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Research Article

# *Moringa Oleifera* for Enhancing Livestock Performance and Product Quality: A Bibliometric Analysis

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**Abstract:** This bibliometric analysis evaluates global research on *Moringa oleifera* as a feed supplement for enhancing livestock performance and product quality. A total of 95 peer-reviewed articles published between 2002 and 2023 were retrieved from Web of Science. Bibliometric indicators revealed mean citations per document of 19.89, average co-authors per document of 5.14, and an annual research growth rate of 10.73%. Publication trends demonstrated steady growth over the study period ($R^2 = 0.598$; $y = 0.6696x - 3.7273$), indicating increasing research interest. South Africa led in publications (n = 12) and citations (n = 449), followed by Egypt (n = 11; 273 citations), India (n = 11; 76 citations), China (n = 9; 213 citations), and Mexico (n = 7; 170 citations). International collaboration was highest among Egypt (n = 8 multi-country articles), Mexico (n = 5), South Africa (n = 2), and Nigeria (n = 2). African countries (South Africa, Egypt, Nigeria, Cameroon, Tunisia) and Asian nations (India, China, Indonesia, Pakistan, Saudi Arabia, UAE, Iran, Japan, South Korea) dominated research output globally. Keyword analysis identified "antioxidant" as the most prominent research theme. Current research focuses primarily on *M. oleifera's* effects on livestock productivity (meat and milk yield), product quality (particularly antioxidant properties), and sensory acceptance. Future research directions should emphasize the health-promoting properties of *Moringa*-enhanced livestock products and their potential contributions to sustainable livestock production and human nutrition. This analysis provides a comprehensive overview of research trends and identifies priority areas for advancing knowledge on *M. oleifera* in animal agriculture.

**Keywords:** *Moringa oleifera*, Bibliometric Analysis, Livestock Performance, Feed Supplementation, Meat Quality, Milk Quality, Antioxidant Activity, Animal Nutrition

## Introduction

Livestock and their products (eggs, meat, as well as milk etc.) are rich foods with respect to nutrients that enhance nutrient-poor meals both as a major portion of the regular meal or through provision of vital nutrients in diets such as vitamins and minerals, among others (Cuchillo-Hilario et al., 2024). Beyond food production, the livestock industry has positive benefits on the health of people, the societies as well as the general economic performance of most communities of the world (Alders et al., 2021). Again, livestock maintains a chief part in food supply by converting low-value feed-resource into milk, meat, and eggs among others for human consumption (Godde et al., 2021). Livestock is further known to supply about 13-17 % of energy and 31 % protein source to the world's diet (Godde et al., 2021).

However, the geometric increase in the dependency of livestock and its products globally has been commendable in the past years. The current major challenge globally is to curtail the rising request for food while conserving vital ecosystem processes (Johnson et al. 2014). Statement from the Food and Agricultural Organization (FAO, 2014), states that by the year 2050, the food industry has

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an enormous challenge to give out 60 % more than the existing food yield (8.5 billion tons/year) to tolerate a growing world population which have been forecasted to be 9.5 billion people. Sadly, evidence abound that the present global livestock production in terms of its yield and products (milk, meat, egg etc.) are not enough to meet the growing need for food demands and nutrition security (Song et al., 2024). This situation has thrown open the need for farmers, researchers and other stakeholders to explore several means of increasing livestock productions to alleviate the societal concerns without compromising the welfare, health and product qualities of livestock (Onwenze et al., 2021).

As part of the several ways to increase livestock yield and product (meat. milk, egg, etc.) quality, the approach of effective feeding programmes to boost their performance have been adopted (Cuchillo-Hilario et al., 2024). Several feedstuffs, ingredients and browse plants have been incorporated into livestock feeding plan for maximum yield, animal performance and product qualities (Akuru et al., 2021; Akintan et al., 2024). One of such feedstuff/ browse plant for efficient livestock use is *Moringa oleifera* (Akintunde et al., 2024). *M. oleifera* is a known environmental and economic significant plant (Akintunde et al., 2024). This plant does not require much care to manage together with the fact that it is rich in bioactive compounds (Falowo et al., 2018). This plant species also possesses effective tolerance to drought as well as environmental stresses. Virtually all its parts contains vital beneficial ingredients including proteins, carbohydrates, minerals and vitamins (Mashamaite et al., 2021). Most part of *M. Oleifera* (including leaves, seed and roots) have a significant content of total phenols, tannins and flavanols (Falowo et al., 2018; Mashamaite et al., 2022; Lungu and Idamokoro, 2024). With this afore-mentioned attributes, it is obvious that the plant is an efficient browse material that has been used to combat nutritional deficiencies in livestock farming. *Moringa oleifera* is well-known significant and essential bio-resourceful plant in Africa containing important macro and micro ingredients and bio-active components with established bio-functional traits such as antioxidant as well as antimicrobial properties. These bio-functional characteristics are critical for promoting healthy and quality animal products (including milk and meat). *M. oleifera* leaves are effective antioxidant agents which when it is integrated into meat, it can enhance quality traits during the process of preserving meat (Lungu et al., 2021). Studies has further reported the utilization of *M. oleifera* plant in livestock feedstuff to boost growth rates, feed conversion ratio, gastrointestinal health as well as general product quality performance of animal (Mukumbo et al., 2015; Nkukwana et al., 2014; Abd El-Hack et al., 2018). In addition, *Moringa oleifera* is a promising biotechnological and "super" tree because it has a high number of uses and it is a source of numerous vital biological compounds (Falowo et al., 2018).

Research on the effect of *Moringa oleifera*'s on livestock productivity and product quality has been carried out and published in few quality journal outlets. From *Scopus* which happened to be a reputable global known indexing source, only four (4) articles dated November 16, 2023 were found. Meanwhile, only 95 papers have been published by Web of Science-indexed journals as dated in November 16, 2023. Due to the more numbers of articles in WoS compared to Scopus the former (WoS) was used for the present study. Conversely, based on the document search, it means that the subject related to the use of *Moringa oleifera* on livestock performance and product quality (meat, milk, egg etc.) for livestock is a novel area to be investigated. Howbeit, from 2002 to 2023 in the *Scopus* website, there was virtually no review article targeted on *M. oleifera*'s usage for improving livestock performance. Due to this fact, carrying out a study to investigate the development of the topics that have been employed by scholars in this discipline was a challenge.

