

PRELIMINARY BIBLIOMETRICS OF PLANT-DERIVED HEALTH FOODS OVER THE LAST DECADE IN THE SCOPUS DATABASE

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ABSTRACT

A growing interest in the medicinal values of foods can be assessed by the rapidity of research publications on foods that exert health benefits. Many foods that are of health benefit to humans, irrespective of their origin (plants, animals) and subjected level of processing (fermentation, cooking, warming, freezing, vacuum-packaging), are variously designated in scientific literature based on their biofunction. Plant-based foods' application vagaries, momentum, and research orientation regarding their health functionality awareness are scarcely studied by bibliometrics from a global perspective. Therefore, a bibliometric search was performed on the *Scopus* database from 2011 (January) to 2021 (April) using a range of search keys covering reports of conceptualized consumable plant-derived foods with health-promoting potential. A total of 362,309 documents on medicinal foods of plant origin were obtained from the database. The data were obtained in comma-separated values (CSV) format and analyzed with Microsoft Excel tools. Of the total documents from the *Scopus* database on the study, 8.01% (29,036) were contributed by African researchers. Comparatively, lead contributors (global; Africa) by group disciplines include biochemistry, genetics, and molecular biology (118,896; 8,236); pharmacology, toxicology, and pharmaceuticals (104,530; 8,581); agricultural and biological sciences (99,053; 9,610), respectively. Similarly, lead contributors by country include China (73,977), India (44,898), USA (44,582), and Nigeria (4,680). This observation shows a higher research propensity towards plant-derived medicinal foods in populous nations due to factors like dietary culture, an increase in vegan and health-nutrition enthusiast populations, and the emergent concerns with the therapeutic use of synthetic pharmaceuticals. The analyzed results gave insights into the research orientation of plant-based foods that promote human health on a global stage and provide future research directions. Knowledge of the various application of plant-based foods may potentiate the United Nations Sustainable Goals initiative on responsible consumption (SDG 12), and health and wellbeing (SDG 3) among the global population.

Key words: medicinal plants, health food, nutraceuticals, dietetics, indexation, health, bibliometrics



INTRODUCTION

Since time immemorial, humanity has relied on plants' material medica for their traditional health care needs. This knowledge heritage transcended generations and has received numerous attention from the scientific community. Studies on the application impact of medicinal plants on human health from a bibliometric perspective are scant and the few extant reports on the subject are limited in scope [1, 2]. Further, the knowledge has not sufficiently impacted the emergence of diseases and their pathological concerns. In recent decades, plant-based beverages, foods, and food products have gained attraction as means for medicinal purposes [2]. This is derived significantly from the growing perception that foods do not only satisfy nutritional, and hunger needs but also sustain a strong physical state and mental wellbeing, lower the risk of disease, and stimulate therapeutic and defense processes in humans [3, 4]. In addition, derived health benefits from consumable plant-based foods, fruits, and nuts were perceived by some schools of thought to evolve from the latent phytochemicals. Consequently, contemporary knowledge of plant-based foods' functions intersects elaborately with health, supporting the principles behind the acceptance of traditional healthcare, dietetics, nutrition, food science, therapeutics, and pharmaceuticals as complementary healthcare sources [5].

There are a variety of arbitrary designations ascribed to foods based on their role in mediating health challenges. One of these is the diversity of health-promoting plant-based foods and their typological designations in literature as medicinal foods, pharmafoods, medifoods, functional foods, probiotics, vitafoods, or fermented foods [6]. Even though each food typology differs in definition from the others, they all functionally overlap and possess the ability to induce prophylactic, therapeutic, and curative benefits when consumed. Hence, in this study, all plant-derived foods that have the traditional potential or ability to induce health benefits directly or indirectly in humans, irrespective of their generic designation and culinary uses, were categorized as health (medicinal) foods. These functionalities (prophylaxis, therapeutic, and curative) were hypothetically attributed to the biochemical release of the residual *phytometabolome* in plants and their complex interactions in the food matrix [7-10]. Furthermore, Tsai [11] identified the significant influence of bioavailability and bioaccessibility of health-promoting compounds in the typological groupings of medicinal foods.

