

Bibliometric analysis of scientific publications about food supplements

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Nowadays, food supplements are becoming increasingly popular based on the assumption of their safety and ability to supply the body with the necessary substances for the optimal course of all physiological processes. This has led to a strong increase in the production and trade of nutritional supplements worldwide, and as a result, scientific knowledge in the field of food supplements is also growing.

This article examines the publishability of articles in the scientific database Scopus concerning the use of dietary supplements. Bibliometric analysis has recently become a popular and rigorous technique for exploring and analyzing the literature. Bibliometrics is a field that uses mathematical and statistical methods to study and quantify the processes of written communications or apply mathematical techniques to study books and other written communication media. The bibliometric method was originally used to review the subjects, authors, scientific research institutions, journals, and research area of literature. Scientific publications on food supplements from 1990 to 2023 were searched in the Scopus database. Data was downloaded from Scopus and analyzed with Python packages. From the perspective of time distribution, the number of relevant studies published on food supplements showed an overall growth trend from 1990 to 2023. The growth rate was relatively fast after 2008, and there was a surge in the number of papers in 2021. This might be related to the COVID-19 pandemic and searching for alternative treatments.

Keywords: bibliometric analysis, food supplements, COVID-19 pandemic, Python

INTRODUCTION

Food supplements differ from conventional foods and medicines. They are defined as substances intended to supplement the regular diet and are "substances containing concentrated nutrients or other elements with a nutritional or physiological effect, alone or in combination" [1]. These substances are available in diverse drug forms — capsules, dragees, tablets, powders, solutions, and others — and are intended to be taken orally.

Food supplements contain vitamins and minerals, plant-based substances - plant parts or concentrated extracts, and others (e.g., amino acids or probiotics). All nutritional supplements are emphasized as not being a substitute for a varied diet. Their task is to supplement and enrich the menu, filling the lack of certain trace elements, vitamins, and minerals. That is why they are called "supplements." The primary purpose of nutritional supplements is to correct dietary deficiencies, maintain adequate intake of certain substances, or support specific physiological processes. They are not medicines and, as such, cannot exert a pharmacological, immunological, or metabolic effect. Therefore, their use is unrelated to treating or preventing diseases [2].

The burgeoning nutritional supplements market is underpinned by the diverse dietary habits and lifestyles of modern individuals living hectic lives. These dietary patterns are shaped by anthropogenic factors, including cultural, economic, and religious, resulting in a wide array of food habits worldwide. Food habits that exclude the intake of a specific group of nutrients or products should be considered with particular attention. Furthermore, the growing consumer demand for products designed to alleviate or prevent symptoms of chronic diseases has been a significant driver behind the recent expansion of the nutritional supplement market.

Therefore, understanding the relationship between nutritional supplements containing vitamins and minerals and diet quality is essential in determining their optimal use. Consumers must be well informed about dietary supplements' health risks and potential benefits to make informed decisions about their use [3].

Specific socio-demographic characteristics and lifestyles characterize users of nutritional supplements containing vitamins and minerals. Supplement use generally increases with age, income, and education. In addition, women are more likely to use nutritional supplements than men.

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However, health status was not a predictor of dietary supplement use [4].

Bibliometric analysis has become a crucial tool for measuring the scientific outputs of various items such as papers, authors, keywords, journals, institutions, and countries in any research field. It helps examine how the relevant field's intellectual, social, and conceptual structure has evolved based on the relationships and interactions between these items. Researchers primarily use this analysis to recognize, evaluate, and comprehend the literature within a specific research field [5, 6].

Bibliometric analysis involves examining scientific publications in a specific field or academic journals using numerical analyses and statistics to gather various outputs. This includes indicators such as number of articles per year, popular topics, universities with the most publications, top journals prolific authors, citation counts, and keywords. This technique is used to map the intellectual structure of a research field or discipline and to understand the field's evolution and the relationships between authors, topics, and papers [7, 8].

EXPERIMENTAL

Scientific publications focused on food supplements from 1990 to 2023 were searched in the Scopus database. The Scopus database was utilized to gather relevant journal articles for the investigation. It was chosen because it covers many top-notch peer-reviewed publications from reputable publishers and is widely used in similar systematic reviews. After collecting the relevant data from Scopus, we analyzed it using various Python packages.