Interestingly, bibliometric studies has the prospect to weigh how impactful a research article through the evaluation of bibliometric findings including citation numbers of articles (Wang et al., 2023). This scholarly approach is capable of helping authors evaluates how effective their research is doing on the global stage as well as pin-point subject areas that are of interest to other scientists (Varela et al., 2018). In addition, it was observed that the scholars who published articles on the discussed subject were mostly from Africa (South Africa, Nigeria, Egypt etc.) and Asia (India, China, Pakistan, Indonesia etc.) among others. This was somewhat expected due to the fact that these nations have a wide spread of distribution of this plant (Falowo et al., 2018; Mashamaite et al., 2022; Lungu and Idamokoro, 2024) and they have also used *Moringa oleifera* as a browse plant for livestock feeding as well as for human use (Akintuntde et al., 2024).

With respect to this study, the common research areas on this subject are the effects of *M. Oleifera* on livestock performance (yield, health, growth etc.) and product quality (milk, meat etc). However, it is unclear on the numbers of studies and citations these published documents had garnered in the previous years, as well as what commonly used words are found in the title, abstract, as well as author's keyword to portrayed the core idea of the researchers (El Mohadba et al., 2020). With respect to this gap, the purpose this study was conducted was to find

out the trend of the research related to the effect of *M. Oleifera* on livestock performance and product qualities (milk, meat etc.) according to previous researches that have been indexed by WoS.

## Materials and Methods

### *Design of Study*

The present study used a bibliometric technique, which is a tool for evaluating research impact and performance of several disciplines and supporting appropriate policy actions in previous years (Kawuki et al., 2021).

### *Source of Data*

The scholarly information as well as data utilized for this work were gotten from the WoS database. The reason for the choice of dataset is that the Web of Science (WoS) remains a perfect data source that covers more than 190 research areas (Petermann-Rocha et al., 2024). The WoS has a broad spectrum of repository of more than 12,000 impactful articles, pointing to a testament of its impact on the global stage (Wang et al., 2024). The dataset further contains important international articles. Being known as a reliable data source, WoS offers unmatched avenue in literature exploration and citation evaluation (Jiang et al., 2018). Furthermore, it is commonly agreed that the use of one dataset for evaluating bibliometric studies is generally the best for most researchers due to the challenges faced in doing this type of research with multiple data outlets that could result to loss of some vital articles when combining several datasets (Sweileh, 2020).

### *Strategy Employed for Data Gathering*

The search strategy used for the study is listed as: T1 [(moringa oleifera*) AND (milk quality* OR milk yield* OR milk production* OR milk taste* OR meat quality* OR meat yield* OR meat production* OR meat taste OR cattle* OR goat* OR sheep* OR poultry* OR cheese* OR yoghurt* OR livestock*)] to retrieve the appropriate documents from WoS published (between 2002 – 2023) and for reproducibility of study.

### *Statistical Analysis of Data*

The data used for this research were downloaded in a BibTex form for evaluation. The study employed descriptive approach to present the outcome of the study. The trends in research and designated bibliometric indices were assembled and analysed with the use of "Bibliometrix app." (Aria and Cuccurullo, 2017). The assessment done in this study comprised of the distribution and frequency of document types, keywords plus, author keywords, most productive nations, organizations, researchers, topic trends, relevant journal outlets and the each journal influence and sum citations, as well as connections among authors as well as keywords. Microsoft excel was used for data mining and visualization of research growth over the years.

### *Inclusion as well as Exclusion Criteria for Study*

The inclusion and exclusion criteria for this research was well elaborated in Figure 1. Previous studies have also use this kind of method to screen data for studies of this nature (Fesseha et al., 2020).

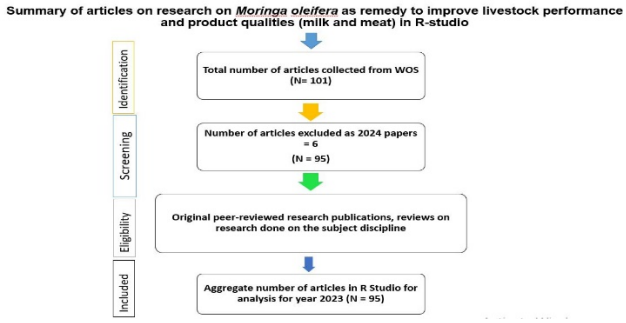


**Fig. 1:**The inclusion and exclusion of publications from 2002 – 2023

## Results and Discussion

We used bibliometric method to evaluate findings from research publications on the utilization of *M. Oleifera* as potential plant material for improving livestock productivities and product qualities (meat and milk) between the year 2002 – 2023 with regards to the data retrieved from WoS. A sum of 95 publications between 2002 – 2023 were analysed. The breakdown of the main information of the assessed articles are presented in figure 2. The sum of academic writers involved in research work on the subject during the studied period were 432, meanwhile the number of single authors were 2. The result had 5.14 % co-authors per article, and 35.79 % global co-authorships. The aggregate sum of citations per article is 19.69 %, while the annual growth rate is 10.73 %. Figure 3 described the polynomial metric fitting curve for the present study. This kind of analysis portrays the annual rise in the number of articles as well as citations with a positive correlation ($R2 = 0.598$; $y = 0.6696x – 3.7273$) between the cumulative number of publications and the years of research on the subject of discourse from 2002 - 2023.

The number of publications on the subject matter from 2002 showed a dwindling and fluctuating propensities with few of the years having no single publication while some years had few number of articles.

