Review [Revisión]
CONCEPTUAL CHARACTERIZATION OF UDDER HEALTH IN DAIRY SYSTEMS: A SYSTEMATIC REVIEW 1962 – 2019 †

[CARACTERIZACIÓN CONCEPTUAL DE LA SALUD DE LA UBRE EN SISTEMAS LECHEROS: UNA REVISIÓN SISTEMÁTICA 1962 – 2019]

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SUMMARY

Background: Dairy industry economics and public health are negatively impacted when udder health is compromised. Intramammary infection is the most important infectious problem generating economic losses to the milk production systems around the world. Affectations of animal generated diseases on public health are well known. Several categories of analysis have been studied to implement prevention and control strategies against intramammary disease. However, the control of these affectations has been considered a complex problem based on various factors. **Objective:** characterize the categories and subcategories of analysis used for the study of udder health published in research papers during the period comprehend between 1962 - 2019. **Methodology:** A systematic review with a broad approach in the research protocol was designed applying the identification phases, screening, choice, and inclusion criteria described in the PRISMA guide. A qualitative synthesis of year of publication, continent, focus, category of udder health analysis, and subcategories of udder health analysis was performed. **Results:** We found that more than half of the papers identified in this topic were published in the last decade of the studied period (1962 - 2019). New categories were incorporated into the timeline, evidencing an evolution in the way of understanding udder health problems. **Implications:** Many of the countries that publish most of the papers have implemented programs and policies on udder health management in recent years. Precisely in the last decade, cultural processes and political processes were incorporated into the study of udder health. This incorporation of new and relevant topics may have been very useful in the design and evaluation of public policies on udder health in those countries. **Conclusions:** These results show the interest in the academic, productive, and political sectors for udder health and its consequences on public health.
Key words: Udder health; analysis categories; subcategories; public health.

RESUMEN

Antecedentes: La economía y la salud pública de la industria láctea se ven afectadas negativamente cuando la salud de la ubre se ve comprometida. La infección intramamaria es el problema infeccioso más importante que genera pérdidas económicas para los sistemas de producción de leche en todo el mundo. Las afectaciones de las enfermedades de origen animal en la salud pública son bien conocidas. Se han estudiado varias categorías de análisis para implementar estrategias de prevención y control de la enfermedad intramamaria. Sin embargo, el control de estas afectaciones se ha considerado un problema complejo en función de varios factores. **Objetivo:** caracterizar las categorías y subcategorías de análisis utilizadas para el estudio de la salud de la ubre publicados en trabajos de investigación durante el período comprendido entre 1962 - 2019. **Metodología:** Se diseñó una revisión sistemática con un enfoque amplio en el protocolo de investigación aplicando las fases: identificación, tamización, elección e inclusión descritas en la guía PRISMA. Se realizó una síntesis cualitativa

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de: año de publicación, continente, enfoque, categoría de análisis de la salud de la ubre y subcategorías de análisis de salud de la ubre. **Resultados:** Encontramos que más de la mitad de los artículos identificados en este tema fueron publicados en la última década del período estudiado (1962 - 2019). Se incorporaron nuevas categorías en la línea de tiempo, evidenciando una evolución en la forma de entender los problemas de salud de la ubre. **Implicaciones:** Muchos de los países que publican la mayoría de los artículos han implementado programas y políticas sobre el manejo de la salud de la ubre en los últimos años. Precisamente en la última década, los procesos culturales y políticos se incorporaron al estudio de la salud de la ubre. Esta incorporación de temas nuevos y relevantes puede haber sido de gran utilidad en el diseño y evaluación de políticas públicas de salud de la ubre en esos países. **Conclusiones:** Estos resultados muestran el interés de los sectores académico, productivo y político por la salud de la ubre y sus consecuencias en la salud pública.

Palabras clave: Salud de la ubre; categorías de análisis; subcategorías; salud pública.

INTRODUCTION

Alteration in udder health caused by intramammary infection (IMI) is one of the main concerns for dairy producers and for public health experts as it negatively impacts economics of dairy industry and the safety of milk for human consumption (Hogeveen and Lam, 2011). Ingestion of milk from infected cows, raw milk, or milk that have underwent problems during pasteurization, may expose humans to antibiotic residuals, pathogens or to toxins from those pathogens (Dangnaw, 2015). In this sense, the study of udder health from various categories of analysis has been of great interest in recent decades. Different ways of observing the problem in a timeline have been identified, evidencing the complexity of this object of study and the need to understand it in a holistic sense to implement effective interventions. The term "udder health" has been reported in scientific research on milk production systems since the 1960s (Stanley *et al.,* 1962), the concept udder health is complex and stills under construction. There are several and diverse categories that define the multiple dimensions in the understanding of the problem. Among the most relevant dimensions identified on udder health are: risk factors (Gussmann *et al.,* 2018), protective factors (Ivemeyer *et al.,* 2009), biological response of the host (Cecchinato *et al.,* 2018), and characterization of the disease (Sørensen *et al.,* 2016). The inflammatory process of the udder caused by microorganisms continues to be the main infectious problem in dairy industry all over the world (Ruegg, 2017). The recovery and maintenance of the health of the udder is a dynamic and complex process that requires systematic interventions to decrease the damage the disease causes over the industry and the risk for public health. It is necessary to systematize the categories described in the scientific literature to organize the theoretical elements necessary to understand the udder health as a complex problem. During theory development and the construction of concepts around the udder health, a holistic approach allows us to understand the phenomena from the complex interactions that characterize this problem under productive conditions. This approach also enables an integrative vision and an explanatory theory that guides towards a multidimensional or multicausal understanding of the phenomena in his complexity and magnitude (Briceño *et al.,* 2010). The udder health has been a phenomenon partially studied in many countries as compared to any other phenomenon. It has been found that the problem is not completely biomedical, nor exclusively cultural. Those listed before are solely, elements of the concept. The problem also is not fully explained by the political aspects in producers are immersed. The problem is suggested to be explained by the subject-object relationship in the environment, i.e., the subject is immersed in the problem. In England, for example, has risen the importance of building conceptual frameworks as diverse and holistic as possible, which can be used as theoretical bases for the comprehension of the affectations on udder health and the design of complex intervention strategies for dairy producers. This conceptual diversity also allows decision-making by animal health professionals, public policy makers and milk producers (Hogeveen and Lam, 2011). The great availability of studies on udder health remarks the importance of carrying out a systematic review under the broad Cochrane approach. This approach establishes a practical tool to synthesize scientific production related to a specific area of interest, recent updates on a field of knowledge, summarize available evidence, and the analysis of the implications of published information (Cardona *et al.,* 2016, O'Connor, 2011). The aim of this study is to characterize the concept of udder health from a systematic review of the categories and subcategories of analysis used in the study of this problem from the published scientific literature during the period 1962 - 2019.

METHODOLOGY

Type of study: systematic review

We applied identification phases, screening, selection and inclusion described in the research protocol in accordance with PRISMA (Preferred

Reporting Items for Systematic Reviews and Meta-Analyzes) guide (Moher *et al.,* 2010).

