Suitability of scienciometric analysis targeting Loop Mediated Isothermal Amplification Assay applied to farm animals

Adequação da análise cienciométrica direcionada ao ensaio de Amplificação Isotérmica Mediada por Alça aplicada à animais de produção

DOI:10.34117/bjdv7n12-345

Recebimento dos originais: 12/11/2021
Aceitação para publicação: 10/12/2021

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ABSTRACT
The objective of the study was to carry out, with the aid of Scopus®, a scientometric analysis of Loop Mediated Isothermal Amplification Assay (LAMP) applied to farm animals. The research has considered articles from January 2000 to December 2019 and only open or closed access articles published in English. The bibliometric matrices were run through RStudio, applying Biblioshiny as a web interface to Bibliometrix resources for R environment. Later, several bibliometric data were collected with the aid of Bibliometrix, most of which were converted into graphs using Microsoft Excel®. The scientometric analysis base of the current study was composed by 438 articles from 504 researched in the Scopus®. Of the 438 articles analyzed, it stands out as results: 1) the years of 2015 (11,4%) and 2019 (11,4%) had equally the highest number of publications in the area; 2) Journal of Virological Methods (12,5%) ranked first in the ranking of journals according to total articles published; 3) China (49,8%), Japan (12,7%) and India (7,1%) have been countries of more published articles; 4) most articles applied the assay to detect microorganisms affecting the farm animals; and, 5) together, the animal groups fish, bovine, poultry, and swine corresponded to 2/3 (71,1%) of the animals used in scientific research using the LAMP method. With all these results, it is concluded that the scientometric analysis showed an overview of the information in the articles about LAMP applied to farm animals.

Keywords: LAMP, publications, animals, scienciometric analysis.

RESUMO
O objetivo do estudo foi realizar, com auxílio do Scopus®, uma análise cienciométrica sobre Amplificação Isotérmica Mediada por Alça aplicada à animais de produção. A pesquisa considerou artigos de janeiro de 2000 a dezembro de 2019, de acesso aberto ou fechado publicados em inglês. As matrizes bibliométricas foram executadas através do RStudio, aplicando a interface Biblioshiny como recurso do Bibliometrix para o ambiente R. Posteriormente, vários dados bibliométricos foram coletados com o auxílio do Bibliometrix, a maioria dos quais foram convertidos em gráficos usando o Microsoft Excel®. A base da análise cienciométrica do presente estudo foi composta por 438 artigos de 504 pesquisados no Scopus®. Dos 438 artigos analisados, destaca-se como resultados: 1) os anos de 2015 (11,4%) e 2019 (11,4%) apresentaram igualmente o maior número de publicações na área; 2) Journal of Virological Methods (12,5%) ficou em primeiro lugar no ranking de periódicos de acordo com o total de artigos publicados; 3) China (49,8%), Japão (12,7%) e Índia (7,1%) foram os países que mais publicaram artigos; 4) a maioria dos artigos aplicou o ensaio para detectar microrganismos que afetam os animais de produção; e, 5) juntos, os grupos animais de peixes, bovinos, aves e suínos corresponderam a 2/3 (71,1%) dos animais utilizados em pesquisas científicas utilizando o método LAMP. Com todos estes resultados conclui-se que a análise cienciométrica mostrou uma visão geral das informações dos artigos sobre LAMP aplicada a animais de produção.

Palavras-chave: LAMP, publicações, animais, análise cienciométrica.

1 INTRODUCTION

Currently, Loop Mediated Isothermal Amplification Assay (LAMP) has been widely used as it is considered a revolutionary and promising amplification assay (WEERAKOON et al., 2018, TUERSONG et al., 2020). The LAMP relies on strategies of strand displacement mechanism in order to carry out the amplification steps and has been claimed to be highly

specific, efficient, and selective, similarly to the Polymerase Chain Reaction (PCR) (NOTOMI et al., 2000; TOMITA et al., 2008).

Despite the important technical and scientific advances of LAMP, the application of the assay to answer research questions has remained modest. In this context, it is uncommon to find scientific papers reporting on the use of LAMP as a tool for both quantitative and qualitative biological investigations. This remains specially true regarding to use of LAMP in biological studies of farm animals, which makes it difficult to integrate their findings and summarize their results in animal production, rendering meta-analyses approaches useless.

The quantitative and qualitative analysis of the scientific literature on a wide variety of subjects is the function of scientometrics, known as "*the science of science*," in which is titled in the academic field (LUTMAN, 1992; PARRA et al., 2019). Thus, a scientometric analysis scrutinizes and evaluates science, innovation, and technology, serving as a means of scholarly communication and mapping the intellectual landscapes of specific subjects (KIM; ZHU, 2018). Scientometric studies are designed to bring forth past and current states of research on a particular subject in each field. The results of scientometric studies benefit scientists who are seeking information in order to guide the preparation of future investigation proposals in the field (HASSAN et al., 2019).

Large-scale scientometric research has become possible due to the creation of public databases that include many articles, authors, institutional addresses, and bibliographic references for each article. One of the most useful of such repositories is the Scopus®, created in 2004 (MONGEON; PAUL-HUS, 2015). Thus, the current study reports on the scientometric analysis of the literature reporting on LAMP applied to farm animals to fully understand the research gap using comprehensive indicators on original research articles deposited in Scopus®.

2 MATERIAL AND METHODS

In the current work, a word of caution is necessary to understand the meaning of the phrase “farm animals”. Herein, farm animals include livestock, poultry and fish as animals kept for agricultural purposes.

2.1 SELECTING PROCEDURES AND DOCUMENT ANALYSES

Based on the relevance of Scopus to survey the scientific literature, the current scientometric analysis included only peer-reviewed original research articles indexed in the Scopus®. In order to gather as much bibliographic data as possible concerning LAMP applied to farm animals, the combinations of the following keywords were used in the search equation:

(TITLE-ABS-KEY ("loop mediated isothermal amplification") AND TITLE-ABS-KEY ("horse") OR TITLE-ABS-KEY ("bovine") OR TITLE-ABS-KEY ("pig") OR TITLE-ABS-KEY ("chicken") OR TITLE- ABS-KEY ("sheep") OR TITLE-ABS-KEY ("poultry") OR TITLE-ABS-KEY ("rabbits") OR TITLE-ABS-KEY ("goat") OR TITLE-ABS-KEY ("fish")) AND (EXCLUDE (PUBYEAR , 2021) OR EXCLUDE (PUBYEAR , 2020)) AND (LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (LANGUAGE, "English")). The equation limited the period for articles selection from January 2000 to December 2019 and only open or closed access articles published in English were considered.

