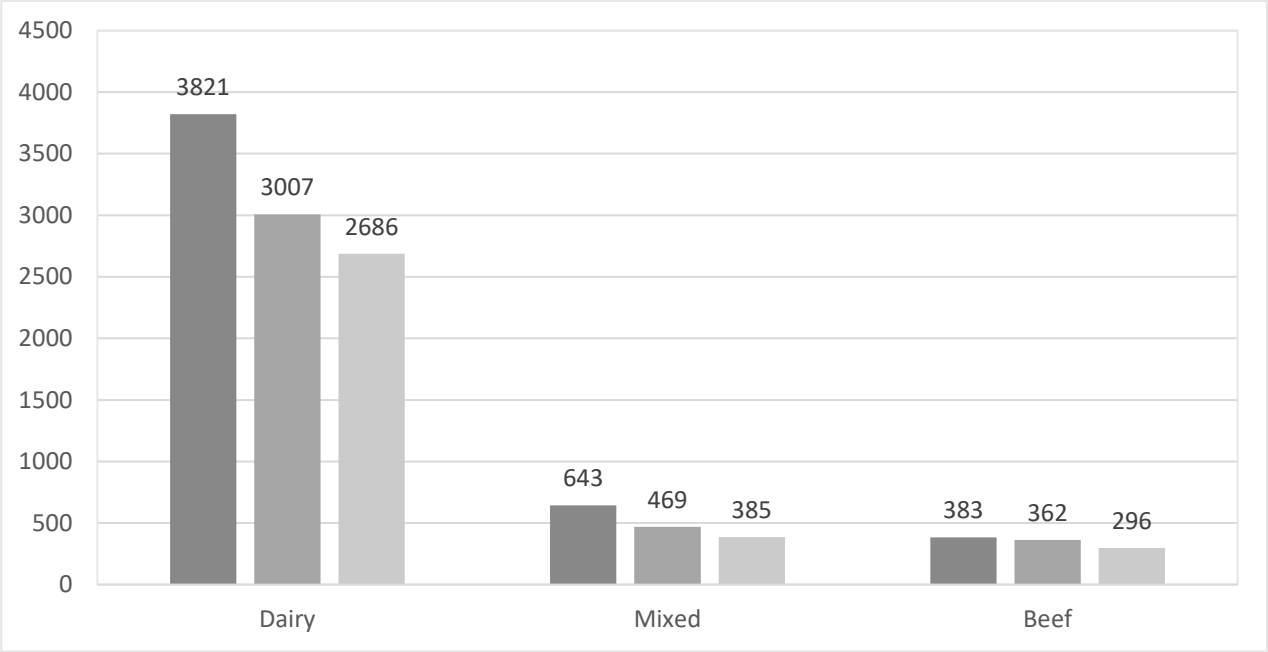


Figure 6 - Distribution of OFES cases, involved in the study, according to the production system.

In total, 11,359 (94.5%) OFES cases were female and only 693 (5.8%) were male, as shown in **Figure 7**. Errore. L'origine riferimento non è stata trovata.OFES cases involving female cattle were 4,581 (40.3%) in 2021, 3,588 (31.6%) in 2022, in 3,190 (28.1%) in 2023; those involving male cattle were 266 (38.4%) in 2021; 250 (36.1%) in 2022 and 177 (25.5%) in 2023. Out of 693 males, 641 (92.4%) were bull calf, while out of 11,359 females, 1499 (13.2%) were heifers, 4562 (40,2%) were young cows and 5284 (46.5%) were old cows. These findings are available in **Table 8.**

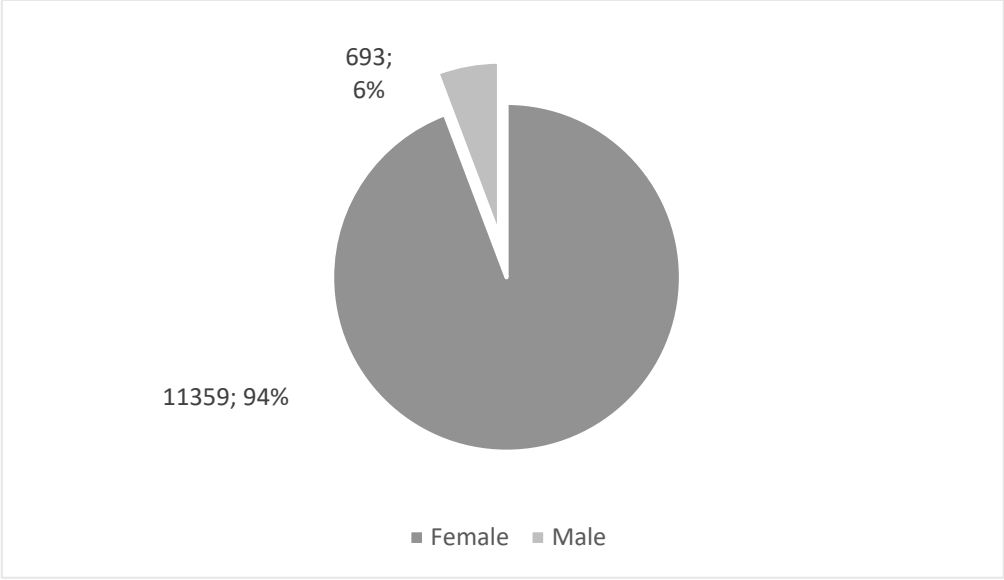


Figure 7 - Distribution of OFES cases, involved in the study, according to sex.

Distribution among age categories throughout the 3 years are available in **Figure 8**: all the categories kept to be well represented in each year, except for old bull that were absent in 2023 and female calf that were absent in 2022.

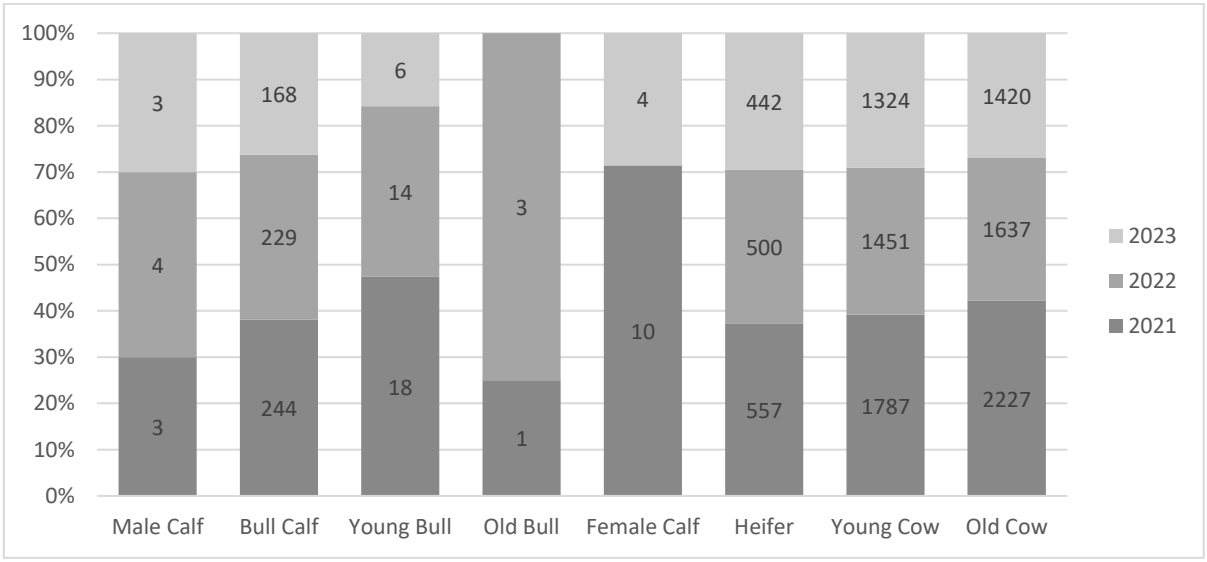


Figure 8 – Distribution of OFES cases according to age categories among years.

In terms of production system (see **Table 9** and **Figure 9**), 78.6% of OFES cases involving male animals were associated with the beef production system.

Specifically, 100% of male calves and 79.4% of bull calves involved in the study came from beef farms. Young bulls originated mainly from beef farms (65.8%), with 26.3% coming from dairy farms. In contrast, older bulls were primarily associated with dairy farms, accounting for 75.0% of cases. Conversely, 83.3% of OFES cases in female animals were linked to the dairy production system. Both young cows and old cows predominantly came from dairy farms (87.2% and 87.3%, respectively), while 57.9% of heifers were from dairy farms and 25.6% from beef farms.

Table 9 - Distribution of OFES cases, involved in the study, according to sex and age categories (animal type), among production systems.

	PRODUCTION SYSTEM			ALL
VARIABLE	**DAIRY**	**MIXED**	**BEEF**	**Total**
SEX				
MALE	47 (6.8%)	101 (14.6%)	545 (78.6%)	693 (100.0%)
FEMALE	9467 (83.3%)	1396 (12.3%)	496 (4.4%)	11359 (100.0%)
ANIMAL TYPE				
MALE CALF	0 (0.0%)	0 (0.0%)	10 (100%)	10 (100.0%)
BULL CALF	34 (5.3%)	98 (15.3%)	509 (79.4%)	641 (100.0%)
YOUNG BULL	10 (26.3%)	3 (7.9%)	25 (65.8%)	38 (100.0%)
OLD BULL	3 (75.0%)	0 (0.0%)	1 (25.0%)	4 (100.0%)
FEMALE CALF	9 (64.3%)	3 (21.4%)	2 (14.3%)	14 (100.0%)
HEIFER	868 (57.9%)	247 (16.5%)	384 (25.6%)	1499 (100.0%)
YOUNG COW	3976 (87.2%)	533 (11.7%)	53 (1.2%)	4562 (100.0%)
OLD COW	4614 (87.3%)	613 (11.6%)	57 (1.1%)	5284 (100.0%)
Total	4847 (100%)	3838 (100%)	3367 (100%)	12052 (100.0%)

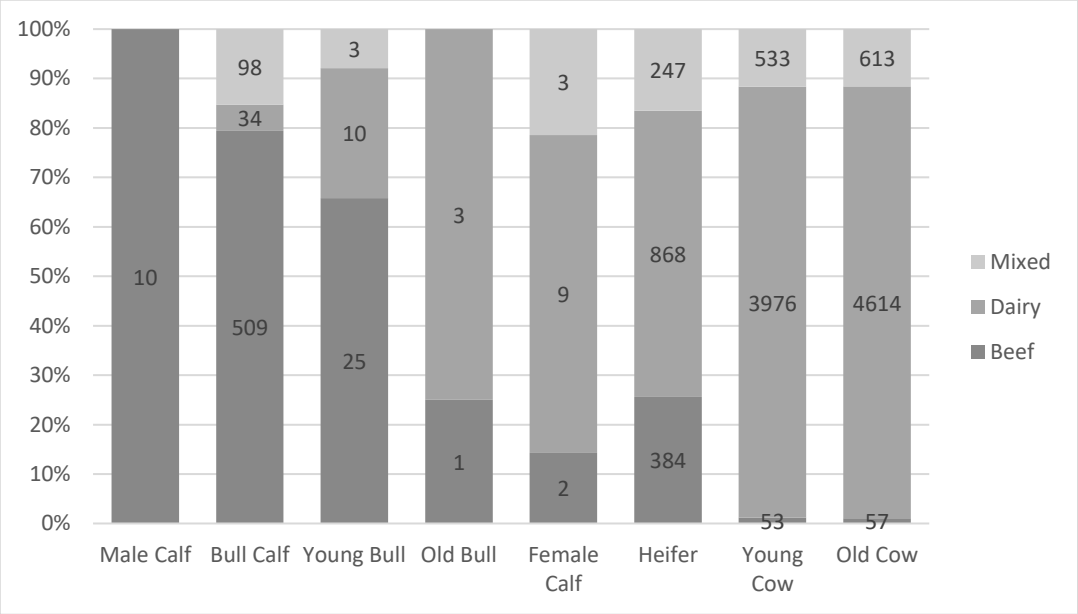


Figure 9 - Distribution of OFES cases according to age categories among production system.

Regarding the manual interpretation of OFES motivations from free-text data, the analysis of the entire 2021-2023 period revealed that the reasons for OFES were categorized as follows: “Locomotion” in 8,362 cases (69.4%), “Recumbency” in 1,597 cases (13.3%), “Calving-related problems” in 1,252 cases (10.4%), and “Other” in 841 cases (7.0%).

Figure 10 shows the yearly distribution of these categories. “Locomotion” issues remained relatively stable in terms of numbers over the three years, but not in percentages: in 2021, there were 2,816 cases (58.1%), in 2022, there were 2,889 cases (75.3%), and in 2023, 2,657 cases (78.9%).

"Recumbency" cases showed a decline, with 941 cases in 2021 (19.4%), 380 cases in 2022 (9.9%), and 276 cases in 2023 (8.2%). "Calving-related problems" also decreased, with 659 cases in 2021 (13.6%), 290 cases in 2022 (7.6%), and 303 cases in 2023 (9.0%). The "Other" category saw a significant reduction from 2022 onwards, with 431 cases in 2021 (8.9%), 279 cases in 2022 (7.3%), and 131 cases in 2023 (3.9%).

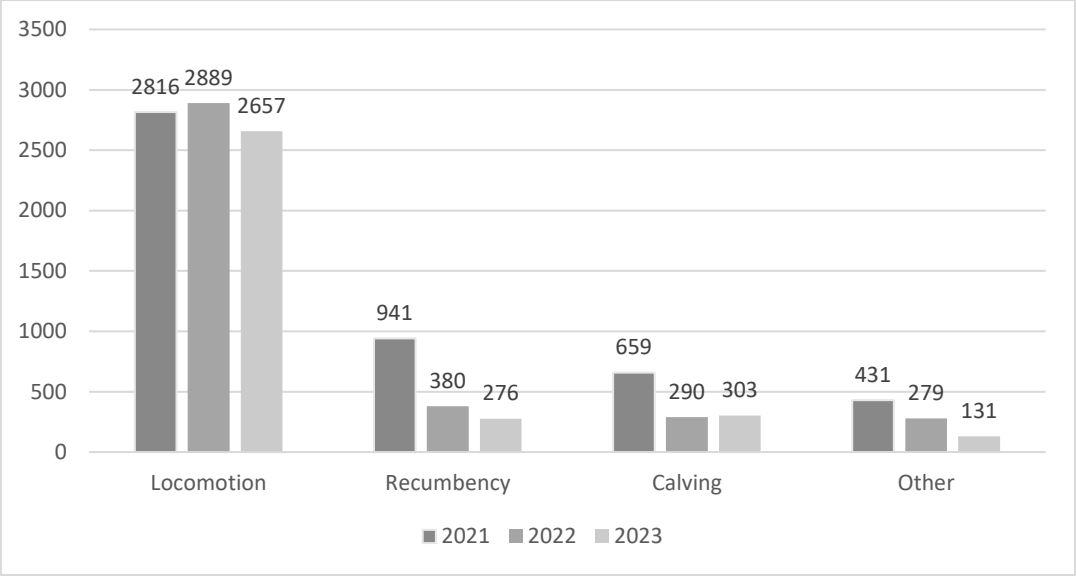


Figure 10 – Distribution of OFES categories among years

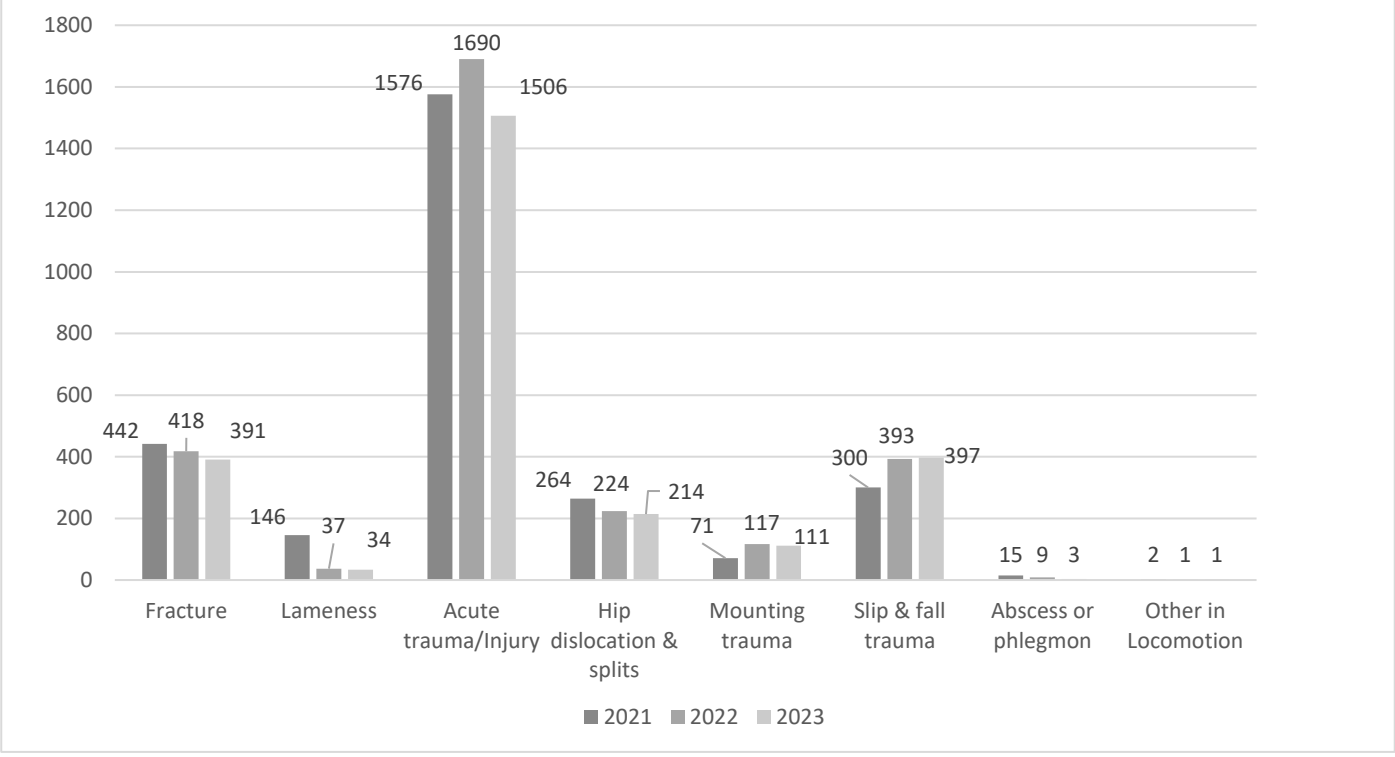


Figure 11 - Distribution of OFES sub-categories, within the "locomotion" category, among years.

