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A review of horse welfare literature from 1980 to 2023 with a text mining and topic analysis approach

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ABSTRACT

Animal welfare protection is a challenge for which policy-makers are demanding scientific-based evidence. Considering horses, the challenge is even greater, as their role in society varies from production to companion animals. This review aimed to describe the evolution and geographical distribution of horse welfare literature over the years, to identify the most studied research topics and to highlight the still present gaps in knowledge. A search on Scopus® bibliometric database was performed using different welfare-related keywords. Predetermined filters were posed on time range, language and subject area. A total of 6584 records were downloaded and screened retaining only the ones dealing with horse welfare and behavioural sciences. Descriptive statistics, text mining (TM) and topic analysis (TA) were performed on the abstract of 801 eligible records. The results showed the number of studies on horse welfare is exponentially increasing, especially in the European continent. 'Transport' was the most frequent word, but also 'behaviour' and 'pain' emerged. Nine topics were identified and covered different subject areas: stress analysis, pain assessment, equitation science, human–horse interactions, breeding management, transport, working equids and health. The evaluation of stress and pain, horse social behaviour and the human–horse relationship resulted to be the most studied aspects related to animal welfare. On the contrary, the concept of positive welfare and the welfare assessment at slaughter of horses were underrepresented, confirming the limited literature on these subjects. This review confirmed the growing impact of research on horse welfare and highlighted how some important areas still do not provide sufficient scientific evidence.

HIGHLIGHTS

- Analysis of the literature related to horse welfare was performed using text analysis techniques to identify trends in words and research topics.
- Results showed that the literature on horse welfare has exponentially grown in the last 43 years, especially in Europe.
- The most studied topics were stress and pain, while studies on the welfare at slaughter and positive welfare indicators were scant.

Introduction

Interest in animal welfare has been growing in recent decades. Studies were driven initially by ethical concepts and popular empathy and later by economic and political interests that have increased around this topic (Lesimple 2020). Society progressively demands scientific-based evidence to define objective and quantifiable parameters to measure the welfare of animals and to provide solutions to major animal welfare issues (Ohl and Van der Staay 2012). Historically,

welfare concerns started with Ruth Harrison's Book and continued with the subsequent Brambell report and the first animal protection legislation (Brambell Committee (Report) 1965; Harrison 2013). This need was raised to protect livestock from the damage caused by intensive farming (Woods 2012). From this starting point, the concept of welfare evolved over the years. Initially, welfare was considered as the absence of negative aspects, measured with environmental and resourced parameters (Lawrence et al. 2018). Indeed,

in the Brambell report, an animal which was free from hunger and thirst, discomfort, fear, pain and diseases, and with the possibility to express normal behaviour was considered an animal in a good state of welfare (Brambell Committee (Report) 1965; Webster 2001). Following this important statement, policy-makers started to propose legislation on animal protection based on the minimal requirement to be accomplished to protect animal welfare. Then, over the years, researchers started to develop a new and more complete welfare concept, no longer based only on the absence of negative conditions, but inclusive of positive emotions (Mellor and Beausoleil 2015). Pioneering in this process, the 'Five Domains Model' is the first one to address the importance of assessing welfare using positive indicators (Mellor and Reid 1994). With this approach, a good welfare status is not only when there are no negative conditions but when the animal has a life worth living (Green and Mellor 2011). From then on, more emphasis has been placed on identifying positive aspects of welfare (Lawrence et al. 2018).

Over the years, the concept of welfare has been applied to other species in addition to livestock animals. In this context, horses tend to be one of the most difficult species to evaluate. Indeed, comparing to other species, there is a difficulty in the standardisation of the environmental and farming conditions to which the horse is subjected (Hausberger et al. 2020). Moreover, horses are considered one of the most versatile species, inclined to be sport, companion, work and farm animals (Dalla Costa et al. 2016). Precisely because of this multiple role, up to date, laws on the protection of horse welfare are less developed than for other species, with only guidelines present in some countries. Moreover, some laws are limited and not exhaustive as they often put horses together with other livestock animals, not considering their different needs related to their multiple uses in society (Fletcher et al. 2022).

Considering the exponential growth of scientific research publications in recent years, it has become necessary to find new methods to approach and screen all these documents (Rodrigues et al. 2014). In fact, bibliometrics was successfully applied to medical area enabling to analyse a vast amount of documents and their main information/characteristics on both a macroscopic and microscopic level, and it has been suggested as a valuable new approach (Tejasen 2016; Kokol et al. 2021). Text mining (TM) is a technique that converts text into numeric information to study the words' frequency distribution and the associations among the most frequent words (Sebastiani 2002) while topic analysis (TA) is a method to discover semantic connections hidden in records, or in general in textual data (Blei 2012). These techniques, even when used on small datasets, can serve in screening and finding out which topics are most studied in a specific research area without reading deeply all the literature documents (Kokol et al. 2022). TM and TA have recently been applied to analyse the subject of beef cattle welfare (Nalon et al. 2020). To date, these methods have still not been applied to horse welfare literature. For this reason, this review aimed to deepen horse welfare-related topics through TM and TA techniques, in order to describe the literature evolution and geographical distribution, to identify the most studied research topics, and to highlight the gaps in knowledge. In that manner, this review serves academics as state of art, helping them to develop a perspective on trends in the welfare-related research area.

Materials and methods

Data set

On the 21 March 2023, a literature search on horse welfare-related topics was conducted. The bibliometric database of Elsevier©, namely Scopus®, was used. The research team set up a search protocol and decided the keywords to use. In particular, the final keywords were 'horse welfare', 'equine welfare', 'foal or mare or stallion welfare', 'horse transport' and 'horse slaughter'. Year range was set from 1980 onwards. English language and selected subject areas (Supplemental material, File S1) were set before starting the search. Each keyword sequence resulted in a number of records that were then downloaded. Data extracted from the identified records were merged and collected on a commercial data sheet (Microsoft Excel®, version 16.0, Redmond, WA) for further analysis. The final spreadsheet contained each record as a row and its information in columns. The information included the title, the authors, the affiliations, the abstract, the year of publication, the type of record (e.g. research article or review) and the source of publication (e.g. journal title). On this final dataset, some automatic exclusions were performed. In particular, records that did not contain information about the authors, the abstract, the source or the type of record were excluded. Moreover, records classified as erratum or retracted were excluded. Finally, the same records (i.e. duplicates) obtained several times by entering different keywords were deleted. After this automatic screening,

one reviewer independently screened all the records collected in the dataset, looking carefully at the title and the abstract of each record. During this process records were selected for their eligibility for final inclusion. Criteria of inclusion were represented by records that dealt with Equidae welfare and behavioural science, while excluded records related to different species or topics (e.g. genomics, infectious diseases and molecular biology). Records that studied equids in general (horses, donkeys and mules) were maintained, while records that included other species (e.g. cows and pigs) were excluded. Records considered not eligible were directly excluded. Those records that were deemed difficult to categorise were reviewed by a welfare expert to be either definitively included or deleted. Information about the exact number of records downloaded from each research string, the preliminary screening and the eligibility process are shown in the flow chart (Figure 1). Each record was associated with a nationality that was extrapolated from the country or geographical region of the affiliation of the corresponding author and, where not present, of the first author. The European nationality was attributed to the records belonging to the European continent. Descriptive statistics on year, country of publication and type of record were performed to profile the scientific corpus using Excel Pivot tables and graphics.