There was however a noticeable increase in research outputs from 2012 (n = 3) to 2022 (n = 22). The growth in publication showed the rising interest for research on *Moringa oleifera* as a plant to improve livestock performance and product qualities (meat and milk) by researchers, organizations and related research agencies. This finding was similar to a previous bibliometric assessment who reported the use of *Moringa oleifera* to improve embryo performance in cows (Mafruchati et al., 2024).


**Fig. 2:** Summary of main information of data retrieved on *Moringa oleifera* as a "super plant" to boost livestock performance and product qualities (milk and meat)

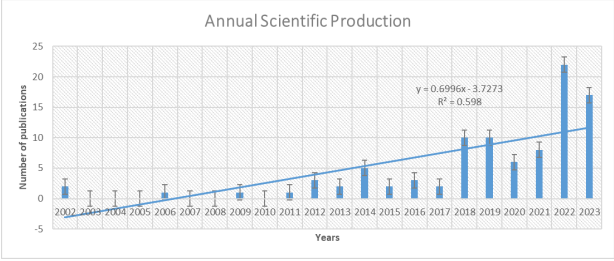


**Fig 3:** Annual number of article publications on *Moringa oleifera* as a "super plant" to boost livestock performance and product qualities

With regards to the number of publications, more articles with reference to numbers on *Moringa oliefera* were published in nations such as South Africa (n = 12), Egypt (n = 11), India (n = 11), China (n = 9), Mexico (n =7) Indonesia and Nigeria (n = 5 each), respectively. Similar to the present findings, El Bilali et al. (2024) also listed countries such as South Africa, Egypt, and Nigeria among other developing nations that do more research with *M. Oleifera*. However, in contrast with our result, other bibliometric studies reported high numbers of research publications mostly from developed countries in other research disciplines (Song et al., 2024; Xie et al., 2024). Several reasons have been given for the growth in research in developed countries as compared to developing nations. One of such reasons is the fact that scientists, government organizations as well as other stakeholders understands the importance of cutting hedge research in solving human needs and improving livelihoods (Idamokoro, 2023). In addition, several research agencies from economical stable nations are highly subsidized by global organizations for research purposes (Song et al., 2024). The high numbers of research work carried out on *Moringa oleifera* for improving livestock performance and products (meat and milk) in many nations of Africa, Asia and part of Central America may be alluded to the fact that this plant is widely spread in these regions (Falowo et al., 2018; Amad and Zentek, 2023). Again, the cultivation of *Moringa oleifera* plant have been used to solve several nutritional and performance requirements of livestock in these regions (Nouman et al., 2014).

The 25 top ranked countries having multiple collaboration publications on research outputs on *Moringa oleifera* as a remedy for improving livestock showed that they mostly partner with colleagues from developing countries with few from economically stable and advance nations including China, USA, Germany, Turkey, Austria, France, and Italy (table 2 and Fig. 3).

This observation is in contrast with findings of previous bibliometric study who reported that research networking are usually common among nations with economical stable economies and advanced in science (Smith et al., 2021). Meanwhile the present findings is inline with other studies who reported scanty networking between developed and developing nations (Orimoloye and Ololade, 2021). The cause for the present observation is pretty obvious and have previously been pointed out. *Moringa oleifera* is widely distributed in many nations of Africa, Asia and part of Central America and its use have been helpful in improving livestock performance in these regions (Amad and Zentek, 2023).

Scholarly exchange of knowledge and expertise in a research area among scientists from diverse countries is so helpful and significant due to the fact that this collaboration generates avenues for efficient executions of ground-breaking study that may foster global influence especially when there is enough financial resources, and adequate facilities to support the research (Lloyd et al., 2023). Again, due to insufficient global collaboration among countries in research may distorted research citations because intellectual exchange of inputs and expertise from different cultures and environmental conditions helps to impact the usefulness of the study, draws more global interest in the study and also improve the citation numbers of the academic study (Ekundayo and Okoh, 2018).

**Table 1:** Top 25 leading nations on *Moringa oleifera* as a "super plant" to boost livestock performance and product qualities (milk and meat) from 2002 – 2023

| S/N | Country | Articles | SCP | MCP | Freq | MCP_Ratio | Country | TC | AAC |
|---|---|---|---|---|---|---|---|---|---|
| 1 | South Africa | 12 | 10 | 2 | 0.126 | 0.167 | South Africa | 449 | 37.4 |
| 2 | Egypt | 11 | 3 | 8 | 0.116 | 0.727 | Egypt | 273 | 24.8 |
| 3 | India | 11 | 11 | 0 | 0.116 | 0 | China | 213 | 23.7 |
| 4 | China | 9 | 9 | 0 | 0.095 | 0 | Mexico | 170 | 24.3 |
| 5 | Mexico | 7 | 2 | 5 | 0.074 | 0.714 | Sweden | 118 | 59 |
| 6 | Indonesia | 5 | 5 | 0 | 0.053 | 0 | Pakistan | 117 | 29.2 |
| 7 | Nigeria | 5 | 3 | 2 | 0.053 | 0.4 | India | 76 | 6.9 |
| 8 | Pakistan | 4 | 2 | 2 | 0.042 | 0.5 | Israel | 61 | 30.5 |
| 9 | Brazil | 3 | 3 | 0 | 0.032 | 0 | Samoa | 51 | 51 |
| 10 | Cameroon | 3 | 2 | 1 | 0.032 | 0.333 | Tunisia | 43 | 14.3 |
| 11 | Tunisia | 3 | 1 | 2 | 0.032 | 0.667 | Iran | 38 | 38 |
| 12 | Israel | 2 | 2 | 0 | 0.021 | 0 | Saudi Arabia | 33 | 16.5 |
| 13 | Saudi Arabia | 2 | 1 | 1 | 0.021 | 0.5 | Korea | 30 | 30 |
| 14 | Sweden | 2 | 0 | 2 | 0.021 | 1 | Tanzania | 29 | 29 |
| 15 | UAE | 2 | 0 | 2 | 0.021 | 1 | Sudan | 28 | 28 |
| 16 | Australia | 1 | 0 | 1 | 0.011 | 1 | Italy | 27 | 27 |
| 17 | Austria | 1 | 0 | 1 | 0.011 | 1 | UAE | 24 | 12 |
| 18 | Croatia | 1 | 1 | 0 | 0.011 | 0 | Nigeria | 19 | 3.8 |
| 19 | Iran | 1 | 0 | 1 | 0.011 | 1 | Croatia | 13 | 13 |
| 20 | Italy | 1 | 0 | 1 | 0.011 | 1 | Australia | 12 | 12 |
| 21 | Japan | 1 | 0 | 1 | 0.011 | 1 | Portugal | 11 | 11 |
| 22 | Korea | 1 | 1 | 0 | 0.011 | 0 | Brazil | 10 | 3.3 |
| 23 | Malaysia | 1 | 1 | 0 | 0.011 | 0 | Cameroon | 10 | 3.3 |
| 24 | Philippines | 1 | 1 | 0 | 0.011 | 0 | USA | 9 | 9 |
| 25 | Portugal | 1 | 0 | 1 | 0.011 | 1 | Indonesia | 4 | 0.8 |