The yearly distribution of sub-categories within each category is detailed in the following figures. **Figure 11** highlights the distribution of sub-categories under the "Locomotion" category. The most common sub-category is "Acute trauma or injury," representing 1,576 cases (55.9%) in 2021, 1,690 cases (58.5%) in 2022, and 1,506 cases (56.7%) in 2023. "Fracture" ranks as the second most frequent sub-category, with 442 cases (15.7%) in 2021, 418 cases (14.5%) in 2022, and 391 cases (14.7%) in 2023. The sub-categories "Hip dislocation and splits" and "Slip and fall trauma" show similar distributions, with 264 cases (9.4%) in 2021, 224 (7.8%) in 2022, and 214 (8.1%) in 2023 for the former, and 300 cases (10.7%) in 2021, 393 (13.6%) in 2022, and 397 (14.9%) in 2023 for the latter. The subcategory "Lameness" accounted for 146 cases (5.2%) in 2021, 37 (1.3%) in 2022 and 34 (1.3%) in 2023

Figure 12 presents the distribution of sub-categories under the "Recumbency" category. The most frequent sub-category was "Palsy/paralysis" with 482 cases (51.2%) in 2021, decreasing to 252 in 2022 (even if equal to 66.3% out of all the year) and 219 (again equal to 79.3%) in 2023. "Unable to stand" and "Metabolic syndrome" were higher in 2021, with 335 cases (35.6%) and 124 cases (13.2%) respectively, declining in subsequent years to 118 (31.1%) and 10 (2.6%) in 2022, and 54 (19.6%) and 3 (1.1%) in 2023, respectively.

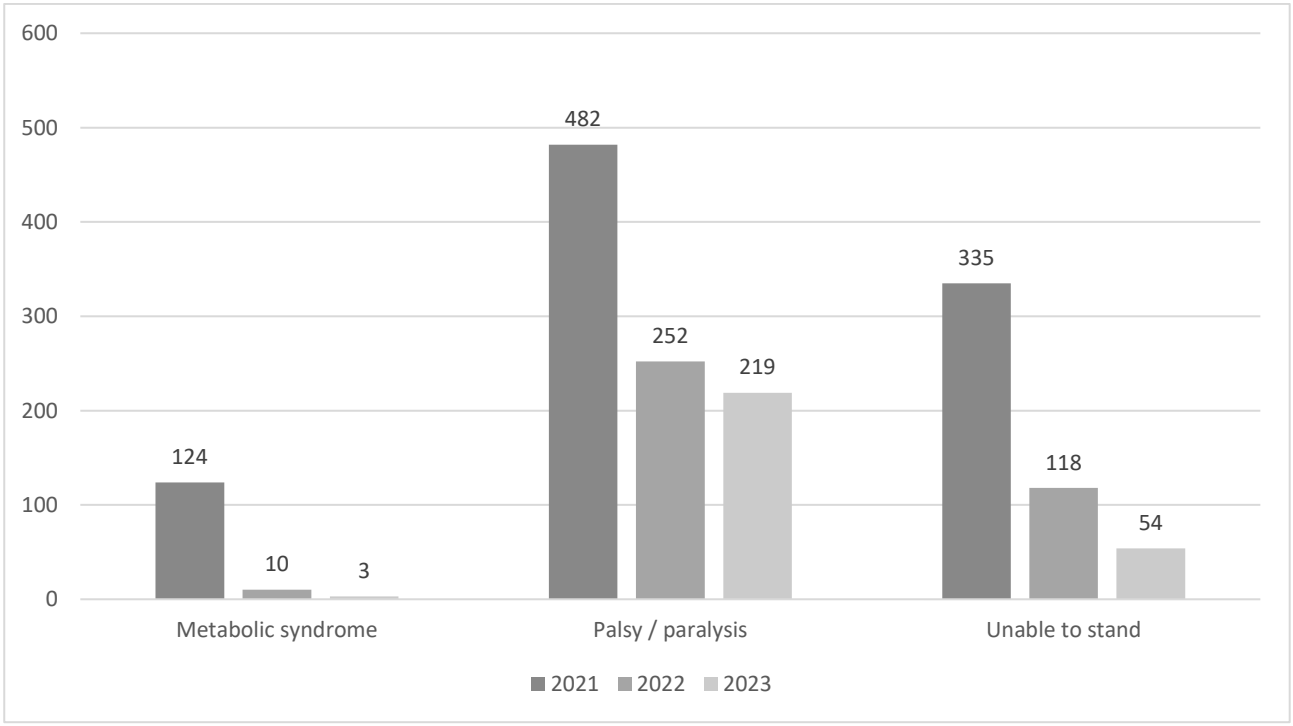


Figure 12 - Distribution of OFES sub-categories, within the "recumbency" category, among years.

Figure 13 illustrates the distribution of sub-categories within the "Calving-related problems" category over the years. The most prevalent sub-category is "Traumatic injuries related to calving", accounting for 228 cases (34.6%) in 2021, 186 cases (64.1%) in 2022, and 241 cases (79.5%) in 2023. Following this, "Palsy/paralysis after calving" is the second most common sub-category, with 165 cases (25.0%) in 2021, dropping to 34 (11.7%) in 2022 and just 7 (2.3%) in 2023. The sub-categories "Metabolic syndrome after calving" and "Dystocia" also appear, with the former having 143 cases (21.7%) in 2021, 20 (6.9%) in 2022, and 1 (0.3%) in 2023, while the latter reported 85 cases (12.9%) in 2021, 40 (13.8%) in 2022, and 37 (12.2%) in 2023.

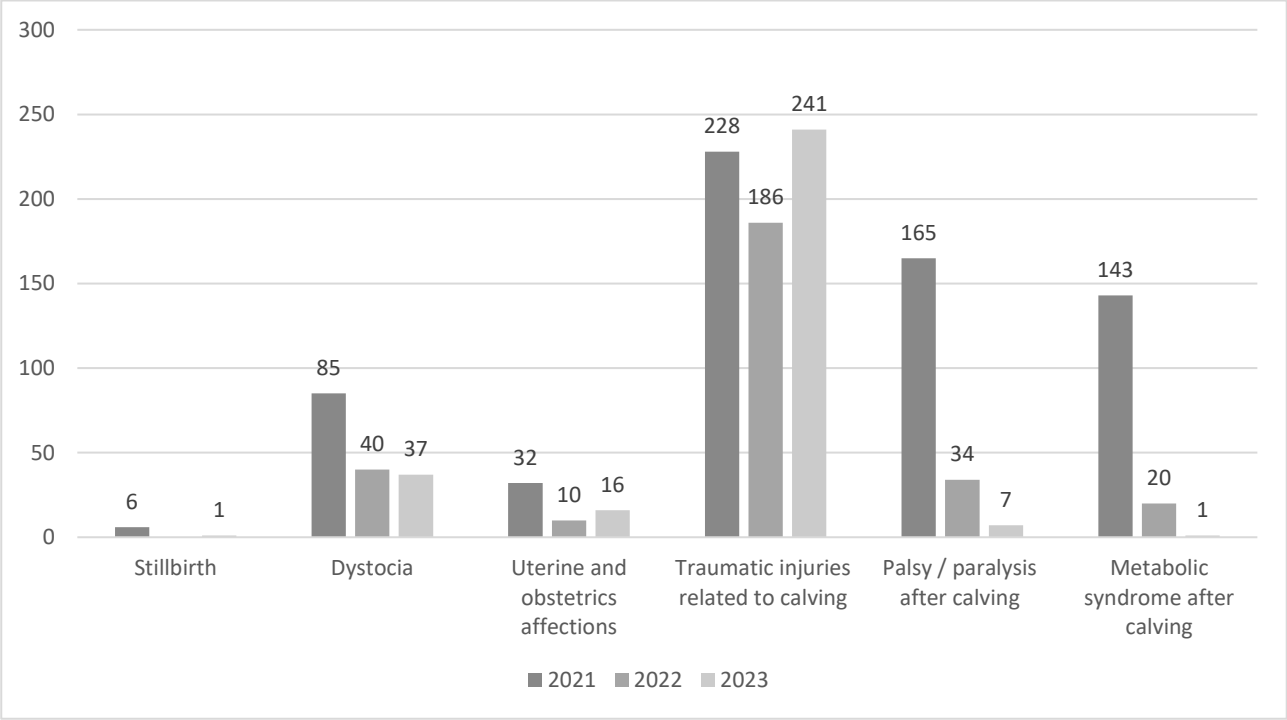


Figure 13 - Distribution of OFES sub-categories, within the "calving-related problems" category, among years.

Figure 14 presents the distribution of sub-categories under the "Other" category. The most frequently reported sub-category was "Generic trauma" which recorded 102 cases (23.7%) in 2021, 163 (58.4%) in 2022 and 78 (59.5%) in 2023, followed by "Empty or illogical" which peaked in 2021, with 145 cases (33.6%), but decreased in the subsequent years to 77 cases (27.6%) in 2022, and 17 cases (13.0%) in 2023.

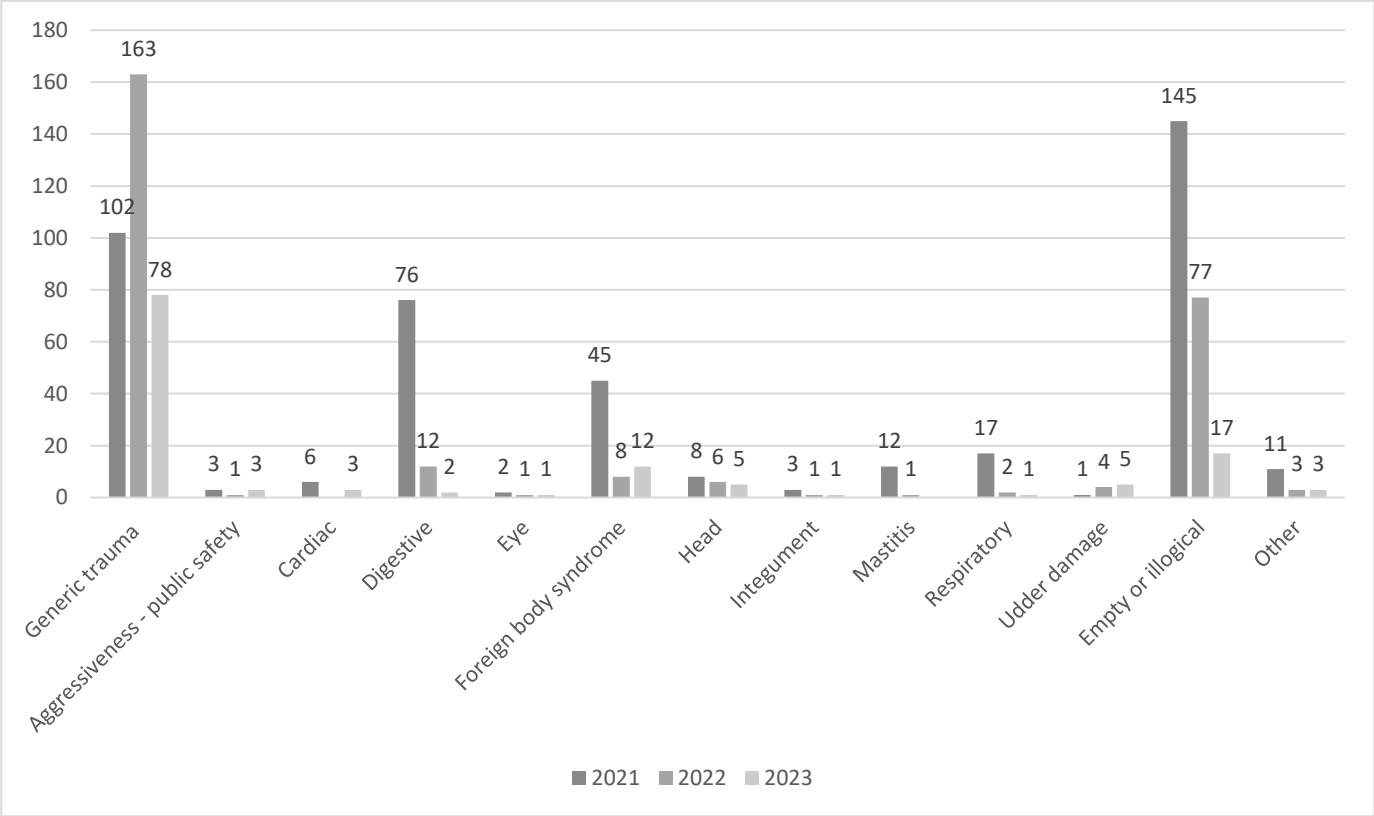


Figure 14 - Distribution of OFES sub-categories, within the "other" category, among years.

In **Table 10** and **Figure 15**, distribution of **categories** (number and percentages) of OFES cases, among each **production system**, such as dairy, mixed and beef, are shown. In all production systems, the "Locomotion" category was the most prevalent, with 6,521 cases (68.5%) in dairy, 1,093 cases (73.0%) in mixed, and 748 cases (71.9%) in beef production systems. "Recumbency" and "Calving-related problems" accounted for 1,333 cases (14.0%) and 1,013 cases (10.6%) in dairy systems. They accounted for 156 and 155 cases (10.4% each) in mixed systems, and 108 cases (10.4%) and 84 cases (8.1%) in beef systems. The "Other" category was more frequent, proportionally, in OFES cases from beef farms, with 101 cases (9.7%).

Table 10 - Distribution of Category and Sub-Category motivations for OFES cases (number and percentages) according to each production system.

OFES Category and Sub-Category	Production system			
	Dairy	**Mixed**	**Beef**	**Total**
Locomotion	6521 (68.5%)	1093 (73.0%)	748 (71.9%)	8362 (69.4%)
Fracture	890 (9.4%)	188 (12.6%)	173 (16.6%)	1251 (10.4%)
Lameness	149 (1.6%)	27 (1.8%)	41 (3.9%)	217 (1.8%)
Acute trauma/Injury	3703 (38.9%)	629 (42.0%)	440 (42.3%)	4772 (39.6%)
Hip dislocation & splits	607 (6.4%)	83 (5.5%)	12 (1.2%)	702 (5.8%)
Mounting trauma	232 (2.4%)	35 (2.3%)	32 (3.1%)	299 (2.5%)
Slip & fall trauma	912 (9.6%)	129 (8.6%)	49 (4.7%)	1090 (9.0%)
Abscess or phlegmon	24 (0.3%)	2 (0.1%)	1 (0.1%)	27 (0.2%)
Other in Locomotion	4 (0.0%)	-	-	4 (0%)
Recumbency	1333 (14.0%)	156 (10.4%)	108 (10.4%)	1597 (13.3%)
Unable to stand	396 (4.2%)	59 (3.9%)	52 (5.0%)	507 (4.2%)
Palsy / paralysis	825 (8.7%)	76 (5.1%)	52 (5.0%)	953 (7.9%)
Metabolic syndrome	112 (1.2%)	21 (1.4%)	4 (0.4%)	137 (1.1%)
Calving-related problems	1013 (10.6%)	155 (10.4%)	84 (8.1%)	1252 (10.4%)
Stillbirth	7 (0.1%)	-	-	7 (0.1%)
Dystocia	107 (1.1%)	25 (1.7%)	30 (2.9%)	162 (1.3%)
Uterine and obstetrics affections	38 (0.4%)	8 (0.5%)	12 (1.2%)	58 (0.5%)
Traumatic injuries related to calving	550 (5.8%)	72 (4.8%)	33 (3.2%)	655 (5.4%)
Palsy / paralysis after calving	164 (1.7%)	35 (2.3%)	7 (0.7%)	206 (1.7%)
Metabolic syndrome after calving	147 (1.5%)	15 (1%)	2 (0.2%)	164 (1.4%)
Other	647 (6.8%)	93 (6.2%)	101 (9.7%)	841 (7.0%)
Generic trauma	280 (2.9%)	31 (2.1%)	32 (3.1%)	343 (2.8%)
Aggressiveness - public safety	1 (0%)	2 (0.1%)	4 (0.4%)	7 (0.1%)
Cardiac	7 (0.1%)	1 (0.1%)	1 (0.1%)	9 (0.1%)
Digestive	79 (0.8%)	5 (0.3%)	6 (0.6%)	90 (0.7%)
Eye	2 (0%)	1 (0.1%)	1 (0.1%)	4 (0.0%)
Foreign body syndrome	47 (0.5%)	10 (0.7%)	8 (0.8%)	65 (0.5%)
Head	8 (0.1%)	6 (0.4%)	5 (0.5%)	19 (0.2%)
Integument	4 (0%)	1 (0.1%)	(0%)	5 (0.0%)
Mastitis	13 (0.1%)	(0%)	(0%)	13 (0.1%)
Respiratory	9 (0.1%)	3 (0.2%)	8 (0.8%)	20 (0.2%)
Udder damage	9 (0.1%)	1 (0.1%)	(0%)	10 (0.1%)
Empty or illogical	176 (1.8%)	30 (2.0%)	33 (3.2%)	239 (2.0%)
Other	12 (0.1%)	2 (0.1%)	3 (0.3%)	17 (0.1%)
Total	9514	1497	1041	12052

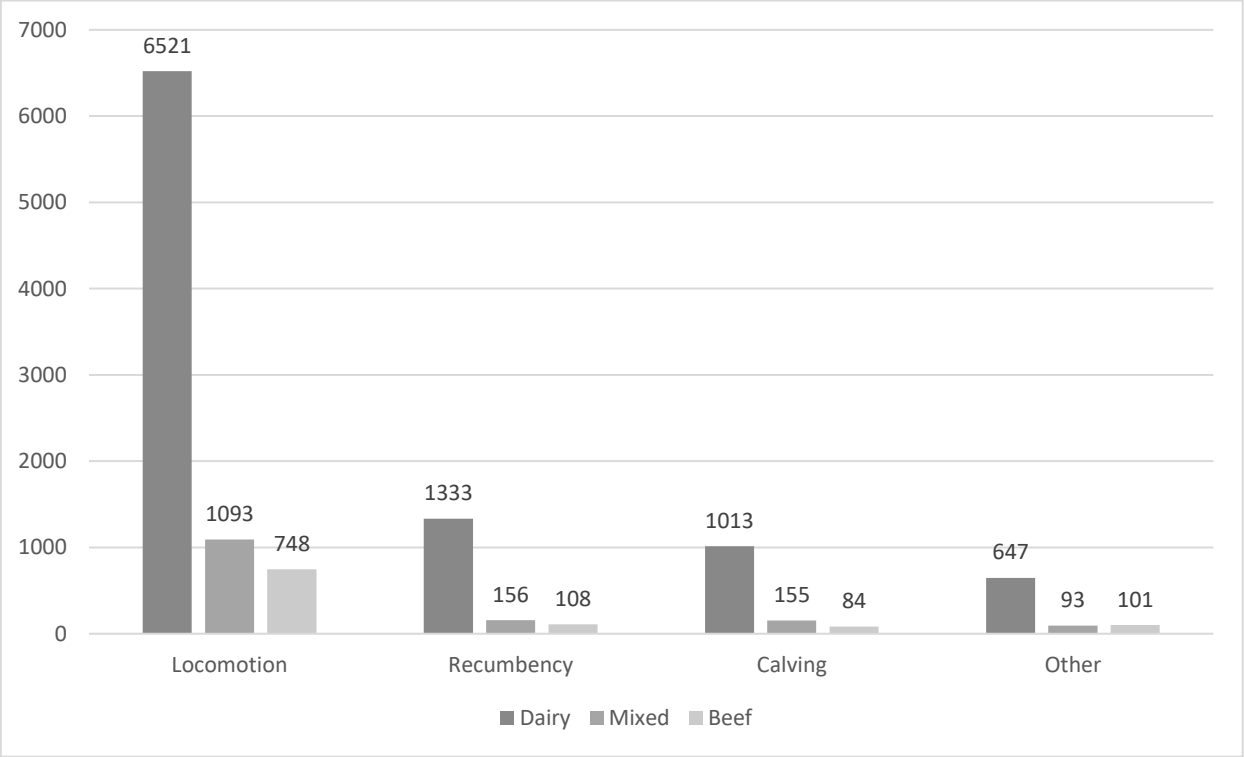


Figure 15 - Distribution of OFES categories among production systems.