Text mining

A separate Excel sheet which included two columns, namely 'progressive ID' and 'abstract' was prepared for the TM analysis. Since some words in the corpus of records were spelt either in American and British English, the authors decided to standardise the corpus of documents using only British English. In particular, the word pairs involved in this handling process were behaviour-behaviour, analyse-analyse, program-programme. Hence, a TM analysis was performed on the abstracts of the included records. The TM analysis was performed in R environment (R Foundation for Statistical Computing, Vienna, Austria. URL, https://www.R-project.org/) using a combination of functions in the packages 'tm', 'SnowballC', 'ggplot2', 'dplyr' and 'tidyverse'. Several pre-processing steps, listed in Table 1, were performed as described in the literature (Sebastiani 2002). Researchers decided to remove the stopwords 'horse', 'horses', 'equine', 'equid', 'equids', 'animal', 'animals', 'welfare', 'test', 'time', 'group', 'groups', 'study', 'studies', 'significant', 'significative', 'significantly' and 'significance', and to perform the text stemming of the scientific corpus. The next step was to build a matrix that contains the records along the rows and the terms along the columns, the so-called document-term matrix (DTM). The term frequency-inverse document frequency technique (TFIDF) was used to weigh the words (Salton and Buckley 1988). The words which have an impact, so arbitrarily chosen by the researchers looking at the weight of each word with a TFIDF $\geq$ 6, were represented as histogram and wordcloud (https://www.wordclouds.com/) in which a bigger character size indicates a higher TFIDF value. Associations with a correlation grade $\geq$0.3 among all the terms of the corpus and the impact terms (TFIDF $\geq$ 6) were identified. In particular, associations were calculated by measuring the frequency with which two words appear together considering that if two words always appear together the correlation is 1 and if they never appear together the correlation is -1.

Topic analysis

The TA approach of Latent Dirichlet Allocation (LDA) (Wang et al. 2016) has been applied to pursue TM to the abstract corpus. A Bayesian probabilistic approach was used to discover different thematic topics from words that tend to occur together in the document. LDA function with Gibbs sampling option of the 'topicmodels' package in R was used (Grün and Hornik 2011). The R library 'tidytext' was used to represent the graphic of the 15 most common words of each topic and their relative probability of belonging to that topic (beta value). The number of topics was fixed before starting the TA. However, since the 'ideal' number is in general not known, several trials with different numbers of topics (i.e. six, nine and twelve) were performed and, with a consensus among the researchers, the two most indicative panels were chosen. To compare these two final panels and decide which one was the most indicative, the baloonplots technique was used using the R library 'ggpubr'. Once the final number of topics was chosen, the researchers decided on a label representing each topic, first independently and then discussing together to achieve a final consensus for naming each topic. Descriptive statistics on the number of papers and the first year of publication of each topic were performed using Excel. Finally, since the topics numeration given by R is random, the cumulative probability (cp) of the first 15 words of each topic was calculated to classify the topics statistically and numbered them accordingly.
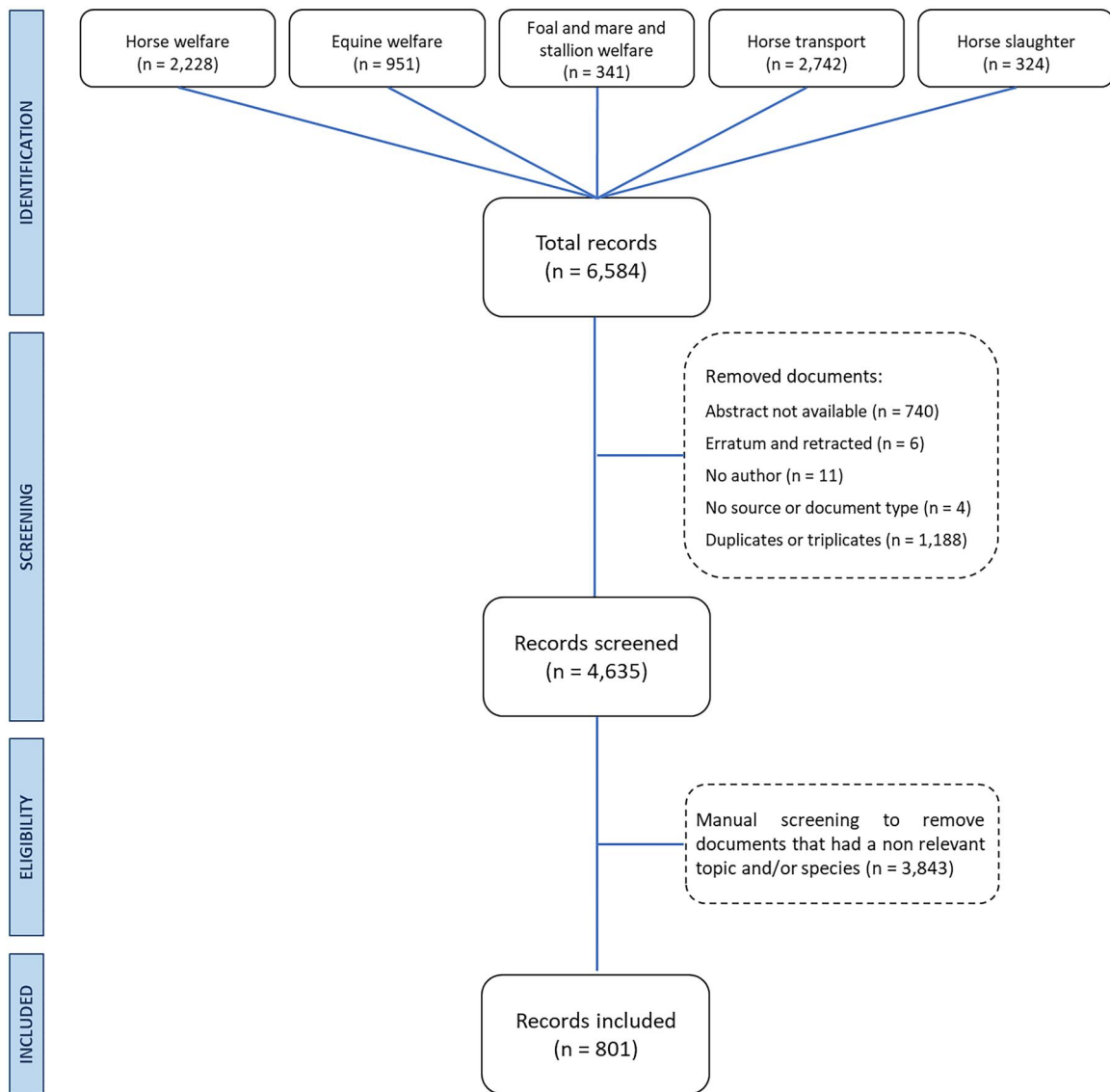
Figure 1. Flow chart of the scientific literature on the number of records found with each keywords sequence and the number of final records included in the review. The number of records excluded and reasons for exclusion are represented by the dashed lines. Examples of not-relevant topics were genomics, infectious diseases, and molecular biology; while not-relevant species were every species different from equids.