Identification of the papers

The research question from which this study started was: What are the categories of analysis that have been addressed in studies on udder health? A specific search of the literature was carried out in the Science Direct, Pubmed, Scielo, LILACS and Google Scholar databases. We used four search strategies according to combinations of the term "udder health" and bovine, cow, dairy, and cattle. Given that "udder health" has emerged as a concept, but a conceptualization of this term has not yet been made, this theoretical study is proposed as a systematic review with a broad approach which, to characterize all the categories and subcategories of analysis that have been studied from the term "udder health" in scientific research, do not incorporate other synonyms. This characterization is expected to provide elements for its conceptualization and that can be useful in the design and implementation of health plans and public policies. The search was carried out on November 22, 2019. Some syntaxes used were: TITLE (udder health) and TITLE-ABSTR-KEY (bovine), ("udder health" [Title]) AND (dairy [Title / Abstract]), (ti :(" udder health ")) AND (ab :(bovine)).

Screening of the papers

Articles containing the above mentioned search terms were considered eligible according to the following description: In Science Direct have the term " udder health " in title and the other terms in title, abstract or keywords; in Pubmed the term " udder health " in title and the other terms in title or summary; in Scielo the term " udder health " in title and the other terms in summary; in LILACS the term " udder health " in title and the other terms in title, summary or subject; and in Google scholar all terms in title. The following inclusion criteria were applied to the eligible articles for their complete review: being an original study; publications on bovine livestock; written in English, Spanish and Portuguese; articles whose object of study were categories and subcategories related to the study of udder health.

Selection of the papers

Quotation texts and Google Scholar patents were excluded. Items that were removed from the databases or were not available. Based on reading the complete text, articles that include animal species other than cattle were excluded. In addition,

the bibliographic references of the included studies were reviewed. No time restrictions were applied retrospectively.

Inclusion of the papers

For studies that achieved the above-described steps, we performed a qualitative synthesis based on the extraction of the variables: title, authors, publication year, continent, approach category analysis of the udder health, and subcategories analysis for udder health.

To guarantee the reproducibility of the search protocol, the selection of articles and the extraction of variables was carried out by us, the three authors. It was previously agreed that discrepancies would be resolved by consensus. The compiled articles were stored in an Excel database and duplicates were eliminated. For the qualitative synthesis through frequency calculation, the SPSS software version 24 was used.

Assessment of risk of bias

Observer bias: In order to control the possible observer bias, we blinded the paper's sources until we completed the stages of inclusion, exclusion, and selection criteria of papers. Authors performed blinding of data during the elaboration of the paper, the authors had no access to paper author names or sources of the data until all the criteria were applied and the final number of papers were chosen. In addition, the authors of this paper declared not having conflict of interest with the data they included in this review.

Selection and misclassification bias: While controlling possible selection and misclassification bias, we were not looking for homogeneous information, or comparing groups, or trying to perform goals as the ones that are the scope of a meta-analysis. In a systematic review as the one we conducted it is not necessary to specify and delimit the type of study of the selected articles because the objective of the study refers to a qualitative synthesis of the information and the intention of systematizing all the available information that allows conceptualizing the Health of the udder. This is why we included all the articles the research and selection criteria point us to and no further classification of papers was needed.

Publication bias: To reduce publication bias, Google scholar was used as an open search engine to identify gray literature, unpublished studies, for example theses. Analytical and graphic methods do not apply, since it is not a meta-analysis. We

acknowledge that articles written in languages other than English, Spanish, and Portuguese were excluded. However, most of the publications on the subject are in these three languages.

We consider other two information biases (recall bias and reportings) might have not affected the outcome or quality of the paper since the information was not collected from sources that might have failed transfering the data.

RESULTS

We obtained a total of 78,327 articles during the initial search using the described routes. After restricting to title, abstract and keywords according to the options of each source, we narrowed the search to 1,019 articles. After discarding 603 duplicates and applying the inclusion criteria in the screening phase (total of 213 articles excluded) and exclusion in the selection phase (15 articles excluded), and adding 3 articles from grey literature, 191 articles were included for the systematic review (figure 1).

We obtained publications registered in 47 countries. The greatest proportion of studies were carried out in Europe, followed by America. The United States, the Netherlands, Sweden, Germany, and Denmark published most of the papers on udder health with 12%, 7.9%, 7.3%, 6.8% and 6.3%, respectively. A vast majority of the studies (98.96%) correspond to quantitative studies, while, noteworthy, two studies opted for a qualitative approach. This highlights the need for a new approach to achieve a different understanding of the phenomenon. In the analysis of the period from 1962 to 2019, a gradual increase in the number of publications on udder health was found. During the last decade 112 publications were found. We obtained seven categories of analysis, 46.6% of which were publications focused on the risk factors category, 15.2% on characterization of the udder health, and 14.7% on the biological response of the animal. However, In the last decades, 8.3% of studies focused on the categories of cultural processes and political processes were published, evidencing a shift in the way of understanding udder health (table 1).
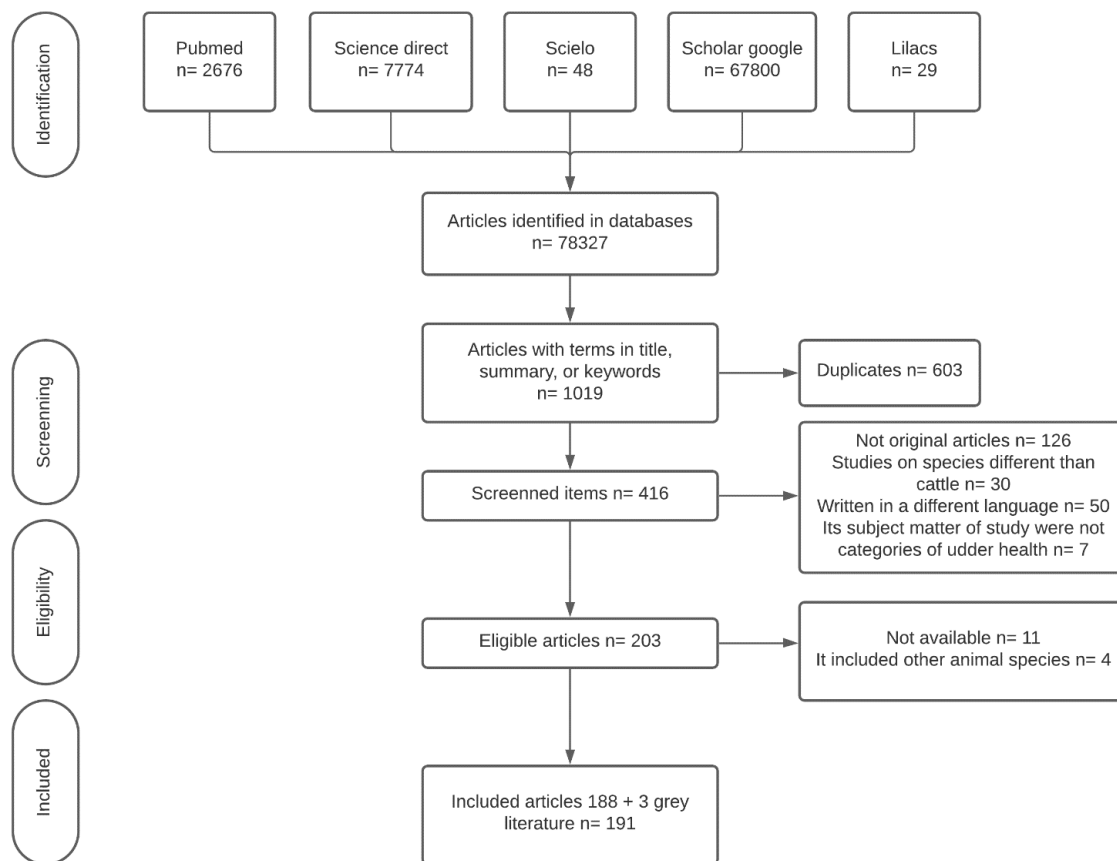
Figure 1. Manuscript selection flowchart.