In order to choose the articles to be included in the scientometric analysis, two examiners independently read title and abstract of each article retrieved by the search engine. In some cases, when the pieces of information were not clear from the title and abstract, the whole article would be read by the examiners. At the end of this step, all articles that did not fit the research topic were excluded from the analysis. Finally, from selected articles, the examiners independently extracted, evaluated, discussed, and cross-checked the data before final annotation on spreadsheets to validate the process.

Upon completion of the selection process, a table containing the metadata from previously selected articles in CSV format was produced in Scopus. The bibliometric matrices were run through RStudio (version 4.0.2 for Windows®, Microsoft Corporation - USA), applying Biblioshiny (version 2.0) as a web interface to Bibliometrix (Version 3.0) resources for R environment (Version 1.3.1093 © 2009-2020 RStudio, PBC). Additional and updated information regarding Bibliometrix® scripts can be found elsewhere. Several bibliometric data were collected with the aid of Bibliometrix, most of which were converted into graphs using the Microsoft Excel® (Product ID: 02260.40000.00000.AA038). The data included number of articles published per year, rank of journals according to number of publications, number of publications per year from journals with the highest ranks, authors with the highest number of publications, authors'affilliation, countries where the work was produced, country of the corresponding author and the most used keywords in the articles. In addition to the Bibliometrix® metadata, other pieces of information were collected from reading each article's title and abstract, namely the variations of LAMP employed in the scientific articles, the types of general application of the LAMP assay, the main food frauds detected by LAMP, and the distribution of types of farm animals used in the studies.

For the analysis of the publications, origins the following parameters were included in this study: institutions with the largest number of publications and the frequency of publication per country. It is noteworthy that in these two parameters, the sum of the total number of articles

was greater than the number of articles analyzed (438), since Bibliometrix® considers individually the authors of each article and, therefore, the same article may contain authors belonging to different institutions and/or countries.

To produce the cloud of most frequently used words from the articles, the WordCloud®, a free online tool, was used to generate the plots. Word clouds will visually assist with the focus of the articles by means of their collection of descriptive words. Two different clouds elaborated, the first using the descriptive words returned automatically from the articles by Bilbiometrix® and the second was created using only the keywords indicated by authors in their documents. Some trimming steps were taken before running the words through Wordcloud® to maximize the results, including word in plural were converted to their singular grammatical inflections and whenever possible acronyms were used to replace long phrases. After trimming, the tables with the words in Microsoft Excel® were converted into CSV format and imported into Wordcloud® to generate the plots. WordCloud® was accessed through the link: https://translate.google.com/translate?hl=pt-BR&sl=en&u=https://www.wordclouds.com/&prev=search&pto=aue.

3 RESULTS AND DISCUSSION

From Scopus®, the combination of keywords retrieved 504 original research articles published in English between 2000 and 2019. Of those, 212 (42.1%) were open access. All 504 scientific papers were written in English but 1 published in French, demonstrating English is the lingua franca in academic and scientific environments. By adopting a common language, authors increase the visibility of their work and their chances to be cited prospectively. Moreover, it facilitates scholar and research networking among peers (FLOWERDEW; PEACOCK, 2001; WOOD, 2001). In order to become known, Murcia & Borba's (2008) had claimed high-quality papers need to be peer reviewed and published in foreign journals, particularly in English, so that they can be easily accessed and read by the largest number of interested parties.

Following selection criteria, 13.1% (66/504) of the published articles were excluded from the analyses. The reasons underling exclusions included repeated articles; studies that did not used LAMP in farm animal; studies published in "short communication" format; did not use LAMP in experimental analysis, only mentioning the methodology in the text; and review articles. Thus, 87% (438/504) articles were selected and composed the scientometric base of the current study.

The early publications of LAMP applied to farm animals dated from 2004, notably four years after the method was developed by Notomi's group (NOTOMI et al., 2000). The years of

2015 and 2019 had equally the highest publications in the area, corresponding to 11.4% (50/438), followed by 2016 (10.3%), 2014 (9.8%), and 2012 (9.4%) as shown in Figure 1. Since its initial publication, the methodology had become more popular, resulting in an average of 27,4 articles published per year using LAMP as the tool for investigating several biological aspects of farm animals. Within the 16 years surveyed, there has been an increment of 3.3x (42/12.7) in the average number of articles published from the first half to the second. It is also noted that the number of publications almost doubled from 2011 to 2012, reaching its publication constancy in the field. An important point that can justify this observation was stressed by Kumar et al. (2017) and Kundapur & Nema (2016) when arguing that the applications of LAMP has extended from in vitro diagnostics to species authentication, to microbiological quality/safety assessment in meats and to testing for genetically modified organisms (GMOs), allergens, pesticides and offering drug resistance. Yang et al. (2018) further added that LAMP has garnered great interest in the scientific community and its popularity stems from the development of many commercially available systems.

Figure 1. Distribution of original research articles published per year from 2000 to 2019 retrieved from Scopus® under the scope of using LAMP on farm animals. Bubble's size indicates the amount of articles/year. The dotted line shows the exponential tendency observed in the bibliometric analysis