SCP: Single Country Publications; MCP: Multiple Country Publications; TC: Total Citations; AAC: Average Article Citations

**Table 2:** The 25 most relevant words used by authors on *Moringa oleifera* as a "super plant" to boost livestock performance and product qualities (milk and meat) from 2002 – 2023

| S/N | Key words (DE) | Occurrences | Keywords plus (ID) | Occurrences |
|---|---|---|---|---|
| 1 | Moringa Oleifera | 50 | Leaves | 19 |
| 2 | Moringa | 9 | Performance | 19 |
| 3 | Milk | 8 | Digestibility | 18 |
| 4 | Growth | 7 | Leaf Meal | 13 |
| 5 | Growth Performance | 6 | Protein | 13 |
| 6 | Meat Quality | 6 | Growth-Performance | 11 |
| 7 | Antioxidant | 5 | Extracts | 10 |
| 8 | Goats | 5 | Dairy-Cows | 9 |
| 9 | Milk Production | 5 | Ruminal Fermentation | 9 |
| 10 | Carcass Characteristics | 4 | Antioxidant Properties | 8 |
| 11 | Digestibility | 4 | Diets | 8 |
| 12 | Fatty Acids | 4 | Extract | 8 |
| 13 | Fermentation | 4 | In-Vitro | 8 |
| 14 | Goat | 4 | Carcass | 7 |
| 15 | Bioactive Compounds | 3 | Growth | 7 |
| 16 | Broilers | 3 | Yield | 7 |
| 17 | Dairy Cows | 3 | Nutrient Digestibility | 6 |
| 18 | Goat Meat | 3 | Quality | 6 |
| 19 | Methane | 3 | Supplementation | 6 |
| 20 | Milk Yield | 3 | Feed | 5 |
| 21 | Nutrition | 3 | Profile | 5 |
| 22 | Ruminal | 3 | Acid | 4 |
| 23 | Sensory | 3 | Acids | 4 |
| 24 | Sheep | 3 | Chemical-Composition | 4 |
| 25 | Silage | 3 | Cows | 4 |

With regards to "keywords" which are often used in bibliometric studies, they are employed to capture the themes of essential issues within a research discipline as well as give the general scope and directions of the study to readers (Chen et al., 2021). They are also employed to show cutting hedge directions of a publication (Synnestvedt et al., 2005). They are commonly required by journals during manuscript submission before review process is done. This is indicative of their importance during article review procedures (Okaiyeto and Oguntibeju, 2021). This study employed the usage of singular (author keywords) and plural (keywords plus) search for the present study to describe the frequently featuring words as keywords on the utilization of *Moringa oleifera* as a plant to improve livestock performance as well as product quality (meat and milk). This approach of keyword search have previously been used by authors to understand and analyse the coverage of trends in academic study that are current and emerging within a research field (Cañas-Guerrero et al., 2013). The use of author keywords is usually recommended in bibliometric evaluation due to the fact that they give an aggregate of scholarly terms that portrays the precise findings in an academic study for a particular discipline; whereas keyword-plus provides a range of references for titles of different articles (Idamokoro and Hosu, 2022).

The keywords that is customarily used in a specific research area reveals the frequently talked about subject matter over a given period by scholars in that discipline. Between the period of 2002 and 2023, an aggregate of 339 author keywords as well as 333 keyword-plus were gathered from WoS on *Moringa oleifera* as a remedial plant to improve livestock performance and product quality (meat and milk) in figure 2. These often used author keywords in this discipline *Moringa oleifera* (n = 50), followed by moringa (n = 9), milk (n = 8), growth (n = 7), growth performance (n = 6), meat quality (n = 6), antioxidant (n = 5), goats (n = 5), milk production (n = 5) and carcass characteristics (n = 4) among others are relevant to the research discipline (table 2). In agreement with the present study, several of the listed keywords have been used for *Moringa oleifera* research work (Nouman et al., 2014; Macambira et al., 2022; Mafruchati et al., 2024). This supports the importance of the afore-mentioned keywords in presenting the scope of this study and its utilized in the discipline.

The result of the 25 most ranked article outlets in table 3 showed that they are relevant sources committed to showcasing research findings on the discussed subject matter in line with livestock production. These top rated journal sources with their h_index score from table 3 include the following; Animal Feed Science and Technology (n = 4; h_index = 4), Animals (n = 5; h_index = 4), Small Ruminant Research (n = 4; h_index = 4), South African Journal of Animal Science also known as SAJAS (n = 4; h_index = 4), Meat Science (n = 3; h_index = 3), and Tropical Animal Health and Production (n = 4; h_index = 3). The type of findings given by the earlier mentioned journal archives as well as their h_index rankings show that they are able to publish research investigations as relates to the discussed subject matter. Some of the top ranked journal sources such as Animal Feed Science and Technology, Small Ruminant Research and Meat Science that topped the list of relevant journals are well-known journal outlets with Elsevier as their publisher.

In table 4, the top leading research organizations that performed more research as relates to the discussed subject matter was presented with nations from South Africa, China, Egypt and Pakistan having more organizations doing research in the field. Most research organizations ranked in this categories had at least 4 research publications and above.