According to the United States, Food and Drug Administration (FDA), medicinal (or medical) foods are foods formulated to be consumed or administered enterally under the supervision of a physician and which are intended for the specific dietary



management of a disease or condition for which distinctive nutritional requirements, based on recognized scientific principles are established by medical evaluation. As paradoxical as the definition may seem, the knowledge application of foods for health gains was *ab initio* an offshoot from the use of herbs, a practice that predates the advent of modern medicine. In addition, ethnobotanical and ethnopharmacological accounts suggest that consuming foods for medicinal benefits is becoming habitual and consumed without a medical evaluation and the supervision of a physician. In Africa, South America, and Asia the consumption of fermented and other health-promoting foods is dictated by the knowledge of traditional culinary heritage handed down several generations [12]. It is, therefore, logical to state that knowledge of and access to nutritious food varies across demographic, cultural, and geographic boundaries [13]. Medicinal foods contain a variable composition of bioactive substances that reacts differentially in the food matrix when consumed responsibly to catalyze and induce specific or systemic physiological mechanisms that improve the human body. Consequently, these generic health foods mediate biochemical actions like signal transduction, buffer actions, phosphorylations, enzymes, hormonal activities, and oxidative stress [14]. Others include cell divisions, membrane functions, pathological disorders and chronic diseases, entero-activities, antimicrobial systems, angiogenesis, organ functions, and other life-sustaining pathways [15, 16].

In recent decades, the world has witnessed the expansion of food knowledge beyond production, processing, and utility for hunger satiety. This trend confirms plant-based foods as drugs or drugs synergia, and how actively people consume foods for sustainable wellbeing [17]. Hence, the growing awareness of the pharmacological benefits of plant-based foods resulted in a corresponding rise in food research to develop cost-effective means of harnessing, optimizing, and commodifying the pharmacological potentials in foods. Also, research efforts are ongoing to improve their pharmacokinetics and effectiveness in the treatment of a wide range of human pathologies including the COVID-19 pandemic [18]. Such studies are however often limited to a food type and functional application biased towards a specific chronic infirmity. Therefore, this study aims to use bibliometrics to assess plant-derived health foods' research and application dynamics between 2011 and 2020. This study is however based on reports that are accessible on the *Scopus* database.

BIBLIOMETRIC SEARCH

The study was conducted using the *Scopus* database (scopus.com) to assess report contributions on plant-based medicinal foods (April 22nd, 2021) in comma-



separated values (CSV). Various search keys (*medicinal foods OR functional foods OR phytochemicals OR therapeutic foods OR pharmacological foods OR anti-inflammatory foods OR antioxidative foods*) were used to retrieve information. The search excluded reports on products that are not consumed in a food matrix, from animal origin, and ingested as herbs. Bibliographic parameters like most cited papers and publications by designations (nutraceuticals, herbs, and non-nutritional foods' compounds) preclude the scope of this study. The study covers the year 2011 to 2020 and the data obtained were analyzed using Microsoft Excel tools.

RESULTS AND DISCUSSION

A total of 362,309 documents were identified on medicinal foods from 164 countries based on the concept of this study. This includes documents from countries that were grouped as undefined (negligible contributions) from 2011 to 2020. This figure attributed 8.01% amounting to 29,036 documents to Africa. The momentum of research and resultant publications on medicinal foods of plant origin in the last decade is supported by the total number of documents observed on the *Scopus* database. This observation may be due to the recent global attention shift from dependency on inorganic foods to organic-based consumables. Suffices it to say more researchers around the world are now focusing more on screening a wider range of biological resources including foods for prospective application as alternative therapeutic options in mitigating emerging health safety concerns, microbial resistance, pandemics, and other skepticism associated with the use of synthetic pharmaceuticals. Most synthetic pharmaceuticals were noted to be unstable, dosage dependent, costly, and limited in distribution. These suggest a tendency to the "boom and bust" concept, a notable challenge confronting the effectiveness of synthetic pharmacopeias and pharmaceuticals that impelled research shift into food as a drug [19, 20]. Furthermore, the chronic exposure of humans to synthetic medication or vaccines could systemically compromise natural immunity, increase treatment ineffectiveness and cost of treatment. Therefore, a rising trend of life-threatening diseases, epidemics, and pandemics across the globe has given impetus to the exploitation of plant-based foods with health inclinations. Moreso, the number of search hits on the *Scopus* database despite representing research activities related to the medicinal benefits of foods, have not found practical applications in solving contemporary global health problems. While the knowledge of foods as medicinal agents is improving, policy support for harnessing their natural health benefits for human wellbeing, and studies on their nutrigenomics, nutrikinetics, and nutraceuticals remained inadequate. Goswami and Ram [21] confirmed this when they reported that "food is medicine" based on the observed bioactivities linked to the innate beneficial contents like antioxidants,



