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A Bibliometric Analysis of Microbiology Publications in Sub - Saharan Africa during Years 2000 to 2014

Yashik Singh[1,*]

[1]Department of Telehealth, Nelson R Mandela School of Medicine, Durban, South Africa

[*]*Corresponding author*: Yashik Singh, Department of Telehealth, Nelson R Mandela School of Medicine, Durban, South Africa. Tel: +27-829408032, Fax: +27-312604737, E-mail: singhyashik@gmail.com

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Abstract

Context: Research, development, and innovation are becoming increasingly important in the rapidly changing political, financial, and social landscape of the world. It is important to understand the landscape of research and development in developing courtiers, as research and development has been shown to improve developing countries' economic growth. The aim of this study was to obtain a snap shot of a bibliometric analysis of the publications in the field of microbiology in sub - Saharan Africa (SSA). Among other questions, this study aimed at determining the most published authors, the most common areas of research, and institutes with the greatest number of publications in this field.

Evidence Acquisition: This study was conceptualised using 3 steps: creating a search strategy that encompasses the major fields of microbiology, creating and executing a search query, and analysing the results. Scopus was chosen as the search engine since it is the largest database of peer - reviewed literature and includes original articles, reviews, conferences, letters, editorials, and articles - in - press, etc.

Conclusions: Although at first glance it may seem that SSA contributed very little towards (less than 2%) the worlds microbiology literature, a closer examination of gross domestic product (GDP) spent on research proves that SSA countries are making inroads in publishing literature. Most literature published over the last 14 years has been journal articles in journals with an impact factor of 3.7. In 2014, most articles were published in journals with an average impact factor of 6.1. In terms of the number of publications by the top authors in the field, it seems as if they quantitatively match other international countries like Brazil and India.

Keywords: Bibliometric Analysis, Sub - Saharan Africa, Microbiology

1. Context

Research, development, and innovation are becoming increasingly important in rapidly changing political, financial, health, and social landscapes of the world (1). The World Bank reported that the United States of America spent 2.97% of their gross domestic product (GDP) on research and development in 2012 (2). The same report indicated that the UK spent 1.72%, Israel spent 3.93%, and Germany spent 2.92% of their GDP on research. Developing countries have also increased their spending of GDP towards research and development over the past few years. The proportion of researchers in developing has increased by 8% (3). South Africa spent 0.76%, Congo and Gambia spent 0.13%, and Mali spent 0.66% of their GDP on research and development (2).

It is important to understand the landscape of research and development in developing courtiers, as research and development has been shown to improve developing countries' economic growth (4). The field of microbiology plays an important role in research and development, and a snapshot of the current status of research in microbiology is valuable. This is of particular value in Sub - Saharan Africa, where resources are scarce. Such information will allow an understanding of what has been achieved, and determine whether the research and development goals of various state agencies and universities have been achieved (5).

However, a bibliometric analysis of microbiology both in developed and developing countries is rare, although such studies in other disciplines are readily available (6-9). Vergidis et al.'s (2005) study evaluated the global trend in research publication for microbiology during 1995 to 2003. A search for the single term "microbiology" in the journal citation reports database retrieved 89 527 articles published in 74 journals. Western Europe produced the highest research production followed by the Unites states of America. Africa performed the worst in terms of research productivity and this was accredited to low GDP

spend on research. Africa published in journals with a mean impact factor of 2.3 while the USA scored a mean impact factor of 3.4. This research studied Africa as a whole and did not give an in depth analysis of African countries. The study also used one keyword to search the database. However, microbiology has many major sub - disciplines that may have been used as keywords or in the text of the articles, instead of the term "microbiology".

A study conducted in 2006 reported a bibliometric study over 1980 to 2000, trying to assess the knowledge base of microbiology, molecular biology, and genetics research in South Africa (10). The study indicated that the number of microbiology articles increased by 60% between 1996 and 2000 in South Africa. The South African contribution to the worlds articles on microbiology was 0.6% in 2000. South Africa on average published in journals with an impact factor of 0.72. The study had a major shortcoming of searching in a database that was dominated by United States of America journals, which may not be where South African researchers would have published their findings.