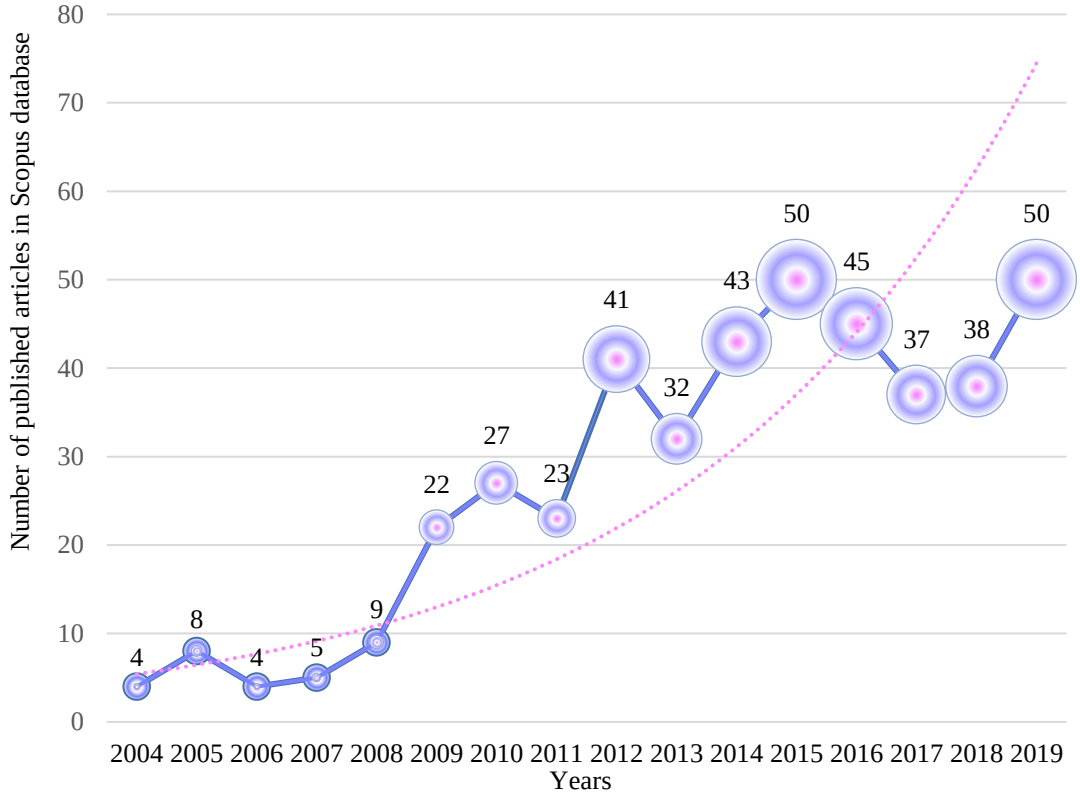


Figure 2. Journals with the highest number of articles on LAMP applied to farm animals resulting of a scientometric analysis using research articles retrieved from Scopus®

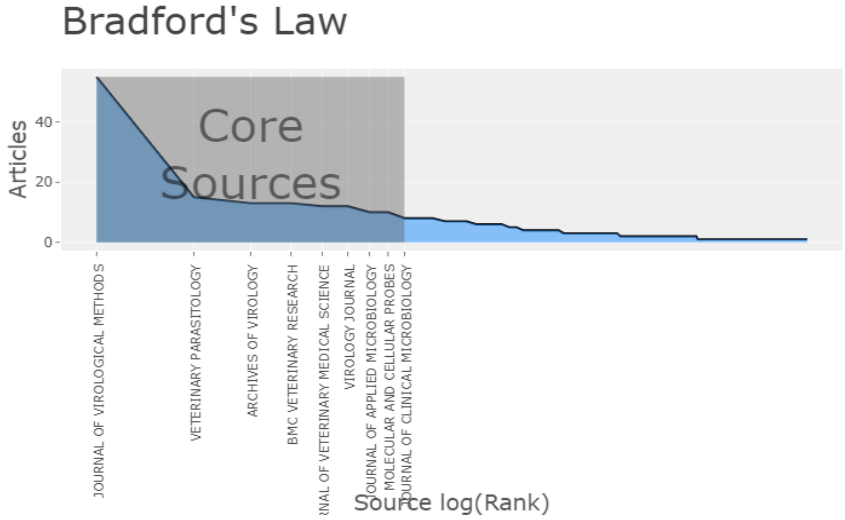


Figure 2 shows the Pareto distribution of Bradford's Law applied on the 438 articles included in the study. In this context, the Journal of Virological Methods became the core from which the nucleus (zone 1) of the journals devoted for LAMP was generated. The Law describes how the literature on a given subject is distributed in the journals, which are organized in descending order according to the number of articles they have that worked on a specific topic (ALABI, 1979). To better illustrate the organization of journals by article productivity, a graph can be generated which groups them into zones, with Zone 1 always being the core of journals that have the most articles particularly devoted to a subject (ALABI, 1979; GARG et al., 1993).

When dealing individually with Bradford's Law Zone 1, the Journal of Virological Methods occupied ranked first with a total of 55 published articles (12.5%) from 2004 to 2019, with 2014 being the year with the highest number of publications (8). Next, the ranking of journals according to total articles published was: Veterinary Parasitology (16 articles or 3.6%), Archives of Virology (13 articles or 3%), BMC Veterinary Research (13 articles or 3%), Journal of Veterinary Medical Science (12 articles or 2.7%), Virology Journal (11 articles or 2.5%), Journal of Applied Microbiology (10 articles or 2.3%), Molecular and Cellular Probes (10 articles or 2.3%), and Journal of Clinical Microbiology (8 articles or 1.8%). Notably, except for Journal of Virological Methods, the journals published 1 to 3 articles per year pertaining to the topic in focus. However, Archives of Virology, BMC Veterinary Research and Journal of Veterinary Medical Science had 4, 4 and 5 publications in the years 2012, 2019 and 2016, respectively (Figure 3), suggesting a migration of the manuscripts to journals with scopes of animal sciences, which in the future may shift the nucleus for the field of LAMP on animals raised for agricultural purposes.

Figure 3. Manuscripts published per year by Bradford's Law Zone 1 journals in a scientometric analysis on LAMP applied to farm animals from 2004 to 2019