Results

Descriptive statistics

Considering the 801 records retained for analysis and their year of publication, there was an exponential increase in the total number of records published per year (Figure 2). Between 1980 and 1990 only a record per year was published while from 2010 till the present this number varies from 22 to 77 per year. In 2023 (until the 21 March, when the search was performed) the total number of records was 22; but this is likely to quadruplicate at the end of 2023. The corresponding author of the analysed records was based mainly in Europe, with a higher rate in the United Kingdom (UK), Italy and France (Figure 3). Research articles represented the most common type of paper (86.4%; 692/801) followed by reviews (9.7%; 78/801), conference papers (1.6%; 13/801), book chapters (0.9% 7/801) and others (1.4%; 11/801).

Text mining

After the pre-processing and the removal of the sparse words, the final number of word roots resulted in 1341. The weights of the terms found (calculated as TFIDF) ranged from 14.43 to 0.38. The completed list of the first 200 words and their relative weight is

Table 1. Name and description of the pre-process steps done before starting the text mining analysis on the corpus of 801 records selected for inclusion in the review.

Pre-process step	Description
Convert the text to lowercase	all capital letters found in the corpus are converted into lowercase letters
Remove strange symbols	Strange symbols and fonts such as '@', '/' or '*' are removed and substituted by a white space
Remove punctuations	Punctuation marks present in the corpus are removed and replaced by a white space
Remove English stopwords	English common language words such as articles prepositions and conjunctions are removed (e.g. 'the', 'a', 'and', 'on', 'at', etc …) as they provide little information about the contents of the corpus.
Remove your stopwords	Remove words chosen by the reviewers which might be very common in the corpus as they are the ones from which the search started (keywords) or are words related to statistics. These words, if included, will give poor discriminative information due to their presence in almost all abstracts retrieved (Wang et al.. 2016).
Remove numbers	Numbers present in the corpus are removed and replaced by white space.
Remove extra white spaces	Extra white spaces formed at the end of the previous processes are removed.
Text stemming	Reduce the words to their root form simplifying the words to their common origin: e.g. 'programming', 'programs' and 'programmers' can be reduced all to the word 'program'.
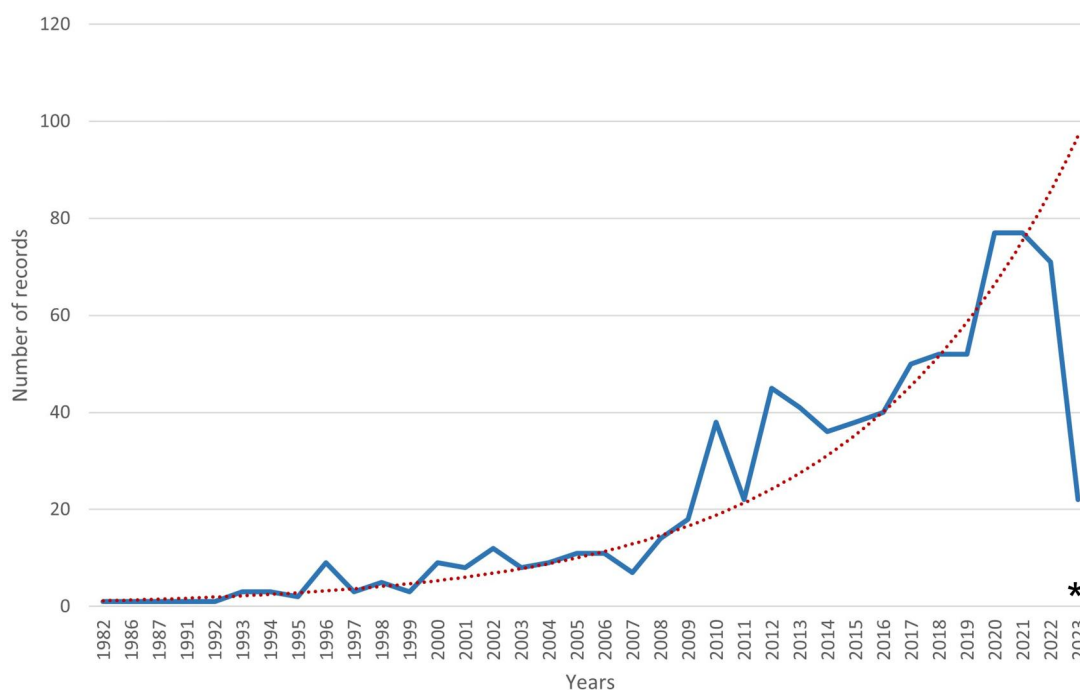
Figure 2. Distribution of the number of 801 records selected for inclusion in the review per publication year (1980–2023). the dashed red line represents the exponential trend. * on the year 2023 indicates that results for that year are related to the period from January to March.

presented in the Supplemental materials (File S2). The most relevant words according to the TFIDF ponderation system (TFIDF $\geq$ 6) are represented with a histogram and a wordcloud (Figure 4). Table 2 shows the correlations found between the most relevant words (TFIDF $\geq$ 6) and the other words of the matrix. The words 'train', 'mare', 'condit', 'respons', 'measur', 'problem', 'stabl', 'differ', 'manag', 'treatment' and 'observ' showed no significant correlation (with correlation grade $\geq$ 0.3) with other words.