phytonutrients, vitamins, minerals, fatty acids, fibers, and polysaccharides in foods' matrix. Also, the connection between rising chronic diseases (diabetes mellitus, obesity, hypertension, allergies, and neurodegenerative disorders) and irresponsible food consumption was observed by the World Health Organization [22] and Saeed [23]. Even though global dietary choices and habits are becoming intentional toward health gains, the impact of processing, contamination (particulate, chemical, or biological), and technology on foods' biofunctional quality is also not fully understood [24]. According to Li [25], biofortification, genetic modulation, and agrosystem practices may paradoxically alter global foods' orientation [26, 27, 28]. Therefore, the retrieval keys used for the study were intended to capture food reports with a strong bias for plant-derived foods that can provoke therapeutic actions, boost natural immunity, and curate degenerative conditions in humans.

Eritrea, Swaziland, Federated States of Micronesia, North Korea and Comoros ranked as the nations with the least number of research reports on plant-based medicinal foods (Figures 1a, b). The total number of documents credited to countries in Africa is less than the volumes of indexed documents from China (73,977), India (44,898), and the United States (44,582). This may be due to the relative differences in the bioeconomic, educational, and technological orientation of these nations when compared with those in Africa. Egypt led other nations with 9725 (33.5%) documents followed by Nigeria (16%), South Africa (15.4%), Tunisia (8.8%), and Algeria (7.2%). Also, sixteen (16) countries had an insignificant number of documents (3-28) relating to the health functions of foods in the database (Table 1). The rankings of China, India, the USA, and Brazil among the nations of the world with the highest indexations on health foods, and Egypt, as well as Nigeria in Africa, were validated in another study [24]. Research and publications about foods with medicinal potential increased at an average rate of 11.8% in both the global and African contexts from 2011 to 2021 (Fig 2). Although more research reports were observed in 2020, the lead contributors by subject area/discipline group on the global scale were Biochemistry, Genetics, and Molecular Biology (118,896 documents). In a subcategory, based on both global and African contributors (global; Africa) by subject area, five lead contributors that were identified include Pharmacology, Toxicology, and Pharmaceutics (104,530; 8,581); Medicine (85,784; 6,932); and Chemistry (89,985; 5,630). The intersection and evolutionary timescale of disciplines like food science, nutrition, dietetics, and food science and technology with basic sciences, and medicines may be responsible for the lack of data under these disciplines. However, African researchers from the Agricultural and Biological Sciences contributed the highest volume of indexed information (9,610) contrary to the observation from a global