However, North West University (based in South Africa), National Research Center (based in India), University of Fort Hare (based South Africa) had the highest number of articles with more than 18 article publications, respectively. In line with this observation, El Bilali et al. (2024) also indicated that several organizations from Africa are active in research of *Moringa oleifera*. Meanwhile, other bibliometric studies often report several institutions from the USA, China and in Europe to contribute significantly to academic knowledge in comparison to developing countries (Ekundayo and Okoh, 2020; Idamokoro and Hosu, 2022).

South Africa is a well-known nation that have invested large funds in research on *Moringa oleifera* thereby making it a leading nation in this field (El-Bilali et al., 2024).

In academic metrics, citation indexes of any academic publication and its global influence is measured via the amount of times that it is cited over the years couple with the amount of times that it is downloaded by people in that field of research. Likewise, the amount of article citations of an academic manuscript is as well linked to the academic strength of other citing scholarly research publications. When a research manuscripts is cited by a high impact factor journal source, it will attract the interest of other scholars in the research discipline which in turn impact the international rating of that research paper. The effect of a scholarly paper within a research area is usually centred on how often the manuscript attracts citation from others in the discipline (Tahim et al., 2016).

**Table 3:** The 25 most relevant journal source on *Moringa oleifera* as a "super plant" to boost livestock performance and product qualities (milk and meat) from 2002 – 2023 based on h_index, citation and article numbers

| S/N | Element | h_index | g_index | m_index | TC | NP | PY_start |
|---|---|---|---|---|---|---|---|
| 1 | Animal Feed Science and Technology | 4 | 4 | 0.25 | 156 | 4 | 2009 |
| 2 | Animals | 4 | 5 | 0.667 | 106 | 5 | 2019 |
| 3 | Small Ruminant Research | 4 | 4 | 0.174 | 209 | 4 | 2002 |
| 4 | South African Journal of Animal Science | 4 | 4 | 0.364 | 61 | 4 | 2014 |
| 5 | Meat Science | 3 | 3 | 0.231 | 342 | 3 | 2012 |
| 6 | Tropical Animal Health and Production | 3 | 4 | 0.214 | 74 | 4 | 2011 |
| 7 | Agroforestry Systems | 2 | 2 | 0.087 | 65 | 2 | 2002 |
| 8 | Animal | 2 | 2 | 0.286 | 73 | 2 | 2018 |
| 9 | Foods | 2 | 2 | 0.25 | 46 | 2 | 2017 |
| 10 | Frontiers in Veterinary Science | 2 | 2 | 0.667 | 10 | 2 | 2022 |
| 11 | Journal of Animal Physiology and Animal Nutrition | 2 | 2 | 0.286 | 50 | 2 | 2018 |
| 12 | Journal of Cleaner Production | 2 | 2 | 0.286 | 37 | 2 | 2018 |
| 13 | Journal of Food Science and Technology-Mysore | 2 | 2 | 0.154 | 64 | 2 | 2012 |
| 14 | Poultry Science | 2 | 2 | 0.286 | 66 | 2 | 2018 |
| 15 | Animal Nutrition and Feed Technology | 1 | 1 | 0.091 | 15 | 1 | 2014 |
| 16 | Annals of Animal Science | 1 | 1 | 0.333 | 5 | 1 | 2022 |
| 17 | Annals of Phytomedicine-An International Journal | 1 | 1 | 0.5 | 2 | 1 | 2023 |
| 18 | Antibiotics-Basel | 1 | 1 | 0.25 | 27 | 1 | 2021 |
| 19 | Applied Sciences-Basel | 1 | 1 | 0.333 | 5 | 1 | 2022 |
| 20 | Ciencia E Investigacion Agraria | 1 | 1 | 0.167 | 3 | 1 | 2019 |
| 21 | Current Research in Nutrition and Food Science | 1 | 1 | 0.167 | 4 | 1 | 2019 |
| 22 | Egyptian Journal of Chemistry | 1 | 1 | 0.333 | 2 | 1 | 2022 |
| 23 | Egyptian Journal of Veterinary Science | 1 | 1 | 0.5 | 3 | 1 | 2023 |
| 24 | Engenharia Agricola | 1 | 1 | 0.091 | 10 | 1 | 2014 |
| 25 | Environmental Technology \& Innovation | 1 | 1 | 0.25 | 38 | 1 | 2021 |

TC: Total Citation; NP: Number of Publications; PY_Start: Publication Start Year

**Table 4:** The 25 leading research organizations involved on *Moringa oleifera* as a "super plant" to boost livestock performance and product qualities (milk and meat) from 2002 – 2023

| S/N | Affiliation | Country | Articles |
|---|---|---|---|
| 1 | North West Univ | South Africa | 20 |
| 2 | Natl Res Ctr | India | 19 |
| 3 | Univ Ft Hare | South Africa | 19 |
| 4 | Univ Autonoma Estado Mexico | Mexico | 9 |
| 5 | Yunnan Agr Univ | China | 8 |
| 6 | Zagazig Univ | Egypt | 7 |
| 7 | Nucl Inst Agr and Biol Coll | Pakistan | 6 |
| 8 | Cairo Univ | Egypt | 5 |
| 9 | Feed Res Inst | ND | 5 |
| 10 | South China Agr Univ | China | 5 |
| 11 | Swedish Univ Agr Sci | Sweden | 5 |
| 12 | Univ Agr Faisalabad | Pakistan | 5 |
| 13 | Univ Dschang | Cameroun | 5 |
| 14 | Univ Malaya | Malaysia | 5 |
| 15 | Coll Vet And Anim Sci | China | 4 |
| 16 | Diponegoro Univ | Indonesia | 4 |
| 17 | Hiroshima Univ | Japan | 4 |
| 18 | King Saud Univ | Saudi Arabia | 4 |
| 19 | Ladoke Akintola Univ Technol | Nigeria | 4 |
| 20 | United Arab Emirates Univ | UAE | 4 |
| 21 | Univ Brawijaya | Indonesia | 4 |
| 22 | Univ Fed Rural Pernambuco | Brazil | 4 |
| 23 | Univ Kentucky | USA | 4 |
| 24 | Univ Porto | Portugal | 4 |
| 25 | Univ Sadat City | Egypt | 4 |