To track trends and innovations in the study of dietary supplements, we conducted a bibliometric analysis of publications containing "food supplement" in their title. We expanded the analysis with a keyword search focusing on the most common food supplements containing probiotics, magnesium, and zinc. Additionally, we reviewed materials on nutritional supplements and their association with COVID-19.

RESULTS

As the first step in article identification, a preliminary search was conducted using the string "food supplement" in the articles' titles to broadly cover the subject and build a solid string for subsequent queries.

Following this, we conducted a search using keywords to find relevant documents on probiotics, zinc, magnesium, and COVID-19 to achieve the study's objectives.

Analysis of publication trend about food supplements

We searched the literature using the Scopus database and yielded 2633 publications for analysis; we searched for papers published between 1990 and 2023 containing the words "food supplement" in the title.

Food supplements consumption has significantly increased over the last two decades. The dietary supplements market is growing in sales and, more importantly, in terms of products available. This inevitably affects scientific knowledge in the field of nutritional supplements. The continuous marketing of new forms and ingredients results in an increase in scientific knowledge in the field. This is visible on Fig. 1, which shows that the number of scientific publications has substantially increased for twenty years, rising from just 9 in 1990 to 161 in 2010. This upward trend continued in the subsequent years, culminating in a peak in 2021 when 186 articles were published. This exponential growth in scientific output is a testament to the expanding interests and capabilities within the research community, and it underscores the increasing pace of scientific discovery and dissemination of knowledge about food supplements.

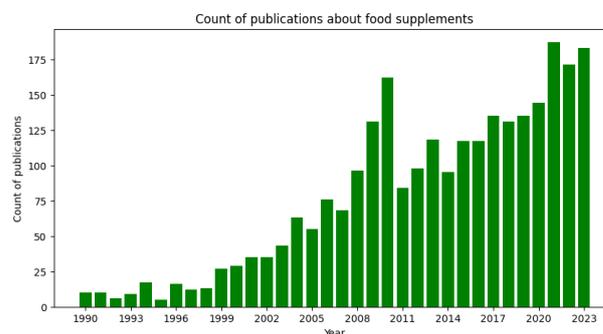


Figure 1. Count of publications including food supplements in the title

The most cited article about food supplements is "Standardized Methods for the Determination of Antioxidant Capacity and Phenolics in Foods and Dietary Supplements," published in 2005. As of 2023, this article has amassed an impressive 4230 citations, making it one of the most widely referenced pieces of research in dietary supplements. This level of attention speaks to the significance and impact of the research and its influence on subsequent studies.

The article was published in the Journal of Agricultural and Food Chemistry, which is far from the top of the journals that publish the most articles on food supplements. In first place with the most significant number of articles is the EFSA Journal,

which is an open-access, free-of-charge online scientific journal that publishes the scientific outputs of the European Food Safety Authority (EFSA), which is the keystone of the European Union (EU) risk assessment regarding food and feed safety.

When analyzing papers by journal, the EFSA Journal published the most papers, establishing itself as a prominent source of research. After that, they formulated the Risk Assessment of Phytochemicals in Food: Novel Approaches and Nutrients. The British Journal of Sports Medicine follows closely behind, contributing significantly to the body of knowledge in this area. Additionally, the journal Food Chemistry and Deutsche Apotheker Zeitung made noteworthy contributions, further enriching the literature on this subject. This demonstrates the diverse range of sources engaged in the topic of nutritional supplements. The indicated data are presented in Fig. 2.

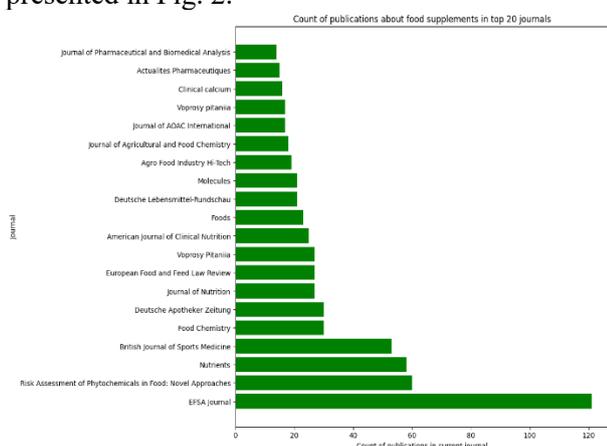


Figure 2. Analyzing publications about food supplements by journal

A peak in scientific publications on food supplements was reported in 2020-2021, when 186 publications were recorded, marking a significant increase in research and interest in this area. This surge in attention can be attributed to the global COVID-19 pandemic, which led to an increased search for alternative therapeutic approaches and strategies for disease prevention.