perspective (Table 2). In contrast with expectations, a few groups of subject areas outside the life sciences also had indexed information about foods' medicinal benefits in the database. They include Computer Science (5,530; 253), Engineering (18,530; 1,090), Material Science (15,528; 970), and Physics and Astronomy (9,972; 606). Disciplines such as decision science, dentistry, art and humanities, business, management, and accounting contributed to the subject on the database, particularly from the African context. This trend logically affirms the versatility and universality of foods. Similarly, the number of institutional affiliations of contributing authors in these countries was relatively higher and each of the institutions tends to support a vision that significantly enhanced the interest and capacity for food-as-drug research. Thus, the commitment of institutional affiliations' to fostering sustainable basic and applied scientific research in the continuous improvement of national agriculture, food safety, and public health benefits may have accounted for the number of documents noted. The Chinese Academy of Sciences, Ministry of Education China, King Saud University, Universidale de Sao Paulo-USP, National Research Center-Egypt, Cairo University, University of Ibadan, and the Federal University of Technology, Akure are some of the leading affiliations where intensive medicinal food research is supported. While multidisciplinary participation also accounted for the rate of indexation increase, it hypothetically strengthens the dimension of knowledge of plant-based foods for healthcare, optimizing bioprocessing, control of critical quality attributes, and molography (a measure of molecular interaction effect).

The data showed an average incremental rate of 11% ($\leq 35,854$ documents per decade) with 57,314 documents indexed in 2020 alone across the world. A similar trend was noted for Africa with an average incremental of 3,193 per year on the database. This suggests a momentous attraction to the ethnopharmacological benefits of foods, food research, and applications. It might also be logical to relate the high number of documents in the year 2020 to rising global health problems and disease outbreaks in the last five years, particularly, in densely populated countries [24]. Additionally, the growing awareness of the potential side effects of vaccines and synthetic pharmaceuticals has boosted the deliberate exploration of safer bioequivalent alternatives like foods to mediate healthcare provisions. The dynamics and orientation of bibliometric parameters obtained from this study are therefore fundamental in analyzing the decision behavior and proclivity of researchers on medicinal foods. While data showed that medicinal foods' research collaboration is not limited by disciplines or affiliations, the study may be a basic reference for future research in ethnobotany, food folklore, pharmacovigilance, and food sociodemography [25-29]. This is in addition to corroborating the dietetical



applications of foods in processed or non-processed forms in mediating human health and psychological wellbeing.

In this study, results showed a linear increase in the number of documents added to the *Scopus* database annually from 2011 to 2020 by individuals (Fig. 2). The lead contributor (Oboh G) from Nigeria had 221 documents about health-benefiting foods indexed in the *Scopus* database followed by Mahomoodally MF (191 documents) from Mauritius. The magnitude of their contributions is lower compared to the 489 indexed documents credited to Ferreira I.C.F.R, and 356 of Barros L who ranked first and second, respectively ahead of other researchers globally (Figures 3c, d).

The data showed the unexpected involvement of authors from some non-life science-based group disciplines like social sciences (accounting, economics, finance, and decision science), mathematical sciences (physics, astronomy, computer science, and planetary science), arts, and humanities in medicinal foods' research. Their attraction to medicinal food research might have been inspired by sociological skepticism associated with genetically modified crops, agrochemical residues, and unstandardized herbal remedies' applications [30, 31]. These related non-biological disciplines are reorienting peoples' perceptions, perspectives, understanding of foods' functions, and facilitating medicinal foods acceptance. This is in addition to improving the awareness for policy reform on their slow integration into the national healthcare system, trade expansion beyond national boundaries, technology, and product marketing, and socioeconomic acceptance. Their contributions may help to reshape the future of consumer science, dietary choices, and the relevance of responsible food consumption in dietetics.

Reports retrieved from the *Scopus* database on foods that induce medicinal benefits for this study comprised research articles and review papers, respectively. African researchers reported a total of 25,396 research articles and 2,455 reviews on the database which amounted to 8.8% and 5% of the global research articles (289,286) and review publications (48,076). Similarly, Erratum from African researchers about the discourse amounted to less than 10% of the global 74 documents while retractions from the database were 7.3% of the total 109 by researchers across the world (Fig. 3a, b).