The 25 most leading articles with respect to total citations (TCs) as well as total number of citations per year (TC/Year) in research on *Moringa oleifera* for improving livestock and product qualities (milk and meat) from 2002 – 2023 were presented in table 5. Several of the research publications were written with its first authors including; Moyo B, Qwele K, Kholif AE, Nouman W and Sanchez NR who are among the academic scholars that had research articles as relates to the discussed subject matter with high number of citations. Howbeit, the names of Kholif AE and Moyo B stood out distinctly among these authors with highly ranked articles because each of them had more than one article with high citations on their published articles (table 5). The exploits in research by these authors (Kholif AE and Moyo B) on the utilization of *Moringa oleifera* for improving livestock production as well as product qualities (milk and meat) cannot be over-emphasized as the global impact of their research findings speaks for itself. Interestingly, Kholif AE is an experienced scientist who is primarily associated with a university in the USA (North Carolina Agricultural and Technical State University). He specializes in research areas including livestock nutrition, dairy production, feed evaluation, as well as feed additives. In one of his research work, the author explored the use *Moringa oleifera* plant to improve livestock production and product (milk) quality (Kholif et al., 2015). The findings of the work showed that, *M. oleifera* can be utilized as a source of protein in feeds of lactating goats to replace sesame meal. According to Kholif et al. (2015), by adding *Moringa oleifera* as feedstuff in diet, improve feed intake, ruminal fermentation, enriches nutrient digestibility as well as increases the yield of milk in goats.

With respect to the utilization of *M. oleifera* leaf diet to improve livestock performance as well as product (meat), the work by Moyo et al. (2012) which happens to be one of the most cited publication (Table 5) reported that the plant possesses some antioxidant potential that could help to protect the ruminant animal against diseases induced by oxidative stress.

**Table 5:** Top 25 most cited publications on *Moringa oleifera* as a "super plant" to boost livestock performance and product qualities

| S/N | First author, year & Journal name | DOI | Total Citations | TC per Year | Normalized TC |
|---|---|---|---|---|---|
| 1 | Moyo B, 2012, Meat Sci | 10.1016/j.meatsci.2012.02.029 | 176 | 13.54 | 2.23 |
| 2 | Qwele K, 2013, Meat Sci | 10.1016/j.meatsci.2012.11.009 | 162 | 13.50 | 1.71 |
| 3 | Kholif AE, 2015, Small Ruminant Res | 10.1016/j.smallrumres.2015.05.007 | 97 | 9.70 | 1.81 |
| 4 | Nouman W, 2014, Turk J Agric For | 10.3906/tar-1211-66 | 91 | 8.27 | 2.92 |
| 5 | Kholif AE, 2016, Anim Feed Sci Technol | 10.1016/j.anifeedsci.2016.04.012 | 82 | 9.11 | 1.66 |
| 6 | Sanchez NR, 2006, Livest Sci | 10.1016/j.livprodsci.2005.09.010 | 81 | 4.26 | 1.00 |
| 7 | Mahfuz S, 2019, Animals | 10.3390/ani9070431 | 77 | 12.83 | 4.67 |
| 8 | Kholif AE, 2018, Animal | 10.1017/S1751731117002336 | 61 | 8.71 | 2.33 |
| 9 | Kholif AE, 2018, Small Ruminant Res | 10.1016/j.smallrumres.2017.10.014 | 51 | 7.29 | 1.95 |
| 10 | Aregheore EM, 2002, Small Ruminant Res | 10.1016/S0921-4488(02)00178-5 | 51 | 2.22 | 1.27 |
| 11 | Cui Y, 2018, Poult Sci | 10.3382/ps/pey122 | 48 | 6.86 | 1.83 |
| 12 | Foroutan R, 2021, Environ Technol Innov | 10.1016/j.eti.2020.101250 | 38 | 9.50 | 2.90 |
| 13 | Mendieta-Araica B, 2011, Trop Anim Health Prod | 10.1007/s11250-011-9803-7 | 37 | 2.64 | 1.00 |
| 14 | Kholif AE, 2019, Agrofor Syst | 10.1007/s10457-018-0292-9 | 36 | 6.00 | 2.18 |
| 15 | Cohen-Zinder M, 2016, Anim Feed Sci Technol | 10.1016/j.anifeedsci.2015.11.002 | 36 | 4.00 | 0.73 |
| 16 | Hazra S, 2012, J Food Sci Technol-Mysore | 10.1007/s13197-011-0383-3 | 34 | 2.62 | 0.43 |
| 17 | Dhawi F, 2020, Foods | 10.3390/foods9091157 | 30 | 6.00 | 2.90 |
| 18 | Lee KY, 2016, J Food Sci Technol-Mysore | 10.1007/s13197-016-2367-9 | 30 | 3.33 | 0.61 |
| 19 | Sarwatt SV, 2002, Agrofor Syst | 10.1023/A:1021396629613 | 29 | 1.26 | 0.72 |
| 20 | Mukumbo FE, 2014, South Afr J Anim Sci | 10.4314/sajas.v44i4.9 | 28 | 2.55 | 0.90 |
| 21 | Abbas TE, 2013, Turk J Vet Anim Sci | 10.3906/vet-1211-40 | 28 | 2.33 | 0.29 |
| 22 | Khan RU, 2021, Antibiotics-Basel | 10.3390/antibiotics10121540 | 27 | 6.75 | 2.06 |
| 23 | Moyo B, 2012, Trop Anim Health Prod | 10.1007/s11250-011-9970-6 | 27 | 2.08 | 0.34 |
| 24 | Zeng B, 2018, J Anim Physiol Anim Nutr | 10.1111/jpn.12660 | 26 | 3.71 | 0.99 |
| 25 | Ben Salem H, 2009, Anim Feed Sci Technol | 10.1016/j.anifeedsci.2008.07.007 | 25 | 1.56 | 1.00 |

The study also reported in their findings that *M. oleifera* leaf meal also protect livestock products (meat) from oxidative deterioration during the post-mortem period which was possibly due to the presence of some polyphenolic compounds in the plant. The inclusion level of *M. oleifera* leaf meal for ruminants according to the study was given as 200 g/head/day (Moyo et al., 2012). The study then

concluded that, the protective potential of *M. oleifera* leaf meal against disease and meat deterioration may describe its widely use in livestock farming and potential health profits.