The distribution of **sub-categories** among production systems is also shown in **Table 10** and these are the main results. In the "Locomotion" category, "Acute Trauma/Injury" is the most prevalent sub-category, with 3,703 cases (38.9% of all dairy cases) in the dairy system, 629 cases (42.0% of all mixed cases) in the mixed system, 440 cases (42.3% of all beef cases) in the beef system.

The sub-category "Fracture" was proportionally higher in OFES cases from the beef sector, accounting for 16.6% (173 cases), compared to the dairy sector (890 cases, 9.4%) and the mixed sector (188 cases, 12.6%). Similarly, "Lameness" was proportionally higher in the beef sector, with 3.9% (41 cases), compared to the dairy sector with 1.6% (149 cases) and the mixed sector with 1.8% (27 cases).

On the other hand, "Hip dislocation and splits" and "Slip and fall trauma" were proportionally higher in OFES cases from the dairy sector, accounting for 6.4% (607 cases) and 9.6% (912 cases), respectively. In the mixed sector, these conditions accounted for 5.5% (83 cases) and 8.6% (129 cases), while in the beef sector, they were less prevalent, accounting for 1.2% (12 cases) and 4.7% (49 cases), respectively.

In the "Recumbency" category, the "Palsy/paralysis" subcategory was the most prevalent in all production system; in the dairy sector, it accounted for 8.7% (825 cases), followed by 5.1% (76 cases) in the mixed sector and 5.0% (52 cases) in the beef sector.

In the category “Calving-related problems”, “Stillbirth” was recorded only in the dairy sector, accounting for 0.1% (7 cases). “Dystocia” was present across all sectors, accounting for 1.1% (107 cases) in dairy, 1.7% (25 cases) in mixed, and 2.9% (30 cases) in beef. “Uterine and obstetric affections” accounted for 0.4% (38 cases) in dairy, 0.5% (8 cases) in mixed, and 1.2% (12 cases) in beef. “Traumatic injuries related to calving” were most prevalent in the dairy sector, accounting for 5.8% (550 cases), followed by 4.8% (72 cases) in mixed and 3.2% (33 cases) in beef. “Palsy/paralysis after calving” accounted for 1.7% (164 cases) in dairy, 2.3% (35 cases) in mixed, and 0.7% (7 cases) in beef. Lastly, “Metabolic syndrome after calving” was recorded at 1.5% (147 cases) in dairy, 1.0% (15 cases) in mixed, and 0.2% (2 cases) in beef.

In the “Other” category, “Generic trauma” was more prevalent in the dairy sector, accounting for 2.9% (280 cases), followed by 2.1% (31 cases) in the mixed sector and 3.1% (32 cases) in the beef sector. “Aggressiveness – public safety” was rare, with 1 case (0.0%) in the dairy sector, 2 cases (0.1%) in the mixed sector, and 4 cases (0.4%) in the beef sector. “Cardiac” issues were recorded at 0.1% in all sectors, with 7 cases in dairy, 1 case in mixed, and 1 case in beef. “Digestive problems” were reported in 0.8% (79 cases) of dairy cases, 0.3% (5 cases) in mixed, and 0.6% (6 cases) in beef. “Eye problems” were uncommon, with 2 cases (0.0%) in dairy and 1 case (0.1%) in both the mixed and beef sectors. “Foreign body syndrome” was noted in 0.5% (47 cases) of dairy cases, 0.7% (10 cases) in mixed, and 0.8% (8 cases) in beef. “Head trauma” accounted for 0.1% (8 cases) in dairy, 0.4% (6 cases) in mixed, and 0.5% (5 cases) in beef. “Integument” sub-category was rare, with 4 cases (0.0%) in dairy, 1 case (0.1%) in mixed, and no cases in beef. “Mastitis” was recorded only in the dairy sector, accounting for 0.1% (13 cases). “Respiratory” issues accounted for 0.1% (9 cases) in dairy, 0.2% (3 cases) in mixed, and 0.8% (8 cases) in beef. “Udder damage” was reported in 0.1% (9 cases) of dairy cases and 1 case (0.1%) in mixed, with no cases in beef. The “Empty or illogical” sub-category accounted for 1.8% (176 cases) in dairy, 2.0% (30 cases) in mixed, and 3.2% (33 cases) in beef. Finally, the “Other” sub-category accounted for 0.1% (12 cases) in dairy, 0.1% (2 cases) in mixed, and 0.3% (3 cases) in beef.

In **Table 11** and **Table 12**, distribution of categories and sub-categories (numbers) of OFES cases for female and male animals, respectively, from **dairy production system**, are shown. Percentages for OFES categories in females from the dairy sector are shown in **Figure 16.**

Table 11 - Distribution of Category and Sub-Category motivations for OFES cases (numbers), for the animal type "Heifer", "Young cow", "Old cow", from a dairy production system (n = 9,458), divided by year. "Female calf" were omitted because they accounted for only 9 cases.

OFES Category and Sub-Category	Animal Type (Dairy production system)								
	Heifer			Young cow			Old cow		
	2021	2022	2023	2021	2022	2023	2021	2022	2023
Locomotion	242	228	210	1032	962	969	904	1015	914
Fracture	64	63	60	160	121	132	100	88	94
Lameness	5	1		38	12	11	58	13	9
Acute trauma/Injury	120	123	103	557	561	533	528	611	538
Hip dislocation & splits	19	12	14	128	87	93	79	95	77
Mounting trauma	3	9	8	27	40	49	25	36	35
Slip & fall trauma	30	20	25	117	136	150	107	167	158
Abscess or phlegmon				4	4		7	5	3
Other in Locomotion	1			1	1	1			
Recumbency	39	25	15	248	112	90	478	186	138
Unable to stand	10	5	3	79	26	12	165	67	27
Palsy / paralysis	28	20	11	139	85	78	242	112	110
Metabolic syndrome	1		1	30	1		71	7	1
Calving-related problems	34	14	13	136	90	85	357	143	140
Stillbirth	1			3			2		1
Dystocia	5	4		16	12	5	34	12	19
Uterine and obstetrics affections	3		1	8	5	4	12	2	3
Traumatic injuries related to calving	17	6	12	62	61	75	110	96	111
Palsy / paralysis after calving	5	4		25	9	1	97	17	5
Metabolic syndrome after calving	3			22	3		102	16	1
Other	24	18	6	120	99	33	180	98	61
Generic trauma	7	10	4	33	65	22	35	62	39
Aggressiveness - public safety									1
Cardiac						1	4		2
Digestive	2			20	4		45	6	2
Eye	1								
Foreign body syndrome	1		1	14	1	1	19	3	7
Head	1			4	1		1	1	
Integument		1		1					1
Mastitis				4			8	1	
Respiratory	2			2			5		
Udder damage					3	1	1	1	3
Empty or illogical	10	7		37	24	7	59	23	6
Other			1	5	1	1	3	1	
Total	**339**	**285**	**244**	**1536**	**1263**	**1177**	**1919**	**1442**	**1253**

Table 12 - Distribution of Category and Sub-Category motivations for OFES cases (numbers), for the animal type "Bull Calf", "Young Bull", "Old Bull", from a dairy production system (n = 47), divided by year. "Male calf" and Category "Calving-related problems" were omitted because they accounted for 0 cases.

OFES Category and Sub-Category	Animal Type (Dairy Production system)								
	Bull Calf			Young Bull			Old bull		
	2021	2022	2023	2021	2022	2023	2021	2022	2023
Locomotion	**13**	**11**	**7**	**3**	**2**	**1**	**1**	**1**	**-**
Fracture	1	3	1	1			1		
Lameness	2								
Acute trauma/Injury	9	6	4	1	2	1		1	
Hip dislocation & splits		1	1	1					
Mounting trauma									
Slip & fall trauma		1	1						
Abscess or phlegmon	1								
Other in Locomotion									
Recumbency	**1**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Unable to stand	1								
Palsy / paralysis									
Metabolic syndrome									
Other	**1**	**-**	**1**	**2**	**2**	**-**	**-**	**1**	**-**
Generic trauma			1		1			1	
Aggressiveness - public safety									
Cardiac									
Digestive									
Eye				1					
Foreign body syndrome									
Head									
Integument	1								
Mastitis									
Respiratory									
Udder damage									
Empty or illogical				1	1				
Other									
Total	**15**	**11**	**8**	**5**	**4**	**1**	**1**	**2**	**-**

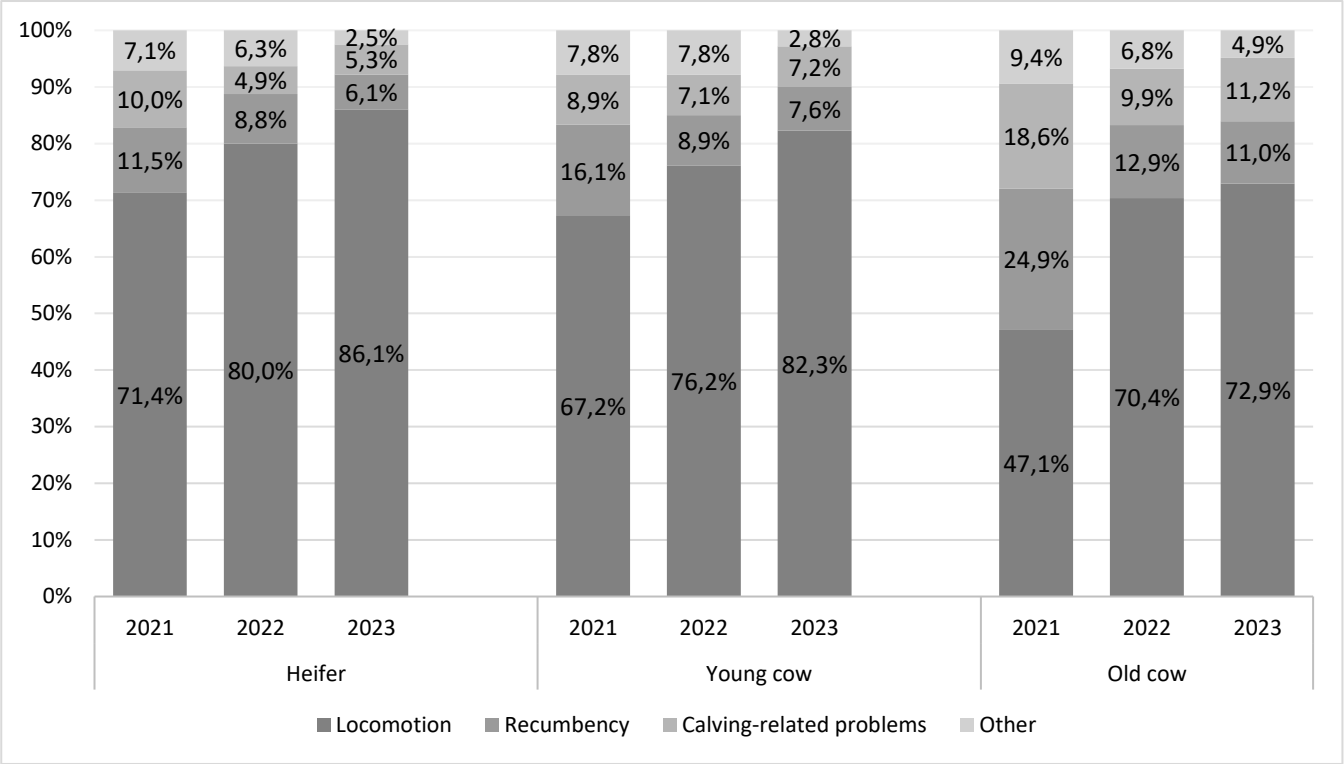


Figure 16 - Distribution of Category motivations for OFES cases (percentages), for the animal type "Heifer", "Young cow", "Old cow", from a dairy production system (n = 9,458), divided by year. "Female calf" were omitted because they accounted for only 9 cases.

In the **"Locomotion" category**, the highest number of cases was consistently found across all years and animal types for females. For heifers, there were 242 cases in 2021 (71.4%), 228 in 2022 (80.0%), and 210 in 2023 (86.1%). In young cows, "Locomotion" accounted for 1,032 cases in 2021 (67.2%), 962 in 2022 (76.2%), and 969 in 2023 (82.3%). Among old cows, this category was also prevalent, with 904 cases in 2021 (47.1%), which increased proportionally in 2022, with 1,015 cases (70.4%), and in 2023, with 914 (72.9%). For males, locomotion cases were found in bull calves, with 13 cases in 2021 (86.7%), 11 cases in 2022 (100%), and 7 cases in 2023 (87.5%). For young bulls, the numbers were smaller, with 3 cases in 2021 (60%), 2 cases in 2022 (50%), and 1 case in 2023 (100%). Among old bulls, there was 1 case recorded in both 2021 and 2022 (100% and 50%, respectively), with no cases in 2023.

In the **"Recumbency" category**, the prevalence for females was higher in old cows during 2021, with 478 cases (24.9%), decreased to 186 in 2022 (12.9%), and 138 in 2023 (11%). For young cows, the numbers were 248 cases in 2021 (16.1%), decreasing significantly to 112 in 2022 (8.9%) and 90 in 2023 (7.6%). In heifers, there were 39 cases in 2021 (11.5%), 25 in 2022 (8.8%), and 15 in 2023 (6.1%). Among males, "Recumbency" was rare, with only 1 case in bull calves in 2021 (6.7%) and no cases in subsequent years or in other animal types.

In terms of **"Calving-related problems"** (in females only), the highest number of cases was found in old cows, with 357 cases in 2021 (18.6%), 143 in 2022 (9.9%), and 140 in 2023 (11.2%). For young cows, the numbers were 136 in 2021 (8.9%), dropping to 90 (7.1%) in 2022 and to 85 (7.2%) in 2023. Among heifers, cases decreased from 34 in 2021 (10%) to 13 in 2023 (5.3%).

In the **"Other" category** for females, there was a general decline in cases across all animal types. For heifers, the number of cases fell from 24 in 2021 (7.1%) to 6 in 2023 (2.5%). In young cows, cases dropped from 120 in 2021 (7.8%) to 33 in 2023 (2.8%). Among old cows, cases decreased from 180 in 2021 (9.4%) to 61 in 2023 (4.9%). For males, "Other" cases were minor. Bull calves had 1 case in both 2021 (6.7%) and 2023 (12.5%). In young bulls, there were 2 cases in 2021 (40%) and 2 cases in 2022 (50%), but none in 2023. Old bulls had 1 case in 2022 (50%) and no cases in other years.

Since female animals and cases from the dairy sector are the most prevalent, the distribution results from **Table 11** reflect the overall trends already described.

However, it should be noticed that within the **"Fracture" sub-category**, heifers had 64 cases in 2021 (18.9%), 63 in 2022 (22.1%), and 60 in 2023 (24.6%). For young cows, there were 160 cases in 2021 (10.4%), decreasing to 121 in 2022 (9.6%) and increasing again to 132 in 2023 (11.2%).

Among old cows, 100 cases were recorded in 2021 (5.2%), with an increase in percentage in 2022 (6.1%, 88 cases) and 2023 (7.5%, 94 cases), even though the overall number of cases decreased.

For males, the "Fracture" sub-category was less frequent, with bull calves showing 1 case in 2021 (6.7%), 3 cases in 2022 (27.3%), and 1 case in 2023 (12.5%). For young bulls, there was only 1 case in 2021 (20%), while old bulls recorded 1 case in 2021 (100%).

In the **"Acute trauma/Injury" subcategory**, heifers had 120 cases in 2021 (35.4%), 123 in 2022 (43.2%), and 103 in 2023 (42.2%). For young cows, there were 557 cases in 2021 (36.3%), 561 in 2022 (44.4%), and 533 in 2023 (45.3%). Among old cows, the numbers were 528 cases in 2021 (27.5%), 611 in 2022 (42.4%), and 538 in 2023 (42.9%). For males, "Acute trauma/Injury" cases were primarily recorded in bull calves, with 9 cases in 2021 (60%), 6 in 2022 (54.5%), and 4 in 2023 (50%). Young bulls had just 1 case in 2021 (20%), 2 cases in 2022 (50%), and 1 case in 2023 (100%). There were no old bull cases in 2021, but 1 case occurred in 2022 (50%).

In young cows and old cows, **"Slip and fall trauma"** increased over the years, from 117 cases (7.6%) in 2021 to 150 cases (12.7%) in 2023 for young cows, and from 107 cases (5.6%) in 2021 to 158 cases (12.6%) in 2023 for old cows.

In "Recumbency", the **"Palsy/paralysis" sub-category** showed significant variation in females. In heifers, cases decreased from 28 in 2021 (8.3%) to 20 in 2022 (7.0%) and 11 in 2023 (4.5%). For young cows, there were 139 cases in 2021 (9.1%), 85 in 2022 (6.7%), and 78 in 2023

(6.6%). Among old cows, 242 cases were recorded in 2021 (12.6%), decreasing to 112 in 2022 (7.8%) and 110 in 2023 (8.8%).

In "Calving-related problems" category, the **"Traumatic injuries related to calving" sub-category** was more prevalent in old cows, with an increase in percentage from 110 cases in 2021 (5.7%), to 96 in 2022 (6.7%), and 111 in 2023 (8.9%). For young cows, cases had similar trend, with 62 in 2021 (4%), 61 in 2022 (4.8%), and 75 in 2023 (6.4%).

The **"Metabolic syndrome after calving"** subcategory was more prominent among old cows, with 102 cases in 2021 (5.3%), but dropping drastically to just 1 case in 2023. In young cows, 22 cases were recorded in 2021 (1.4%), but this number decreased to 0 by 2023. Among heifers, very few cases were reported.

Regarding the category "Other", in the **"Generic trauma"** subcategory, the number of cases remained relatively low across all animal types and years. For heifers, there were 7 cases in 2021 (2.1%), which increased to 10 cases in 2022 (3.5%), before dropping to 4 cases in 2023 (1.6%). In young cows, the trend was less consistent, with 33 cases reported in 2021 (2.1%), rising sharply to 65 cases in 2022 (5.1%), and then falling back to 22 cases in 2023 (1.9%). Among old cows, there were 35 cases in 2021 (1.8%), which increased to 62 cases in 2022 (4.3%), before decreasing to 39 cases in 2023 (3.1%).

In **Table 13** and **Table 14**, distribution of categories and sub-categories (numbers) of OFES cases for female and male animals, respectively, from **mixed production system**, are shown. Here, only the results for the categories are described.

In the **"Locomotion" category,** among heifers, there were 62 cases in both 2021 (65.3%) and 2022 (79.5%), with a slight decrease to 57 cases in 2023 (77%). For young cows, the percentage of cases increased yearly, from 60.5% (135 cases) in 2021 to 88.3% (151 cases) in 2022, and then to 90.6% (126 cases) in 2023. Among old cows, a similar trend is observed: 49.6% (137 cases) were recorded in 2021, increasing significantly to 83.1% (152 cases) in 2022, and then slightly increasing to 83.8% (129 cases) in 2023.

Table 13 - Distribution of Category and Sub-Category motivations for OFES cases (numbers), for the animal type "Heifer", "Young cow", "Old cow", from a mixed production system (n = 1,393), divided by year. "Female calf" were omitted because they accounted for only 3 cases.