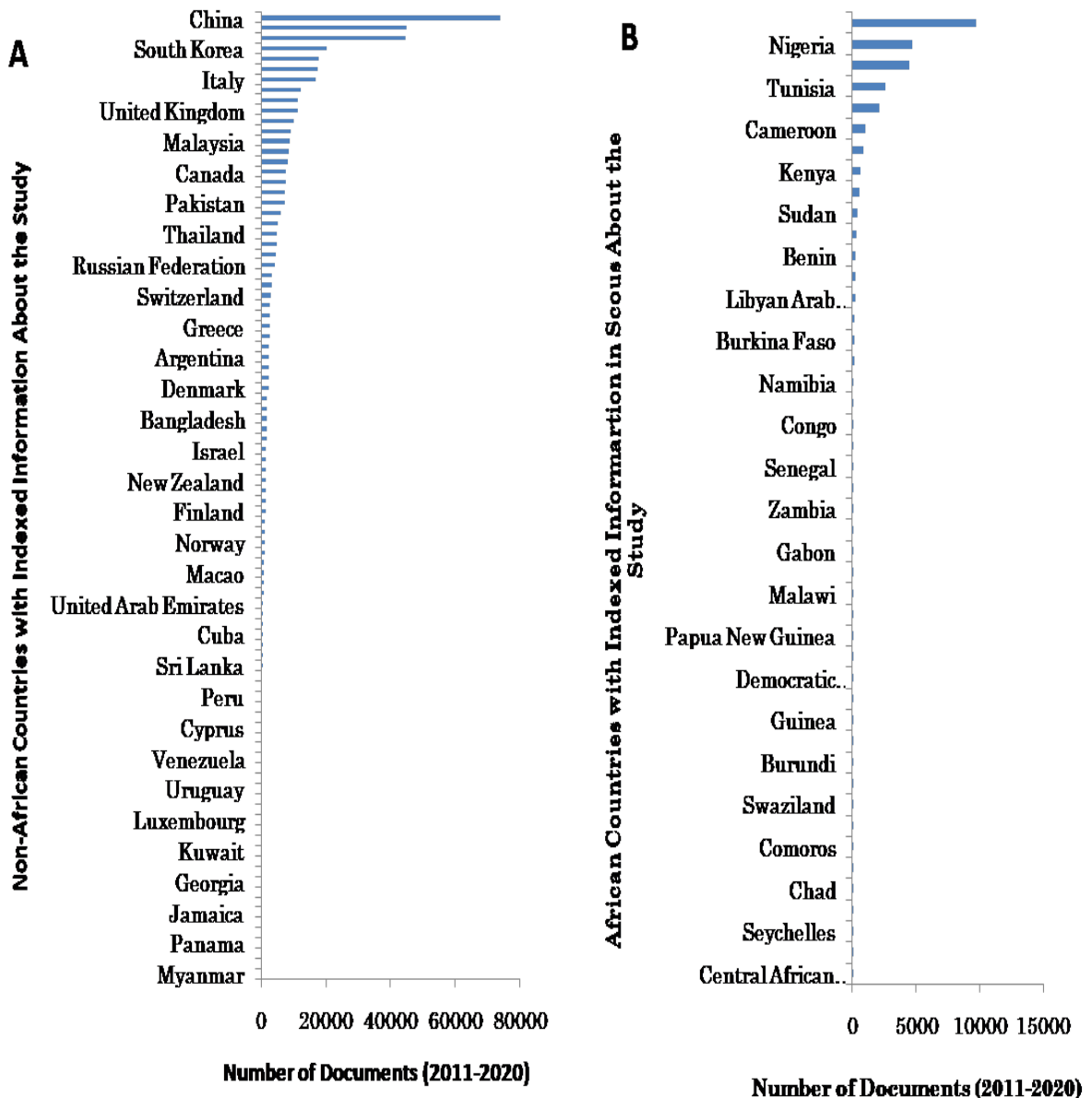


Figure 1: Identified document distribution (number of documents) by country about the study on the *Scopus* database. A – Non-African countries with documents on the study; B - African countries with documents on the study