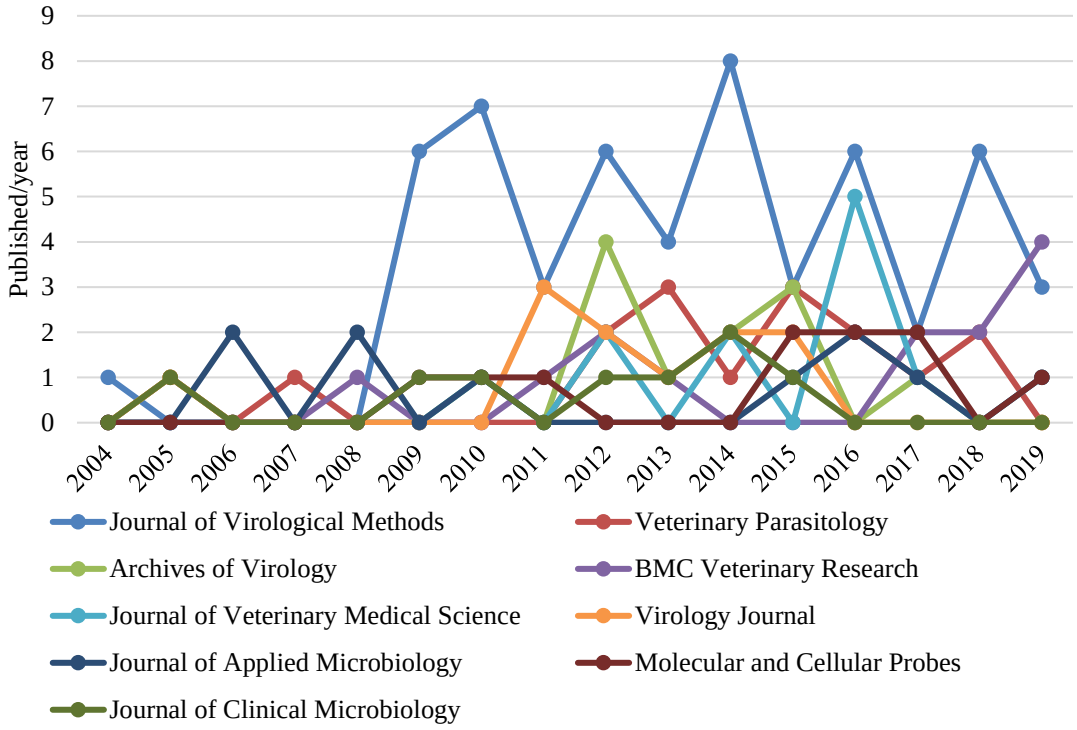


Figure 4. Ranking of the twenty authors with the largest number of publications per year on LAMP applied to farm animals

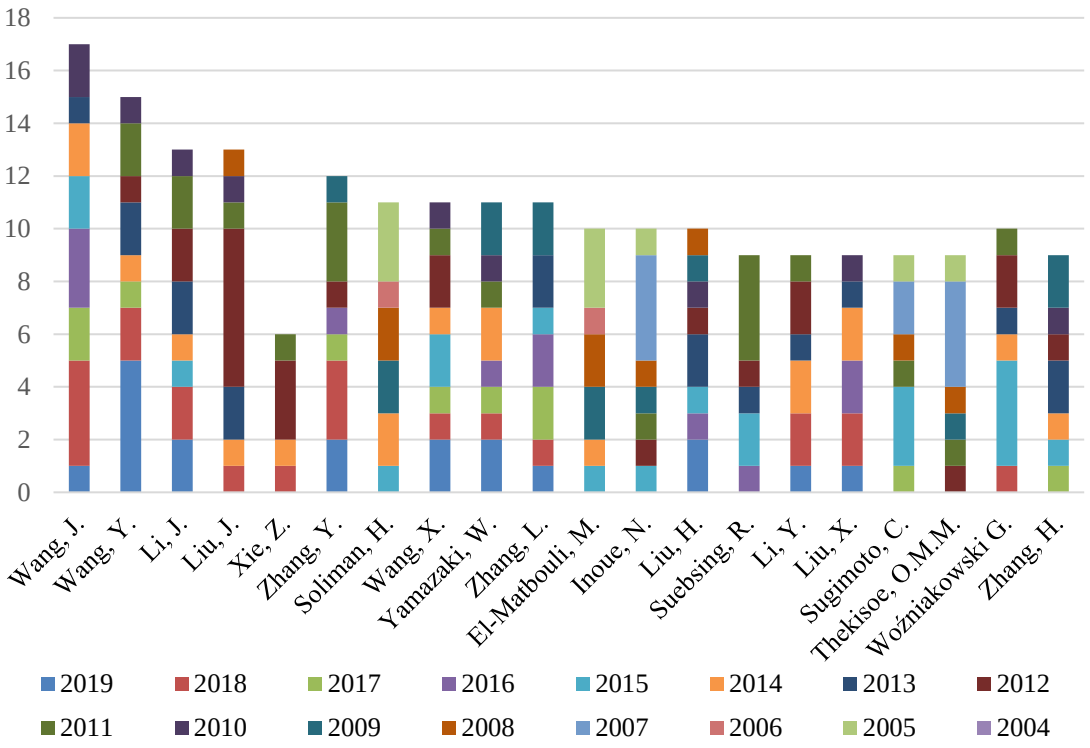
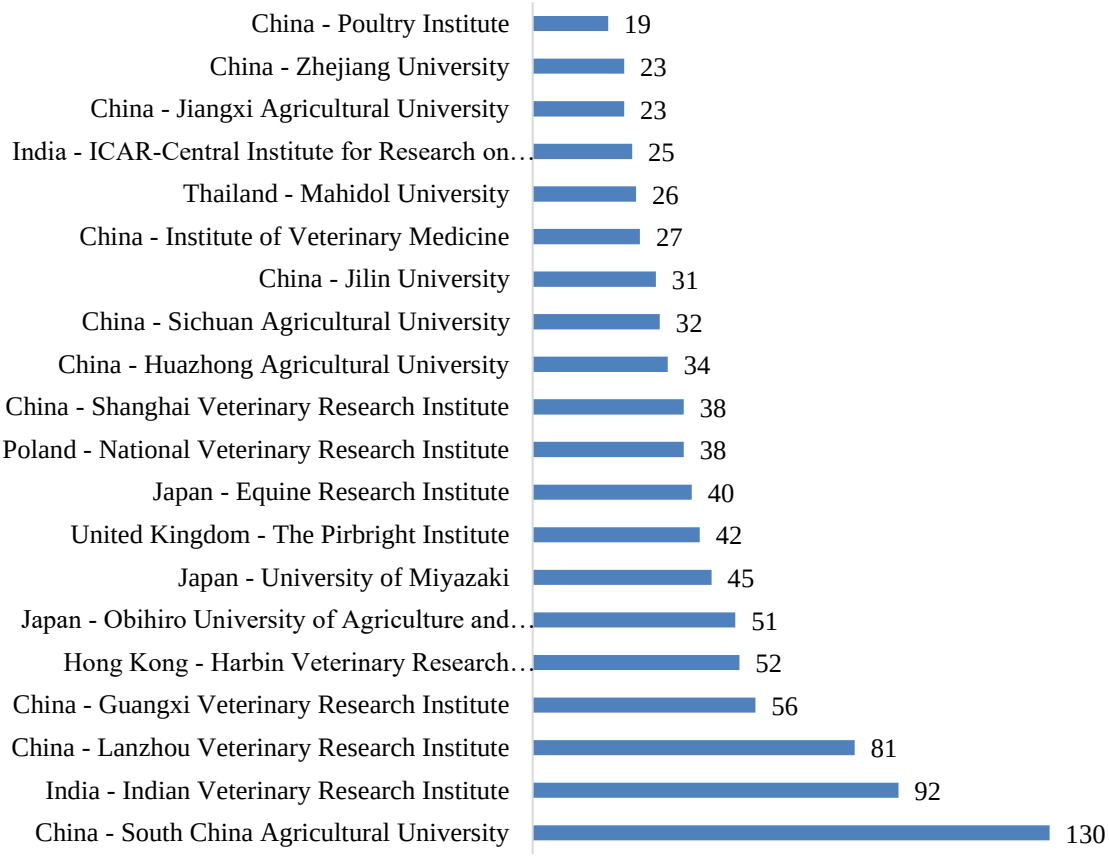