Table 1. Distribution of analysis in udder health.

		n	%
Continent of origin of the study	Africa	12	6.3
	America	43	22.5
	Asia	11	5.8
	Europe	122	63.9
	Oceania	3	1.6
Publications by period	Studies between 1962 and 1969	2	1
	Studies between 1970 and 1979	2	1
	Studies between 1980 and 1989	10	5.2
	Studies between 1990 and 1999	10	5.2
	Studies between 2000 and 2009	55	28.8
	Studies between 2010 and 2019	112	58.6
Analysis categories in the udder health study	Characterization of udder health	29	15.2
	Risk factor's	89	46.6
	Protective factors	25	13.1
	Cultural processes	3	1.6
	Cultural and political processes	2	1
	Cultural processes, political processes, and economic processes	1	0.5
	Economic processes	2	1
	Economic processes and risk factors	2	1
	Political processes	8	4.2
	Political processes and protective factors	2	1
	Biological response of cattle	28	14.7

We obtained 10 subcategories for the studies published on the Risk Factors category. The most studied subcategory was production and infrastructure practices with 37.1% (total 99 articles published). For the category protective factors, 56% of the published studies had nutrition as the central subcategory. Meanwhile, 71.4% of the studies on the bovine biological response category aimed to analyze the genetic subcategory (table 2).

We obtained 21 subcategories for the category Characterization of udder health, where type of microorganism (13.8%) and infrared thermography (10.3%), were the subcategories with the greatest number of publications (table 3).

Table 2. Subcategories of the categories risk factors, protective factors and biological response of the bovine analyzed in udder health.

Category	Subcategories	n	%
Risk factors	Animal behavior disturbances	2	2.2
	Coinfections	5	5.6
	Weather conditions	2	2.2
	Determinants of antibiotic use	15	16.9
	Concomitant non-infectious diseases	1	1.1
	Udder status	8	9.0
	Associated with milking	21	23.6
	Pathogenic potential	1	1.1
	Production and infrastructure practices	33	37.1
	Breed	1	1.1
Protective factors	Animal welfare	2	8.0
	Nutrition	14	56.0
	Production and infrastructure practices, extension program	1	4.0
	Organic production	7	28.0
	Extension program	1	4.0
Biological response of cattle	Inbreeding depression	1	3.6
	Physiological state	1	3.6
	Genetics	20	71.4
	Immunomodulator	1	3.6
	Cow resistance-immunity	5	17.9

The categories cultural processes, political processes, and economic processes have been incorporated in recent years to the study of udder health as individual categories or in combination with the other categories. Table 4 shows the subcategories of the cultural processes category referred to in the publications as: Beliefs-values-attitudes, behaviors, knowledge, motivations. For the category political processes, the subcategories included in the published studies were:

appropriation of objectives, participation, health planning, communication, social influences in decision-making, trust-norms of reciprocity, networks, and rules. For the category economic processes, the publications focused on the subcategories: investment expenses in mastitis, economic losses due to mastitis. Nine studies focus on health planning, covering political process not only in prevention and control processes, but also in the sustainability of udder health (table 4).

Figure 2 reflects the evolution in the incorporation of categories in udder health research. In each decade, new categories of analysis were incorporated. Between 1962 and 1979 all published research on udder health focused on the study of risk factors. Between 1980 and 1989 the category characterization of the udder was incorporated into the study of risk factors (figure 2). In the last decade of the 20th century, in addition to the categories previously described, the categories protective factors and biological response of the bovine were raised as problematic objects of study. Between 2000 and 2009, in addition to the study of these categories, novel studies were incorporated with the interest of understanding the economic processes related to the health of the udder. Finally, between 2010 and 2019 there was one of the most prominent changes in the study of the udder health, where the object of study was no longer only the cow but the producer and his relationship with other actors in the production chain, as an active subject in the health-disease processes of the udder. This type of scientific understanding is made through the categories cultural processes and political processes.

DISCUSSION

National plans, programs, and campaigns for the control of mastitis and the promotion of udder health have been implemented for many decades in accordance with contemporary needs. In the 1960s, the 5-point plan was implemented. With it, measures were implemented to control clinical and subclinical mastitis. At the time, the high incidence of clinical mastitis caused by contagious pathogens was improved with simple strategies. However, the production systems, the production levels and the genetics of the cows have been radically altered. The management systems have been drastically transformed, and consequently, the management of the health of the udder has evolved and has become more complex. The health of the udder has increasingly been affected by environmental pathogens, which prevention requires the understanding and consideration of various risk factors. In recent years through successful studies

and programs for udder health care such as Australia's Countdown Downunder, New Zealand's Smart SAMM Plan, the Dutch Udder Health Program, the Norwegian Program of Mastitis Control, and the DairyCo Mastitis Control Plan of

Table 3. Subcategories of the characterization of udder health category analyzed in udder health.

| Category	Subcategories	n	%
Characteri-zation of udder health	Activity and electrical conductivity	1	3.4
	Combined analysis of milk parameters	1	3.4
	Biofilm with Staphylococcus aureus	1	3.4
	Calculation of a single measure of SCC	1	3.4
	Haptoglobin concentration in milk	1	3.4
	Concentration of CD 2+ and B CD21 + T lymphocytes	1	3.4
	Sugar concentrations in milk	2	6.9
	Enzymes	1	3.4
	Clinical examination	2	6.9
	Herd udder health indicators	2	6.9
	Predictive method of milk production (normal - abnormal) at the fourth quarter level	1	3.4
	Biochemical parameters of milk	1	3.4
	Test Zagreb mastitis test (MTZ)	1	3.4
	Benchmarks for SCC	1	3.4
	Online cell count (OCC)	1	3.4
	Sofware based on SCC	1	3.4
	Flow cytometry technique to assess udder health	1	3.4
	Triple parameter technique to determine subclinical health status of the udder	1	3.4
	Infrared thermography	3	10.3
	Type of microorganism	4	13.8
	Validation of the CPK (capacity index) model for determining the annual prevalence of subclinical mastitis	1	3.4

Table 4. Subcategories of the categories cultural processes, economic processes, and individual political processes in udder health field.