Analysis of publication trend about food supplements and COVID-19

The public health crisis brought on by the COVID-19 pandemic prompted a heightened interest in utilizing dietary supplements as a potential means of bolstering the immune system, minimizing the risk of inflammation, and potentially offering protection against the emerging disease. Additionally, concerns and hesitations regarding the availability and efficacy of COVID-19 vaccines in various regions of the world have further spurred

interest in exploring dietary supplements as an alternative or complementary approach to promoting health and potentially mitigating the impact of the virus.

Global economic and health-related issues have arisen since the declaration of the COVID-19 pandemic in March 2020. The pandemic has led to a surge in demand for dietary supplements, including vitamins and minerals, as potential additions to the treatment of COVID-19. These DS are believed to have the ability to boost the immune system and reduce disease severity. Despite the development of several COVID-19 vaccines and the availability of numerous pharmacological therapies, the demand for food supplements has significantly increased worldwide. This increased interest in dietary supplements showcases a growing interest in alternative or complementary approaches to managing and supporting overall health, especially in the context of the pandemic. As individuals seek ways to protect themselves and support their well-being during these challenging times, the market for dietary supplements has experienced notable growth. Exploring the potential benefits of dietary supplements in managing COVID-19 represents a significant area of interest for researchers and healthcare professionals alike.

The confluence of these factors has driven a significant uptick in scientific inquiry and publications focused on food supplements as researchers and health professionals seek to understand the potential role of dietary supplements in supporting immune function and overall health during the global health crisis. Consequently, the intersection of the COVID-19 pandemic and the heightened demand for strategies to enhance immune function and mitigate health risks has catalyzed a notable surge in interest and research activity related to dietary supplements.

Therefore, we conducted an additional keyword search to find scientific publications specifically addressing food supplements and the COVID-19 pandemic. The data obtained are presented in Fig. 3.

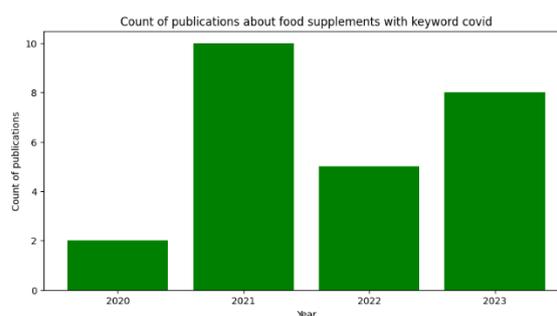


Figure 3. Publications about food supplements with the keyword “COVID”

In 2020, only 2 scientific publications with food supplements in the title included the keyword COVID-19 were found. However, in 2021, this number significantly increased, reaching 10 publications. This sharp rise in scientific interest and attention toward COVID-19 underscores the impact and relevance of this global health crisis. The increased research and publications reflect the urgency and importance of understanding and addressing the challenges posed by the COVID-19 pandemic.

When we searched using the keyword “COVID”, we discovered 25 scientific publications specifically addressing food supplements in relation to the pandemic. Among these publications, the most cited one is titled "Immune-Boosting, Antioxidant, and Anti-inflammatory Food Supplements Targeting Pathogenesis of COVID-19," which has garnered 213 citations in scientific databases up to 2023. It is worth noting that all articles about food supplements and their impact on the COVID-19 pandemic are authored in English. Furthermore, most of these articles are published in *Nutrients*, an international, peer-reviewed open-access journal.

In contrast, the journal ranks third in publication when discussing scientific articles on food supplements. In this case, the *EFSA* journal is the most preferred. These data are presented in Fig. 4.