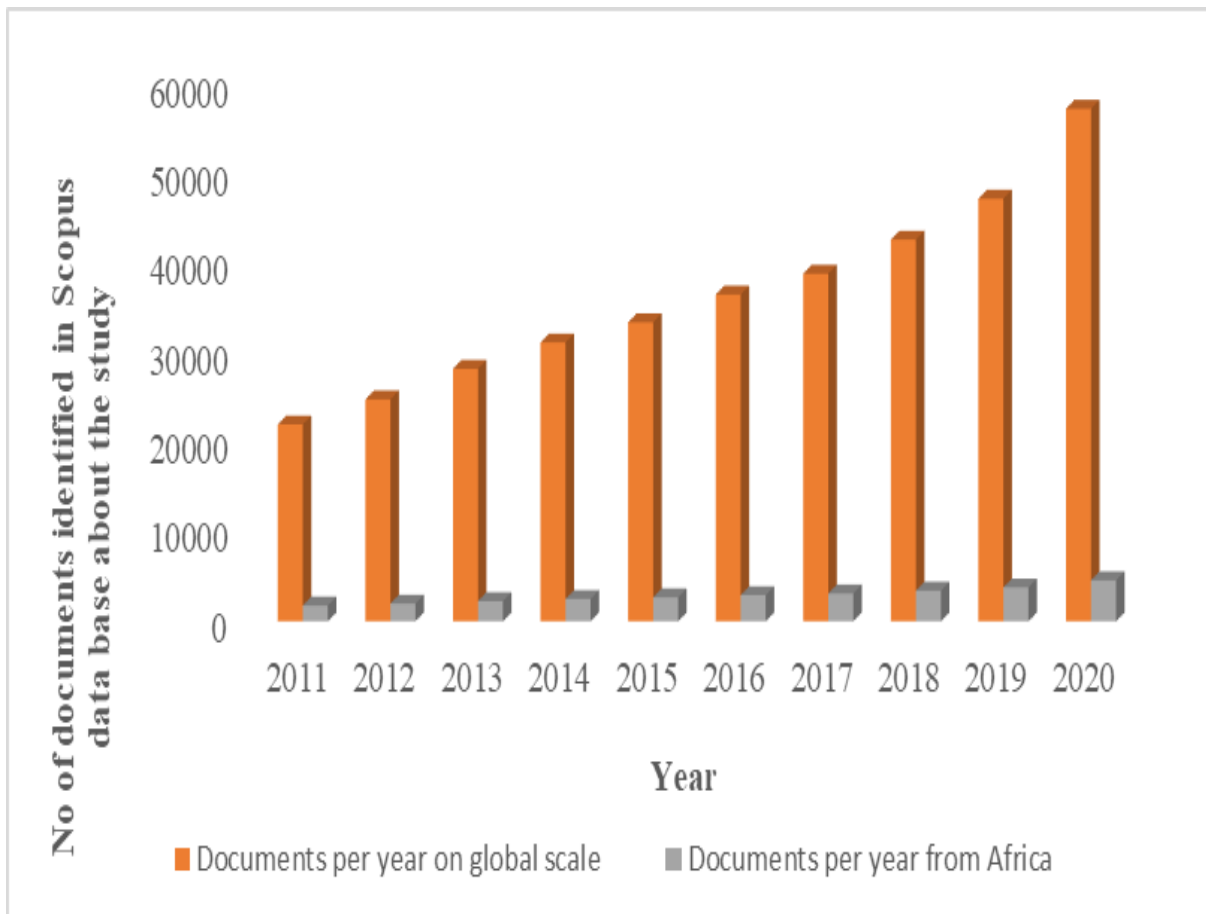


Figure 2: Comparative view of documents about the study indexed in the Scopus database in the past 10 years from global and African researchers

Over 79.8% of the publications on foods that have medicinal properties indexed in the Scopus database are research-based and empirical. This is followed by Reviews (13.3%) and Book Chapters (4.3%) while Retracted, Erratum, and Conference papers ranked as the least indexed documents on the database. A similar pattern was observed for the indexations of medicinal foods reported by African authors. Despite favorable data, Lawrence [32] and Kumwenda [33-35] recognized that medicinal foods' research in many developing countries including Brazil, India, and Nigeria may be disoriented and inconsistent due to a lack of government commitment, political upheavals, poor policy support framework, poverty, infrastructural, knowledge, and technology-transfer limitations. On the other hand, the insignificant representations of retracted articles and errata contributions from African authors conflicted with the reality of research conditions and may nonetheless suggest possible compliance by African authors to ethical concerns in food studies [32-34]. The quality process of cognitive peer review of the Scopus-indexed journals confirmed this observation by returning a low

incidence of errata for African authors who reported the outcome of their study on medicinal foods.