Category	Subcategories	n	%
Cultural processes	Beliefs-values-attitudes	1	33.3
	Beliefs-values-attitudes, behaviors, knowledge, motivations	2	66.7
Cultural and political processes	Beliefs-values-attitudes, behaviors, knowledge, motivations; appropriation of objectives, participation, health planning, rules, communication	2	100
Cultural, political, and economic processes	Beliefs-values-attitudes, behaviors; communication; investment expenses in mastitis, economic losses due to mastitis	1	100
Economic processes	Cost-effectiveness	1	50
	Investment expenses in mastitis, economic losses due to mastitis	1	50
Economic processes and risk factors	Investment expenses in mastitis, economic losses due to mastitis, Determinants of antibiotic use	2	100
Political processes	Appropriation of objectives	1	12.5
	Communication	1	12.5
	Social influences on decision-making, trust-norms of reciprocity, networks, rules	1	12.5
	Health planning	2	25
	Health planning, social influences, networks, and communication	3	37.5
Political processes and protective factors	Health planning, animal welfare	2	100

Great Britain, it has been recognized that the implementation of a national udder health program requires detailed and close-to-farm evaluations and specific advice for each producer. This merits knowledge, motivation, broad participation, excellent communication, financial support, industrial and political cooperation and above all a tenacious determination (Green *et al.,* 2012).

Through this systematic review, a gradual increase in the number of publications on udder health was found in the period between 1962 and 2019, where in the last decade the largest number of publications has a peak of 112 articles and the incorporation of categories of analysis focused on the producer, recognizing the latter as a political subject in its fundamental cultural context in the implementation and evaluation of programs and public policies on udder health. These results show a high interest of the academic, productive, and political sectors for udder health and its consequences on public health (Ruegg, 2017).
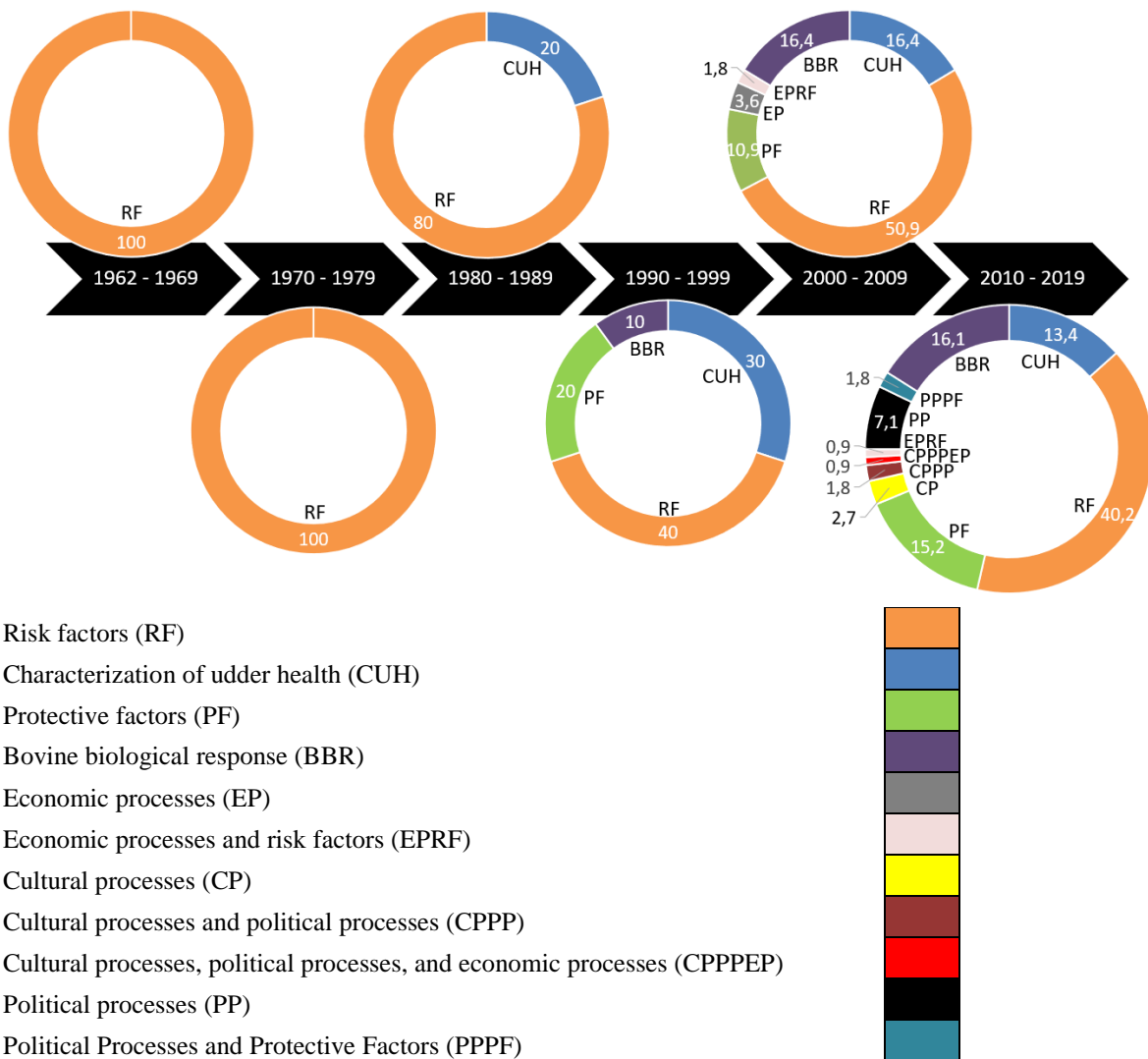
Figure 2. Timeline for the articles classified according to categories of analysis of udder health by decades during the period 1962-2019.

Ruegg (2017) in his review of 100 years of mastitis detection, management and prevention, cites Murphy (1956) and his study "Mastitis: The Struggle for Understanding" where he described years of experience with ineffective mastitis control programs in New York and Connecticut, concluding that the problem is greater than any effort to understand it, despite the dissemination and implementation of eight points to define the disease and the need to propose specific control programs based on the type of pathogenic microorganism associated with the disease (Ruegg, 2017). In the last century mastitis control programs have become more effective, research has made great contributions to improving milk quality and farm productivity, with results such as the eradication of *Strep. Agalactiae* in various regions.

According to Ruegg (2017) despite progress, in most regions, mastitis remains the economically most important bacterial disease of dairy cattle (Ruegg, 2017).

Impact of udder health problems on public health

Clinical mastitis independent of its classification as mild (abnormal appearance of milk as the only sign), moderate (abnormal appearance of milk accompanied by inflammation and redness of the mammary gland), or severe (the cow shows systemic signs of the disease) (Pinzón-Sánchez and Ruegg, 2011), presents easily observable anomalies in the milk that could be recognized by the producer to discard it, preventing this altered

milk to reach the food chain. When the milk comes from cows with subclinical mastitis it does not show visible changes, it is accidentally or intentionally mixed with bulk milk, it enters the informal food chain. The latter makes this milk a potential danger for humans and for the deterioration of the quality of dairy products. It has been found that, although pasteurization is likely to destroy most bacteria that affect humans, the consumption of raw milk or poorly pasteurized milk could favor the spread of bacteria (Dangnaw, 2015), increasing the risk to develop resistance to antibiotics (WHO, 2014).