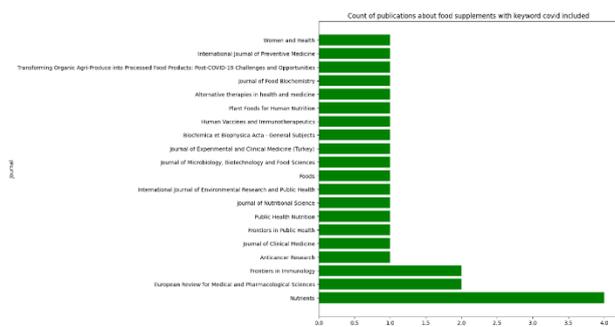


Figure 4. Analyzing publications about food supplements with the keyword “COVID” by journal

Fig. 5 shows a word cloud generated from keywords with the highest frequency included in publications about food supplements and COVID-19, visually representing vital thematic elements in the dataset. These terms strongly emphasize topics related to the immune system and SARS. Other prevalent terms, including “dietary supplements”, “vitamin”, “antioxidant”, and “minerals”, contribute to a rich thematic landscape. The prominence of these terms in the word cloud indicates their recurrent presence in the dataset, offering researchers valuable insights into the focal points of research contributions and potential areas of emphasis within the analyzed period. By identifying

the most frequently occurring terms in the dataset, researchers can gain a deeper understanding of the prevalent topics and subjects that have been the research focus during the analyzed period. This analysis provides a foundation for further exploration and investigation into specific topics that garnered significant attention within the research community. Furthermore, it allows for identifying emerging trends and areas of interest, which can inform future research directions and contribute to advancing knowledge within the field.



Figure 5. Word cloud about publications for food supplements with “COVID” included as a keyword

Analysis of publication trend about food supplements and probiotics

In addition to reviewing the scientific publications on dietary supplements related to COVID-19, we also reviewed materials concerning the fast-growing probiotics segment.

Probiotics are food supplements containing live microorganisms intended to maintain or improve the "good" bacteria (normal microflora) in the human body.

Modern science is continually discovering more possibilities for using these products as an adjunct to the primary therapy for various diseases, ranging from gastrointestinal tract (GIT) disorders to stress and migraine. The increasing popularity of these products is also evident in scientific databases [9].

The effects of probiotic supplementation on metabolic issues such as hyperglycemia, hypertension, and hyperlipidemia have been extensively studied [10].

Numerous studies are being conducted on probiotics' behavior in the body and their potential effect on health. Although many possible positive effects from the use of probiotics exist, there is still no consensus on how probiotics can support the therapy of various diseases. This inevitably results in an increasing number of scientific articles on probiotics. The results show that 112 articles were published on probiotics between 1990 and 2023, representing a significant increase. Fig. 6 displays data related to scientific publications with “probiotics” as a keyword.

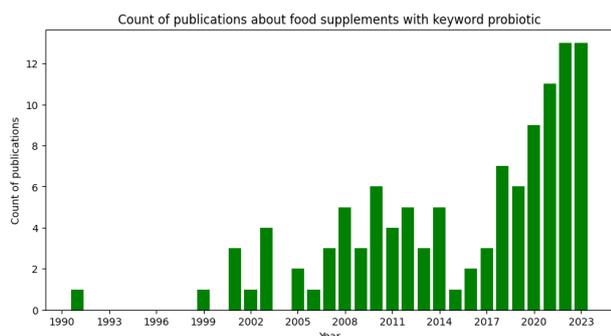


Figure 6. Data related to scientific publications with “probiotics” as a keyword.

Probiotics became popular in scientific publications after 2000 when the number of articles published in the world's databases increased. This is probably due to increasing scientific knowledge and successful marketing strategies to push probiotics into the pharmaceutical market. The significant majority of these articles are published in *Nutrients*, followed by *Frontiers in Microbiology* and *Pharmazeutische Zeitung* (Fig. 7).

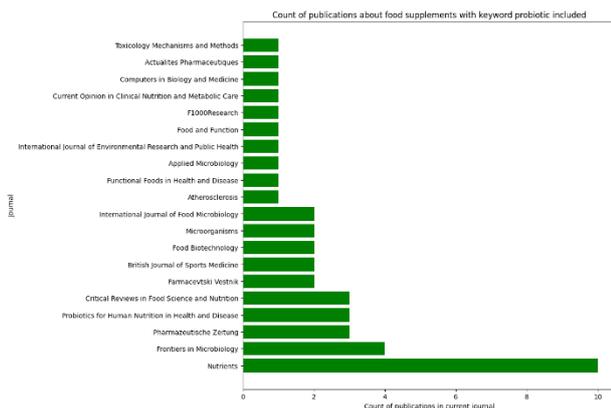


Figure 7. Analyzing publications about food supplements with keyword “probiotics” by journal

The most cited article about probiotics is “The role of functional foods, nutraceuticals, and food supplements in intestinal health”.