OFES Category and Sub-Category	Animal Type (Mixed production system)								
	Heifer			Young cow			Old cow		
	2021	2022	2023	2021	2022	2023	2021	2022	2023
Locomotion	62	62	57	135	151	126	137	152	129
Fracture	15	21	14	23	23	15	15	21	16
Lameness	1		1	6	1	2	11	1	1
Acute trauma/Injury	37	35	36	78	88	71	77	94	68
Hip dislocation & splits	4	3	4	14	10	13	13	11	10
Mounting trauma				3	7	6	3	9	6
Slip & fall trauma	5	3	2	11	22	19	17	16	28
Abscess or phlegmon							1		
Other in Locomotion									
Recumbency	13	4	7	43	6		55	11	2
Unable to stand	6	1		17	1		25	4	1
Palsy / paralysis	6	3	7	19	5		19	5	1
Metabolic syndrome	1			7			11	2	
Calving-related problems	7	5	7	32	9	10	59	9	16
Stillbirth									
Dystocia	4	1	1	2	4	1	10		1
Uterine and obstetrics affections			2	2		1	2		1
Traumatic injuries related to calving	1	4	3	13	3	8	19	7	14
Palsy / paralysis after calving	2		1	11	2		18	1	
Metabolic syndrome after calving				4			10	1	
Other	13	7	3	13	5	3	25	11	7
Generic trauma	5	2		3	3	1	7	4	4
Aggressiveness - public safety			1						
Cardiac							1		
Digestive				1			3	1	
Eye			1						
Foreign body syndrome		2		3			3	1	1
Head			1		1	1	1		
Integument	1								
Mastitis									
Respiratory				2			1		
Udder damage						1			
Empty or illogical	5	3		4	1		9	5	2
Other	2								
Total	95	78	74	223	171	139	276	183	154

Table 14 - Distribution of Category and Sub-Category motivations for OFES cases (numbers), for the animal type "Bull Calf" and "Young Bull", from a mixed production system (n = 101), divided by year. "Male calf", "Old bull" and Category "Calving-related problems" were omitted because they accounted for 0 cases.

OFES Category and Sub-Category	Animal Type (Mixed Production system)					
	Bull Calf			Young Bull		
	2021	2022	2023	2021	2022	2023
Locomotion	36	25	16	1	1	1
Fracture	9	9	5			1
Lameness	3					
Acute trauma/Injury	23	13	7		1	
Hip dislocation & splits		1				
Mounting trauma				1		
Slip & fall trauma		2	4			
Abscess or phlegmon	1					
Other in Locomotion						
Recumbency	7	7	1			
Unable to stand	3	1				
Palsy / paralysis	4	6	1			
Metabolic syndrome						
Other	2	4				
Generic trauma	1	1				
Aggressiveness - public safety		1				
Cardiac						
Digestive						
Eye						
Foreign body syndrome						
Head		2				
Integument						
Mastitis						
Respiratory						
Udder damage						
Empty or illogical	1					
Other						
Total	45	36	17	1	1	1

For bull calves, there were 36 cases in the "Locomotion" category in 2021, accounting for 80% of all cases, which decreased to 25 cases in 2022 (69.4%) and 16 cases in 2023 (94.1%). For young bulls, 1 case was recorded each year in 2021, 2022, and 2023, accounting for 100% of all cases.

In the **"Recumbency" category**, the highest prevalence was among old cows, with 55 cases in 2021 (19.9%), dropping to 11 in 2022 (6%) and 2 cases in 2023 (1.3%). Heifers had 13 cases in 2021 (13.7%), decreasing to 4 cases in 2022 (5.1%) and rising to 7 cases in 2023 (9.5%). Among

young cows, there were 43 cases in 2021 (19.3%), but this dropped to 6 cases in 2022 (3.5%), with no cases in 2023. For males, bull calves had 7 cases in both 2021 (15.6%) and 2022 (19.4%), but this number dropped to just 1 case in 2023 (5.9%). There were no cases in this category for young bull.

In the **"Calving-related problems" category**, found only in females, old cows showed more cases, with 59 in 2021 (21.4%), decreasing to 9 in 2022 (4.9%) and rising slightly to 16 cases in 2023 (10.4%). Among young cows, the number of cases declined from 32 in 2021 (14.3%) to 9 in 2022 (5.3%) and 10 in 2023 (7.2%). Heifers had a stable number of cases, with 7 cases in 2021 (7.4%), 5 in 2022 (6.4%), and 7 cases in 2023 (9.5%).

The "**Other category"** showed variable trends across both sexes. Among old cows, there were 25 cases in 2021 (9.1%), decreasing to 11 cases in 2022 (6%) and 7 cases in 2023 (4.5%). For young cows, the number of cases decreased from 13 in 2021 (5.8%) to 5 in 2022 (2.9%) and 3 in 2023 (2.2%). Heifers showed a similar trend, with 13 cases in 2021 (13.7%) decreasing to 7 in 2022 (9%) and 3 in 2023 (4.1%). For males, bull calves had 2 cases in 2021 (4.4%) and 4 in 2022 (11.1%), but no cases in 2023. Young bulls did not report any cases in this category.

In **Table 15** and **Table 16**, distribution of categories and sub-categories (numbers) of OFES cases for female and male animals, respectively, from the **beef production system**, are shown.

Table 15 - Distribution of Category and Sub-Category motivations for OFES cases (numbers), for the animal type "Heifer", "Young cow", "Old cow", from a beef production system (n = 494), divided by year. "Female calf" were omitted because they accounted for only 2 cases.

OFES Category and Sub-Category	Animal Type (Beef production system)								
	Heifer			Young cow			Old cow		
	2021	2022	2023	2021	2022	2023	2021	2022	2023
Locomotion	66	94	82	19	14	4	12	7	6
Fracture	14	18	20	3	2	2	1	2	
Lameness	7	3	2	1		1	2		
Acute trauma/Injury	39	61	55	12	5	1	8	3	4
Hip dislocation & splits	1	1	2	3	2				
Mounting trauma	5	5	1						1
Slip & fall trauma		6	2		5		1	2	1
Abscess or phlegmon									
Other in Locomotion									
Recumbency	20	12	10	4	1	2	4	2	3
Unable to stand	6	9	3	3		1	4		2
Palsy / paralysis	12	3	6	1	1	1		2	1
Metabolic syndrome	2		1						
Calving-related problems	17	17	27	3	2	1	12	1	4
Stillbirth									
Dystocia	7	6	10	2	1		4		
Uterine and obstetrics affections	3	2	3		1	1	2		
Traumatic injuries related to calving	4	8	14	1			1	1	4
Palsy / paralysis after calving	3	1					3		
Metabolic syndrome after calving							2		
Other	20	14	5	2		1	4	2	
Generic trauma	2	5	1	1			1	2	
Aggressiveness - public safety	2		1						
Cardiac									
Digestive		1					1		
Eye									
Foreign body syndrome	2	1	1						
Head									
Integument									
Mastitis									
Respiratory	5	1	1						
Udder damage									
Empty or illogical	8	6	1	1		1	2		
Other	1								
Total	123	137	124	28	17	8	32	12	13

Table 16 - Distribution of Category and Sub-Category motivations for OFES cases (numbers), for the animal type "Male Calf", "Bull Calf", "Young Bull", from a beef production system (n = 544), divided by year. "Old bull" and Category "Calving-related problems" were omitted because they accounted for 1 and 0 cases, respectively.

OFES Category and Sub-Category	Animal Type (Beef Production system)								
	Male Calf			Bull Calf			Young Bull		
	2021	2022	2023	2021	2022	2023	2021	2022	2023
Locomotion	2	4	2	136	155	127	9	5	2
Fracture	1	1		32	46	29	1		
Lameness				11	6	7			
Acute trauma/Injury	1	3	2	74	78	79	8	5	2
Hip dislocation & splits				2	1				
Mounting trauma				4	11	5			
Slip & fall trauma				12	13	7			
Abscess or phlegmon				1					
Other in Locomotion									
Recumbency				27	11	7	1	2	1
Unable to stand				15	3	4		1	1
Palsy / paralysis				12	8	3		1	
Metabolic syndrome							1		
Other	1		1	21	16	9	2	2	1
Generic trauma	1			4	6	5	2	1	1
Aggressiveness - public safety				1					
Cardiac				1					
Digestive				4					
Eye					1				
Foreign body syndrome				3		1			
Head				1		3		1	
Integument									
Mastitis									
Respiratory					1				
Udder damage									
Empty or illogical				7	7				
Other			1		1				
Total	3	4	3	184	182	143	12	9	4

In the **"Locomotion" category**, heifers accounted for a higher number of cases over the years, with 66 cases in 2021 (53.7%), increasing to 94 cases in 2022 (68.6%), and slightly decreasing to 82 cases in 2023 (66.1%). For young cows, the cases were lower, with 19 cases in 2021 (67.9%), 14 cases in 2022 (82.4%), and a sharp drop to 4 cases in 2023 (50%). Among old cows, there were 12 cases in 2021 (37.5%), decreasing to 7 cases in 2022 (but accounting for 58.3%) and 6 cases in 2023 (accounting for 46.2%). For males, bull calves had a significant number of cases in the "Locomotion" category, with 136 cases in 2021 (73.9%), rising to 155 cases in 2022 (85.2%), and slightly decreasing to 127 cases in 2023 (88.8%). For young bulls, the number of cases decreased over the years, with 9 cases in 2021 (75%), 5 cases in 2022 (55.6%), and 2 cases in 2023 (50%). Male calves had minimal representation, with only 2 cases in 2021 and 2023, and 4 cases in 2022.

In the **"Recumbency" category**, heifers showed 20 cases in 2021 (16.3%), dropping to 12 cases in 2022 (8.8%) and 10 cases in 2023 (8.1%). Young cows had 4 cases in 2021 (14.3%), dropping to 1 case in 2022 (5.9%), and increasing slightly to 2 cases in 2023 (25%). For old cows, the numbers were consistent but low, with 4 cases in 2021 (12.5%), 2 in 2022 (16.7%), and 3 cases in 2023 (23.1%). Among males, bull calves had 27 cases in 2021 (14.7%), decreasing to 11 cases in 2022 (6%), and 7 cases in 2023 (4.9%). Young bulls showed 1 case in 2021 (8.3%), 2 cases in 2022 (22.2%), and 1 case in 2023 (25%). Male calves reported no cases in this category.

As shown in **Table 2**, **body localisation of injuries** was determined, within "Locomotion" category, for 3 sub-categories such as: "Fracture", "Lameness" and "Acute Trauma/Injury". These results are shown in **Table 17, Figure 17** and **Figure 18**, in relation to a total of 6,240 cases.

The majority of cases were localised to the hindleg, with 4,280 cases (68.6% of the total), predominantly in the "Acute trauma/Injury" subcategory, which accounted for 3,311 cases (52.7% of the total). The foreleg was the second most affected area, with 444 cases (7.1%), primarily due to "Acute trauma/Injury" (282 cases). Injuries not specifically localised to either the foreleg or hindleg amounted to 533 cases (8.5%), again mostly from "Acute trauma/Injury" (502 cases). The spinal/back area had 361 cases (5.8%), and the hip/pelvic region accounted for 435 cases (7.0%). Other areas, like the shoulder/neck, had minimal cases (27 cases, 0.4%), while unspecified locations totalled 160 cases (2.6%).

Table 17 - Body localisation reported for the locomotion sub-categories of "fracture", "lameness", and "acute trauma/injury"

	Sub-categories in Locomotion			
Body localisation	**Fracture**	**Lameness**	**Acute trauma/Injury**	**Total**
Foreleg	140	22	282	444
Hindleg	880	89	3311	4280
Leg (not specified)	31	/	502	533
Spinal/back	10	/	351	361
Hip/pelvic	147	/	288	435
Shoulder/neck	2	/	25	27
Not specified	41	106	13	160
Total	1251	217	4772	6240

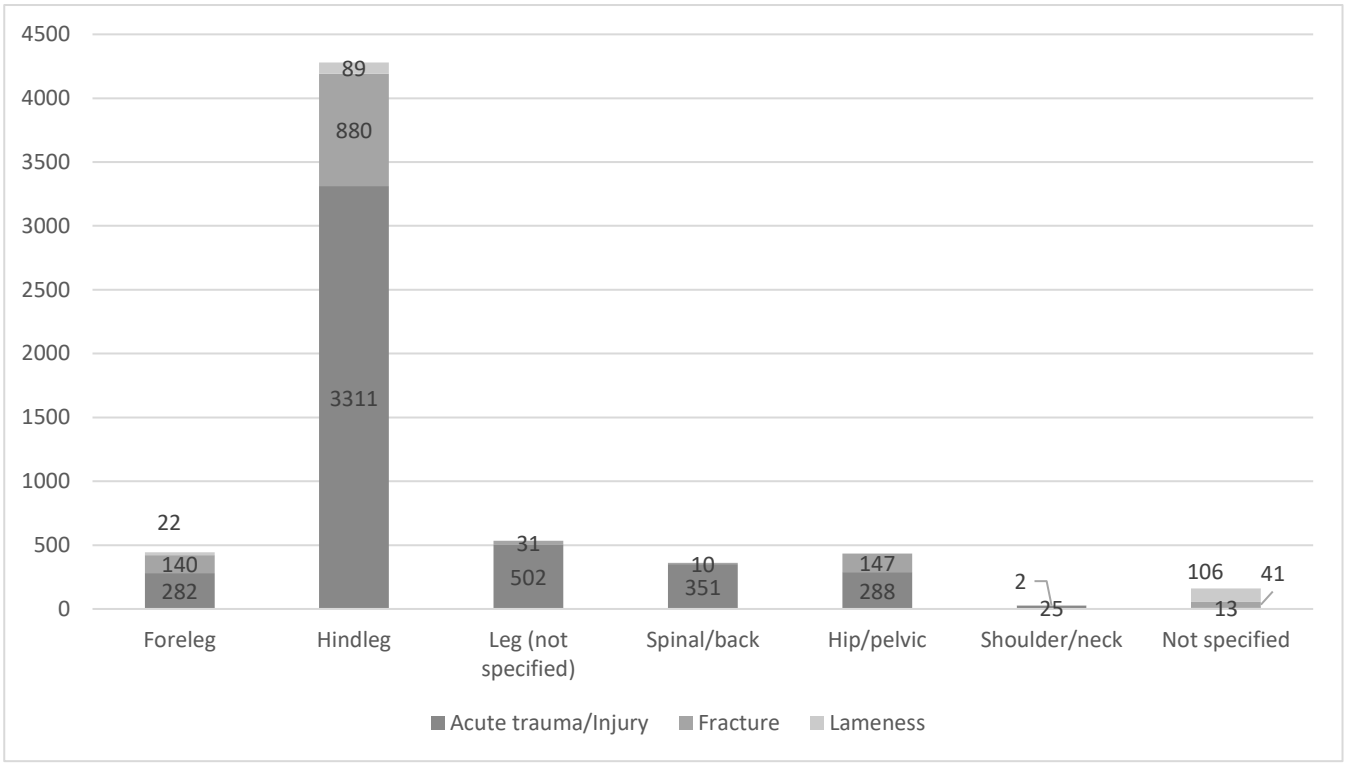


Figure 17 – Visualisation of the body localisation of injuries reported for the sub-categories "acute trauma/injury", "fracture" and "lameness", within the "Locomotion" category.

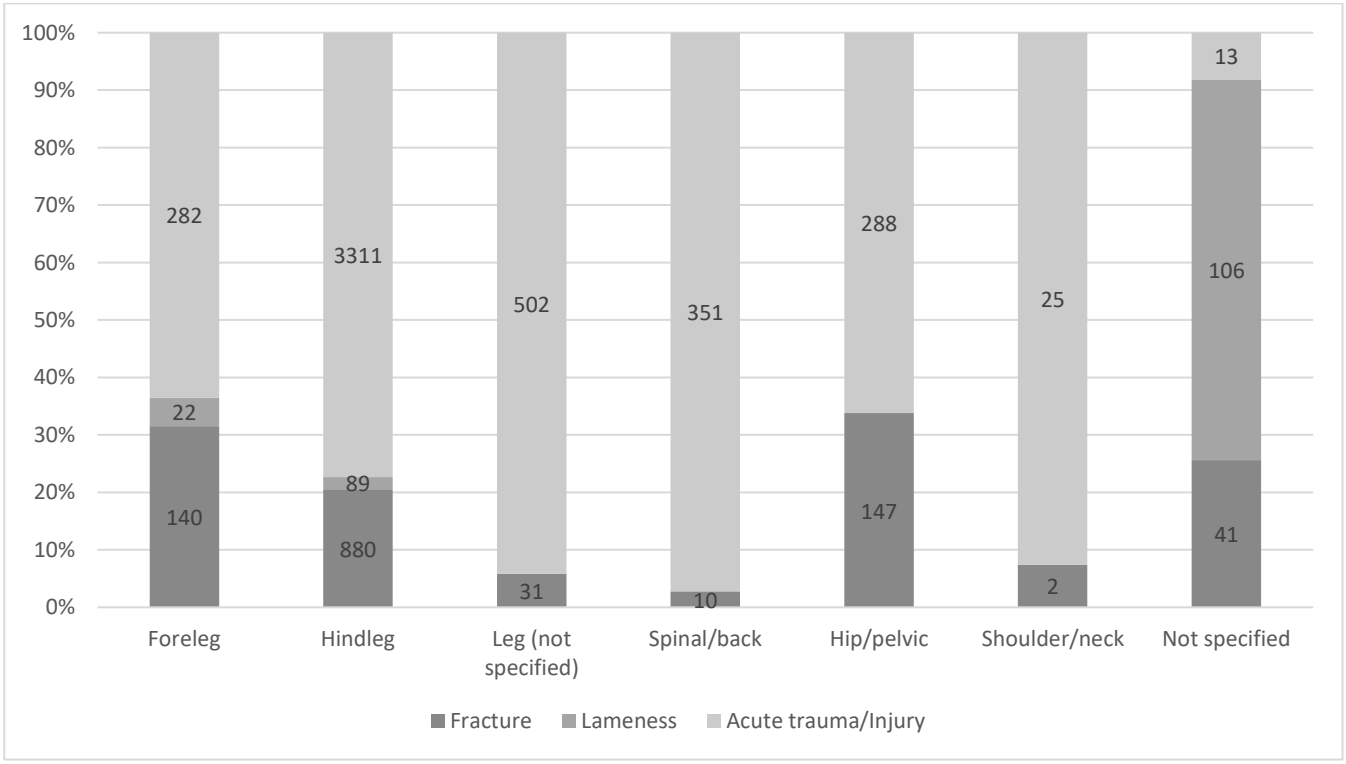


Figure 18 – Occurrence in % of body localisation among the locomotion sub-categories "fracture", "lameness", and "acute trauma/injury".

3.2Results from the machine learning (artificial intelligence) approach

The Term Frequency-Inverse Document Frequency (TF-IDF) analysis revealed the presence of 1,351 different words in the OFES motivation column into the LCA electronic dataset. Due to space limitations, in **Table 18** only the top 30 words (in Italian and English) are shown with their respective TF-IDF scores and true frequencies. The words with the highest TF-IDF scores are those that are particularly significant in the corpus, indicating that they frequently appear in specific rows while being less common across others. For instance, the term "trauma", which has a TF-IDF score of 1700.30 and a frequency of 4,403 occurrences, is identified as highly relevant.