Topic analysis

Figure 5 shows the BalloonPlot made to select the optimal panel of number of topics between six and nine possible topics. Figure 6 represents the histograms of the first 15 words of the chosen nine topics, which were considered as the optimal panel of topics. Table 3 shows the labels that were given by the authors to each of them. The distribution of the records according to the research topic was indicated in an Excel sheet (available on request to the corresponding author). The TA performed with six and twelve a-priori numbers of topics are instead shown in the Supplemental materials (Files S3 and S4). The enumeration of the topics from 1 to 9 was based on the cumulative probabilities (cp) of the weight of the 15 most relevant words in each topic.

Table 3 shows for each of the nine topics, the cp, the chosen label, the total number of papers
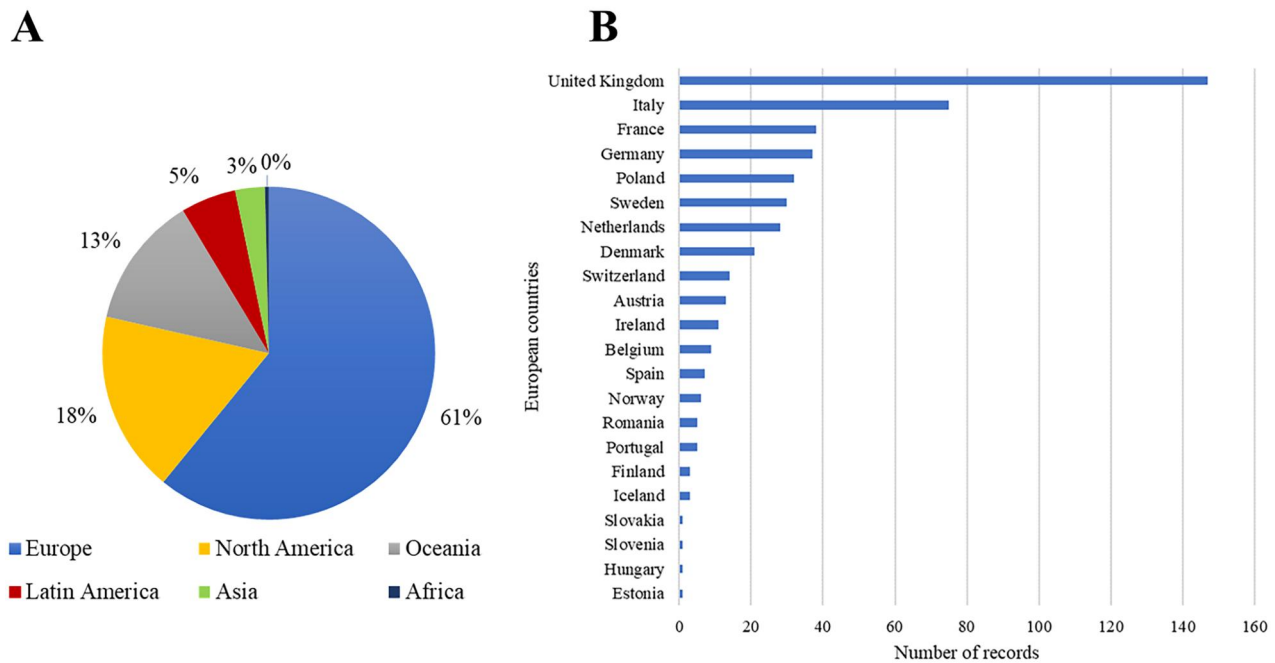
Figure 3. Panel A indicates the pie chart with the distribution of 801 records selected for inclusion in the study by regions and subregions. Panel B represents the distribution of the included number of records by each European country. The countries are based on the nationality of the corresponding authors.
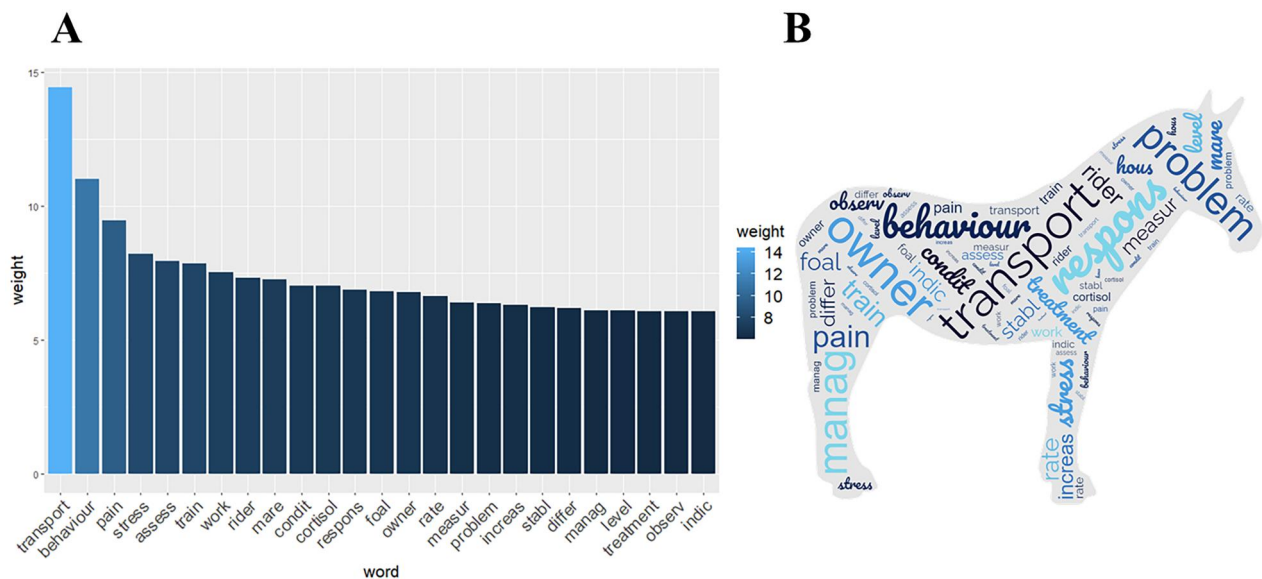

Figure 4. Panel A shows the histogram of the most relevant words (TFIDF $\geq$ 6) of 801 records selected for inclusion in the study and their respective weights. Panel B shows the wordcloud representing the same words. The size of the words is proportional to the weight they have in the corpus.

and the year when the first record related to that topic was published. The topics studied the longest were 'human-horse interactions' (Topic 9) and 'breeding management' (Topic 4), while the most recent topic was 'equitation science and horse-rider relationship' (Topic 3), followed by 'working horses' welfare' (Topic 6) and 'pain and mental state evaluation' (Topic 2).