In turn, the presence of antibiotic residues in post-treatment mastitis milk is one of the main public health concerns that negatively impacts the dairy industry and the safety of milk for human consumption (Green *et al.,* 2012). Antibiotics commonly used in veterinary medicine include β-lactams, such as penicillin; Aminoglycosides, such as streptomycin and neomycin; Tetracyclines, such as doxycycline and minocycline; Macrolides, such as erythromycin; and chloramphenicol, many of them belonging to the same classes of antibiotics commonly used in the treatment of bacterial infections in humans (WHO, 2014). The consumption of milk with antibiotic residues can generate indirect effects such as the presentation of toxic manifestations on organs, teratogenic and carcinogenic effects. Indirect effects of milk from cows with mastitis are associated with stimulation of resistant bacteria, anaphylactic shock, allergic reactions, alteration of intestinal flora and other tissues, development of pathogenic bacteria, and decreased synthesis of vitamins (WHO, 2014; CORPOICA, 2003; MINSALUD-FAO, 2014).

Data collected by the Ministry of Health and Social Protection - INS of Colombia for 2011, found that between 1990 and 2010, 19 studies in Colombia evaluated the presence of antimicrobials in milk. Most of these studies focused on the identification of beta- lactams, tetracyclines, and sulfonamides. The prevalence of antimicrobial residues in milk vary according to the study. In other countries the findings are of public health concern, in Kenya antibiotics were found in 8% of raw milk and 8.2% in pasteurized milk; in Mexico the results for sulfonamides in four pasteurizing companies show figures of 47.2%, 58.3%, 44.7% and 50% respectively; In Peru, 20.67% of samples were positive for antibiotics in milk from markets and 21.21% from stores and farms, in Italy 49% of the samples were positive for penicillin G, 5.6% for amoxicillin and 3.8 % to cephalosporins; and in Brazil, a large milk processor found 30.8% of milk samples with antibiotic residues, tetracyclines ,

neomycin, beta- lactams , gentamicin, chloramphenicol, streptomycin, and dihydrostroptimycin being the identified antibiotics. These studies have provided sufficient evidence to show that heat treatments performed on milk such as pasteurization do not eliminate antimicrobial residues, therefore, the use of antibiotics in cattle constitutes a risk to public health and raises the need for strategies to a planning in the use of antibiotics that guarantees both the health of the udder and the health of the consumer (MINSALUD, 2011).

Milk can be contaminated with antibiotics due to a few reasons including overuse of antibiotics, inability to identify treated animals, failure to apply antibiotics according to the proposed prescription, ignorance about the withdrawal or retention period of the milk from treated animals and the purchase of cows treated with antibiotics. These reasons are dependent on human behavior, health planning and decision making on the farm (Dangnaw, 2015).

Countries that publish the most on udder health

Another result not isolated from the previous discussion has to do with the countries that publish the most on the subject. In this systematic review it was identified that the United States, the Netherlands, Sweden, Germany, and Denmark are the countries that have published the most on udder health. European countries such as Great Britain, the Netherlands, Denmark, Belgium, and Germany have successfully implemented campaigns and programs through public policies around the improvement of udder health, public health care and strengthening of the productive sector. These countries have recognized that active and voluntary participation of the producers is required for the implementation of new methodologies, based on the advances of research and the Ideas of analysis of new categories in relation to this object of study and despite the technological and technical advances that have facilitated the production process. It is essential to build new knowledge focused on the communities dedicated to the productive sector, their culture, and the relationships they establish between actors. European experience showed that to transfer practical knowledge on udder health, communication with producers is as important as the technical content of the message, and it is necessary to consider that today's milk producers are not comparable to producers of ten or twenty years ago. It is required to reflect on question if the focus of the intervention should be whether the support on the processes. Programs and policies have been designed considering emerging elements

such as: communication, mentality, motivation, and others necessary for the efficient fulfillment of the objectives of the policies or their restructuring (Hogeveen and Lam, 2011).

Categories focused on the milk producer as a study subject in udder health problems

In accordance with the previous discussion, this systematic review made it possible to identify, in addition to the traditionally studied categories, that 8.3% of the published studies whose objectives studied human processes related to udder health through two categories: cultural processes and political processes.

Cultural processes related to udder health

In some European countries, the approach to the problem from the categories of cultural and political order has become a way to build scientific knowledge around the understanding of the behavior of milk producers in relation to udder health, the evaluation of programs and health policies for dairy production systems and the identification of critical points for their reformulation (Jansen *et al.,* 2009; Jansen *et al.,* 2010a; Jansen *et al.,* 2010b; van den Borne *et al.,* 2014).

From the category of cultural processes and the theory of planned behavior, it has been studied how the knowledge, values, beliefs, attitudes, and motivations of milk producers influence behaviors or practices that condition the control of mastitis and the promotion of udder health. (Jansen *et al.,* 2009; Schewe *et al.,* 2015). In this sense, the cultural heterogeneity of the communities constitutes a central element for udder health planning and policy implementation (Jansen *et al.,* 2010b).

Some studies have described perceptions and attitudes of the producers that influence the management of the health of the udder, among these, stand out the attitudes in relation to the science that supports the advice, the credibility in the adviser or sources of information, social benefits, and costs to implement the advised measures, the opinions and actions of respected colleagues, and the individual's confidence in their ability to implement the recommendation effectively (Jansen *et al.,* 2010b).

The communication strategies with the producers and the actors of the dairy chain in the context of the implementation of prevention and promotion programs established by the udder health policies

have recognized these actors as fundamental to achieve the proposed objectives, since the characterization of producers has shown this as a culturally inhomogeneous population. During a Dutch udder health program, it was shown that when the communication strategies of animal disease prevention programs are tailored to the different types and needs of producers, there are ample opportunities to reach them in such a way that they are can effectively change the management of mastitis (Jansen *et al.,* 2010b).

During the Dutch udder health program, it was found that the way in which management measures are carried out can be as important as the fact that they are carried out, showing the importance of attitude as well as knowledge to improve behavior related to the udder health (van den Borne *et al.,* 2014). Precisely, one of the consequences turned into drastic decisions in milk production systems are culling or premature slaughter of valuable animals. A study in Denmark shows the relevance of the attitude and preference of producers towards slaughter and its relationship with knowledge about other production practices that could change this decision, raising the need to seek communication and education alternatives to increase compliance with veterinary councils (Gussmann *et al.,* 2019).

A study validated an instrument for measuring udder health using the test- retest method evaluated the knowledge, beliefs, motivations, and attitudes that determine behaviors or practices related to udder health found that given the cultural heterogeneity (Dufour *et al.,* 2010). When milk producers were included in this type of studies voluntary, they, generally, have a progressive attitude, which was evidenced by the changes in the answers to the questions in the second interview, their concern for improving udder health, and the enthusiasm for modifying management practices that could benefit udder health on their farms (Dufour *et al.,* 2010).

Moreover, the human-animal relationship and its association with livestock stress and udder health were studied in organic dairy farms in Germany and Denmark (Ivemeyer *et al.,* 2018). The results indicate that the positive attitudes and interactions of the employees that generate a positive human-animal relationship and allow early recognition of the problem, they should be considered in mastitis control programs, in addition to preventive measures related to adequate housing and management (Ivemeyer *et al.,* 2018).