Table 18 – The Term Frequency-Inverse Document Frequency (TF-IDF) analysis revealed 1,351 different words. This table presents the top 30 words (in Italian and English) with their respective TF-IDF scores and true frequencies.

Original Word	English Word	TF-IDF Score	Frequency
trauma	trauma	1.700,30	4.403
post	post	1.187,99	2.894
arto	leg	998,95	2.524
posteriore	hind/rear	884,85	1.981
treno	quarter	810,65	1.491
scivolamento	slipping	744,95	1.138
lesione	injury	709,44	1.770
paresi	paresis	673,12	1.038
frattura	fracture	598,25	1.189
dx	right (abbrev.)	545,18	1.074
sx	left (abbrev.)	527,74	1.036
traumatica	traumatic	479,89	893
arti	legs	478,84	871
lussazione	dislocation	350,59	688
bacino	pelvis	284,06	414
parto	calving	253,59	417
posteriori	hind/rear (plural)	245,43	423
sospetta	suspect	233,96	510
nessuna	none	221,00	221
sospetto	suspect	199,89	342
coxofemorale	coxofemoral	185,86	306
destro	right	184,39	310
partum	partum	169,73	265
probabile	probable	150,94	312
scavalcamento	mounting	137,66	185
zoppia	lameness	135,94	187
ant	anterior (abbrev.)	133,81	207
anteriore	anterior	129,42	210
sosp	suspect (abbrev.)	125,55	214
lesioni	injuries	121,18	196

In **Table 19,** distribution of TF-IDF scores and true frequencies are shown. The minimum TF-IDF score recorded was 0.26, corresponding to a true frequency of 1.00. The first quartile revealed a TF-IDF score of 0.70, also with a true frequency of 1.00, meaning that 25% of the terms had a TF-IDF score below this value. The median TF-IDF score was 0.92, again with a true frequency of 1.00, representing the midpoint of the dataset where half of the terms had scores lower than this threshold and appeared only once. The third quartile showed a score of 2.60, with a true frequency of 4.00. The maximum TF-IDF score reached an impressive 1,700.30, with a true frequency of 4,403.00, highlighting the most significant term's prominence in the corpus. Lastly, the average TF-IDF score was 15.02, with an average true frequency of 28.57.

Table 19 – Results from the Term Frequency-Inverse Document Frequency (TF-IDF) analysis: distribution of TF-IDF scores and true frequencies of 1,351 different words used by Official Veterinarians during ante-mortem inspections.

Statistic	**TF-IDF Score**	**True frequency**
Minimum	0,26	1,00
First quartile	0,70	1,00
Median	0,92	1,00
Third quartile	2,60	4,00
Maximum	1.700,30	4.403,00
Average value	15,02	28,57

Thanks to the TF-IDF method, words within each row of the dataset were categorized in 5 clusters, as presented in **Table 20**. Cluster 0 is characterized by terms related to limbs, including “arti” (limbs), “posteriori” (posterior), and various references to trauma, such as “trauma” and “lesione” (lesion). Cluster 1 focuses on the concept of trauma, with keywords like “arto” (limb), “trauma”, and “sospetto” (suspected, adjective), emphasizing suspected injuries. Cluster 2 contains words associated with specific conditions such as “scivolamento” (slipping) and various trauma-related terms, highlighting incidents of injury. Cluster 3 reveals terminology surrounding paresis and traumatic injuries, including “paresi” (paresis), “lesione”, and “traumatica” (traumatic), suggesting a focus on functional impairments resulting from injuries. Lastly, Cluster 4 includes terms related to hindquarters adverse effects, with words like “treno” (hindquarters / hind legs), “parto” (calving), and “paralisi” (paralysis).

Table 20 – List of 5 Clusters of words identified by the Term Frequency-Inverse Document Frequency (TF-IDF) analysis and related (Italian) keywords

Cluster 0	**Cluster 1**	**Cluster 2**	**Cluster 3**	**Cluster 4**
arti	arto	scivolamento	paresi	treno
posteriori	post	trauma	trauma	posteriore
trauma	sx	sospetto	lesione	trauma
post	dx	bacino	traumatica	post
scivolamento	frattura	sosp	lussazione	paresi
lesione	trauma	post	bacino	lesione
paresi	posteriore	lesione	parto	traumatica
traumatica	lesione	treno	post	sospetto
anteriori	destro	posteriore	coxofemorale	scivolamento
sospetto	ant	arto	partum	paralisi

A visual representation of these five clusters is provided in **Figure 19:** the clusters exhibited significant overlap and were unable to effectively categorize the motivations.

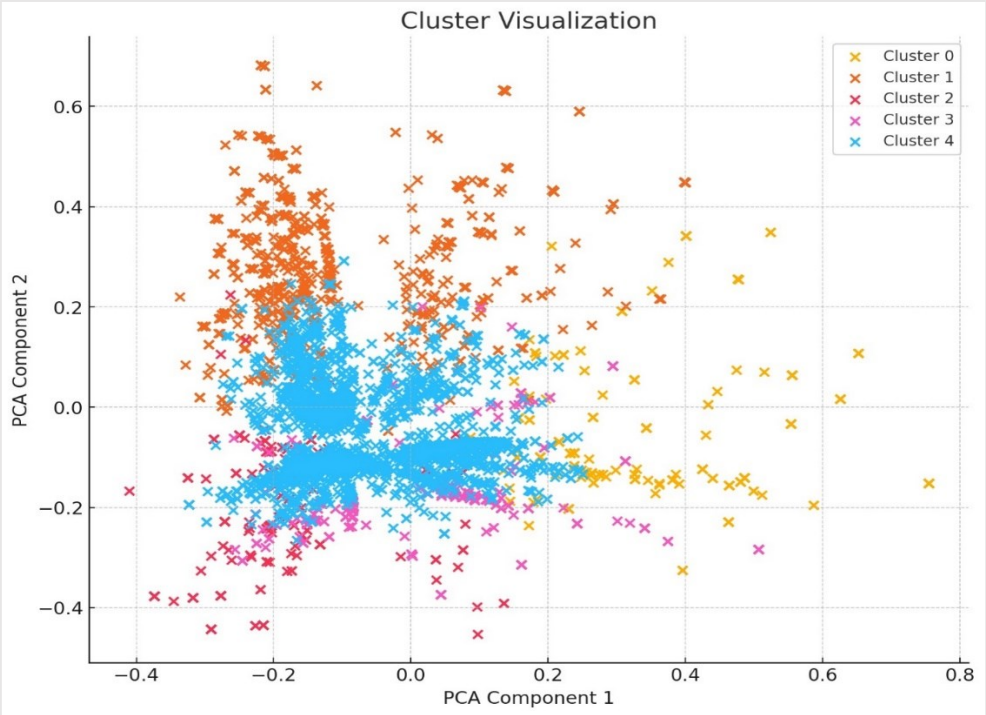


Figure 19 - Visualization of 5 Clusters of words derived from the Term Frequency-Inverse Document Frequency (TF-IDF) analysis.

In addition, since each row (representing a single motivation) was assigned to a cluster, the silhouette score for each row's cluster was calculated. **Table 21** presents the distribution of silhouette scores across the five clusters related to 11,827 motivations used by OVs during *ante-mortem* inspections. The minimum silhouette scores for clusters 0, 1, 2, and 3 were negative, while cluster 4 had a minimum score of 0.15. The first quartile scores ranged from -0.04 (cluster 2) to 0.33, with

cluster 4 again showing the highest value. The median scores varied, from 0.00 (cluster 2) to 0.16 (cluster 1), with cluster 4 achieving the highest median of 0.78, reflecting stronger clustering. Similarly, the third quartile scores reinforced this trend, as cluster 4 maintained its superior score of 0.78. The maximum silhouette scores were highest in cluster 1 at 0.33 and in cluster 4 at 0.78, while the average scores indicated overall better performance in cluster 4 (0.62) compared to the others.

Table 21 – Results from the Term Frequency-Inverse Document Frequency (TF-IDF) analysis regarding the silhouette distribution of the five clusters in relation to each motivation (about 11,827 total rows) used by Official Veterinarians during ante-mortem inspections.

Statistic of silhouette scores	Cluster 0	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Minimum	-0.18	-0.15	-0.23	-0.16	0.15
First quartile	0.03	0.10	-0.04	0.08	0.33
Median	0.08	0.16	0.00	0.12	0.78
Third quartile	0.09	0.28	0.01	0.21	0.78
Maximum	0.11	0.33	0.03	0.25	0.78
Average value	0.06	0.18	-0.02	0.14	0.62
Total number of rows	1,115	1,710	5,799	2,392	811

Regarding the final step of the artificial intelligence approach, three elaborations of supervised machine learning (ML) were run. The third one was the one with the highest performance. Motivations from 2021 and 2022 were used to train the ML techniques, in particular for training the ML software in learning how motivations (in Italian) were transcoded in English category and sub-category. The model was then run again to analyse all the dataset, including 2023 for the first time.

In **Table 22**, results regarding comparison of the supervised machine learning with human interpretation of categories and sub-categories across the years 2021, 2022, and 2023 are shown.

For categories, out of 12,052 motivations, 99.0% (4,800) of interpretations were consistent in 2021, 99.6% (3,821) in 2022, and 99.2% (3,339) in 2023, resulting in an overall consistency of 99.2% (11,960). Similarly, the analysis of sub-categories showed a consistency rate of 98.0% (11,806) overall, with consistent results of 98.0% (4,749) in 2021, 98.2% (3,767) in 2022, and 97.7% (3,290) in 2023. The inconsistency in sub-categories was slightly higher than in categories, at 2.0% (246) overall, with the highest being 2.3% (77) in 2023.

Table 22 – Comparison of supervised machine learning results with the human interpretation of categories and sub-categories.

CONSISTENCY WITH HUMAN INTERPRETATION		2021	2022	2023	Total
CATEGORY	Consistent	4,800 (99.0%)	3821 (99.6%)	3339 (99.2%)	**11960 (99.2%)**
	Not consistent	47 (1.0%)	17 (0.4%)	28 (0.8%)	**92 (0.8%)**
SUB-CATEGORY	Consistent	4749 (98.0%)	3767 (98.2%)	3290 (97.7%)	**11806 (98.0%)**
	Not consistent	98 (2.0%)	71 (1.8%)	77 (2.3%)	**246 (2.0%)**

3.3Results from the post-mortem inspections at slaughterhouse

During post-mortem inspection, each carcass was assessed as either fit for human consumption or not, based on the official veterinarians' visual inspections, palpations, and incisions of both carcasses and offal, in addition to laboratory results. As shown in **Figure 20**, an average of 93.4% of animals subjected to OFES were deemed fit for human consumption; however, this trend declined over the years: 94.8% in 2021, 93.8% in 2022, and 90.9% in 2023.

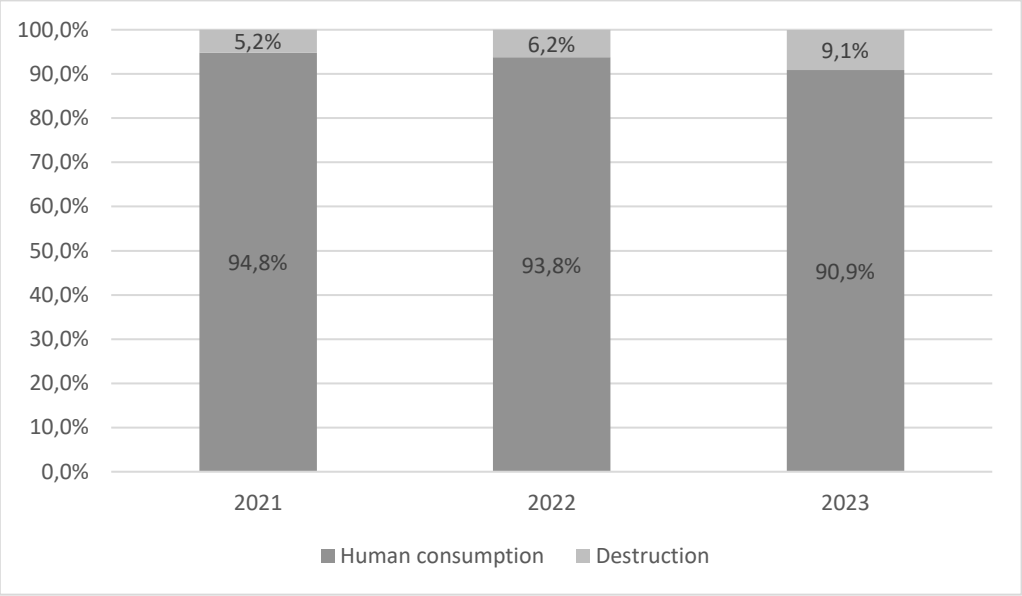


Figure 20 - Outcomes of post-mortem inspections of OFES carcasses (n=12,051): distribution of carcass destinations for human consumption and destruction among years. One carcass was excluded due to missing data

When analysed by production system (see **Figure 21**), animals coming from farms with a mixed production system exhibited a higher average percentage of discarded carcasses (7.3%) compared to animals coming from the dairy and beef farms, which had averages of 6.5% and 6.6%, respectively. In the beef cattle category, the percentage of discarded carcasses displayed a distinct trend: it was 4.2% in 2021, increased to 8.8% in 2022, and then decreased to 7.1% in 2023, as illustrated in **Table 23**.

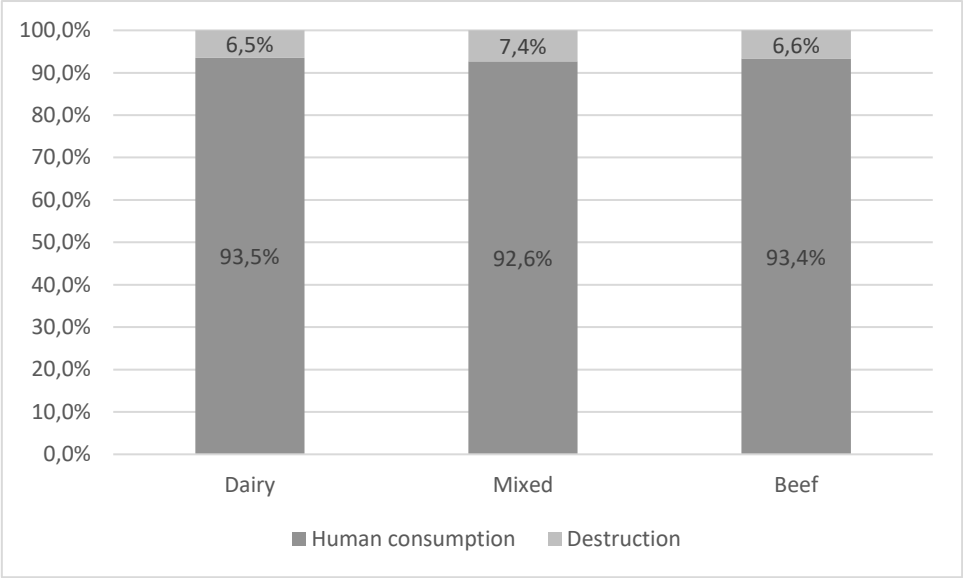


Figure 21 - Outcomes of post-mortem inspections of OFES carcasses (n=12,051): distribution of carcass destinations for human consumption and destruction among production systems. One carcass was excluded due to missing data.

Table 23 - Outcomes of post-mortem inspections of OFES carcasses (n=12052): distribution of carcass destinations for human consumption and destruction across production systems and years.

Carcass destination at *post-mortem* inspection	**Production system**								
	Dairy			**Mixed**			**Beef**		
	2021	2022	2023	2021	2022	2023	2021	2022	2023
Human consumption	3626	2832	2440	603	438	345	367	330	275
Destruction	195	175	246	40	31	39	16	32	21
Empty						1			
Total	3821	3007	2686	643	469	385	383	362	296

With regard to the animal type, as shown in **Figure 22**, no carcasses were condemned in old bulls and young bulls, whereas old cows and young cows exhibited 377 (7.1%) and 266 (5.8%) cases of carcass condemnation, respectively. Concerning younger animals, the number of condemned carcasses for bull calves and heifers was 39 (6.1%) and 109 (7.3%), respectively; both male and female calves showed 2 condemned carcasses, representing the highest condemnation rates at 20.0% and 14.3%, respectively, even though these percentages were calculated on very few total cases, such as from 10 OFES cases in male calves and 14 OFES cases in female calves.

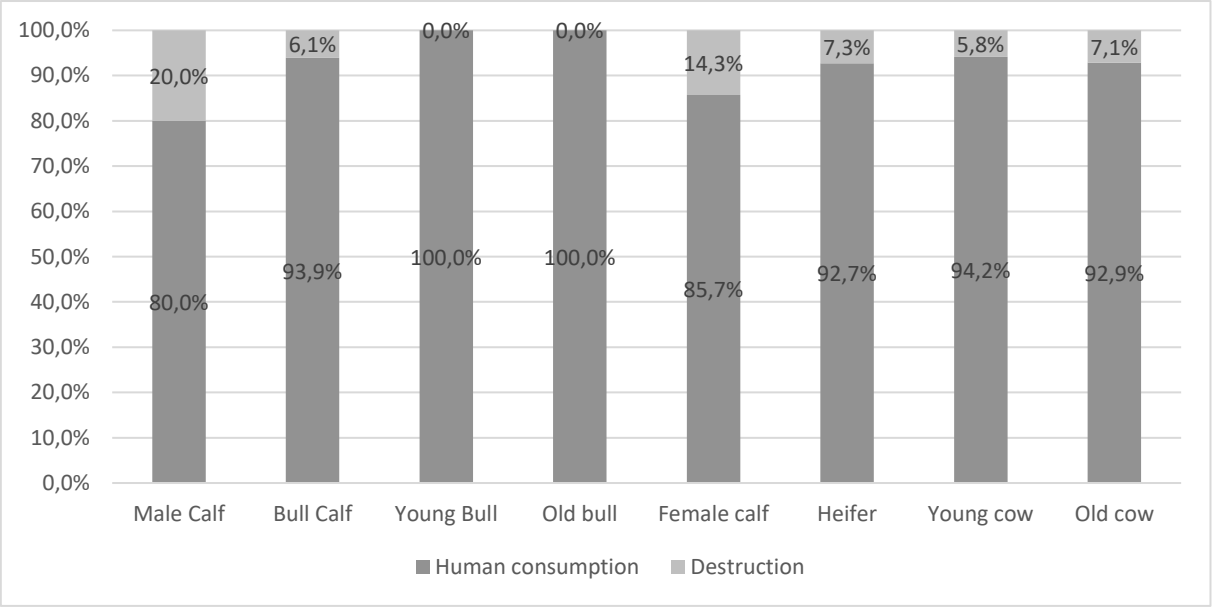


Figure 22 - Outcomes of post-mortem meat inspections (n=12,051): distribution of carcass destinations for human consumption and destruction among animal type. One carcass was excluded due to missing data.

Regarding destinations of carcasses, as illustrated in **Figure 23**, carcasses considered not fit for human consumption increased from 4.3% in 2021 to 9.3% in 2023, from 4.7% in 2021 to 9.6% in 2023, from 6.3% in 2021 to 9.2% in 2023 in relation to "Locomotion", "Calving-related problems" and "Other" categories, respectively. On the other hand, carcasses not fit for human consumption had a decreasing trend in the "Recumbency" category, going from 7.5% in 2021 to 6.2% in 2023.