Discussion

This review allowed to deeply analyse the type of studies conducted on horse welfare in the last 43 years by applying TM and TA techniques. Thanks to the present review, it was possible to understand the subject and the topics that have had more scientific attention, and the ones that still need to be investigated. The TA

captured some themes of known relevance, but also more hidden topics, such as the welfare of working horses and horse-rider interaction. However, it is important to underline that more recent or of less

Table 2. Associations between the most relevant words (TFIDF ≥ 6) and the other words present in the corpus of 801 records selected for inclusion in the review.

Words (TFIDF ≥ 6)	Words associated (grade of correlation ≥0.3)
Transport	road (0.49); unload (0.33)
Behaviour	stereotyp (0.33)
Pain	scale (0.57); facial (0.39); recognit (0.31)
Stress	salivari (0.36)
Assess	tool (0.35); protocol (0.32)
Work	lesion (0.32)
Rider	accid (0.37)
Cortisol	salivari (0.56); concentr (0.48); metabolit (0.46); saliva (0.37)
Foal	wean (0.41); separ (0.37)
Owner	euthanasia (0.3)
Rate	heart (0.83); forward (0.30)
Increas	decreas (0.37)
Level	basal (0.33)
Indic	awin (0.33)

The grade of correlation is written between brackets. The minimum grade of correlation was set ≥0.3. Words can be partially cut because of the text-stemming process that reduced the words to their roots.

scientific interest themes may not have been discovered by the technique.

The number of papers related to horse welfare topic is growing exponentially. This confirms an increasing interest in all areas of welfare, in line with the history of this subject. Starting from the 1990s, scientists agreed on the definition of animal welfare and its measurability, transforming it into a scientific concept (Broom 2011). From the 1990s an increase in the publication of papers on horse welfare was noted. Interestingly, even though horses are not exclusively considered production animals, attention to their welfare has grown in parallel with other livestock species (e.g. beef cattle) (Nalon et al. 2020). Although it was initiated and desired primarily for livestock, the need to provide animal welfare has also grown for other species that were not strictly production species, such as horses. From the descriptive statistics, Europe was the most common geographical area where the papers came from. This confirms the pioneering and driving role that this continent has played in the field of animal protection and welfare promotion. As
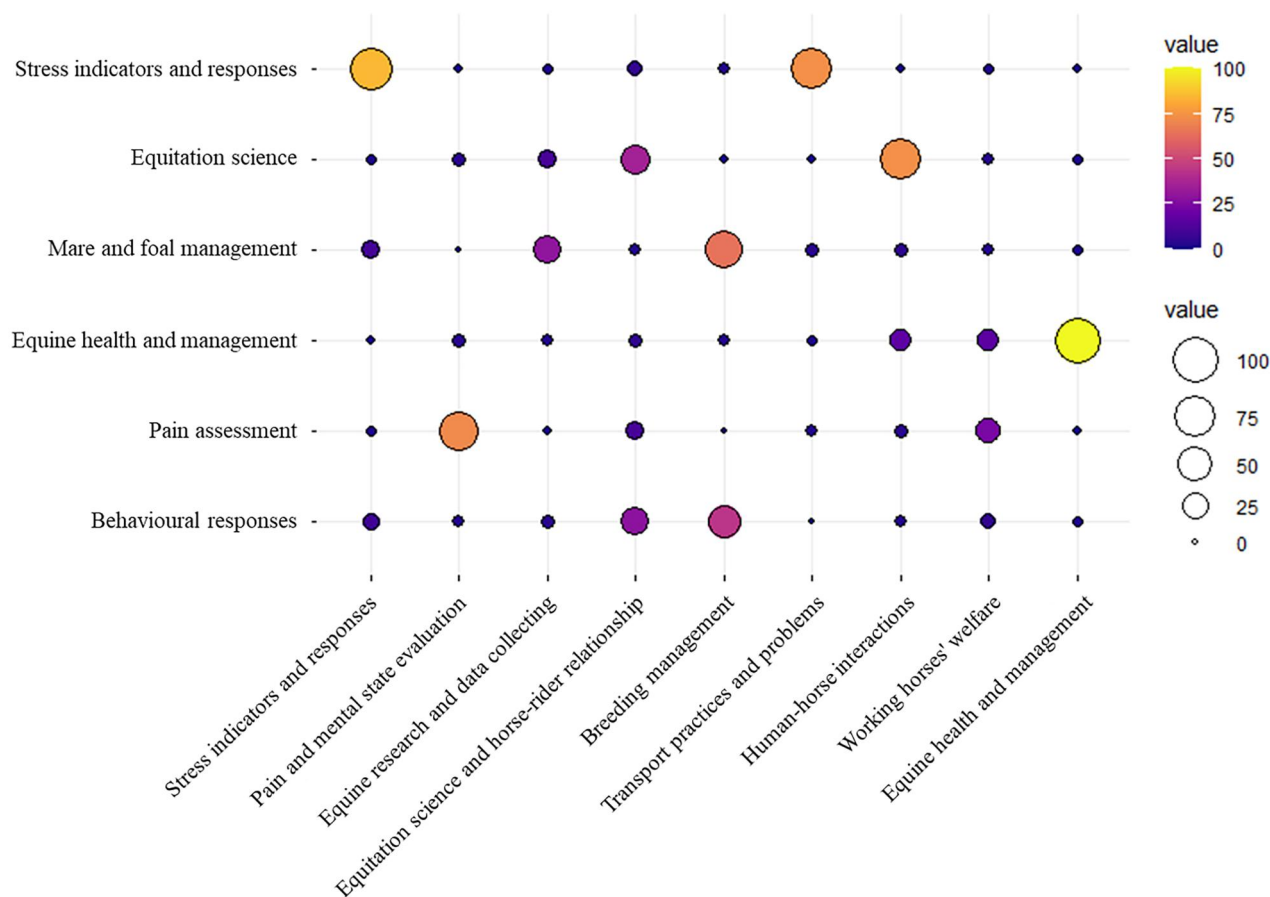