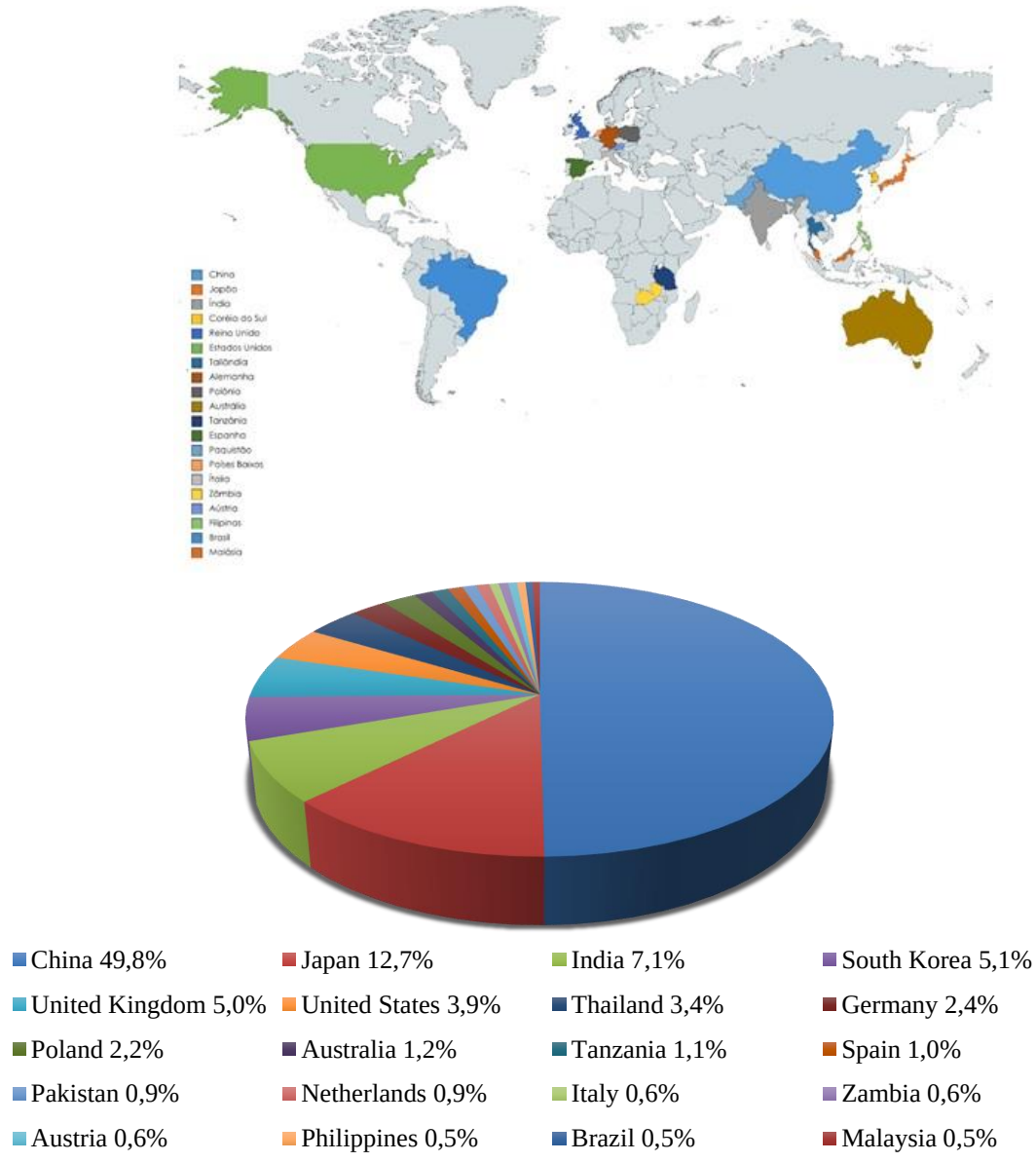
Figure 4 presented the twenty authors who published from 9 to 17 articles in the period 2000 to 2019. Rørstad & Aksnes (2015) claimed there is a large difference in the publications among scientists, as a relatively small proportion of them contribute most of the publications. This observation is true in the present study, as 14 authors contributed ≥10 publications, corresponding to 37.9% (166/438) of the articles analyzed (Figure 4). Rørstad & Aksnes (2015) also demonstrated that variance in terms of publication rates is influenced by the gender, age and academic position of the researchers, research funds availability, working conditions, talent, among numerous other research parameters that affect individual scientific performance.

Figure 5. Distribution of articles reporting on LAMP applied to farm animals from 2004 to 2019 based on author's institutional affiliation of the twenty institutions more frequently publishing in the field



In terms of institutions with the largest number of publications, the one that stood out was the South China Agricultural University, with 14.4% (130/905) publications (Figure 5), a figure that is likely to be underestimated as publications in Chinese language scientific journals were left out. Indeed, this result is related to the following result obtained in the frequency of publication by country (Figure 6), since China ranked first in all analyses.