In table 6, the top leading scientists on research work done with respect to total number of citations and h_index indices based on the discussed subject matter were listed. These leading authors include Gouda GA, Kholif AE, Muchenje V, Masika PJ, Morsy TA, Moyo B and Mlambo V (n = 6; n = 7; n = 5; n = 4; n = 5; n = 4; n = 4) are placed in their order of influences to this discipline of discussion, accordingly. From the scholarly achievements of these researchers and based on their work with *Moringa oleifera* plant for improving livestock and animal product quality, they had h-indexes of 6, 6, 5, 4, 4, 4, and 3 (with citation numbers of 341, 346, 405, 377, 222, 377 and 28), respectively. H-index is usually utilized to calculate how influential researchers and papers are ranked in the world (Huang et al., 2019). Importantly, the h_index standards for calculating any author's research impact on the world platform is an essential method in bibliometric evaluation due to its wide accuracy level to reproduce the required influence of a particular researcher in the science world and their contributions to knowledge over the years (Guilak, and Jacobs, 2011).

Another significant area of bibliometric assessment within a scientific field is the aspect of networking as well as collaboration among scholars, nations as well as research institutions due to the fact that it forms a standard that promotes new discoveries in any discipline of study. Research networking further helps to foster collaboration among scholars, nations, or research agencies with the same goal and research interest. Research networking further creates avenue for inter-disciplinary academic fellowship of expertise from various views among scholars who have similar perspectives in research for the sole purpose of realizing a loftier research impact with global significance (Wenwen et al., 2019). Study collaboration also increase the quality of any findings. Other essential benefits of collaboration networking includes state of the art innovations, local and international exchange of expertise, publishing of findings with global impact and in high impact journals (Bozeman et al., 2013).

Our result of countries collaboration in research on the current subject matter of discourse is presented in figure (4). The figure depict different colours in different groups with respect to their collaboration with other nations. The diverse nodes further depicts each country while the strokes connecting the different countries have varied level of thickness. The connection of this strokes indicates the strength in ties among these various countries. Egypt had the most network connections (MCP = 8) with other nations due to the thickness a s well as the numbers of strokes and the size of its node connected to these countries.

**Table 6:** 25 top leading authors doing research on *Moringa oleifera* as a "super plant" to boost livestock performance and product qualities

| S/N | Element | h_index | g_index | m_index | TC | NP | PY_start |
|---|---|---|---|---|---|---|---|
| 1 | Gouda GA | 6 | 6 | 0.6 | 341 | 6 | 2015 |
| 2 | Kholif AE | 6 | 7 | 0.6 | 346 | 7 | 2015 |
| 3 | Muchenje V | 5 | 5 | 0.385 | 405 | 5 | 2012 |
| 4 | Masika PJ | 4 | 4 | 0.308 | 377 | 4 | 2012 |
| 5 | Morsy TA | 4 | 5 | 0.4 | 222 | 5 | 2015 |
| 6 | Moyo B | 4 | 4 | 0.308 | 377 | 4 | 2012 |
| 7 | Mlambo V | 3 | 4 | 0.429 | 28 | 4 | 2018 |
| 8 | Salem AZM | 3 | 3 | 0.429 | 47 | 3 | 2018 |
| 9 | Abd El-Hack ME | 2 | 2 | 0.4 | 24 | 2 | 2020 |
| 10 | Afzal A | 2 | 2 | 0.5 | 26 | 2 | 2021 |
| 11 | Anele UY | 2 | 2 | 0.286 | 87 | 2 | 2018 |
| 12 | Barbabosa-Pliego A | 2 | 2 | 0.333 | 33 | 2 | 2019 |
| 13 | Camacho-Diaz LM | 2 | 2 | 0.333 | 33 | 2 | 2019 |
| 14 | Cohen-Zinder M | 2 | 2 | 0.222 | 61 | 2 | 2016 |
| 15 | Elghandour Mmmy | 2 | 2 | 0.333 | 33 | 2 | 2019 |
| 16 | Galyean Ml | 2 | 2 | 0.286 | 87 | 2 | 2018 |
| 17 | Hameed A | 2 | 2 | 0.5 | 26 | 2 | 2021 |
| 18 | Hugo A | 2 | 2 | 0.167 | 190 | 2 | 2013 |
| 19 | Hussain T | 2 | 2 | 0.5 | 26 | 2 | 2021 |
| 20 | Khan A | 2 | 2 | 0.154 | 61 | 2 | 2012 |
| 21 | Khusro A | 2 | 2 | 0.333 | 33 | 2 | 2019 |
| 22 | Leibovich H | 2 | 2 | 0.222 | 61 | 2 | 2016 |
| 23 | Mnisi CM | 2 | 3 | 0.667 | 11 | 3 | 2022 |
| 24 | Olafadehan OA | 2 | 2 | 0.286 | 66 | 2 | 2018 |
| 25 | Pedraza-Hernandez J | 2 | 2 | 0.333 | 33 | 2 | 2019 |

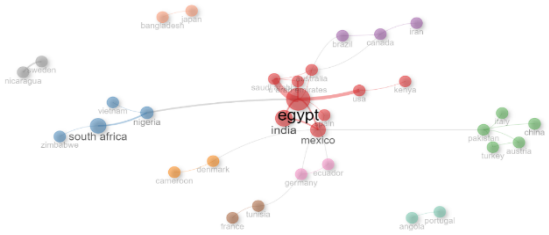


**Fig. 4:** Research collaboration among nations carrying out studies on *Moringa oleifera* as a "super plant" to boost livestock performance and product qualities (milk and meat)

However, on the contrary our result was not in consonant with results of other bibliometric assessments who reported that the USA is the country that has more networking with other countries of the world when it comes to doing research in several science discipline (Xie et al., 2024).