Figure 5. Balloon plot between six topics and nine topics calculated using 801 records selected for inclusion in the study. In the y axis, the six topics choice is represented. In x axis, the nine topics choice is represented.
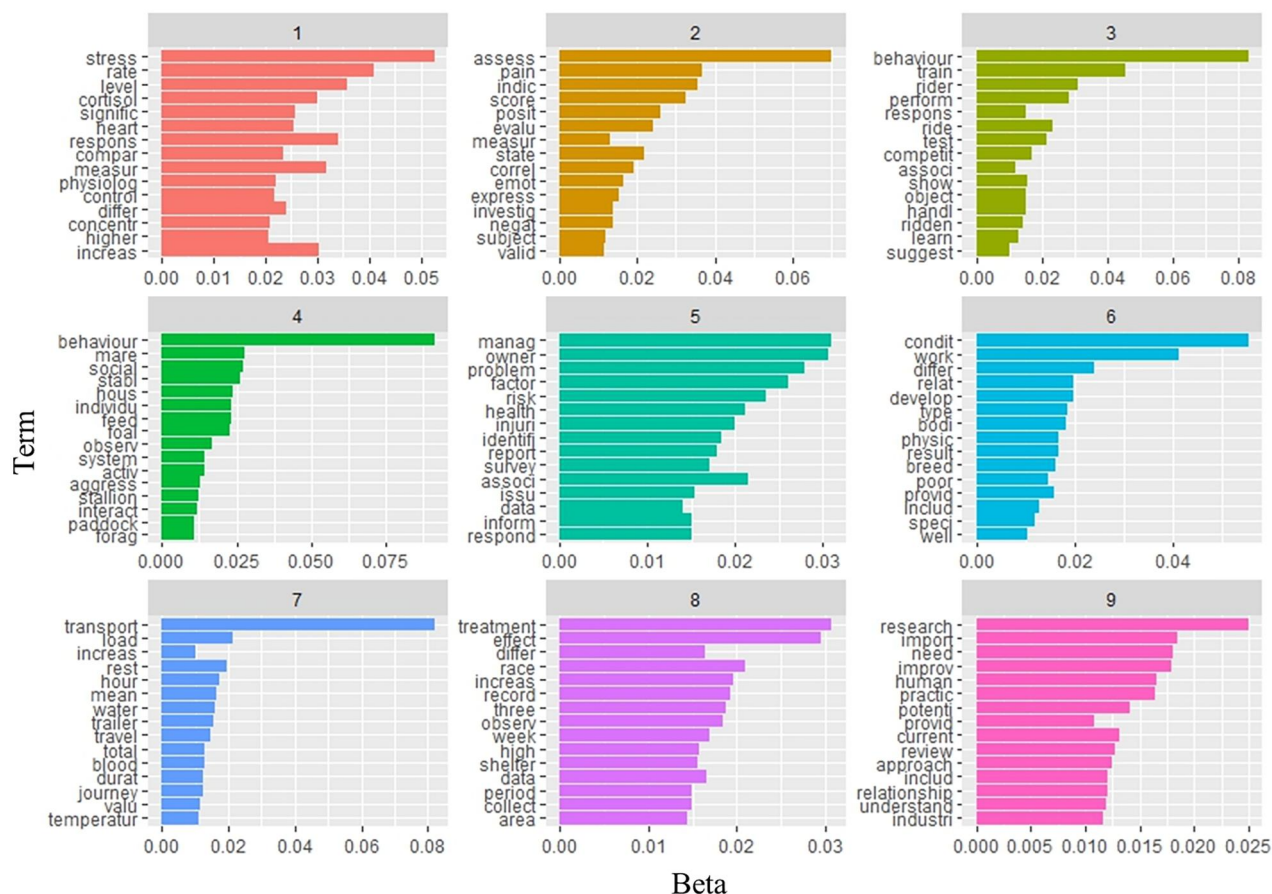
Figure 6. Histograms indicating the most frequent 15 words within the nine topics (term) of 801 records selected for inclusion in the study. Beta indicates the relative probability of each term belonging to that topic.

Table 3. Numbers and names (label) of the nine topics revealed with topic analysis of 801 records selected for inclusion in the review.

Number of the topic	Cumulative probabilities	Label of the topic	Number of records per topic	Year of the first publication within the topic
1	0.439	Stress indicators and responses	109	1993
2	0.362	Pain and mental state evaluation	84	1997
3	0.359	Equitation science and horse–rider relationship	90	2001
4	0.359	Breeding management	116	1986
5	0.315	Equine health and management	109	1993
6	0.312	Working horses' welfare	54	1998
7	0.286	Transport practices and problems	84	1992
8	0.283	Equine research and data collection	51	1996
9	0.224	Human–horse interactions	104	1982

Number of records included in each topic, and first year of publication. The final labels have been chosen with the consensus of the researchers.

expected, articles came mainly from horse culture countries, such as the UK, Italy, France and Germany. In fact, the 2015 European Equestrian Federation (EEF) report shows that these four nations have the largest number of sport horses in Europe (EEF 2015). Moreover, the UK has been considered the motherland of animal welfare (Brambell Committee (Report) 1965; Harrison 2013). The interest and sensitivity of British researchers towards this topic is therefore very high. Nevertheless, it is important to emphasise that the minor role of the other countries, highlighted in the analysis, could be mainly due to a lack of funding, infrastructures and access to horses and not to their minor interest in animal welfare. Furthermore, nationality was based only on the affiliation of the corresponding author and this could have been a bias;

some studies could have been carried out overseas but with European researchers as corresponding, and being attributed to Europe.

'Transport', 'behaviour' and 'pain' were the three most frequent words (with higher TFIDF weight). Indeed, transport has always been considered a welfare concern and studies have been conducted to find out the best transport conditions for horses transported to different locations, including slaughterhouses (Padalino 2015). The word 'behaviour' was certainly one of the most recurrent in welfare studies as behaviour was analysed in multiple situations, such as during transport, farming, training and horse-human interactions to measure the welfare of the horses (Cooper and Mason 1998; Rivera et al. 2002; Padalino 2015). Not surprisingly, 'pain' has also been a very studied subject; Pain was initially studied in relation to its management in clinical situations such as post-surgery (Gaynor and Muir 2014). In recent decades, pain has become more explicitly related to welfare, with the development of pain scales including no more clinical but mainly behavioural parameters (Dalla Costa, Minero, et al. 2014). These scales could be used by non-veterinarians and for the purpose of welfare assessment (Lanci et al. 2022). Hence, it is reasonable that the main words identified with TM are related to these welfare aspects.