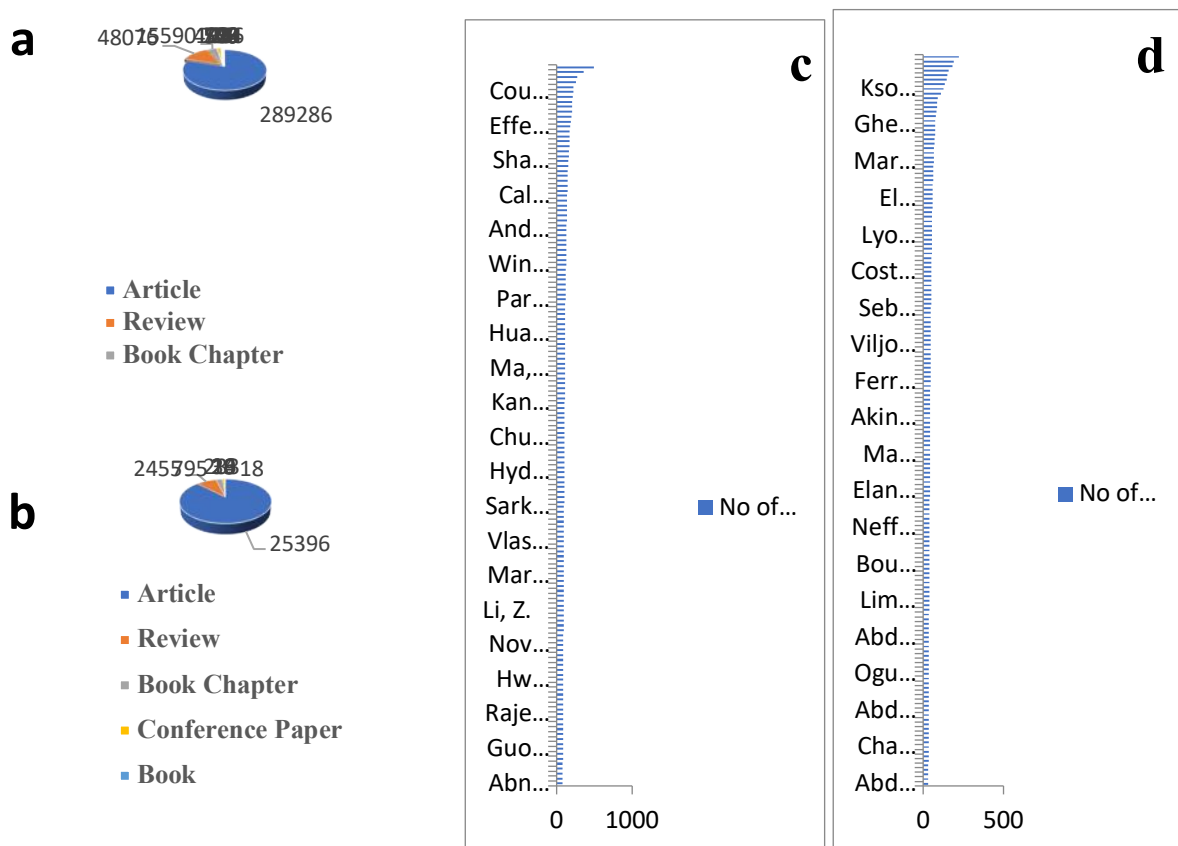


Figure 3: Documents on the Scopus database about the study and contributing authors; a – world distribution of documents by types; b – distribution by document types written by African authors; c - number of indexed documents on the database by authors around the world; d- number of indexed documents about the study by African authors

While foods have the capacity to satisfy hunger needs, potentiate human health, lower the risk of infections and diseases, and exert therapeutic effects when responsibly consumed, their bibliographic study is uncommon. Even though such a study might give broader perspectives on the bio-functionality of foods, more understanding may be required of the biochemical, physiological, and biological processes underlying their health attributes [36, 37]. Foods that were over-processed, nanonized/capsulated, biofortified, supplemented, or derived from genetically engineered crops may alter the health impact of food in humans [38-40]. Therefore, paradigm shifts in food research orientation from food production, food processing, and no hunger to the dietetical benefits of foods as well as

optimization technologies that potentiate their health and safety values needs to be prioritized.