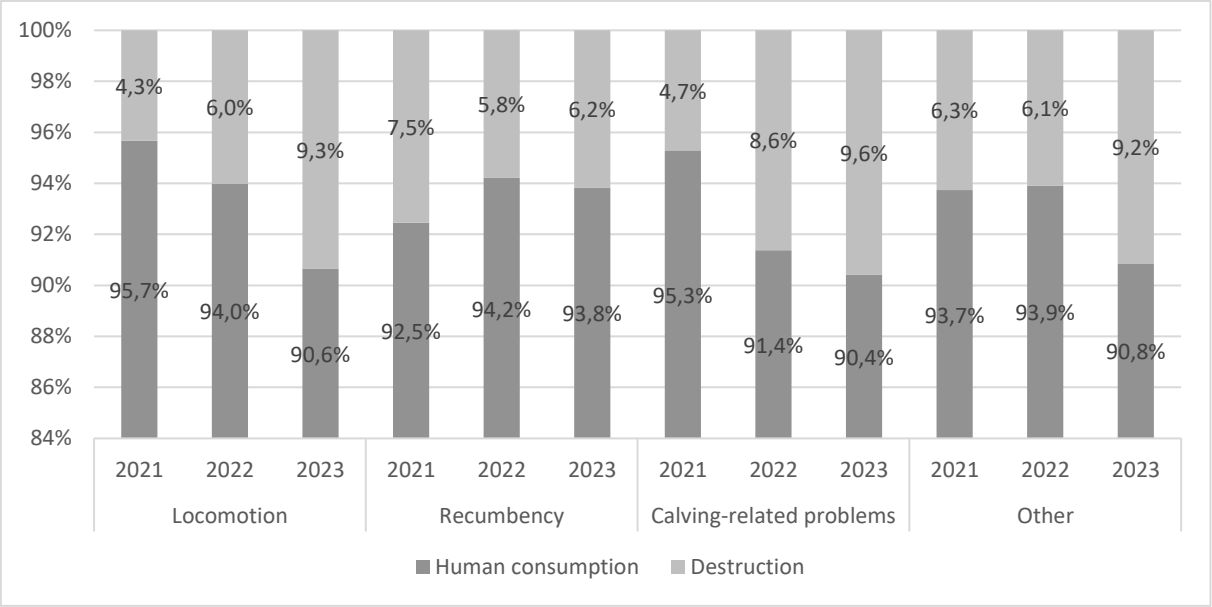


Figure 23 - Outcomes of post-mortem meat inspections (n=12,052): distribution of carcass destinations for human consumption and destruction among OFES categories.

Data regarding the destinations of carcasses among the sub-categories of OFES reasons are presented in **Table 24**. The sub-category "Lameness" in "Locomotion" showed an increase in destroyed carcasses, with percentages of 2.7% in 2021, 5.4% in 2022, and 11.8% in 2023. Similarly, "Palsy/paralysis" in "Recumbency" increased from 2.4% in 2021 to 2.9% in 2022 and 14.3% in 2023. Additionally, "Uterine and obstetrics affections" in "Calving-related problems" rose from 12.5% in 2021 to 18.8% in 2023, while "Generic trauma" in the "Other" category increased from 3.9% in 2021 to 5.5% in 2022 and 11.5% in 2023.

Table 24 - Outcomes of post-mortem inspections of OFES carcasses (n=12,051): distribution of carcass destinations for human consumption and destruction across OFES categories, sub-categories, and years. One carcass was excluded due to missing data.

	Year					
	2021		2022		2023	
	Human Consumption	Destruction	Human Consumption	Destruction	Human Consumption	Destruction
Locomotion	**2694**	**122**	**2715**	**174**	**2408**	**248**
Fracture	427	15	392	26	357	34
Lameness	142	4	35	2	30	4
Acute trauma/Injury	1507	69	1580	110	1352	153
Hip dislocation & splits	252	12	214	10	195	19
Mounting trauma	68	3	110	7	99	12
Slip & fall trauma	283	17	374	19	371	26
Abscess or phlegmon	13	2	9		3	
Other in Locomotion	2		1		1	
Recumbency	**870**	**71**	**358**	**22**	**259**	**17**
Unable to stand	311	24	106	12	51	3
Palsy / paralysis	447	35	242	10	206	13
Metabolic syndrome	112	12	10		2	1
Calving-related problems	**628**	**31**	**265**	**25**	**274**	**29**
Stillbirth	6				1	
Dystocia	78	7	33	7	34	3
Uterine affections	28	4	10		13	3
Traumatic injuries related to calving	220	8	169	17	219	22
Palsy / paralysis after calving	161	4	33	1	6	1
Metabolic syndrome after calving	135	8	20		1	
Other	**404**	**27**	**262**	**17**	**119**	**12**
Generic trauma	98	4	154	9	69	9
Aggressiveness - public safety	3		1		3	
Cardiac	6				3	
Digestive	68	8	11	1	2	
Eye	2		1		1	
Foreign body syndrome	41	4	7	1	11	1

Head	7	1	4	2	5	
Integument	3		1		1	
Mastitis	11	1	1			
Respiratory	16	1	2		1	
Udder damage	1		3	1	4	1
Empty or illogical	138	7	74	3	16	1
Other	10	1	3		3	
Total	**4596**	**251**	**3600**	**238**	**3060**	**306**

Among the condemned carcasses (n=795), a written reason related to anatomopathological findings was reported in only 29.2% (232) of the cases (**Table 25**). However, this percentage reached a peak of 42.5% in 2022. Out of the 232 destroyed (whole) carcasses that were justified, 32.3% exhibited widespread hematomas, 26.7% demonstrated multiple organ impairment, 20.6% had lesions associated with circulatory and metabolic disorders, and 15.5% were related to abscesses or phlegmon.

Table 25 - Outcomes of post-mortem inspections of OFES carcasses: distribution of reasons for whole carcass condemnations (n=795) over the years.

	Year			Total
	2021	**2022**	**2023**	
Hematoma	23 (37.0%)	30 (29.7%)	22 (31.8%)	75 (32.3%)
Multiorgan impairment	7 (11.2%)	37 (36.6%)	18 (26.0%)	62 (26.7%)
Circulatory and metabolic disorders	19 (30.6%)	11 (10.8%)	18 (26.0%)	48 (20.6%)
Inflammatory disorders	11 (17.7%)	17 (16.8%)	8 (11.5%)	36 (15.5%)
Abscess or phlegmon	1 (1.6%)	2 (1.9%)	1 (1.4%)	4 (1.7%)
Other	-	3 (2.9%)	1 (1.4%)	4 (1.7%)
Fracture	-	1 (0.9%)	1 (1.4%)	2 (0.8%)
Generic trauma	1 (1.61%)	-	-	1 (0.4%)
Empty or illegible	189 (75.2%)	137 (57.5%)	237 (77.4%)	563 (70.8%)
Total	**251 (100.0%)**	**238 (100.0%)**	**306 (100.0%)**	**795 (100.0%)**

In addition, out of 795 condemned carcasses, 513 reported a negative result (conclusion) from the laboratory analyses. In 270 cases, the reason for the negative result was specified, particularly concerning bacteriological analyses. **Table 26** illustrates the distribution of laboratory results among the reasons for whole carcass condemnations.

Table 26 - Outcomes of post-mortem inspections of OFES carcasses: out of 795 condemned carcasses, 270 reported laboratory findings. This table illustrates the distribution of laboratory results among the reasons for whole carcass condemnations.

	Circulatory & metabolic disorders	**Empty or illegible**	**Hematoma**	**Inflammatory disorders**	**Multiorgan impairment**	**Total**
Total bacterial count (mesophilic count)	7 (53,8%)	137 (65,6%)	16 (76,2%)	3 (75%)	14 (60,9%)	177 (65,6%)
Clostridium spp.	4 (30,8%)	44 (21,1%)	4 (19%)	1 (25%)	2 (8,7%)	55 (20,4%)
Pseudomonas spp.	-	1 (0,5%)	-	-	-	1 (0,4%)
Salmonella spp.	1 (7,7%)	16 (7,7%)	1 (4,8%)	-	5 (21,7%)	23 (8,5%)
Serratia liquefaciens	-	1 (0,5%)	-	-	-	1 (0,4%)
Shigella spp.	-	-	-	-	1 (4,3%)	1 (0,4%)
Staphylococcus spp.	1 (7,7%)	7 (3,3%)	-	-	1 (4,3%)	9 (3,3%)
Streptococcus spp.	-	3 (1,4%)	-	-	-	3 (1,1%)
Total	**13 (100%)**	**209 (100%)**	**21 (100%)**	**4 (100%)**	**23 (100%)**	**270 (100%)**

The majority of laboratory results were linked to total bacterial counts (65.6%), with significant proportions of *Clostridium* spp. (20.4%) and *Salmonella* spp. (8.5%). Hematomas showed the highest prevalence among the reasons for condemnations, particularly for total bacterial counts (76.2%). Other bacterial findings included *Pseudomonas* spp., *Serratia liquefaciens*, *Shigella* spp., *Staphylococcus* spp., and *Streptococcus* spp.

Among the 11,256 carcasses designated for human consumption, 25.7% (2,887 cases) reported exclusions of specific parts, categorized by localization and anatomopathological findings across the years 2021, 2022, and 2023 (see **Table 27**). The most excluded parts were the legs and joints, which accounted for 39.3% of exclusions, showing an increasing trend over the years (from 37.6% in 2021 to 44.9% in 2023). The second most frequent exclusion category was multiorgan, accounting for 20.0%, with a rising trend from 16.6% in 2021 to 21.4% in 2023. Issues related to the liver and hepatic lymph nodes accounted for 18.9% of exclusions, showing a decreasing trend from 21.5% in 2021 to 13.6% in 2023. Among all known exclusions related to legs and joints, 89.3% (1,014 cases) were due to hematomas. In contrast, for liver and hepatic lymph node exclusions, 77.1% (422

cases) were associated with circulatory and metabolic disorders, such as steatosis, telangiectasia, and jaundice.

Table 27 - Outcomes of post-mortem inspections of OFES carcasses: numbers and percentages of exclusions, of whole carcasses or specific parts from 2,887 carcasses deemed fit for human consumption, categorized by localization and anatomopathological findings, across different years. Out of all 11,256 OFES carcasses, fit for consumption, 8,369 were excluded due to missing data at the post-mortem inspection.

	Year			Total
	2021	**2022**	**2023**	
Legs and joints	406 (37.6%)	364 (36.7%)	366 (44.9%)	1136 (39.3%)
Hematoma	344	329	341	1014
Inflammatory disorders	29	23	11	63
Generic trauma	29	3	2	34
Fracture	4	9	12	25
Multiorgan	179 (16.6%)	224 (22.6%)	175 (21.4%)	578 (20.0%)
Multiorgan impairment	179	224	175	578
Liver and hepatic lymph nodes	232 (21.5%)	204 (20.6%)	111 (13.6%)	547 (18.9%)
Circulatory and metabolic disorders	189	150	83	422
Inflammatory disorders	20	42	15	77
Abscess or phlegmon	21	7	8	36
Parasitic lesions	2	4	3	9
Other		1	2	3
Lower respiratory system	145 (13.4%)	119 (12.0%)	85 (10.4%)	349 (12.1%)
Inflammatory disorders	109	83	45	237
Circulatory and metabolic disorders	35	33	39	107
Parasitic lesions	1	1		2
Other		2	1	3
Half or whole carcass*	62 (5.7%)	32 (3.2%)	45 (5.5%)	139 (4.8%)
Hematoma	19	17	25	61
Circulatory and metabolic disorders	24	10	11	45
Inflammatory disorders	12	4	7	23
Other	7	1	2	10
Heart and pericardium	28 (2.6%)	25 (2.5%)	21 2.6%)	74 (2.6%)
Inflammatory disorders	26	24	20	70
Circulatory and metabolic disorders	1	1	1	3
Parasitic lesions	1			1
Spleen/Kidenys	14 (1.3%)	16 (1.6%)	4 (0.5%)	34 (1.2%)
Inflammatory disorders	12	11	3	26
Circulatory and metabolic disorders	2	5	1	8
Gastro-intestinal system and peritoneum	9 (0.8%)	-	3 (0.4%)	12 (0.4%)
Inflammatory disorders	9		3	12
Head and oral cavity	2 (0.2%)	7 (0.7%)	5 (0.6%)	14 (0.5%)
Inflammatory disorders	2	2	1	5
Other		5	4	9
Integumentary system and mammary gland	3 (0.3%)	-	1 (0.1%)	4 (0.1%)
Hematoma	1		1	2
Inflammatory disorders	2			2
Total	**1080 (100.0%)**	**991 (100.0%)**	**816 (100.0%)**	**2887 (100.0%)**

*In this category, 89 whole carcasses, that were classified as fit for human consumption in the dataset, were also noted as condemned. This inconsistency may be attributed to transcription errors.

It remains unclear whether the remaining carcasses were fully approved for human consumption or if the relevant information regarding the exclusion of some body parts was simply missing from the Veterinary register. Additionally, it was observed that 89 whole carcasses were classified as fit for human consumption but also condemned. This inconsistency could be attributed to transcription errors.

No significant differences were observed in the distribution of body part exclusions across OFES categories attributed to motivations collected at *ante-mortem* inspections. As illustrated in **Figure 24**, the "Locomotion" category consistently showed an upward trend over the years, mirroring its overall increase in OFES cases. Similarly, the categories "Recumbency" and "Calving-related problems" showed a significant overall decline across all types of exclusion localizations over the three-year period.

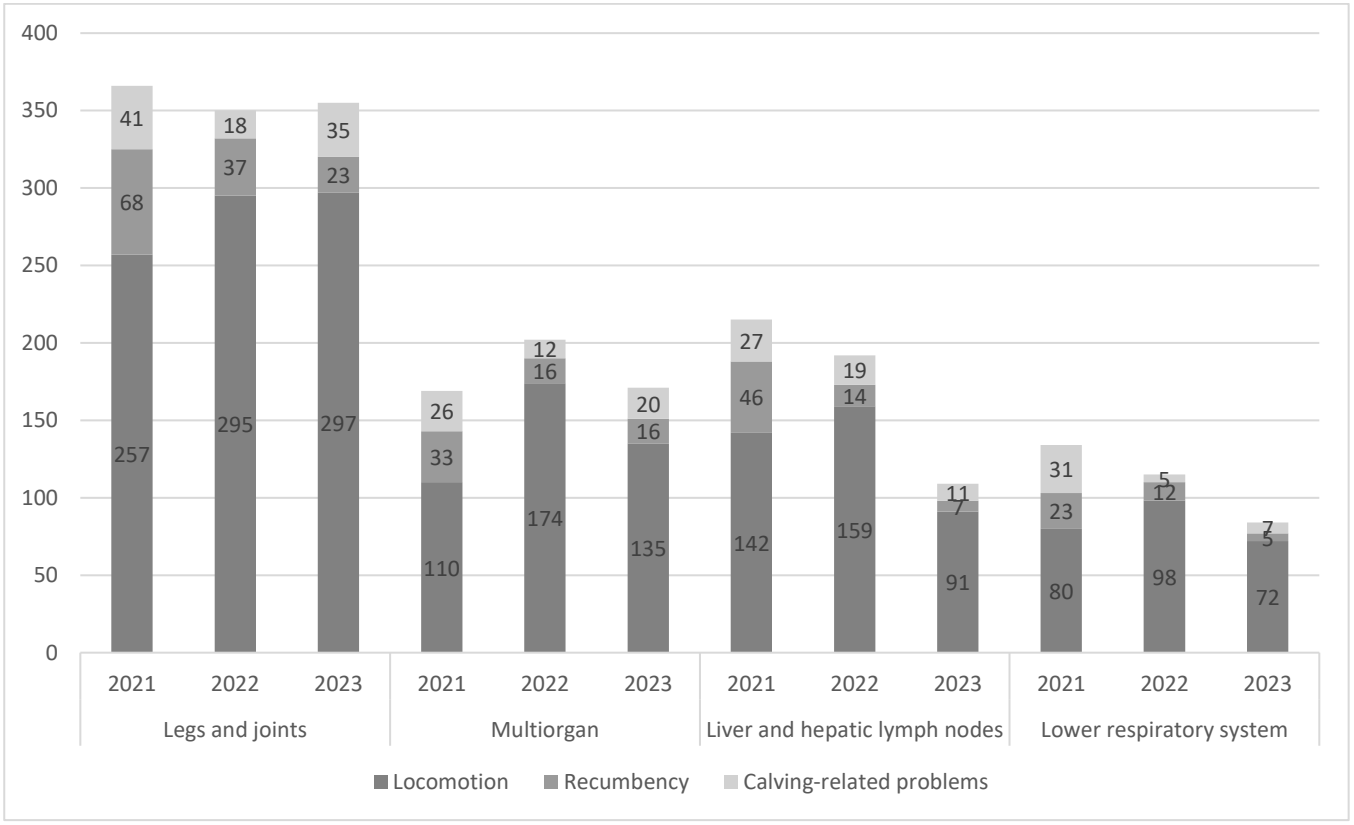


Figure 24 - Outcomes of post-mortem inspections of OFES carcasses: distribution among years of body parts excluded during post-mortem inspections of 11,256 carcasses deemed fit for human consumption, focusing on OFES categories related to "Locomotion," "Recumbency," and "Calving-related problems."

DISCUSSION

4.1Description of motivations for On-Farm Emergency Slaughter collected during the ante-mortem inspections

This study primarily aimed to analyse On-Farm Emergency Slaughter (OFES) cases delivered to the slaughterhouses under the jurisdiction of the Local Competent Authority (LCA) of Brescia from 2021 to 2023. It provided valuable insights into the trends, reasons, and characteristics of animals subjected to OFES, revealing a gradual decline in OFES cases, particularly in the delivery of carcasses to these slaughterhouses.

The OFES motivations considered in this study are closely linked to the well-documented issue of downer cow syndrome, a condition where a cow becomes recumbent and is unable to stand for a prolonged period. This syndrome often arises as a secondary complication from conditions such as calving-related injuries (e.g., nerve compression), metabolic disorders (such as milk fever or ketosis), or severe trauma (like fractures or muscle damage). The inability to rise can lead to further complications, including muscle compression, nerve damage, and ischemia, worsening the cow's condition (Stull et al., 2007). Prompt intervention is crucial, as prolonged recumbency increases the risk of a poor prognosis, animal welfare concerns, and the necessity for emergency slaughter or euthanasia.

Locomotory issues, such as fractures and acute trauma, were the most prevalent reasons for OFES, accounting for an average of 70% of all cases, reflecting the acute and traumatic nature of these events. In contrast, the incidence of recumbency and calving-related problems, which accounted for nearly 20% and 14% of cases, respectively, in 2021, decreased over the years. Unfortunately, it's unlikely that such a significant decrease occurred in such a short period due to changes in farm management. Instead, the drop in recumbency and calving-related cases is more likely due to stricter decisions made by Official Veterinarians (OVs) during on-farm *ante-mortem* inspections, in accordance with the updated interpretation of EU regulations.