These terms have also been raised by the LDA analysis and constitute the core of some of the topics found. The nine topics identified included different aspects of welfare, such as health, behavioural problems, pain and management. This confirms the multi-disciplinarity of welfare and how the concept of welfare itself is broad. The themes found are easily referable to the four principles of good feeding, good housing, good health and appropriate behaviour outlined in the Welfare Quality protocol (Dalla Costa, Murray, et al. 2014). According to the cumulative probabilities, the statistically most important topic was 'stress indicators and horses' responses'. Stress has been considered a major welfare impairment for a long time (Budzyńska 2014). Horses can cope with stress through behavioural and physiological responses, such as changes in form and frequency of certain behaviours, changes in heart rate and heart rate variability, and hormone release, such as cortisol and catecholamines (Schmidt et al. 2010; Mills and Nankervis 2013). With these bases, researchers looked for these changes to measure stress and tried to find ways to reduce it when present. However, the assessment of stress is not simple, as an important role is played by animal's intrinsic ability to cope with the environment which may result in different grades of stress (Koolhaas et al. 1999).

Topic 1 'stress indicators and horses' responses' included records with a scientific focus on the behaviour of horses in various stressful situations such as transport (Schmidt et al. 2010) and exercise (Kang and Lee, 2016). In addition, some records focused on finding different solutions to reduce stress, especially housing-related ones. In particular, recent articles have evaluated the effects of massage and music (Kędzierski et al. 2017) and slow feeder hay bags in stabled horses (Correa et al. 2020). The weaning phase has also been analysed, looking for the least stressful method of separation for both mare and foal (Moons et al. 2005; Merkies et al. 2016; Delank et al. 2023). This important welfare theme was also raised by the association found between the word 'foal' and 'wean' and 'separ'. Finally, it is interesting to note that although there are already validated methods for stress assessment, researchers are continually searching for new, more welfare-friendly indicators. For example, it is no longer necessary to take blood cortisol, which can cause additional stress during sampling (Strzelec et al. 2011), because salivary and hair cortisol are also highly reliable (Peeters et al. 2011; Sauveroche et al. 2020). Confirming the increase in studies using salivary cortisol, the TM technique found an association between the words 'stress' and 'salivary'. Moreover, recently other indicators such as body surface temperature, measured with a thermal imaging camera (de Mira et al. 2021), or eye blinking (Merkies et al. 2019) are being evaluated to determine their accuracy for this purpose.

Topic 2 'pain and mental state evaluation' was the second most important topic identified with the cumulative probabilities. It is interesting to note that this topic encloses papers related to two different subjects, one related to the negative state of pain that horses can experience during their life, and the other related to the analysis of the horses' mental state. The study of pain is founded on the need to recognise, measure and reduce it. However, the recognition of pain is challenging in horses mainly because as prey species they tend to hide pain-related behaviours (Taylor et al. 2002). Thus, similarly to what described above for stress parameters, researchers are finding the most sensitive and accurate indicators to identify and recognise even small states of pain. In particular, the majority of protocols involve the use of pain scales, which can include facial expressions (Dalla Costa, Minero, et al. 2014), behaviours and postures (Bussières et al. 2008). In the last few years, to try to

increasingly objectify pain assessment, Andersen and colleagues have also considered the use of machines (Andersen et al. 2021). Recently, the ridden horse pain assessment was developed and 24 behaviours were found to be indicative of pain in these horses (Dyson 2022). The second focus of this topic is the evaluation of horses' emotions and mental states. Emphasising the importance of positive emotional states in the analysis of welfare was the first step to transforming welfare assessment from the absence of negative states to the presence of positive ones. Indeed, in the 'Five Domains Model' (Mellor et al. 2020), the mental state of the animals became one of the parameters to be assessed focusing on positive emotional states (Mellor and Beausoleil 2015). Negative behaviours and emotions can greatly reduce the horse's welfare, thus mental state is included in the welfare principle of 'appropriate behaviour' (Dalla Costa, Murray, et al. 2014). Moreover, the TM system found an association between the word 'behaviour' and the word root 'stereotyp', as stereotypy is an animal-based measure used in the assessment of appropriate behaviour. However, stereotypies have been a subject of debate for their controversial role as welfare indicators. In fact, a stereotypy certainly develops in situations of poor welfare, but it can easily become similar to a scar and be not anymore linked with the original stressor (Henderson 2007; Hothersall and Casey 2012).

The third interesting topic that emerged from the analysis was 'equitation science and horse-rider relationship'. Within this topic, different training methods are critically analysed in light of the welfare impairment they can cause (Polito et al. 2007; McGreevy and McLean 2009). Other more general aspects of human–horse relationships were identified in Topic 9 'human-horse interactions', which, even though resulted to be the last important topic considering cp, is one the most ancient. In fact, human–horse relationship has a long history and has changed over time. While the horses were initially domesticated for their meat, their role has rapidly changed, becoming more and more work, companion and sport animals (Digard 1999). This mixed role results in interactions with people of different degrees of experience, from non-professional riders to professional breeders, caretakers, and veterinarians (Hausberger et al. 2008). Despite this difference in experience, horse-related accidents do often occur to both professional and non-professional horse people (Hausberger et al. 2008). In any case, an interspecific misunderstanding has been found to be the main reason for these horse-related human injuries (Thompson et al. 2015). It is worth highlighting that

the TM technique found an association between 'work' and 'lesion' and between 'rider' and 'accident'. For this reason, there is a real need to understand how to communicate with horses and develop a better relationship with them (Hausberger et al. 2008). For instance, human body language when interacting with horses has been widely studied (Ladewig 2019). Moreover, the use of horses for horseback riding has gained more and more relevance, and so has the literature about welfare concerns related to riding, confirming why Topic 3 revealed to be the third most important one.

The fourth topic in order of importance considering the cumulative probabilities is 'breeding management'. The words inside the topic include concepts related to the management of the different reproductive categories and their main issues (e.g. 'mare', 'social', 'foal', 'aggression', 'stallion' and 'paddock'). Records within this topic analyse the importance of social horse–horse relations and the main challenges in the management of the different reproductive categories. In particular, there has always been much discussion on the possibility of keeping stallions in groups, since in most cases they are kept isolated and without social contact (Christensen et al. 2002; Burger et al. 2012), obviously creating social deprivations that affect the welfare of this category (Popescu et al. 2019). As a result of this type of management, stallions may become aggressive (Sarrafchi and Blokhuis 2013). Researchers are still finding different solutions to provide adult stallions opportunities for closer contact with conspecifics and are encouraging breeders to keep them in groups (de Oliveira and Aurich 2021; Gehlen et al. 2021). One of the most innovative and promising solutions was recently suggested by Zollinger and colleagues, the so-called 'social boxes', in which stallions are housed individually but with the allowance of closer physical contact thanks to vertical bars between the boxes. This solution resulted in a significant increase in positive social interactions between individuals without the occurrence of significant injuries (Zollinger et al. 2023). On the other hand, the main welfare problems of mares, who often spend their lives in groups, are not related to social deprivation, but rather to career length and feeding regime (Benhajali et al. 2010; Maśko et al. 2018). Moreover, for both mares and foals, one of the major welfare issues is related to the critical and stressful moment of weaning (Søndergaard and Jago 2010; Merkies et al. 2016). Concerning foals, also early interaction with humans and orphans' artificial feeding may compromise welfare, causing permanent behavioural problems (Henry et al. 2012).