CONCLUSION, AND RECOMMENDATIONS FOR DEVELOPMENT

This study showed the interest and demographic orientation of researchers around the world towards health-benefiting foods. The results obtained suggest that plant-based foods induce health benefits in both humans and animals because their matrix is laced with bioactive phytochemicals. Even though the underlying biochemical mechanisms responsible for the potentiation of human wellbeing and appropriate standardization of intake are not yet fully understood, foods are becoming attractive as complementary drugs critical for public health management as corroborated by the volume of documents observed on the Scopus database. Responsible food consumption has for millennia contributed remotely to improving health by boosting humans' natural defenses against infections or acting as prophylactic, promoting longevity and physical fitness. Therefore, this study contributes to understanding the dynamics of the classes of foods that exert health benefits and the results may be useful in addressing the United Nation's Sustainable Development Goals (3, 12). Already, the world is experiencing an increase in the demand for organic-based diets or natural foods which are highly prized on the international stage and potentiate many nations' bioeconomy. While the study confirms the therapeutic and pharmacological attributes of plant-based foods, agrosystem practices, biotechnologies, preservation, and processing technologies formed the basic strategies for the optimization of foods' bioactive principles as well as their assimilation for quality pharmacokinetics. Consequently, the growing awareness of foods' physiological and biochemical functions in human health improvement has led to households' dietary changes or habitual choices. The knowledge of foods' functional benefits, innate health potentials, level of processing, genetic status, and chemical inputs affects consumers' choices of foods. Researchers belonging to different disciplines and institutional affiliations across the world are still unlocking the non-hunger satiety potentials of varieties of foods through research (funded or unfunded) that focuses on the manipulation of factors (technology, genetic, processing, physical, biological, and production) for optimal health benefits on consumption. These efforts are meant to promote the acceptance and application of foods for human therapeutic, nutrition, and well-being.

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Conflict of Interest

There is no conflict of interest among the authors on the submission of this article as validated by the completed copy right form.



Table 1: List of African Countries and International Nations with an Insignificant Number of Documents in *Scopus* about the study

African Country	No of Documents	Non-African Country	No of Documents
Central African Republic	3	North Korea	14
French Guiana	3	Federated States of Micronesia	15
Djibouti	5	Barbados	17
Seychelles	5	Dominican Republic	17
Mauritania	8	Monaco	17
Chad	10	Bhutan	21
Liberia	10	French Polynesia	24
Comoros	13	Macedonia	25
Eritrea	16	New Caledonia	25
Swaziland	16	Afghanistan	26
Lesotho	18	Laos	29
Burundi	19	-	-
Gambia	21	-	-
Guinea	24	-	-
Angola	25	-	-
Democratic Republic Congo	28	-	-

Table 2: Distribution of documents about the study on the Scopus database across subject areas

Subject Area	No of doc. the world	No of doc. from Africa
Biochemistry, Genetics and Molecular Biology	118896	8236
Pharmacology, Toxicology and Pharmaceutics	104530	8581
Agricultural and Biological Sciences	99053	9610
Chemistry	89985	5630
Medicine	85784	6932
Chemical Engineering	28759	1652
Immunology and Microbiology	23955	1720
Environmental Science	23762	2637
Engineering	18530	1090
Materials Science	15528	970
Nursing	13889	724
Physics and Astronomy	9972	606
Multidisciplinary	8871	819
Neuroscience	7584	267
Computer Science	5530	253
Energy	5210	555
Social Sciences	4984	423
Veterinary	4937	631

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