In general, studies agree that the values and attitudes of managers, owners, and employees of

the production system regarding the health of the udder and the quality of the milk, can affect the incidence of mastitis and the use of antimicrobials. These cultural subcategories are an integral part of mastitis control and health prevention and promotion processes. Researchers on the subject highlight the need for a comprehensive approach to intervene in mastitis that incorporates the analysis of human dimensions (Schewe *et al.,* 2015).

Political processes related to udder health

Advice and the formation of knowledge and support networks are established as political processes analyzed in the study of udder health. In Switzerland, the study of three strategies to improve the health of the udder: 1.) personalized advice, 2.) personalized advice plus veterinary support, and 3.) personalized advice plus participation in study groups, revealed that improving the health of the udder in a period as short as one year is complex. However, the organization of study group meetings between milk producing peers is established as a promising tool to reduce the use of antimicrobials in dairy herds and, at the same time, to keep udder health steady. The producers who were assigned to the preferred group generated a positive effect on the degree of implementation of the recommendations given by consultants, veterinarians, or peers. Therefore, the cultural diversity of the producers is an aspect to be considered in the programs to improve the health of the udder (Tschopp *et al.,* 2015).

The cultural diversity of the producers has been characterized. Different types of producers have been described, among them the "hard-to-reach producers", who due to different circumstances are not reached by educational materials and recommendations for the improvement of practices in mastitis control programs. This characterization has made possible to understand that, although it would be expected that this group would be more problematic compared to the population that is incorporated into health programs, this is not always the case. It is important for the success of the interventions to identify the importance of recognizing the type of producer in its social complexity to reach him and make him participate in the information of the programs and processes to support the planning of the health of the udder. Thus, the producers that were supposed to be difficult to reach by veterinarians were not a homogeneous group. They were not always misinformed about udder health and they did not always experience udder health problems. Thus, producers can be classified into four categories based on their trust in external sources of

information about mastitis and their orientation towards the outside world: proactivists, the ones who wait and watch, the ones who do it, and the lonely traditionalists. Communication strategies must be adapted to diverse populations, this requires a proactive role for veterinarians and extension specialists (Jansen *et al.,* 2010b). Indeed, communication has been found to be a critical issue in program implementation and veterinarians or other dairy farm advisers continue to play an important role in udder health management and mastitis treatment (Falkenberg *et al.,* 2019). In the Netherlands it was identified that communication strategies to change producers' management practices can be improved when both the objective of the strategy and the different motivations of producers to work on udder health are considered. When targeting complex and multi-factorial issues, such as the overarching goal of improving udder health, the traditional core route using educational tools appears to be effective in reaching motivated producers. However, in addition to the central route, the peripheral route can be applied to influence the behavior of producers by including implicit persuasion techniques instead of arguments in campaigns. To reach as many farmers as possible, both communication strategies should be used (Jansen *et al.,* 2010c).

The category of political processes has been approached in research on udder health through the study of public policies of restricted use of antimicrobials and improvement policies (Santman-Berends *et al.,* 2016). Other studies have analyzed planning processes in animal health and welfare, showing that planning constitutes is an important strategy to integrate the participation and to incentive producers (Tremetsberger *et al.,* 2015a), generating measurable results in the incidence of subclinical mastitis and the somatic cell count in the farm (March *et al.,* 2012). Starting with the Dutch udder health program in 2009, there were changes, such as an increase in the average number of animals per herd and the use of antimicrobials was restricted by a new policy aimed at preventing the development of antimicrobial resistance. This implied that antimicrobials that were supplied to producers by veterinary practitioners had to be registered and controlled. Restrictions were applied to the use of second and third generation antimicrobials and all prophylactic applications of antimicrobials, such as treatment of the dry cow was prohibited in the Netherlands. The result of these policies seems to have improved udder health and implied for communities the need to optimize management practices to prevent mastitis and maintain udder health, and in turn the need to reevaluate risk

factors in the policy context through health planning processes (Santman-Berends *et al.,* 2016).

The health study of milk production from the udder health concept has made possible to understand the factors that promote or hinder health management. Among these, social influences have been recognized as determining factors in decision-making and planning in health as a political process mediated by producers and dialogue with government institutions as fundamental to achieve the objectives of udder health programs (Jansen *et al.,* 2010b; Tremetsberger *et al.,* 2015a; Swinkels *et al.,* 2015). In accordance with the above, a planning program in animal health and welfare implemented in dairy farms in Denmark, Norway, the Netherlands, Germany, Austria, and Switzerland demonstrated that it can be a feasible option to minimize the incidence of antibiotic treatments for the udder, while they are able to prevent mastitis without affecting neither the health of the cow, her longevity nor her productivity (Ivemeyer *et al.,* 2012a). Likewise, the approach for udder health management program in South Africa demonstrated that the proactive and voluntary participation of producers had a positive effect on the prevalence of *Staphylococcus aureus* resistant to antibiotics and recognizes that the participation of all producers is necessary for these strategies to be effective (Karzis *et al.,* 2018). A similar behavior was recorded in the Netherlands, where a reduction in the monthly average of the somatic cell count was observed in milk tanks from farms that completed the tools and agreements provided by a dairy company (Steeneveld *et al.,* 2014).

Animal health and welfare planning is a strategy to integrate farmer participation and incentive. This methodology was first introduced in the British livestock industry and became mandatory in most United Kingdom insurance schemes that began in 2000 (Tremetsberger *et al.,* 2015a). Interventional studies (Bennedsgaard *et al.,* 2010; Ivemeyer *et al.,* 2012b) also applied the animal health and welfare planning approach. These studies emphasize the initial assessment of health and well-being by an outsider, the implementation of farm-specific measures, and the constant review and adaptation of the measures as key aspects. The structured process has included the dairy owner objectives and strategies, the participation of all relevant people and the recognition of the positive aspects on the farm (Tremetsberger *et al.,* 2015a; Tremetsberger and Winckler, 2015b).

It has been found that the improvement of health and well-being can be facilitated by health plans based on education, law enforcement or incentives. Advisory activities in livestock production have frequently focused on the dissemination of knowledge in a top-down approach and on the provision of technical information for improvement. However, more recently, producer participation and collective action have been considered crucial for successful interventions (Tremetsberger *et al.,* 2015a).

A study of priority setting on unregulated animal health issues in Ireland, involving experts and producers, provided a strong insight into the potential of implementing inclusive strategies to define health priorities based on the realities of the communities in his territory. The authors positively highlight the influential nature of communities in the formulation of national policy, as a basis for interdisciplinary and multisectoral cooperation, and as fundamental efforts to promote the taking of responsibilities of all interested parties (Hogeveen and Lam, 2011, More *et al.,* 2010).

CONCLUSIONS

In the last decade, interest in the study of udder health has increased. Likewise, in several of the countries with the highest number of publications on the subject, udder health campaigns, plans, policies, and programs have been implemented.

The evolutionary process in the study of udder health was identified, through the incorporation of new categories over time, highlighting in the last decade studies on cultural processes and political processes related to udder health.