The bibliometric studies in the field of microbiology did not include a report on authors, subject areas, and institutions that published the research etc. There has also been no recent study investigating the research production in the field of microbiology. Most studies also dealt with developed countries, and very few with African countries.

Thus the aim of this study was to obtain the latest snap shot of a bibliometric analysis of publications in the field of microbiology in sub - Saharan Africa. Among other questions, this study aimed at determining the most published authors, the most common areas of research, and institutes that published most in the field of microbiology.

2. Evidence Acquisition

This study was conceptualised using 3 steps: creating a search strategy that encompasses the major fields of microbiology, creating and executing a search query, and analysing the results. In order to overcome any bias and limitations of only searching literature for a single term "microbiology", a search strategy comprising of many terms describing microbiology was created. To this end, the published scopes of 3 international peer reviewed journals were analysed. The keywords of the African journal of microbiology research, the Journal of applied microbiology, and the Journal of microbiology were amalgamated. General terms used in conjunction with microbiology were also added.

Analysing the scope of the 3 journals resulted in a search strategy that consisted of 44 terms. The query of the search strategy was: "animal microbiology" or " biotechnology" or " evolutionary microbiology" or " food microbiology" or " microbial ecology" or " microbial genetics" or "microbial physiology" or "plant microbiology" or " public health microbiology" or " water microbiology" or " beverage microbiology" or " biodegradation" or "animal health microbiology" or "antimicrobials" or "bacteriology" or "biochemistry" or "biodefense" or "bioinformatics" or "bioremediation" or "biotransformation" or "cellular biology" or "clinical microbiology" or "environmental or "microbiology" or "food microbiology" or "genomics" or "host-microbe interaction" or "immunology" or "industrial microbiology" or "intestinal microbiology" or "microbial ecology" or "microbial pathogenesis" or "microbial systematics" or "molecular biology" or "molecular or microbiology" or "mycology" or "parasitology" or "phycology" or "plant health microbiology" or "prebiotics" or "probiotics" or "synthetic microbiology" or "systems microbiology" or "virology" or "microbiology".

Scopus was chosen as the search engine, since it is the largest database of peer - reviewed literature and includes original articles, reviews, conferences, letters, editorials, articles - in - press, etc. (11, 12). In 2013, Scopus had 50 million records, 21 000 titles and 5 000 publishers. Scopus indexes more than 20 000 journals and includes the entire PubMed. It contains more than 4 300 life science journal titles that cover microbiology, molecular biology, virology, biochemistry etc. All types of publications were searched for each sub - Saharan African country, using the search query. The keywords were searched for in publication title, abstract, and keywords. The results were limited to all publications from 2000 to October 2014.

3. Results

In order to determine the quantitative contribution of each SSA (Sub - Saharan Africa) country, the Scopus database was searched to determine the number of publications that particular countries contributed towards. This is reported in Table 1. In order to understand, who was publishing in the field in SSA, the top 40 authors, institutions, and journals were determined. This is shown in Tables 2 to 4. To understand the areas of publications, Table 5 reports the number of publications per area identified by Scopus.

4. Discussion

From 2000 to date, the Sub - Saharan African countries produced 18 992 publications in the domain of microbiology. This constitutes 1.7% of the 1098 433 worldwide publications indexed by Scopus. Quantitatively, this is 77% of the