The application of machine learning techniques, including Term Frequency-Inverse Document Frequency (TF-IDF) and supervised models, facilitated the identification of key patterns and clusters within the free-text motivations provided by OVs. These methods enhanced the categorization and consistency of the data, offering more precise insights into the causes of OFES. Furthermore, a machine learning model was trained to categorize free-text motivations, representing a valuable tool for reducing manual interpretation and saving both time and effort. The developed

code has the potential to be applied to other veterinary topics, expanding its utility beyond OFES analysis.

The analysis of data related to *post-mortem* inspections at the slaughterhouses revealed important trends regarding the suitability for human consumption of the OFES carcasses involved in the study. A significant majority of the carcasses were deemed fit, although there was an increase in the percentage of condemned carcasses. The most frequently excluded parts were the legs and joints, which showed an upward trend over the years. In contrast, issues related to the liver and hepatic lymph nodes demonstrated a decline. While the findings suggest a decrease in chronic conditions, the lack of detailed data on the reasons for carcass condemnation makes the interpretation of trends difficult.

As of December 31, 2023, Italy's cattle population is around 5.5 million head, making it the 6th largest among EU Member States (EU-27) in terms of cattle numbers based on EUROSTAT (https://ec.europa.eu/eurostat/databrowser/view/APRO_MT_LSCATL__custom_12066158/default/table?lang=en – accessed 05.07.2024).

The country is divided into 20 Regions, each functioning as an administrative and veterinary authority.

Based on free consultation of the Italian National Livestock Registry, **Table 1** summarizes the details of cattle population, cattle ordinary slaughtered in slaughterhouses and cattle emergency slaughtered on-farm, in relation to the whole Country, the region of Lombardy and the territory of Brescia. In the Lombardy region, located in the central-northern part of Italy and noted for its intensive farming systems in the Po Valley, 1.52 million head of cattle are reared annually, representing 27.6% of the national population. Of these, approximately 0.5 million head (9% of the national population) are raised within the jurisdiction of the Local Competent Authority (LCA) in the province of Brescia.

The annual number of cattle slaughtered in Italy is approximately 2.5 million, representing 45% of the national cattle population. In Lombardy, around 610,000 cattle are slaughtered annually, which accounts for 40.2% of the regional population. Within the LCA territory of Brescia, approximately 69,000 cattle are slaughtered each year, representing "only" 15.08% of the local population. This can be due to the fact that cattle can be sold (and transported) to other slaughterhouses located in nearby provinces or regions for business reasons (for instance, achieving better prices for meat unit, etc.).

The slaughter of cattle through on-farm emergency slaughter accounts for only 0.5% of the total cattle slaughtered in Italy, compared to 1.6% in Lombardy and 4.8% in Brescia. The reason why

these percentages are so high in Brescia, compared to regional and national contexts, is difficult to clearly understand, as many factors could be involved. These may include economic considerations, consistency of the dairy cattle population, logistical decisions regarding transportation, and the availability of slaughter facilities that accept OFES carcasses. In particular, it should be noted that these numbers and percentages (**Table 1**) related to slaughtered animals (both ordinary and on-farm emergency slaughter) reflect cases reported at the slaughterhouse level (not at the farm level). So, at first glance, it appears that the slaughterhouses in the province of Brescia could be either more densely populated or more committed to collecting OFES carcasses from farms in Brescia, as well as from other provinces and regions, compared to those in other areas.

This could be assumed also by looking at the information illustrated in Errore. L'origine riferimento non è stata trovata.**,** which displays the numbers and percentages of cattle found dead, emergency slaughtered, or euthanised for welfare reasons on-farm, at national, regional and local levels (Italy, Lombardy, and Brescia, respectively). These data reflect the number of cattle that died on-farm (due to one of the three reasons mentioned), based on cases reported at the farm level.

It is clear that the number of animals slaughtered at the slaughterhouses (both ordinary and on-farm emergency slaughter) in a given territory does not correspond to the total number of animals slaughtered across all farms in that area. Farms may sell live animals to slaughterhouses throughout the national territory, while those undergoing on-farm emergency slaughter are sent to any slaughterhouses accessible within a two-hour travel time.

In this scenario, the significant decline in OFES cases within the slaughterhouses under the jurisdiction of the LCA in Brescia over the past three years (-20.8% in 2022 and -30.5% in 2023, compared to 2021) does not have an equivalent at the local or national level. In particular, when examining the total OFES cases at the national, regional, or local level (**Table 28**), it is evident that at the national level, OFES cases nearly doubled from 11,444 cases in 2021 to 21,836 cases in 2023. This corresponds to 0.2% and 0.4% of the total cattle population (**Figure 25**), with an increase from 4.1% to 7.2% out of all cattle that died on-farm (**Figure 26**). Further analysis is necessary to understand this rise, since it may be linked to changes in the automated recording and reporting of OFES events at the national level, within the Italian National Livestock Registry, following the Italian MoH Circular (No. 13895 of 05.04.2022). In fact, before this date, there was no uniform method for collecting such information across the entire country.

At the regional level, OFES cases increased from 10,393 cases in 2021 to 11,740 cases in 2023 (+13.0%), corresponding to 0.7% and 0.8% of the total cattle population (**Figure 25**) and 7.6% and 8.1% out of all cattle that died on-farm (**Figure 26**). Interestingly, at the local level (Brescia), OFES cases declined from 3,044 cases in 2021 to 2,682 cases in 2023 (apparently, a decrease of -

11.9%); however, this corresponds to 0.6% of the total cattle population in each year in Brescia (**Figure 25**), and to 6.3% of all cattle that died on-farm in 2021, decreasing to 5.1% in 2023 (**Figure 26**).

Further analysis should be conducted to accurately understand these trends, as an increase in animals found dead on-farm is observed at all levels (national, regional, and local) (**Table 28**, **Figure 25**, **Figure 26**), revealing potential significant issues related to animal welfare.

What remains unknown is whether the increase in the number of cattle found dead on-farm (within a cattle population that is still decreasing) is related to changes in the interpretation of "accident" and, consequently, in the treatment of downer animals with chronic conditions, as they are no longer eligible for OFES cases. Alternatively, this increase could stem from other factors. For instance, while animals no longer eligible for OFES may be euthanised on-farm, such cases might not be adequately recorded in the National Livestock Registry. Additionally, the increase in the number of cattle found dead on-farm may be due to an increase in the recording and reporting of other types of deaths, such as those attributed to calves before their identification.

Table 28 – Numbers of cattle that were found dead, emergency slaughtered, or killed for welfare reasons on-farm in Italy, Lombardy, and the province of Brescia during 2021, 2022, and 2023.

	Italy			**Lombardy**			**Brescia**		
	2021	**2022**	**2023**	**2021**	**2022**	**2023**	**2021**	**2022**	**2023**
Total No of cattle population[a]	5,639,573	5,494,077	5,420,566	1,555,413	1,531,182	1,517,160	470,312	460,079	456,836
No of cattle found dead on-farm[b]	268,511	289,344	282,827	126,312	137,095	133,596	45,323	50,892	50,177
No of cattle emergency slaughtered on-farm[b]	11,444	17,719	21,836	10,393	10,920	11,740	3,044	2,700	2,682
No of cattle killed for welfare reasons on-farm[b]	718	571	572	276	226	220	33	13	16
Total No of cattle dead on farm (sum of the previous three items)	280,673	307,634	305,235	136,981	148,241	145,556	48,400	53,605	52,875

Data sources:
[a] Italian National Livestock Registry – Statistics section. https://www.vetinfo.it/j6_statistiche/#/report-pbi/11 (accessed 09 October 2024)
[b] Italian National Livestock Registry – Statistics section. https://www.vetinfo.it/j6_statistiche/#/report-pbi/12 (accessed 09 October 2024)

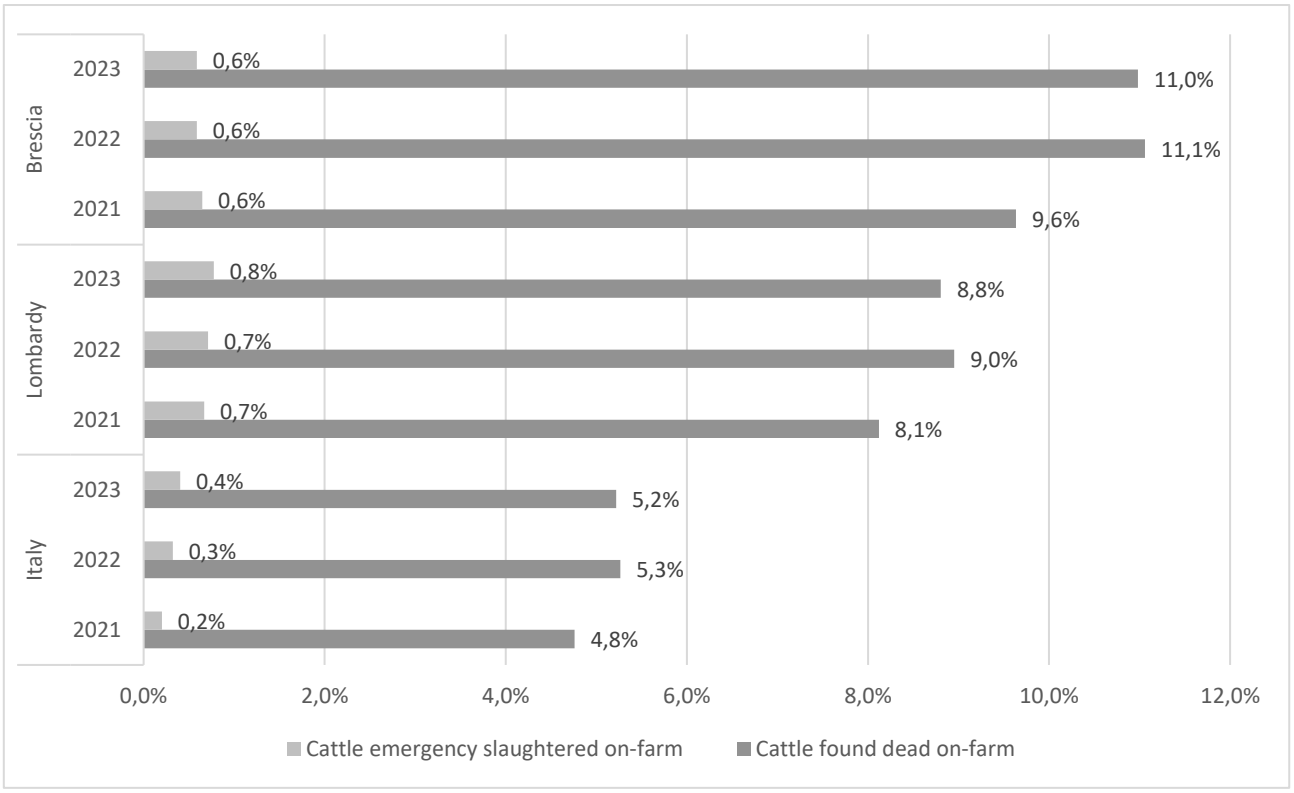


Figure 25 - Graphical illustration of percentages of cattle that were found dead and emergency slaughtered on-farm in Italy, Lombardy, and the province of Brescia during 2021, 2022, and 2023, out of the total number of their respective cattle populations. Partial and total numbers are available in Table 28.

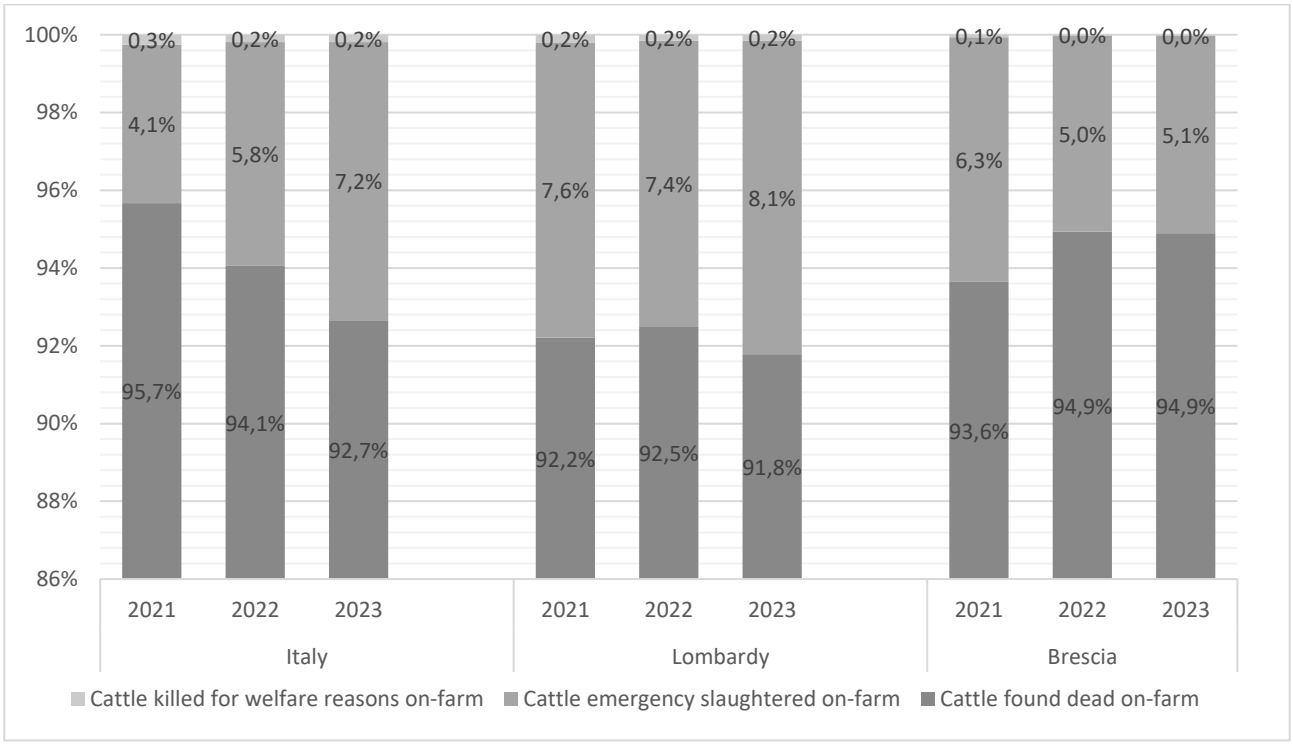


Figure 26 – Graphical illustration of percentages of cattle that were found dead, emergency slaughtered, or killed for welfare reasons on-farm in Italy, Lombardy, and the province of Brescia during 2021, 2022, and 2023, out of the total number of cattle that died on-farm. Partial and total numbers are available in ***Errore. L'origine riferimento non è stata trovata.****.*

Further research is required to investigate the potential relationship between the revised OFES guidelines by the Italian MoH and this increase in on-farm mortalities. It is possible that the re-interpretation of which animals are eligible for OFES has led to two secondary effects: *i)* an increase in cattle found dead on-farm due to their new ineligibility for OFES, combined with a lack of willingness or ability to treat them for recovery; *ii)* an increase in proactive culling of slightly ill or injured cattle (e.g., end-of-career cows) while they are still fit for transport, thus preventing further deterioration in their condition.

Throughout the entire study period, 94% of OFES cases involved female animals (11,359), with 83.3% (9,467) of these coming from the dairy sector. In contrast, beef farms presented a different trend: out of 1,041 animals, 52.4% were male (545) and 47.6% were female (496).

This is not surprising, as several studies (Skúladóttir et al., 2022b; McDermott et al., 2022; Mandel et al., 2022) have shown that dairy cattle are at a higher risk of acute injuries and subsequent OFES compared to beef cattle. Additionally, the beef cattle production system in Italy is significantly composed of males originating from cow-calf systems in other countries. According to the Italian National Livestock Registry (BDN) statistics available at vetinfo.it, on 30th June 2024 there were 971,686 male cattle raised for beef production out of a total of 2,362,757 beef cattle, accounting for 41.1% of the beef cattle population.

As shown in **Figure 5**, OFES cases were consistently more frequent on Mondays (averaging 848 cases) and Tuesdays (averaging 720 cases). This trend may be attributed to the accumulation of negative events affecting cows over the weekend, on Saturdays and Sundays. In contrast, the number of OFES cases decreased in the middle of the week, particularly on Wednesdays (642 on average) and Thursdays (654 on average), but saw an increase on Fridays (averaging 716 cases), likely due to the upcoming partial suspension of the service over the weekend. Saturdays (averaging 434 cases) and Sundays (averaging 4 cases) recorded the fewest OFES cases. It is possible that the small number of cases recorded on Sundays may be due to transcription errors. This is partly in line with the findings from Cullinane et al. (2010), where most emergency and casualty slaughters occurred predominantly on Tuesdays and Wednesdays, likely reflecting slaughterhouse availability and work practices. A significant welfare issue is that animals suffering from an accident over the weekend may not be slaughtered until the following Monday. Since animal welfare must be the priority in the decision-making process, if OFES services are unavailable and waiting would lead to further suffering, the decision should be to euthanise the animal. However, as shown in Errore. L'origine riferimento non

è stata trovata., this practice is not as common in Italy. Many discussions have arisen on how to tackle this issue, but few practical options are probably viable. On one hand, the extension of OFES services should be managed from both the Official Veterinarians' perspective and the private slaughterhouses, increasing the availability of OFES services during weekends and public holidays. This would ensure that animals suffering from accidents receive timely *ante-mortem* inspections and, if necessary, slaughter. In some cases, the use of "mobile abattoirs" has also been suggested.

On the other hand, farmers and veterinarians should be sensitized to develop clear emergency protocols that prioritize the rapid assessment and treatment of injured animals, including euthanasia if necessary, to minimize suffering. In this context, a survey conducted in Ireland (McDermott et al., 2023) revealed that farmers' decisions regarding the management of acutely injured animals are significantly influenced by the opinions of their private veterinary practitioners. Specifically, 45.6% of dairy farmers and 55.5% of beef farmers reported that their private veterinary practitioners' views played a major role in their decision-making process. Additionally, the majority of both dairy (72.5%) and beef farmers (76%) considered OFES beneficial for animal welfare.

Regarding the prevalence of OFES categories, nearly 70% of all cases within the 3 years were attributed to locomotory issues. Of the 8,362 locomotory cases, 57.1% were subcategorised as "Acute trauma/injury", with almost two-thirds of these cases affecting the hind legs. Unfortunately, the lack of specific terms used in the descriptions often made it difficult to fully understand the circumstances leading to the animal's adverse condition. This ambiguity was highlighted in the TF-IDF analysis, which revealed that terms such as "trauma" or "traumatic" were frequently used without providing additional context or details about the actual injury or event.

This challenge can be attributed to the difficulties that OVs face during AM inspections, particularly when dealing with downer animals. In many cases, veterinarians have limited or incomplete anamnesis, relying heavily on information provided by the farmer. As a result, OVs can exclude serious infectious diseases that deem the animal unfit for slaughter but distinguishing between a truly acute injury and a sub-acute/chronic condition can be difficult. This issue in accurately documenting cases is supported by Skúladóttir et al. 2022b, who noted similar limitations in the quality and detail of official veterinary certificates.

The remaining 42.9% of locomotory cases were classified under different sub-categories, with "fractures" and "slip and fall trauma" being the most prevalent. These cases, often considered as "true" acute accidents, increased in 2022 and 2023, likely following updates to the interpretation of the word "accident" at national level. It might be noted that in the sub-category "slip and fall trauma", many injuries were attributed to farmyard accidents involving machinery, handling facilities, or

excessively slippery floors. Interestingly, hip dislocations were also notably prevalent, raising the question of whether they should be classified solely as a result of slip-and-fall trauma in healthy animals (for instance, due to mounting on slippery floors) or as co-occurring with other factors, for instance when animals are already weakened, such as after calving or due to other health conditions (Huxley, 2006; Koralesky et al., 2018).