Figure 6. Countries ranked by the frequency distribution of scientific research articles on LAMP applied to farm animals from 2004 to 2019 retrieved from Scopus®



China and Japan together contributed with 62,5% authors and, therefore, stood out, since together the other eighteen countries contribute with a total of 37,5% corresponding authors. Furthermore, the results suggested China and Japan are the countries mostly interested in applying LAMP to understand biological aspects of farm animals in the world. This asymmetry a priory is not worrisome if the nations commit to the Declaration of Science and Use of Scientific Knowledge (WCS/UNESCO, 1999). However, scientific ability is crucial for governments to decide scientific priorities and funding, which in turn will lead the country development, a parameter intrinsically dependent on critical thinking and highly trained people.

Our observations were supported by Xie & Freeman (2019) who reported China has accounted for up to 37% of global scientific publications, overtaking the United States in the forefront of research. Setting aside issues of research integrity and quality, the reasons subjacent to China's contribution to global science rely heavily in the stimuli driven by investments in basic research (COURTIOUX et al., 2019). In addition, Gaulé & Piacentini (2013), studying graduate students and their link to U.S. scientific productivity, found that group of Chinese researchers enrolled in U.S. doctoral programs had a strong publication history, due primarily to financial support received from Chinese institutions.

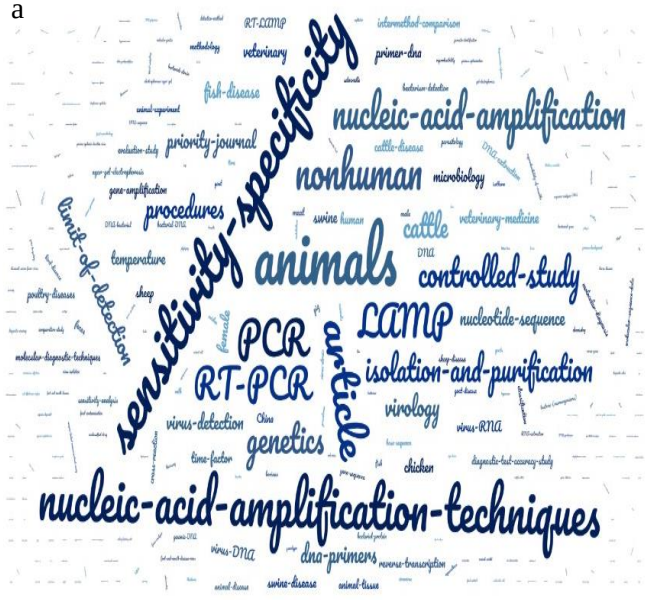
Alongside China, Erfanmanesh et al. (2013) pointed out Japan was among the top 5 countries in scientific and technological productivity when scientometric analyses were carried out on articles deposited in the Web of Science (WoS) and Scopus® databases. Some universities from Japan, Singapore, and China, including Hong Kong have been ranking among the 100 top-ranked universities worldwide and their evolution has been increased steadily over the past decade. Erfanmanesh et al. (2013) also justified the accomplishments of India in science e technology that led the country to occupy the third place in number of publications worldwide. The authors claimed Asian countries have improved their scientific positions through the formulation of efficient interactions between politics, economics, and science. They reported 7.9%, 6.5%, and 2.3% of the publication deposited in the Scopus® were from China, Japan, and India, respectively, declaring them as 3 top-ranked Asian countries with respect to scientific performance.

From the 438 articles, we obtained 2,602 descriptive words that were repeated 14,954 times and when inserted in Wordcloud, a plot generated a cloud with about 36% of those words, corresponding exactly to the most common 742 keywords, was automatically generated (Figure 7a). The remaining 1,860 words were not included in the cloud as they were relatively undersized due to their limited repletion and therefore would not be readable in the final plot. When considering the most frequent ones, "animal", "sensitivity and specificity", "nucleic acid amplification techniques", and "article" appeared 601 (4%), 501 (3.4%), 310 (2.1%), and 309 (2.1%) times, respectively. The number of times the remaining words were cited varied from 251 to 2 times. Figure 7b, on the other hand, shows the keywords used by the authors in their documents. A total of 9.8% (43/438) of the peer reviewed and published articled showed no keywords amidst their contents. In the cloud of keywords, only words ranging from 2 to 262 were included, corresponding of about 65% (1101/1696) of the retrieved keywords. Additionally, from the word clouds in Figure 7 is evident the strong relationship and/or interdependence of descriptive and keywords. In short, by evaluating the entire word cloud configuration it was

possible to better understand the relevant topics in the research and how they were interrelated. This observation is supported by Heilig & Vob, 2014. If one takes the keywords collectively, to date it is possible to infer that conventional and reversed transcribed LAMP have been use mostly as assays for rapid detection of pathogens on farm animals and are considered sensitive methods suited to on-site use.

Figure 7. Word clouds depicting the most frequently used descriptive words (a) and authors' selected keywords (b) in the manuscripts regarding LAMP applied to farm animals from articles deposited in Scopus® from 2004 to 2019