The beliefs-values-attitudes, behaviors, knowledge, and motivations constitute the subcategories of the category cultural processes. Participation, appropriation of objectives, communication, social influences in decision-making, trust-norms of reciprocity, networks, rules, and health planning represent the subcategories of the political processes category. The findings show these as fundamental categories to improve udder health through health programs and the implementation of public policies.

We hope that this theoretical construction can be useful in decision-making, in the design and planning of programs and policies in udder health that favor both the productive sector and the health of the final consumer of the dairy chain.

Veterinary Microbiology and milk farmers of Antioquia.

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REFERENCES

Bennedsgaard, T.W., Klaas, I.C. and Vaarst, M., 2010. Reducing use of antimicrobials — Experiences from an intervention study in organic dairy herds in Denmark. *Livestock Science*, 131(2), pp. 183–192. https://doi.org/10.1016/j.livsci.2010.03.018

Briceño, J., Cañizales, B., Rivas, Y., Lobo, H., Moreno, E., Velásquez, I. and Ruzza, I., 2010. La holística y su articulación con la generación de teorías. *Educere,* 14(48), pp. 73–83. https://www.redalyc.org/articulo.oa?id=35616720008

Cardona, J., Higuita, L. and Ríos, L., 2016. Revisiones sistemáticas de la literatura científica. Bogotá: Fondo editorial ediciones Universidad Cooperativa de Colombia. https://ediciones.ucc.edu.co/index.php/ucc/catalog/book/24

Cecchinato, A., Bobbo. T., Ruegg, P.L., Gallo, L., Bittante, G. and Pegolo, S., 2018. Genetic variation in serum protein pattern and blood β-hydroxybutyrate and their relationships with udder health traits, protein profile , and cheese-making properties in Holstein cows. *Journal of Dairy Science*, 101(12), pp. 11108-11119. http://dx.doi.org/10.3168/jds.2018-14907

CORPOICA - Corporación Colombiana de Investigaciones Agropecuarias, 2003. Los residuos de medicamentos en la leche. Problemática y estrategias para su control [Internet]. Neiva: El Poira S.A. https://bibliotecadigital.agronet.gov.co/bitstream/11348/3870/2/20061024154510_control estratégico residuos medicamentos en la leche.pdf

Dangnaw, G., 2015. Public Health Significance of Bovine Mastitis. *World Journal of Biology and Medical Science*, 2(4), pp. 20–31. https://core.ac.uk/download/pdf/199937202.pdf

Dufour, S., Barkema, H.W., DesCôteaux, L., DeVries, T.J., Dohoo, I.R., Reyher, K., Roy, J-P and Scholl, D.T.,. 2010. Development and validation of a bilingual questionnaire for measuring udder health related management practices on dairy farms. *Preventive Veterinary Medicine*, 95(1), pp. 74–85. https://doi.org/10.1016/j.prevetmed.2010.02.018

Falkenberg, U., Krömker, V., Heuwieser, W. and Fischer-Tenhagen, C., 2019. Survey on routines in udder health management and therapy of mastitis on German dairy farms. *Milchwissenschaft*, 72(1),pp. 11–5. https://www.researchgate.net/publication/332351038_Survey_on_routines_in_udder_health_management_and_therapy_of_mastitis_on_German_dairy_farms

Green, M.J., Breen, J.E., Hudson, C., Black, H., Cross, K., and Bradley, A.J., 2012. National mastitis control schemes: experiences from implementation of a nationwide scheme in Great Britain. In: Hogeveen, H., Lam, T.J.G.M., editors. Udder Health and Communication [Internet]. Wageningen: Wageningen Academic Publishers; pp. 21–32. https://doi.org/10.3920/978-90-8686-742-4_1

Gussmann, M., Denwood, M., Kirkeby, C., Farre, M. and Halasa, T., 2019. Associations between udder health and culling in dairy cows. *Preventive Veterinary Medicine*, 171, pp. 104751. https://doi.org/10.1016/j.prevetmed.2019.104751

Gussmann, M., Græsbøll, K., Toft, N., Nielsen, S.S., Farre, M. and Kirkeby, C., 2018. Determinants of antimicrobial treatment for udder health in Danish dairy cattle herds. *Journal of Dairy Science,* 101(1), pp. 505–17. http://doi.org/10.3168/jds.2017-12994

Hogeveen, H., Lam, T.J.G.M., 2011. Udder health and communication [Internet]. Netherlands: Wageningen Academic Publishers. https://link.springer.com/book/10.3920/978-90-8686-742-4

Ivemeyer, S., Simantke, C., Ebinghaus, A., Poulsen, P.H., Sorensen, J.T., Rousing, T., Palme, R. and Knierim, U., 2018. Herd-level associations between human–animal relationship, management, fecal cortisol metabolites, and udder health of organic dairy cows. *Journal of Dairy Science,* 101(8), pp. 7361–7374. https://doi.org/10.3168/jds.2017-13912

Ivemeyer, S., Smolders, G., Brinkmann, J., Gratzer, E., Hansen, B., Henriksen, B.I.F., Huber, J., Leeb, C., March, S., Mejdell, C., Roderick, S., Stöger, E., Vaarst, M., Whistance, L.K., Winckler, C. and Walkenhorst, M., 2012a. Effects of health and welfare planning on the use of antibiotics and udder health in European dairy farms. In: Hogeveen, H., Lam, T.J.G.M., editors. Udder Health and Communication [Internet]. Wageningen: Wageningen Academic Publishers; pp. 69-76 https://doi.org/10.3920/978-90-8686-742-4_5

Ivemeyer, S., Smolders, G., Brinkmann, J., Gratzer, E., Hansen, B., Henriksen, B.I.F., Huber, J., Leeb, C., March, S., Mejdell, C., Nicholas, P., Roderick, S., Stöger, E., Vaarst, M., Whistance, L.K., Winckler, C. and Walkenhorst, M., 2012b. Impact of animal health and welfare planning on medicine use, herd health and production in European organic dairy farms.

Livestock Science, 145(1), pp. 63–72. https://doi.org/10.1016/j.livsci.2011.12.023

Ivemeyer, S., Walkenhorst, M., Heil, F., Notz, C., Maeschli, A., Butler, G. and Klocke, P., 2009. Management factors affecting udder health and effects of a one year extension program in organic dairy herds. *Animal*, 3(11), pp. 1596–1604. https://doi.org/10.1017/S1751731109990498

Jansen, J., Renes, R.J., Lam and T.J.G.M., 2010c. Evaluation of two communication strategies to improve udder health management. *Journal of Dairy Science*, 93(2), pp. 604–612. https://doi.org/10.3168/jds.2009-2531

Jansen, J., Steuten, C.D.M., Renes, R.J., Aarts, N. and Lam, T.J.G.M., 2010b. Debunking the myth of the hard-to-reach farmer: Effective communication on udder health. *Journal of Dairy Science,* 93(3), pp. 1296–1306. https://doi.org/10.3168/jds.2009-2794

Jansen, J., van den Borne, B.H.P., Renes, R.J., van Schaik, G., Lam, T.J.G.M. and Leeuwis, C., 2009. Explaining mastitis incidence in Dutch dairy farming: The influence of farmers' attitudes and behaviour. *Preventive Veterinary Medicine*, 92(3), pp. 210–223. https://doi.org/10.1016/j.prevetmed.2009.08.015