Topic 5 'equine health and management' is one of the first to be studied and still one of the most important. Papers included in this topic confirmed the central role of health and good management in ensuring horse welfare. Studies on the different housing management strategies are very numerous, mainly because the environmental and horse usage variables are multiple and all need careful analysis. In recent years, researchers have focused on the analysis of the stabled horse management and welfare, as it is the one most likely to raise ethical concerns and the one with the most evident structural problems for ensuring social interactions (Dalla Costa et al. 2016). However, it is interesting to note that even situations in which horses are kept following their natural needs, such as in a herd, can cause major welfare issues (Dai et al. 2023). Severe injuries could occur if the herd has not been properly balanced. In addition, the distance to reach the water and its availability, the presence/absence of shelter for refuge from adverse weather conditions and insects are central themes to be taken into consideration when assessing the welfare of the herd (Mejdell and Bøe 2005; Gorecka and Jezierski 2007). Appropriate management is therefore the basis of all the different housing systems (Dalla Costa et al. 2017).

'Working horses' welfare' (Topic 6) is a relatively recent and, according to the authors, important topic. Working horses are indeed a diffuse reality, especially in rural and peri-urban areas of developing countries (Tadich and Stuardo Escobar 2014). These horses are mainly used to transport materials and are the sole source of income for their owners, who often use them to exhaustion (de Aluja 1998). Therefore, precisely for the fundamental role these horses have, the owners should understand how important is to guarantee a good welfare standard to them (Tadich and Stuardo Escobar 2014). Since working equids are often not included in animal health policies and regulations (Fröhlich et al. 2020), researchers have focused on finding methods to assess the welfare of these animals (Tadich and Stuardo Escobar 2014).

Topic 7 'transport practices and problems' describes the theme of 'transport' in both production and sport horses. The word 'transport', which was the first word according to the TFIDF analysis, was associated with the words 'road' and 'unload' as expected, as transport by road is the most common way of transport in horses. In fact, it is worth noting that almost all horses experience at least one transport during their life (Padalino 2015). Conversely, horse transport by air is still a not-deepened area of research and should be considered as an important gap in knowledge. In fact, horses are the most frequent species to travel by air after men (Cullinane 2014), with a median of 10,000 horses movements by plane every year (Felici et al. 2023). Regardless of the type of journey, transport represents an important risk factor for horse welfare as it can cause behavioural and health problems (Nielsen et al. 2022). For this reason, transport conditions should be highly regulated all over the world in order to guarantee minimum welfare standards. Protocols to assess welfare during transport should be developed and tested also considering pre- and post-transport aspects (Nielsen et al. 2022).

Many important topics were highlighted by TA but some themes, which play a fundamental role in the welfare of the horse, were not revealed, indicating a minor scientific attention to them. First of all, the theme of the welfare of horses kept for meat production was not highlighted by the technique as a separate topic. In fact, even though the word 'slaughter' was inserted as one of the keywords in the initial Scopus® search, it ranked very low, confirming an important gap of knowledge in this area. Although about 800,000 horses are slaughtered worldwide every year (FAOSTAT 2023), the literature on this subject is very limited and inconsistent, especially regarding the evaluation of welfare on-farm of horses kept for meat (Minero and Canali 2009) and protocol to assess welfare at slaughter (Fletcher et al. 2022). Only limited studies regarding travelling circumstances of meat horses were included in Topic 7 'transport practices and problems'. Secondarily, although partially found in Topic 2, the evaluation of welfare through positive indicators only emerged to a limited extent. This is in line with the history of animal welfare science and indicates a slowly growing trend towards ensuring a high quality of life for animals. Positive welfare in animal species is now an active topic of discussion worldwide (Lawrence et al. 2018). It is therefore expected by the authors that in the near future, more positive indicators will be identified to assess horse welfare too.

Based on the performed analysis, some final considerations can be made. First of all, it is desirable that the growing interest in horse welfare subject in terms of research and public awareness will be followed and outlined in the coming years new laws, developed specifically for this species. Regulations must be more precise and exclusive for equids, which manifest different needs from other livestock, especially because of their multiple uses. The second consideration concerns horses destined for slaughter. Although this is still a

highly represented category of animals, and they could have many welfare issues, the papers dealing with these topics are very limited and often only deal with transport conditions, neglecting the farming context and the moment of slaughter.

Some limitations related to the used method must be emphasised. First, although the search strings to insert in the Scopus® were deeply discussed, some synonyms, such as wellbeing, may have not been included and thus less records could have been retrieved. Secondly, the search was limited to the database of Elsevier©, Scopus®, and so some papers published in journals not included in Scopus® could have not been considered. Moreover, Scopus® search does not include the so-called 'grey literature', which would have been an additional and complementary resource to our corpus of records. Furthermore, some settings decided before starting the search, such as the English-only language of the abstracts, and the screening criteria adopted may have partially reduced the number of papers analysed. Finally, it is necessary to highlight that with this method of analysis the 801 records were not fully read but only the title and abstract were considered.

Notwithstanding the limitations, this review analysed the literature related to horse welfare, identifying the major topics studied and the ones that need more scientific-based evidence.

Conclusions

This review highlights the topics studied in the field of equine welfare and those yet to be studied, using TM and TA techniques. Horse welfare literature is exponentially growing and Europe is a pioneer and leader in this field. The multidisciplinary nature of the subject was confirmed by the different nine topics identified. The statistically most important topics focused on stress, pain, equitation and breeding management issues, highlighting that negative indicators of welfare are more studied. On the contrary, themes of production horse welfare and positive indicators assessment were not retrieved with the TA. In conclusion, even with the limitations associated with the type of analysis, this review suggests to other researchers how to apply these innovative bibliometric techniques and what studies are more urgently needed.

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Disclosure statement

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Data availability statement

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