Table 1. The Number of Publications per Country from 2000 to Date

Country	Number of Publications	Country	Number of Publications	Country	Number of Publications
Angola	36	Gabon	233	Nigeria	2766
Benin	225	The Gambia	264	Reunion	36
Botswana	185	Ghana	517	Rwanda	76
Burkina Faso	442	New Guinea	33	Sao Tome and Principe	0
Burundi	0	Guinea-Bissau	0	Senegal	487
Cameroon	813	Kenya	1641	Seychelles	0
Cape Verde	0	Lesotho	0	Sierra Leone	0
Central African Republic	65	Liberia	0	Somalia	0
Chad	0	Madagascar	241	South Africa	6302
Comoros	0	Malawi	243	Sudan	352
Congo	176	Mali	213	Swaziland	0
Congo (DRC)	30	Mauritania	0	Tanzania	792
Cote d'Ivoire	296	Mauritius	90	Togo	79
Djibouti	0	Mozambique	140	Uganda	757
Equatorial Guinea	0	Namibia	62	Western Sahara	0
Eritrea	0	Niger	90	Zambia	264
Ethiopia	714	Zimbabwe	333		

Table 2. The Top Authors and the Number of Publications Published from 2000 to Date

Author's Name	Number of Publications	Author Name	Number of Publications	Author Name	Number of Publications	Author Name	Number of Publications
Kuete, V.	99	Aseffa, A.	61	Rybicki, E. P.	45	Ndung'u, T.	38
Ndip, R. N.	93	Viljoen, A. M.	61	Skjerve, E.	42	Conway, D. J.	37
Cowan, D. A.	84	Afolayan, A. J.	59	Warren, R. M.	42	Molyneux, M. E.	37
Wingfield, M. J.	79	Klugman, K. P.	59	Lall, N.	41	Garin, B.	36
Dicks, L. M. T.	77	Van Helden, P. D.	58	Simpore, J.	41	Portaels, F.	36
Marsh, K.	74	Varsani, A.	52	Goulder, P. J. R.	40	Whittle, H.	36
Eloff, J. N.	70	Doumbo, O. K.	51	Peeters, M.	40	Olaniran, A. O.	36
Van Staden, J.	70	Traore, A. S.	51	Adegbola, R. A.	39	Stevens, W.	36
Okoh, A. I.	68	Horak, I. G.	49	Jongejan, F.	39	Todorov, S. D.	36
Martin, D. P.	64	Van Vuuren, S. F.	49	Morris, L.	39	Feldman, C.	36
Kremsner, P. G.	63	Walker, B. D.	48	Shaw, G. M.	39		

number of publications produced by Brazil and approximately 23% of publications produced by China. This is also equivalent to 45% of the publications from India. China spends 1.98% of their GDP on research. Brazil spends 1.2% and India spends 0.81%. Sub - Saharan Africa spends approximately 0.2% to 0.3% of its GDP on research (13). Thus, although the number of publications from Sub - Saharan countries may seem low, compared to the amount of GDP that is spent, Sub - Saharan African counties are exceeding expectations.

Thirty - four percent of the SSA (Sub - Saharan Africa) countries did not produce any publications associated with microbiology indexed in Scopus. South Africa, Nigeria, and Kenya contributed the most to the publications and accounted for 57% of all publications from SSA. The remaining contributing countries produced an average of

Table 3. A List of the Top 40 Institutes That Have Published Studies in Microbiology in Peer Reviewed Journals in SSA

Institution	Number of Publications	Institution	Number of Publications
Universidade de Sao Paulo	5627	Prins Leopold Instituut voor Tropische Geneeskunde	322
Fundacao Oswaldo Cruz	2291	University of the Western Cape	301
Universidade Federal do Rio de Janeiro	2107	National Institute for Communicable Diseases	298
UNESP - Universidade Estadual Paulista	1963	Addis Ababa University	281
Universiteit van Pretoria	1320	University of Zimbabwe	275
University of Cape Town	1060	Imperial College London	274
Universiteit Stellenbosch	976	University of Fort Hare	260
University of KwaZulu-Natal	759	University of the Free State	259
Empresa Brasileira de Pesquisa Agropecuaria - Embrapa	729	National Institute of Allergy and Infectious Diseases	256
London School of Hygiene & Tropical Medicine	694	Obafemi Awolowo University	250
Universidade Federal de Pernambuco	604	Medical Research Council Laboratories Gambia	246
Makerere University	554	International Livestock Research Institute Nairobi	244
University of Ibadan	490	University of Ghana	243
Kenya Medical Research Institute	480	Onderstepoort Veterinary Institute	242
Universite de Yaounde I	433	University of California, San Francisco	236
Centers for Disease Control and Prevention	432	CIRAD Centre de Recherche de Montpellier	231
Universidade Federal da Bahia	423	Universidade Federal Rural de Pernambuco	225
University of Nairobi	369	Pontificia Universidade Catolica do Rio Grande do Sul	223
Institut Pasteur, Paris	356	IRD Centre de Montpellier	219
Organisation Mondiale de la Sante	327	CNRS Centre National de la Recherche Scientifique	212