Jansen, J., van Schaik, G., Renes, R.J. and Lam, T.J.G.M., 2010a. The effect of a national mastitis control program on the attitudes, knowledge, and behavior of farmers in the Netherlands. *Journal of Dairy Science*, 93(12), pp. 5737–5747. https://doi.org/10.3168/jds.2010-3318

Karzis, J., Petzer, I.-M., Donkin, E.F. and Naidoo, V., 2018. Proactive udder health management in South Africa and monitoring of antibiotic resistance of Staphylococcus aureus; in dairy herds from 2001 to 2010. *Journal of the South African Veterinary Association*, 7;89(0), pp. 1–8. http://doi.org/10.4102/jsava.v89i0.1490

March, S., Brinkmann, J. and Winckler, C., 2012. Improvement of udder health following implementation of herd health plans in organic dairy farms: results of a pilot

study in Germany. In: Hogeveen, H., Lam, T.J.G.M., editors. Udder Health and Communication [Internet]. Wageningen: Wageningen Academic Publishers; pp. 91-99 https://doi.org/10.3920/978-90-8686-742-4_8

Ministerio de Salud y Protección Social, Organización de las Naciones Unidas para la Alimentación y la Agricultura – FAO., 2014. Perfil sanitario nacional de leche cruda para consumo humano directo [Internet]. https://www.minsalud.gov.co/sites/rid/Lists/BibliotecaDigital/RIDE/VS/PP/SNA/Perfil-sanitario-nacional-leche-cruda.pdf

Ministerio de Salud y Protección Social, Unidad de Evaluación de Riesgos para la Inocuidad de los Alimentos UERIA, Instituto Nacional de Salud INS, 2011. Identificación de riesgos químicos asociados al consumo de leche cruda bovina en Colombia [Internet]. Bogotá: Imprenta Nacional de Colombia; https://www.minsalud.gov.co/sites/rid/Lists/BibliotecaDigital/RIDE/IA/INS/Er-peligros-quimicos-en-leche.pdf

Moher, D., Liberati, A., Tetzlaff, J. and Altman, D.G., 2010. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *International Journal of Surgery,* [Internet]. 8(5), pp. 336–341. https://doi.org/10.1016/j.ijsu.2010.02.007

More, S.J., McKenzie, K., O'Flaherty, J., Doherty, M.L., Cromie, A.R. and Magan, M.J., 2010. Setting priorities for non-regulatory animal health in Ireland: Results from an expert Policy Delphi study and a farmer priority identification survey. *Preventive Veterinary Medicine*, 95(3), pp. 198–207. https://doi.org/10.1016/j.prevetmed.2010.04.011

O'Connor, D.G.S.H.J. (editores), 2011. Chapter 5. Defining the review question and developing criteria for including studies. In: Higgins JPT, Green S (editores), Cochrane Handbook of Systematic Reviews of Intervention Version 510 (publicado March 2011) The Cochrane Collaboration. www.cochrane-handbook.org

Pinzón-Sánchez, C. and Ruegg, P.L., 2011. Risk factors associated with short-term post-treatment outcomes of clinical mastitis. *Journal of Dairy Science*, 94(7), pp. 3397–3410. https://doi.org/10.3168/jds.2010-3925

Ruegg, P., 2017. A 100-Year Review: Mastitis detection, management, and prevention. *Journal of Dairy Science*., 100, pp. 10381–10397. https://doi.org/10.3168/jds.2017-13023

Santman-Berends, I.M.G.A., Swinkels, J.M., Lam, T.J.G.M., Keurentjes, J. and van Schaik, G., 2016. Evaluation of udder health parameters and risk factors for clinical mastitis in Dutch dairy herds in the context of a restricted antimicrobial usage policy. *Journal of Dairy Science*, 99(4), pp. 2930–9. https://doi.org/10.3168/jds.2015-10398

Schewe, R.L., Kayitsinga, J., Contreras, G.A., Odom, C., Coats, W.A., Durst, P., Hovingh, E.P., Martínez, R.O., Mobley, R., Moore, S. and Erskine, R.J., 2015. Herd management and social variables associated with bulk tank somatic cell count in dairy herds in the eastern United States. *Journal of Dairy Science*, 98(11), 7650–7665. https://doi.org/10.3168/jds.2014-8840

Sørensen, L.P., Bjerring, M. and Løvendahl, P., 2016. Monitoring individual cow udder health in automated milking systems using online somatic cell counts. *Journal of Dairy Science*, 99, pp. 608–620. http://dx.doi.org/10.3168/jds.2014-8823

Stanley, D.E., Kesler, E.M. and Bortree, A.L., 1962. Effect of a Fluctuating Milking Vacuum on Certain Measures of Udder Health1. *Journal of Dairy Science*, 45(11), pp. 1343–1347. http://doi.org/10.3168/jds.S0022-0302(62)89623-4

Steeneveld, W., Velthuis, A.G.J. and Hogeveen, H., 2014. Short communication: Effectiveness of tools provided by a dairy company on udder health in Dutch dairy farms. *Journal of Dairy Science,* 97(3), pp. 1529–1534. https://doi.org/10.3168/jds.2013-7132

Swinkels, J.M., Hilkens, A., Zoche-Golob, V., Krömker, V., Buddiger, M., Jansen, J. and Lam, T.J.G.M., 2015. Social influences on the duration of antibiotic treatment of clinical mastitis in dairy cows. *Journal of Dairy Science*, 98(4), pp. 2369–2380. https://doi.org/10.3168/jds.2014-8488

Tremetsberger, L., Leeb, C. and Winckler, C., 2015a. Animal health and welfare planning improves udder health and cleanliness but not leg health in Austrian dairy herds. *Journal of Dairy Science*, 98(10), pp. 6801–6811. https://doi.org/10.3168/jds.2014-9084

Tremetsberger, L. and Winckler, C., 2015b. Effectiveness of animal health and welfare planning in dairy herds: A review. *Animal Welfare*, 24(1), pp. 55-67. http://doi.org/10.7120/09627286.24.1.055

Tschopp, A., Reist, M., Kaufmann, T., Bodmer, M., Kretzschmar, L., Heiniger, D., Berchtold, B., Wohlfender, F., Harisberger, M., Boss, R., Strabel, D., Cousin, M.E., Graber, H.U. and Steiner, A., 2015. A multiarm randomized field trial evaluating strategies for udder health improvement in Swiss dairy herds. *Journal of Dairy Science*, 98(2), pp. 840–860. https://doi.org/10.3168/jds.2014-8053

van den Borne, B.H.P., Jansen, J., Lam, T.J.G.M. and van Schaik, G, 2014. Associations between the decrease in bovine clinical mastitis and changes in dairy farmers' attitude, knowledge, and behavior in the Netherlands. *Research in Veterinary Science*, 97(2), pp. 226–229. https://doi.org/10.1016/j.rvsc.2014.06.017

WHO. 2014. Antimicrobial resistance: global report on surveillance. Geneva: WHO Press. https://apps.who.int/iris/bitstream/handle/10665/112642/9789241564748_eng.pdf;jsessionid=495FF2AF99E5E6DE90B4FB81CDDE3B60?sequence=1