Word cloud, visually representing vital thematic elements in the dataset, is presented in Fig. 8.



Figure 8. Word cloud about publications for food supplements with “probiotics” included as a keyword

These terms suggest a strong emphasis on topics related to gut microbiota and metabolic health in the human body. Other prevalent terms, including “food supplements”, “inflammation”, “health”, “dietary”, and “probiotics”, contribute to a rich thematic landscape.

Analysis of publication trend about food supplements and microelements zinc and magnesium

According to our thorough analysis, we included the keywords zinc and magnesium in the current research. These essential components are widely present in numerous nutritional supplements and are gaining popularity among consumers. Zinc and magnesium are utilized to rectify deficiencies and uphold and enhance the body's overall tone and condition, playing a crucial role in supporting various bodily functions. Their utilization extends beyond addressing deficiencies, as they are also instrumental in promoting overall health and well-being. Therefore, we add the keywords zinc and magnesium to the search.

The role of zinc-containing dietary supplements has been known for a long time, but in recent decades, considerable data have emerged regarding its importance in immune modulation. The obtained results are presented in Fig. 9.

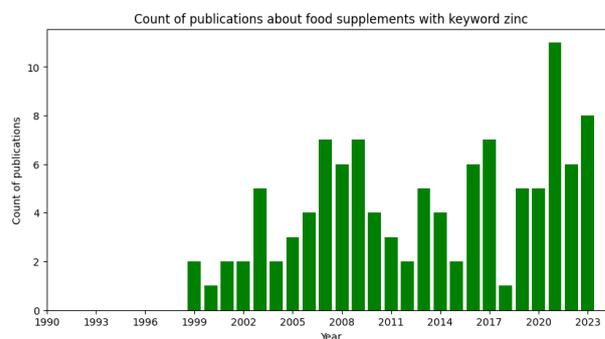


Figure 9. Number of publications including food supplements in the title and “zinc” as a keyword

Magnesium is the fourth most abundant cation in the body. It has several functions in the human body, including its role as a cofactor for more than 300 enzymatic reactions. Many studies have reported that reduced magnesium levels are associated with many chronic diseases. Magnesium can play important therapeutic and preventive roles in several conditions, such as diabetes, osteoporosis, bronchial asthma, preeclampsia, migraine, and cardiovascular diseases [11].

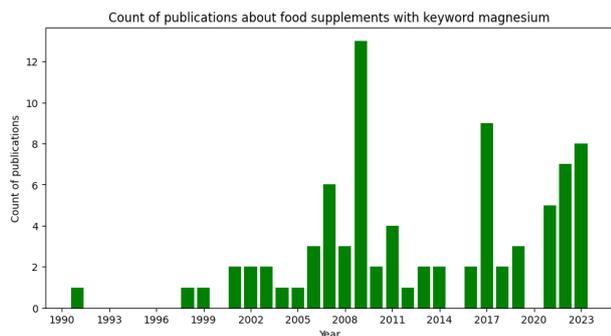


Figure 10. Number of publications including food supplements in the title and “magnesium” as a keyword

Based on the previous data, it is clear that the number of scientific publications about nutritional supplements, particularly zinc and magnesium, has increased in recent years. Notably, the pandemic has impacted this field of study. While food supplements are not included in the guidelines for treating the disease, a growing number of scientific publications have suggested the potential benefits of zinc, vitamin D, vitamin C, and magnesium [12].

The rise in research on nutritional supplements can be attributed to the growing interest in exploring alternative and complementary approaches to health. As people become more health-conscious, there is a greater focus on the potential role of nutritional supplements in supporting overall well-being, immune function, and disease prevention.

The EFSA journal published the most articles on food supplements with the additional keywords zinc and magnesium, followed by Nutrients. When searching with the keyword zinc, both journals displayed an equal number of published scientific articles for the specified period, which is 12.