The prevalence of locomotory injuries aligns with findings from other studies, including Cullinane et al. (2010), Pištěková et al. (2004), Večerek et al. (2003), and Broom and Corke (2002), where the majority of these injuries were the result of bone fractures. Similarly, in the present study, fractures were notably higher in heifers from the dairy sector and bull calves from the beef sector, with 21.5% of dairy heifers (187 out of 868 cases) and 21.0% of beef bull calves (107 out of 509 cases) affected. This could be due to the nature of these animals being more impulsive and less trained to human handling compared to older (dairy) animals, which are more used to humans due to regular management practices (Grandin, 1997; Cullinane et al., 2010).

On the other hand, lameness accounted for only 1.6% of cases in dairy animals and 3.9% in beef animals, which contrasts with a previous study in Norway (Skúladóttir et al., 2022b), where 21% of all OFES cases were attributed to lameness, since it was permitted by the Norwegian guidelines for OFES in place at that time. The findings from the present research are consistent with a study conducted in British Columbia, Canada (Koralesky et al., 2018), which reported that only 9% of all cattle subjected to OFES were due to lameness. This finding, in the Italian context, could be seen as positive, as lameness is typically considered a chronic condition, which may not align with the definition of "accident". Furthermore, the occurrence of lameness was higher in 2021 than in subsequent years, indicating again a shift in the decision-making processes by OVs. Some public guidelines from Italian regions, such as the Emilia Romagna Region (2022), emphasize that lameness and other chronic conditions should be carefully evaluated through an appropriate clinical examination during the *ante-mortem* inspection and, generally, should not be considered eligible for OFES.

Despite the overall reduction in OFES cases, the high prevalence of locomotory issues remains a significant animal welfare concern, underscoring the importance of continued focus on prevention, management, and timely intervention in cases of injuries.

Within female animals from the dairy sector, the "Recumbency" and "Calving-related problems" categories showed a significant decline, particularly in old cows, decreasing from 24.9% and 18.6% in 2021, respectively, to 11.0% and 11.2% in 2023 (**Figure 16**). This decline is likely due to the updated interpretation of the term "accident" by the Italian MoH. Before April 2022, metabolic

syndromes were explicitly considered eligible for OFES, despite these conditions not necessarily being acute or resulting from an accident. As a result, from 2022 onwards, cases of palsy/paralysis and metabolic syndrome decreased significantly (both in "Recumbency" and "Calving-related problems" categories). The findings suggest that the stricter interpretation of regulations over time, as also discussed by Cullinane et al. (2010), may have played a key role in reducing OFES cases related to non-acute or chronic conditions. From an economical point of view, it can be argued that animals whose carcasses are not sold for meat consumption and that either die on the farm or are euthanised, resulting in the destruction of their carcasses, represent a loss in the efficiency of farming systems.

In contrast, the same cannot be said for "Traumatic injuries related to calving", which includes all cases of neuromuscular damage due to compression from trauma occurring during calving, including dislocation of the pelvic bones. These motivations still remain explicitly eligible for OFES under the current Italian guidelines. Consequently, these cases did not show a decline but rather increased: from 4.0% in 2021 to 6.4% in 2023 in dairy young cows, and from 5.7% in 2021 to 8.9% in 2023 in dairy old cows.

Again, such conditions, even though eligible for OFES, still represent a significant welfare issue within the broader context of downer cow syndrome. These issues should be addressed at the farm level through preventive and corrective measures aimed at improving calving management and also refining breeding practices, in order to reduce their incidence. Effective management of cows from the dry-off period through the early postpartum phase is crucial. Unfortunately, these findings support the hypothesis put forward by Skúladóttir et al. (2022b) (in the case of lameness) that the availability of OFES may provide veterinarians and farmers with an "easy out", relying on emergency slaughter rather than focusing on proper management of calving to prevent complications, as well as appropriate treatment of sick animals.

4.2Machine learning (artificial intelligence) approach

The analysis conducted using the Term Frequency-Inverse Document Frequency (TF-IDF) method provided significant insights into the reasons for OFES reported by OVs during *ante-mortem* inspections. A total of 1,351 unique words were identified in the electronic dataset within the OFES reason column. The descriptive statistics from the TF-IDF analysis provided a comprehensive overview of the distribution of scores and true frequencies, revealing a minimum score of 0.26 and a maximum score of 1,700.30. Notably, several words emerged as highly relevant, such as “trauma”, “traumatic”, “injury” and “paresis”. This suggests that terms referring to traumatic or accidental events were frequently encountered in the motivations provided by veterinarians, even if these terms were not only associated with locomotor injuries but also with lesions related to calving and conditions like paresis or paralysis.

The clustering of words into five distinct groups illustrated the complexities involved in categorizing the motivations. Despite the identification of these clusters, the analysis indicated significant overlap among them (**Figure 19**), reflecting the challenges of assigning clear categories to the motivations based on the TF-IDF results.

The silhouette scores calculated for each motivation further supported this finding (**Table 21**). In fact, silhouette scores assess how well an object fits within its assigned cluster by comparing its similarity to its own cluster versus other clusters. These scores can range from -1 to 1: a score close to 1 indicates strong alignment with its cluster, while a negative score suggests possible misclassification into the wrong cluster. In this study, the silhouette scores were predominantly low, except for Cluster 4, highlighting significant variability in clustering quality across different motivations. This indicates also a weak cohesion within the clusters provided by the TF-IDF analysis and suggests that the categories or groups of motivations were not well-defined. The TF-IDF analysis helped in revealing that the same words were used in several occurrences, highlighting that many times it was quite difficult to properly categorize motivations without a certain subjectivity, as already described by previous experience (Cullinane et al., 2010).

These results underscored the inherent difficulties faced by OVs during AM inspections, particularly when the anamnesis was limited and few signals could be detected on the animal. This highlights the necessity for specific training for veterinarians conducting *ante-mortem* inspections on farms, providing them with uniform knowledge and expertise needed to better assess the health and welfare of downer animals and accurately interpret the motivations behind emergency slaughter cases.

Additionally, the findings statistically highlighted the challenges encountered by the author in distinguishing between various motivations, which further emphasized the subjective nature of interpreting reasons presented in free-text format. This can also be seen in the differences between the categorization used in this study and that of previous research, from which parts of the methodology were adopted (Skúladóttir et al., 2022b; Cullinane et al., 2010). Despite these differences, the existence of these earlier studies offered valuable reference points. They allowed the author to minimize subjectivity when addressing uncertain cases. By aligning with established categories in the literature, the author was able to make more informed and consistent decisions, adopting a more structured approach even when the descriptions did not completely match.

Nevertheless, thanks to the TF-IDF analysis, it was possible to better prepare the dataset for the supervised machine learning approach. By utilizing a predefined list of categories and sub-categories (**Table 2**), the machine learning algorithms had the chance to more accurately understand OFES motivations, thereby minimizing potential errors stemming from typographical variations. Various supervised techniques were employed in the categorization process, but it was encouraging to observe, at the end, a high level of consistency achieved with human interpretation, with an impressive 99.2% consistency across the three years studied. This indicates that the machine learning model effectively aligns with the categorization made by the author's human intelligence. This outcome not only validates the methodology employed but also highlights the potential of machine learning to assist in classifying motivations related to OFES.

The future steps (starting in 2025) will involve implementing a non-supervised machine learning model on the OFES dataset from 2024. This will include the application of deep learning models, such as Recurrent Neural Networks (RNNs) and Transformers like BERT, to capture more intricate relationships within the data. These advanced models are expected to enhance classification accuracy and effectively adapt to new real-world scenarios.

Currently, the results demonstrate the effectiveness of combining traditional approaches with advanced machine learning techniques to analyse complex veterinary data.

The insights gained from this analysis provide a solid starting point for the development of more robust classification systems that could be integrated into the Italian MoH platform, called “ClassyFarm”. Future research will indeed focus on refining these methodologies, not only for the classification of data related to OFES but also for other veterinary information, collected in the field or obtained from diagnostic laboratories, with the aim of significantly improving animal welfare management practices.

4.3 Findings at the post-mortem inspections at slaughterhouse

The *post-mortem* analyses performed on the carcasses of animals subjected to OFES revealed several important trends regarding the suitability of carcasses for human consumption and the reasons for condemnation. Results showed that 93.4% of carcasses undergoing the OFES process were deemed fit for consumption. This aligns with findings by Finazzi et al. (2023), who reported a 6.3% destruction rate among carcasses of animals subjected to OFES.

However, this study observed a gradual decline in the number of OFES cases over the years, without a corresponding decrease in the percentage of condemned carcasses (5.2% in 2021 versus 9.1% in 2023). This trend needs further investigation, as it may be linked to random factors, such as spontaneous changes in attitudes or work practices due to a generational shift among Official Veterinarians. It could also be a secondary effect of the revision of eligibility criteria for OFES during the *ante-mortem* inspection, which has generated a response to a stricter approach during *post-mortem* inspections, in relation to what should be considered appropriate for OFES cases. Additionally, it should not be overlooked that the implementation of an electronic OFES register among the LCA of Brescia, both at the *ante-mortem* and *post-mortem* inspections, may have generated a hyper-corrective reaction among Official Veterinarians, leading them to make more stringent decisions compared to the past. Furthermore, since April 2022 (Italian MoH Circular No. 13895 of 05.04.2022), 10% of carcasses are required to undergo HPLC testing for drug residues, which has greater sensitivity. This may have led to an increase in the number of carcasses condemned for this reason. Unfortunately, this information has not been included in the electronic dataset of the LCA of Brescia, making it currently inaccessible.

The lack of documented reasons for carcass condemnation complicates the understanding of its increasing rate over the years. Out of 795 destroyed carcasses, only 232 (29.1%) had a recorded reason for condemnation. This missing data makes it challenging to identify the underlying causes of the observed trends.

Notably, among the 795 condemned carcasses, 513 reported a negative conclusion from laboratory analyses. Unfortunately, only 270 of these cases (see **Table 26**) provided a clear illustration of the distribution of laboratory results among the reasons for whole carcass condemnations. Within this group, a significant 65.6% of laboratory findings were linked to total bacterial counts, and 20.4% were associated with *Clostridium* spp. This highlights the prevalence of bacterial contamination in condemned carcasses, which serve as indicators of ongoing bacteremia or septicemia resulting from the specific injury or accident suffered by the downer animal.

Consequently, the entire carcass was destroyed in compliance with EU Regulation 2019/627, Article 45, letter (f), leading to additional economic losses for the farmers.

This finding is in line with the evidence that out of the 232 justified destroyed (whole) carcasses (**Table 25**), 32.3% exhibited widespread hematomas, 26.7% demonstrated multiple organ impairment, 20.6% had lesions associated with circulatory and metabolic disorders, and 15.5% were related to abscesses or phlegmon. Additionally, out of 270 cases reporting lab results, 8.5% of carcasses were found to be infected with *Salmonella* spp., which is particularly concerning, as these pathogens are known to pose serious health risks to humans in foodborne infections.

A closer examination of different production systems reveals that mixed farms had a higher percentage of condemned carcasses (7.3%) compared to dairy and beef production systems, which had slightly lower condemnation rates (6.5% and 6.6%, respectively). Although the difference in condemnation rates among production systems is relatively small, it can be argued that mixed farms, lacking a specific focus on either dairy or beef production, may exhibit less organized management practices. This could result in delayed interventions when calling the OVs for *ante-mortem* inspections. As a consequence, animals may remain downer for longer periods, which increases the risk of secondary complications such as muscle damage and necrosis due to prolonged recumbency. This situation further heightens the likelihood of carcass condemnation and the concerns for animal welfare.

Among the 11,256 carcasses designated for human consumption, again only 25.7% (2,887 cases) reported exclusions of specific parts (see **Table 27**).

The most frequently excluded parts were the legs and joints, which accounted for 39.3% of exclusions, reflecting an increasing trend over the years (from 37.6% in 2021 to 44.9% in 2023). This trend is related to the increasing trend of OFES cases attributed to locomotory issues at the *ante-mortem* inspection. Notably, among all known exclusions related to legs and joints, 89.3% (1,014 cases) were attributed to hematomas. These hematomas could actually result from acute accidents that occurred to the animals or from the secondary effects of prolonged recumbency. Further studies should be conducted to distinguish between these two conditions at the slaughterhouse.

Conversely, issues related to the liver and hepatic lymph nodes accounted for 18.9% of known exclusions, though this category exhibited a declining trend, decreasing from 21.5% in 2021 to 13.6% in 2023. Among these exclusions, 77.1% (422 cases) were associated with circulatory and metabolic disorders, including conditions such as steatosis, telangiectasia, and jaundice. The significant decreasing trend in liver impairment could reinforce the evidence that the OFES categories related to sub-acute or chronic conditions (all three categories different from “Locomotion” category) showed

a notable decline over the years. This trend may be attributed to the already described update in the interpretation of the term “accident” by the Italian MoH.

However, these findings closely align with the results reported by Finazzi et al. (2023), which underscore significant health concerns related to the liver and hepatic lymph nodes in OFES cattle. Their study identified lesions, with steatosis recognized as a primary pathology, exhibiting a prevalence rate of 60.5% in carcasses from OFES animals. The high prevalence of steatosis, along with conditions such as lameness and palsy/paralysis, raises significant concerns, particularly for dairy cows during the early lactation period. The physiological demands of lactation predispose these cows to metabolic disorders, thereby increasing the risk of complications that may ultimately result in carcass condition. Interestingly, the present study found that old cows had a higher rate of condemned carcasses (7.1%) compared to young cows (5.8%) (see **Figure 22**). The relationship between older age and the likelihood of having condemned carcasses can partly be attributed to the prolonged exposure of older dairy cows to various pathogens and disease-promoting factors throughout their productive life, in contrast to younger cows. A recent study (Ciui et al., 2023) found that cattle over three years old exhibited significantly higher levels of lesions in offal and carcasses compared to younger animals. This finding could be a consequence that older animals face repeated and prolonged exposure to diverse pathogens, leading to a higher prevalence of pathology within this age group. Other research supports these findings, showing that older cattle are more susceptible to conditions such as pneumonia and chronic diseases, which can contribute to a greater incidence of carcass condemnations (Jacobs et al., 2023; Pighin et al., 2016). Furthermore, Finazzi et al. (2023) did not find significant differences in the prevalence of these lesions between carcasses from ordinary slaughtered animals and those from on-farm emergency slaughter. Unfortunately, the present study lacked data on the lactation stages of the cows at the time of OFES, but further research is essential to establish a clearer relationship between the lesions observed at slaughter and the specific lactation stages of the cows.

The analysis of the distribution of body parts excluded during *post-mortem* inspections of 11,256 carcasses deemed fit for human consumption, in relation to the OFES categories attributed during *ante-mortem* inspections, revealed no significant differences. As illustrated in **Figure 24**, the “Locomotion” category consistently showed an upward trend over the years, reflecting its overall increase in OFES cases. In contrast, the categories “Recumbency” and “Calving-related problems” exhibited a significant overall decline across all types of exclusion locations over the three-year period. Further investigation should be conducted to analyse why the distribution of exclusions among OFES categories closely aligns with the overall distribution of OFES categories. For example, the recording of condemned parts of carcasses may simply be operator-dependent, potentially failing

to accurately reflect the true distribution of the information collected. This observation aligns with the overall limited data available in the *post-mortem* dataset, underscoring the need for additional data extraction (when possible) focused on results from both the slaughterhouse and laboratory analyses.

CONCLUSIONS

The present study has provided important insights into the trends, reasons, and characteristics associated with On-Farm Emergency Slaughter across four regions and 15 provinces in Northern Italy, specifically focusing on carcasses transported to slaughterhouses located in the province of Brescia from 2021 to 2023.

The observed gradual decline in OFES cases delivered to the slaughterhouses in Brescia may be linked, as secondary effect, to the guidelines changes introduced by the Italian Ministry of Health in 2022. This underscores the critical role that updated interpretations of EU regulations have played in shaping OFES decision-making. The redefinition of key terms like “accident” has likely contributed to more stringent evaluations by Official Veterinarians during *ante-mortem* inspections, particularly regarding animals suffering from chronic conditions, leading to a reduction in OFES cases associated with these non-acute issues. This shift reflects a move towards more structured and restrictive interpretations of OFES eligibility, which may have implications for both animal welfare and decision-making at the farm level.

The analysis of OFES motivations revealed that locomotory issues - such as fractures and acute trauma - were the most common reasons for emergency slaughter, accounting for the majority of cases. Interestingly, a significant reduction in the incidence of recumbency and calving-related problems over the study period suggests a response to the tighter OFES eligibility guidelines. However, further research is needed to establish whether this decline is the result of improved veterinary decision-making and farm management practices, or if it is primarily attributable to the revised interpretation of EU regulations. The persistence of traumatic calving injuries highlights the continued challenges in managing these issues, indicating a need for ongoing efforts to improve calving management and breeding practices aimed at reducing such occurrences and enhancing overall animal welfare.

The study also demonstrated the effective use of artificial intelligence (AI) tools, such as Term Frequency-Inverse Document Frequency (TF-IDF) analysis and machine learning models, in categorizing the free-text motivations provided by Official Veterinarians. These techniques not only improved the consistency and precision of the data but also reduced the time and effort required for manual analysis. The application of AI offers great potential beyond the scope of OFES analysis, as these tools can be adapted to other areas of veterinary data analysis, supporting more efficient and standardized data management across various veterinary contexts. Additionally, ongoing refinement of machine learning models is necessary to enhance their accuracy and applicability in veterinary data analysis, ultimately contributing to more effective animal welfare management practices.

The findings from the *post-mortem* inspections indicate an overall trend showing a decline in chronic conditions, likely attributed to changes in the interpretation of what constitutes an "accident". However, it remains unclear how animals with chronic (subclinical) pathologies are now managed and treated. Moreover, no significant differences were observed in the motivations for excluding carcass parts compared to the reasons for which the animals underwent OFES. This suggests that cattle undergoing OFES may not be at a higher risk of specific pathologies compared to cattle that died differently. Factors related to the farmer's managerial strategies, or economic considerations, or the availability of official veterinarians for *ante-mortem* inspections, or the willingness of nearby slaughterhouses to manage OFES carcasses, etc., may be more critical in determining the final "type" of death for the cattle.

To gain a deeper understanding of these dynamics, further research should be conducted to examine the conditions of cattle transported to the slaughterhouse for presumed voluntary culling, alongside those that died on-farm due to OFES, euthanasia, or were found dead (i.e., voluntary versus involuntary culling). Such research would provide valuable insights into the broader issue of welfare for dairy cows at the end of their productive lives and explore the implications of stricter OFES guidelines on on-farm mortalities.

In conclusion, this study highlights the evolving landscape of OFES practices in Northern Italy, driven by changes in national guidelines and enhanced by advanced data analysis techniques. By understanding the health and welfare implications associated with these different scenarios, more effective categorization of farms could be implemented, also through the application of the ClassyFarm system. This would enable the development of corrective and preventive management strategies aimed at improving the conditions of cattle and enhancing their quality of life.

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