The keyword co-occurrence analysis for our study was also assessed. Keyword evaluation assist to explain the varied perceptive of research that is in accordance with the current subject matter. From figure 5 indicates that the main author keywords in this field using a threshold of co-occurrences as well as the fifty most-frequent coincidences of essential keywords for *Moringa oleifera* studies as relates to livestock production and products. This technique of bibliometric assessment gives a hint of the latest theories in accordance with the discipline. The main keywords for this study were "moringa oleifera", "moringa", "milk", "growth", "growth performance", "meat quality", "antioxidant", "goats", "milk production" and "carcass characteristics". Interestingly other associated concepts that appeared to be derivatives to the concept of the discussed topic as linked to *Moringa oleifera* and livestock production including "digestibility", "fermentation", "bioactive compounds", "boilers" and "dairy cows". All these keywords points to the varied conceptual frameworks adopted to describe the intersection of the present topic of discourse (*Moringa oleifera* as relates to livestock production and product quality). In line with the present findings other related studies also found similar results (George et al., 2021; Mafruchati et al., 2024).

The trending topics (from 2002 to 2023) for the present subject of discourse is in figure 6 and it shows the horizontal lines that depict the timeframe of topics over the twenty-one years studied periods (2002 – 2023), while the radius of the circle is directly proportionate to the number articles of the trending subject. The darker the intensity of the circle's colour, the higher the citation numbers that the topic trend acquires. For terminologies to be part of this graph, the frequency of the word through the study period must be more than 10 times. Top trending topics of author keywords on *Moringa oleifera* as a super plant to boost livestock production and product quality (milk and meat) research with high frequency terms over the years include antioxidant, moringa, growth, milk production, *Moringa oleifera*, meat quality, growth performance and milk. These afore-mentioned scholar keyword's top the ranks with high term occurrences (between 10 – 50) from 2018 to 2023.

## *Study Limitations*

The present study was carried out with data solely from WoS data source, thus it probably may not have included all published papers on *Moringa oleifera* as a "super plant" to boost livestock performance and product qualities (milk and meat). Nonetheless, as earlier mentioned, WoS dataset is an extensively accepted knowledge base that is utilized as a data bank among academics and scientists globally. It is recommended that other promising alternative datasets such as PubMed, Scopus and Google Scholar among others can be used in the future to allow for capture of a broader data for this kind of study.

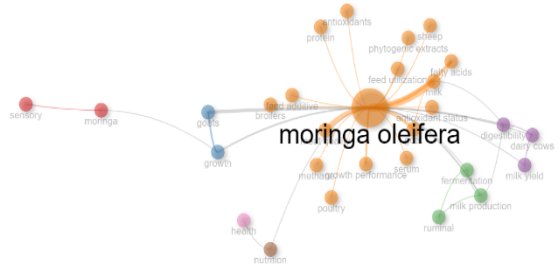


**Fig. 5:** Networking strength of author keywords of global research on *Moringa oleifera* as a "super plant" to boost livestock performance and product qualities (milk and meat)

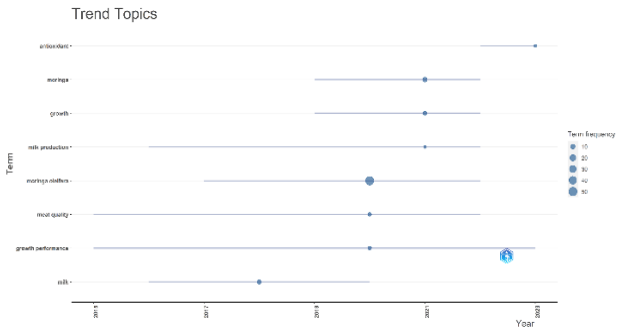


**Fig. 6:** Trending topics (author keywords) on *Moringa oleifera* as a "super plant" to boost livestock performance and product qualities (milk and meat) research with high frequency terminologies over 10 – 50

## Conclusion

Result on the bibliometric evaluation of research on the utilization of *Moringa oleifera* as a "super plant" to boost livestock performance and product qualities (milk and meat) indicates that it is gaining more significant attention as observed from the annual scientific production from 2002 to 2023. This growth is very encouraging due to the significance of the discussed topic especially as it relates to its use to boost livestock performance and animal products. South Africa ranked first position with respect to number of articles produced and global citations in the field (n = 12; n = 449), followed by Egypt (n = 11; n = 273), India (n = 11; n = 76), China (n = 9; n = 213) and Mexico (n = 7; n = 170). Egypt, Mexico, South Africa and Nigeria were the leading nations (n = 8; n = 5; n = 2; n = 2) with the highest number of Multiply Country Publications (MCP). The trending hotspot topic that stood out as author keywords in this discipline was "antioxidant". Several nations from Africa (South Africa, Egypt, Nigeria, Cameroun, Tunisia) and Asia (India, China, Indonesia, Pakistan, Saudi Arabia, UAE, Iran, Japan, Korea) were dominated in this research discipline when compared to other nations globally.

The research trend of the current discipline initially appeared to concentrate on the use of *Moringa oleifera* for boosting livestock performance (growth, health) and production (meat and milk yield), but more recently on product quality (antioxidant property of products) and consumer's acceptance. Conversely, the health benefits of this plant make it stands out as a potential alternative feed source or ingredients for enhancing better livestock performance and healthy food production.

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## Authors' Contributions

**Emrobowansan Monday Idamokoro and Augustine Suh Niba:** Logistics and support, Data curation, Analysis Visualization, Writed original draft, Manuscript edited.

## Ethics

This article is original and contains unpublished material. The corresponding author confirms that all of the other authors have read and approved the manuscript and no ethical issues involved.

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