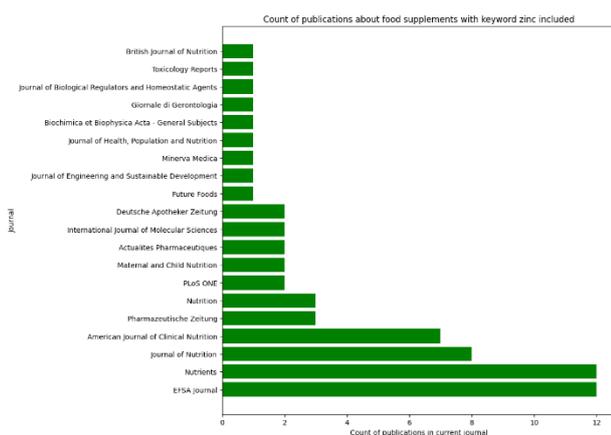


Figure 11. Analyzing publications about food supplements with keyword “zinc” by journal

The most cited article including zinc and magnesium as a keyword is “Foods, Fortificants, and Supplements: Where do Americans get their nutrients?” it has 392 citations.

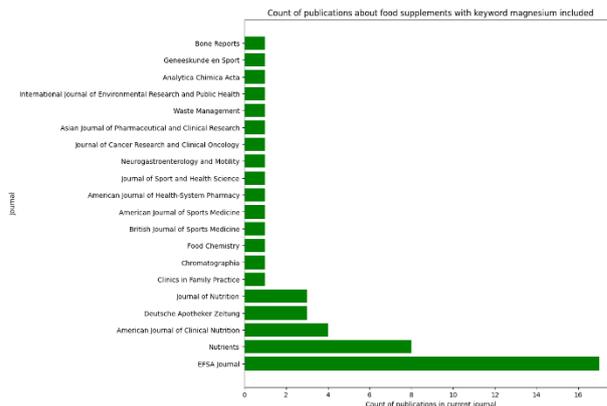


Figure 12. Analyzing publications about food supplements with keyword “magnesium” by journal

The following figure presents a word cloud visually representing vital thematic elements in the dataset.



Figure 13. Word cloud about publications for food supplements with “zinc” included as a keyword

The relationship of zinc with other minerals, such as magnesium and calcium, is visible (Fig. 13). Apart from them, the term "food supplements" most clearly stands out. The situation is similar to the word cloud generated from keywords with the highest frequency when we search with the keyword magnesium. Apart from its relationship with other minerals such as potassium, zinc, and calcium, the appearance of amino acids as a term is also noticeable (Fig. 14). This points out a complex network of crucial interrelated components when examining dietary supplements.



Figure 14. Word cloud about publications for food supplements with “magnesium” included as a keyword

CONCLUSIONS

Bibliometric analysis is a method for quantitatively analyzing academic publications, including research articles, journals, and other scholarly publications. It involves evaluating patterns, citations, and other bibliographic data to gain insights into the impact and influence of research within a specific field or discipline. Bibliometric analysis can provide valuable information about trends, collaborations, and the overall landscape of scholarly work, making it an essential tool for researchers, academic institutions, and funding agencies. Bibliometric analysis is increasingly used to review trends and progress in different fields and research areas.

Regarding time distribution, the number of relevant studies published on food supplements showed an overall growth trend from 1990 to 2023. The growth rate was relatively fast after 2008, and there was a surge in the number of papers in 2021. This increase may be related to the COVID-19 pandemic and the search for alternative treatments.

The COVID pandemic has led to significant changes in the pharmaceutical sector, including the food supplements segment. The market has witnessed a surge in demand for products that support immune and digestive health. Selling supplements such as probiotics, vitamins, omega-3 fatty acids, and others has grown immensely. These factors are having a positive impact on the market and are leading to an increased scientific interest in the field.

Moreover, the global health crisis brought about by the pandemic has heightened interest in identifying ways to boost immune health and resilience. This has increased emphasis on the potential benefits of specific nutrients such as probiotics, zinc, vitamin D, vitamin C, and magnesium in supporting human health.

It is important to note that while the scientific community continues to explore the potential benefits of nutritional supplements, further research

is needed to fully understand their effectiveness and safety, particularly in specific health conditions and individual needs. Therefore, ongoing research and evidence-based analysis will be essential in determining the role of food supplements in promoting health.

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