276 publications each. Some countries seem to have published exceptionally well, including Gambia with 264 publications in spite of spending only 0.02% of its GDP on research in 2009 (2).

As shown in Figure 1, there was a significant increase in the number of papers that were published by SSA from 2000 to 2011. Each year there was an average of 96 extra publications compared to the previous year. Although from 2011, there has been a decrease in the number of publications produced by SAA. This, however, is also the trend shown in other developing countries like India and Brazil, where there is either a plateau or decrease in the rate of growth of publications. This may be attributed to the fact that microbiologists from SAA are now starting to focus on the qualitative quality of their research. In 2000, the top 3 journals that published the most results had an average impact factor of 3.2, while in 2014 the impact factor increased to 6.1.

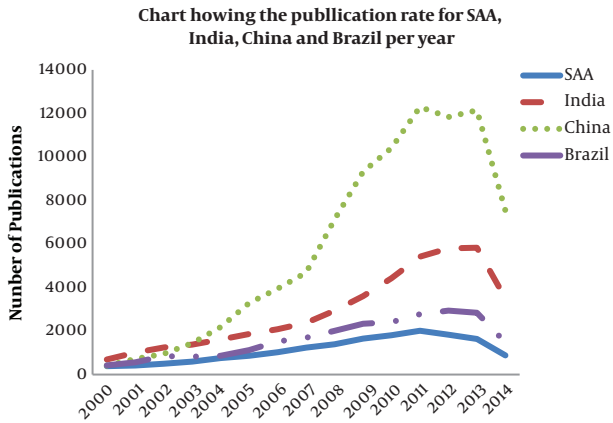

Figure 1. Number of SSA publications from 2000 to October 2014.

In total, approximately 5000 microbiologists contributed to articles published in SSA. Each author produced an average of 7 papers each. The top 40 SSA authors produced an average of 55 ± 16 ($\alpha = 0.05$) articles during the study period. Approximately, 60% of all authors produced 5 or less papers. The average number of articles published

Table 4. A List of the Top 40 Journals That Have Published Most on Microbiology in SSA

Journal	Number of Publications	Journal	Number of Publications
Plos One	559	Clinical and Vaccine Immunology	128
Malaria Journal	451	Tropical Medicine and International Health	125
Journal of Clinical Microbiology	431	International Journal for Parasitology	118
Tropical Animal Health and Production	330	Journal of the South African Veterinary Association	113
American Journal of Tropical Medicine and Hygiene	323	Journal of Applied Microbiology	107
Journal of Virology	303	Plos Medicine	105
Antimicrobial Agents and Chemotherapy	259	South African Medical Journal	105
Plos Neglected Tropical Diseases	243	Preventive Veterinary Medicine	97
Onderstepoort Journal of Veterinary Research	228	Experimental and Applied Acarology	86
East African Medical Journal	222	Pakistan Journal of Biological Sciences	84
BMC Infectious Diseases	188	Water Science and Technology	84
South African Journal of Botany	177	Medecine Tropicale	77
Infection and Immunity	163	Journal of Biological Chemistry	76
Journal of Infectious Diseases	157	Nigerian Journal of Parasitology	76
International Journal of Food Microbiology	150	Water SA	75
Bulletin De La Societe De Pathologie Exotique	149	Plos Pathogens	74
Journal of Antimicrobial Chemotherapy	138	Journal of Acquired Immune Deficiency Syndromes	73
Journal of Ethnopharmacology	137	Clinical Microbiology and Infection	72
Archives of Virology	134	Acta Tropica	71
Applied and Environmental Microbiology	128	African Journal of Microbiology Research	68