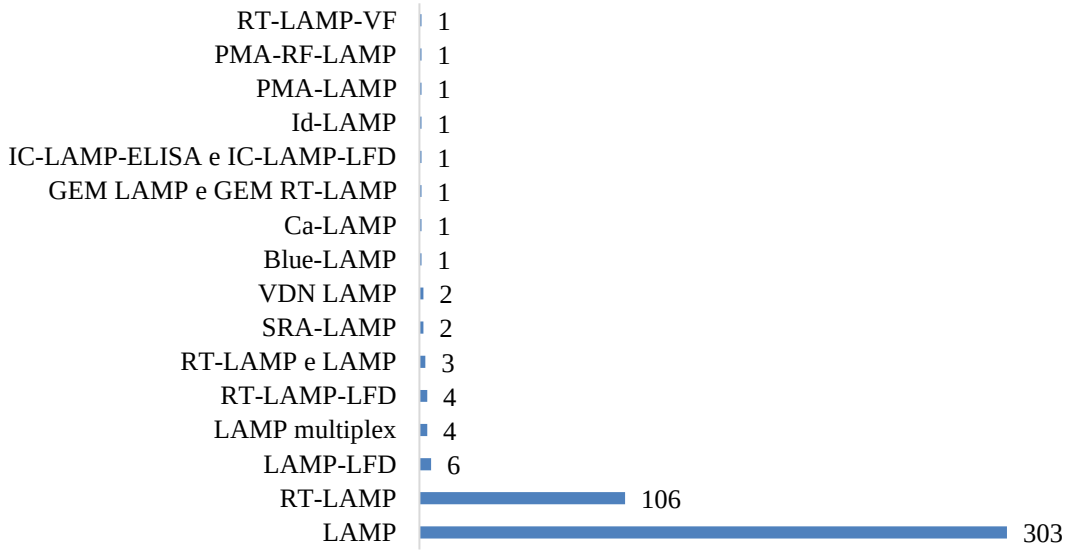
a



b

The variations of LAMP employed by the authors in their scientific research are shown in Figure 8. The conventional LAMP assay remains the most frequently used methodology in the field, reported in 69.2% (303/438) of the articles retrieved from Scopus®. The second most common assay was RT-LAMP, reported in 24.2% (106/438) of the documents analyzed, which uses a combination of reverse transcriptase, DNA polymerase, and primers designed to target RNA molecules (THI et al, 2020). The remaining documents (6.6%) reported on several other types of LAMP, generally defined by the combination of the original nomenclature of the assay and some additional methodological modification designed to answer a specific research question (LIU et al., 2017, YOUN et al, 2017; FANG et al., 2018). Methodological variations and adaptations are very common in science and are good indicators of the versatility and adaptability of original methods. Albeit some of the variations will remain of limited use, other may increase sensitivity and specificity of an assay and in due time become the preferred research strategy for a specific field.

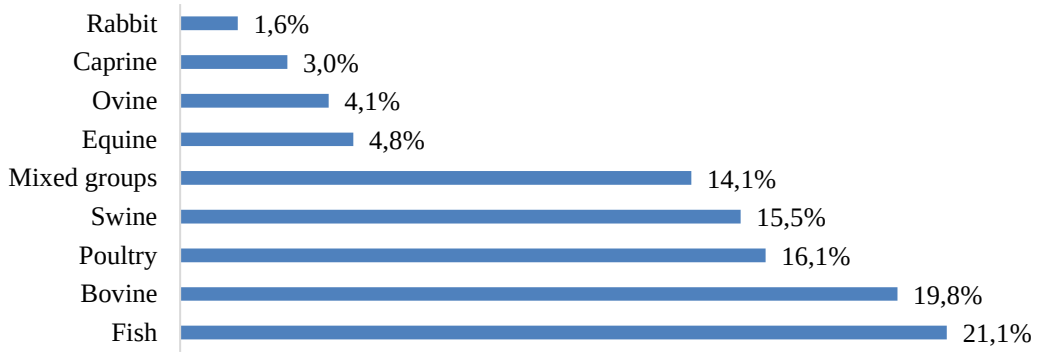
Figure 8. LAMP assay variations reported in the documents retrieved from Scopus® dealing with the assay applied to farm animals from 2004 to 2019. The acronyms are reverse Transcription Loop-Mediated Isothermal Amplification Technique and a Vertical Flow Visualization Strip (RT-LAMP-VF), Propidium Monoazide Treatment with Real-Time Fluorescent Loop-Mediated Isothermal Amplification (PMA-RF-LAMP), Propidium Monoazide Treatment Loop-Mediated Isothermal Amplification (PMA-LAMP), LAMP em Disco (Id-LAMP), Immunocapture Loop-Mediated Isothermal Amplification Assay Enzyme-Linked Immunosorbent (IC-LAMP-ELISA) and Immunocapture Loop-Mediated Isothermal Amplification Assay Lateral-Flow Dipstick (IC-LAMP-LFD), RNA GEM Tissue Enzyme combined with Loop-Mediated Isothermal Amplification (GEM LAMP) with GEM Tissue Enzyme Reverse Transcription Loop-Mediated Isothermal Amplification (GEM-RT-LAMP), Calcein-Loop-Mediated Isothermal Amplification (Ca-LAMP), Loop-Mediated Isothermal Amplification Assay with Pre-Addition of Hydroxynapthol Blue (Blue-LAMP), Loop Mediated Isothermal Amplification (LAMP) Assay for In-Field Detection of *Dichelobacter Nodosus* with aprv2 (VDN LAMP), Serum Resistance-Associated Gene Loop Mediated Isothermal Amplification (SRA-LAMP), Reverse Transcription Loop-Mediated Isothermal Amplification (RT-LAMP), Reverse Transcription Loop-Mediated Isothermal Amplification Coupled with a Lateral Flow Dipstick (RT-LAMP-LFD), Multiplex Loop-Mediated Isothermal Amplification (multiplex LAMP) and Loop-Mediated Isothermal Amplification Coupled with a Lateral Flow Dipstick (LAMP-LFD)



With respect to the applicability of LAMP within distinct research contexts using farm animals, most articles applied the assay to detect microorganisms affecting the stock, corresponding to 92.2% (404/438). On the other hand, 3.7% (16/438) of the studies focused on using LAMP to detect food fraud in meat or milk, while 2.5% (11/438) used LAMP for sexing of animals, mostly livestock embryos, and 1.6% (7/438) of the documents were methodological reports describing approaches sought to optimize the original assay for the detection of DNA from farm animals. It is noteworthy that for the implementation of all these distinct research approaches, varied types of biological samples were collected and analyzed from a range of livestock, poultry, and fish. The most frequently used biological samples for LAMP assays have been obtained from blood, feathers, fecal matter, liver, lung, mucus, kidney, muscle, saliva, semen, serum, skin, spleen, and urine (ALHASSAN et al., 2007; DAS et al., 2012; PAWAR et al., 2015; INOSHIMA et al., 2016; KUROSAKI et al., 2016; SUWANCHAROEN et al., 2016;

ADEDEJI et al.,2017; HOWSON et al., 2017; LJUNGSTRÖM et al.,2018; OYHENART, 2018; ZHANG et al., 2019).

Figure 9. Frequency distribution of the animal groups included in the reports dealing with the application of LAMP assay on farm animals retrieved from Scopus® from 2004 to 2019.



As mentioned earlier in this article, the applications of LAMP assay are most diverse because the versatility of the method itself. Consequently, the interest for the assay application has been increasing steadily among researchers. Within the period surveyed in the current scientometric analysis, from 2004 to 2019, there was a 12,5x growth in the publication of works using LAMP on farm animals, yet most articles reported on the detection of microorganisms, focusing on health, welfare, and animal productivity within the scope of veterinary clinical medicine. Most of the reports dealt with the detection and diagnosis of infectious agents associated viral-, bacterial- or vector-borne diseases in farm animals. The second class of reports using LAMP focused on the detection of food fraud, aimed at meat from buffalo, cattle, horse, and cod; milk from cows and goats; and mixed meat products and sausages. Figure 9 shows the farm animals mostly cited in the reports included in this analysis. Interestingly, LAMP was predominantly applied to fish for both pathogen detection and fraud investigation, corresponding to 21.2% (93/438) of the documents returned from Scopus®. Bovine, poultry, and swine were the other animal groups cited in the reports, accounting for 19.8%, 16.1%, and 15.5% of total publications.