Table 5. List Areas Which Published Work on Microbiology

Area	Number of Publication	Area	Number of Publications
Medicine	8559	Materials Science	165
Immunology and Microbiology	6024	Nursing	161
Agricultural and Biological Sciences	5184	Mathematics	123
Biochemistry, Genetics and Molecular Biology	4533	Physics and Astronomy	95
Pharmacology, Toxicology and Pharmaceutics	1844	Neuroscience	74
Environmental Science	1661	Energy	58
Veterinary	1593	Dentistry	57
Chemistry	731	Health Professions	52
Chemical Engineering	470	Business, Management and Accounting	49
Engineering	382	Arts and Humanities	39
Earth and Planetary Sciences	261	Economics, Econometrics and Finance	39
Social Sciences	209	Psychology	21
Multidisciplinary	200	Decision Sciences	8
Computer Science	182	Undefined	3

by the top SAA authors are in par with the international standards set by Brazil (an average of 57 papers) and India (an average of 59). There were approximately 2400 institutions that produced publications relating to SAA. Each institute produced an average of 24 publications each. Of the top 10 institutes that published the most articles pertaining to SAA, only 4 were from SAA. In fact, all 4 institutes were from South Africa in particular. The top 40 institutes produced an average of 550 publications. From 2000 to present, 1087 journals/conferences/publishers published work pertaining to SAA. Each published an average of 12 pieces of work relating to microbiology. Table 4 shows the list of the top 40 journals that have published work relating to SAA. The journal that published the most pub-

lications over the study period had an impact factor of 3.7. The top 40 journals/conferences/publishers published an average of 167 publications. The African journal of microbiology research appears in the top 40 list of journals/conferences/publishers.

Table 5 shows the most cited domains that the authors of the SAA papers felt their work consisted off. There were 29 unique domains, in which the work published during the study period were categorized. Medicine led the rest of the domains by 43%. Immunology and microbiology and agriculture and biological science followed medicine. Overall, 82% of all publications were original journal articles, 7% were review papers, and 2.6% were conference papers. Results indicate an improvement in the publication of microbiology research reported in previous studies. The total number of institutes that published studies that dealt with microbiology increased significantly (14). There was also a significant rise in the impact factor of journals that researchers published in since 2003. The contribution of South Africa to the world's microbiology publications as reported by Molatudi and Pouris, 2006 has remained the same.

5. Conclusion

Although at first glance it may seem that SAA contributed very little towards (less than 2%) the world's microbiology literature, a closer examination of GDP spend on research proves that SAA countries are making inroads in publishing literature. The first step towards publishing more research will be to spend more GDP on research. The extra capital will create resources desperately needed to conduct research. At the moment, it seems that outside countries are conducting research in SAA, and are publishing from their own institutions. Hence, one method of increasing research output from SSA, will be a policy implementation that all research carried out in SAA should include an SSA institution. The other issue that needs to be addressed is the actual writing of papers and capital required for article processing fees. Institutions need to have a budget allocated to publishing papers, with incentives for authors, such as paying conference fees or purchasing books or access to journals. The SSA with other developing countries also needs to create accredited journals for themselves that focus on SSA and authors of developing countries and research carried out by local institutions.

Most literature published over the last 14 years has been journal articles in journals with an impact factor of 3.7. In 2014, most articles were published in journals with an average impact factor of 6.1. In terms of the number of publications by the top authors in the field, it seems as if they quantitatively match other international countries like Brazil and India. This paper has the benefit of showing a snap shot of the state of publications in the field of microbiology over the past 14 years for SAA countries. This type of analysis for the entire SAA has not been done as far as the authors are aware. Further studies are suggested to include various open access journals in the search strategy.

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