For Siqueira (2018), in recent decades the growth of aquaculture production has contributed to the Blue Revolution. Worldwide, Asian countries, especially China, have been leading the blue revolution, breeding fish and aquatic animals. Aquaculture was an ancient activity in Asian countries, which benefited tremendously from the technologies within the contemporaneous mode of production. The author claimed in the current aquatic commercial breeding systems the use of balanced and supplemented feed and lower gravity of water would

allow the production of meat to increase up to 7x when compared to the production of cattle. However, fish can be easily lost due to pathogen-borne diseases, increasing the risk of negative economic impact on fish farming. The risk and losses can be reduced or completely avoided by the rapid detection of disease-causing microorganisms to prevent, contain, and control the spread of the diseases in aquaculture settings (SOLIMAN et al., 2014). Henceforth, LAMP could become the first-ier choice and possibly the gold standard assay for pathogen detection in aquatic breeding farms. To support this rationale, the results of our scientometric study showed that LAMP assay was useful to detect Mycobacterium marinum infecting fish and water (TSAI et al., 2019); Salmonid Herpesvirus 3 (SalHV-3) and epizootic epitheliotropic disease virus (EEDV) in hatchery-raised lake trout (ZHANG, 2019); among many other applications that, when added together, totaled the largest quantity of articles (93) on LAMP applied to farm animals.

Regarding the use of LAMP on the bovine group could be justified in part by the fact that since 1960, the overall productivity of cattle herds has substantially increased due to advances in nutrition, disease control, and genetic studies combined with adequate herd management, breeding, and selection based on scientific knowledge (THORNTON, 2010). Brumatti et al. (2011) believed the meat production, particularly in beef cattle, should be and efficient economic activity specially in production systems where genetic and economic evaluations are considered to establish animal breeding programs strategically designed for selecting the desired traits in the herd. In general terms, a promising trend in animal husbandry has been noticed which in turn increases farm balance and efficiency, leading to economic gains without sacrificing animal health and welfare, genetic diversity, food quality and safety under environmental sustainability practices in cattle industry (NIEUWENHOVEN et al., 2013). Additionally, in the livestock sector, at least 1.3 billion people are employed globally and it is the agricultural subsector that grows the most in developing countries. Besides the sector has been an important supplier of nutrients, contributing 17% of kilocalorie consumption and 33% to protein consumption worldwide (ROSEGRANT et al. 2009; THORNTON, 2010). Nevertheless, poultry and pork remain the main sources of animal protein, accounting for about 70% of the meat produced in the world (OECD-FAO, 2011). By looking at the findings in the current scientometric analysis, it is readily understandable why the LAMP assay ranked second, third, and fourth for research in cattle (87 articles or 19.8%), poultry (71 articles or 16.1%), and swine (68 articles or 15.5%), respectively. The method has also been useful to detect disease-borne pathogens that commonly affect these animals, such as: Streptococcus suis in pigs (BOONYONG et al., 2019), Escherichia coli in poultry (KOGOVŠEK et al., 2019), Salmonella sp. in chickens (LIU et al., 2019),

Mycoplasma bovis (APPELT et al., 2019) and Cryptosporidium parvum in cattle (DOMINGO et al., 2018).

4 CONCLUSION

Although the combinations of the specific keywords, regarding the use of LAMP on farm animals, were able to return several studies from Scopus®, about 1:10 retrieved articles had no relation to the scope of the topic statement. Thus, exclusion parameters had to be applied to prevent the inclusion of inadequate documents in the analysis. The remaining collection of documents resulted in an adequate overview of the application of LAMP on farm animals, corresponding to an exponential growth over time. The observed increasing trend has not yet reached its plateau.

With respect to Zone 1 of Bradford's Law, the Journal of Virological Methods lead the trend in the number of publications from 2009 to 2018. By correlating one of the scopes of this journal - animal virology - to the types of samples used in the assay, the most frequent keywords in the articles, and the detection target by LAMP, there was a correlation of these parameters to support the conclusion that pathogenic microorganisms infecting farm animals, especially viruses and bacteria, have remained the major focus of research using LAMP. However, a trend of publications to journals focusing on animal sciences was observed, suggesting a shift in Zone 1 will be reached in the future, and manuscripts reporting the use of LAMP on farm animals will most likely be published in journals that cover scientific and technological aspects of veterinary medical sciences, production, and breeding of animals for agricultural purposes.

Asian countries, especially China, followed by European countries and the United States of America are the global leaders of publications on LAMP applied to farm animals and consequently the three most frequent institutions reporting on the use of LAMP were South China Agricultural University, Indian Veterinary Research Institute, and Lanzhou Veterinary Research Institute, all from Asian countries.

Together, the animal groups fish, bovine, poultry, and swine corresponded to 2/3 (71,1%) of the animals used in scientific research using LAMP as the elected assay to investigate and answer scientific questions. Fish lead the group, corresponding to 21,1% of animals reported in original articles dealing with the application of LAMP. This trend is supported by Blue Revolution that has taken up globally, indicating the growth of technified aquaculture production in recent decades, especially in Asian countries. The growth in consumption and production of fish also increased the risk of financial losses due to viral or bacterial diseases. Therefore, LAMP has been the first-ier method of choice for the early detection of pathogens in the animals and in

the aquatic environment. These observations also held true for the other animal groups. Conventional and reversed transcribed LAMP have been the most frequently used methods for rapid detection of pathogens on farm animals, suited to on-site use.

ACKNOWLEDGMENTS

The authors express their gratitude to Dr. Flávia Melo Rodrigues for her kind suggestions and contribution to the manuscript. We also kindly thank Mr. Sean M. Quail for proofreading the draft. S.A.R. held a PhD scholarship from Fundação de Amparo à Pesquisa do Estado de Goiás (FAPEG). C.B.M.C. held a PhD scholarship and H.S.G.S. held a MSc scholarship both from the National Council for the Improvement of Higher Education (CAPES). This work has been partially supported by CAPES.

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