



# A Bibliometric Analysis of Soy-based Beverages and Tofu: A Global Perspective

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## ABSTRACT

**Background:** Due to their high protein content, soybeans are the most popular crop in Asia and are widely consumed. Global consumption of soy-based foods includes tofu and soymilk, among others. Soymilk is known among consumers who have lactose intolerance issues and is categorized as a plant-based beverage. There have been numerous initiatives worldwide to improve the consumer-friendliness of soymilk and tofu. The number of research papers on soymilk and tofu has expanded significantly since the late 1990s, notably in developed nations.

**Methods:** For this study, we compiled and examined published studies on tofu and soymilk. On VOS Viewer, the acquired data were examined for the annual publishing trend, contributing authors and the correlation between these factors.

**Result:** Japan was found to be the most producing country, followed by the US and China, with a total of 1895 and 3635 papers relating to soymilk and tofu, respectively, which exhibited a growing tendency over time. Both the Journal of Agricultural and Food Chemistry and Food Chemistry are short-listed as the best journal for publishing the data related to soymilk and tofu.

**Key words:** Bibliometric analysis, Soymilk, Tofu, VOS viewer.

## INTRODUCTION

Originally from Asia, the soybean (*Glycine max*) was brought to the United States by Mr. Samuel in 1765 (Chen *et al.*, 2012). One of the most valuable crops in the world is soybeans, which are also used as an oil seed crop, livestock and aquaculture feed and a feedstock for biofuels. Soybeans are also a staple food in most Asian nations and a good source of protein for the human diet. One of the "biotech foods" that has been genetically modified (GM) and is currently employed in an increasing number of food products is soybean, which has grown to become a significant global crop (Molina *et al.*, 2012).

Soybeans are high in protein and have a high oil content; by weight, oil makes up about 60% of dry soybeans (Henkel, 2000), 35% of the remaining ingredients are carbs, while 5% or so is ash. Soybeans also include a wealth of essential vitamins, flavonoids and polysaccharides (Sasi *et al.*, 2022). Because of their high soy protein content, which includes considerable amounts of the essential amino acids that the human body cannot produce, soybeans are a fantastic source of complete protein. According to reports, soybeans have a high concentration of isoflavones (1-5 g/g dry soybean) that may have beneficial impacts on health, including alleviating postmenopausal women's symptoms, lowering the risk of osteoporosis, preventing cardiovascular illnesses and having antimutagenic actions (Zhu *et al.*, 2020).

Soybeans have been used by Asian people in a variety of ways for more than a thousand years. These soy foods have recently started to enter Western diets and societies. In the modern world, soy meals come in a wide variety (Kumar *et al.*, 2022). In addition to the high protein and isoflavone content, soybeans also contain anti-nutritional

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factors (ANFs) including phytic acid and flatulence factors such as raffinose and stachyose that hinder consumer acceptance (Fig 1) (Sasi *et al.*, 2022). To combat ANFs, rectify the nutritional imbalance and lessen the off-flavor from soy-based foods, many treatments have been examined. One method for enhancing nutritional quality is fermentation, which breaks down phytic acid, converts glucoside to aglycone isoflavones and produces bioactive substances such as vitamins (B<sub>2</sub>, B<sub>6</sub>, B<sub>9</sub> and B<sub>12</sub>) and  $\gamma$ -amino butyric acid (GABA) (Thakur *et al.*, 2015; Hong *et al.*, 2021; Lee *et al.*, 2015). Fermented soymilk has health-beneficial properties as anti-diabetic (Tiss *et al.*, 2020), anti-obesity (Lee *et al.*, 2013), anti-osteoporotic (Chiang *et al.*, 2012), anti-hypertensive (Tsai *et al.*, 2006), improved gastrointestinal system (Vieira *et al.*, 2021), overcome cardio-

vascular disease (Hussin *et al.*, 2020) and anti-cancer (Gourineni *et al.*, 2011).

Researchers from all over the world are adding an exponential amount of literature to the field of soymilk and tofu research. Bibliometric analysis has made it possible to be resourceful to comprehend the condition of research and development trends thoroughly and methodically. To assess trends in the subject of study, bibliometric methods combine knowledge mapping and analysis methods to introduce a quantitative evaluation of literature (Fasogbon and Adebo, 2022). It is essential for the decision-making process in science. For instance, it can assist investors in supporting scientific research as well as researchers by giving them a comprehensive view of products and processes and ways to better serve customers (Escortell *et al.*, 2020). As a result, bibliometric methods have been used in this work to understand the research status and development trends in

soy products like soymilk and tofu, as well as to offer crucial insight into the most influential authors, journal publications and collaboration countries while inspiring researchers in their future research in this field.

## Software and methodology

### Software

A variety of software programs were used to compile the dataset and to illustrate it for the reader's convenience. For the drawing, we used ChemSketch (version 14.00) and Inkscape (Version 1.1.0) and for the bibliographical analysis, we used VOS viewer (version 1.6.18) and MS Excel (2019).

### Collection of bibliographic information

On August 20, 2022, a search for records about the field of soy goods, such as soymilk and tofu, was carried out. This collection made use of the Dimension. in and Scopus

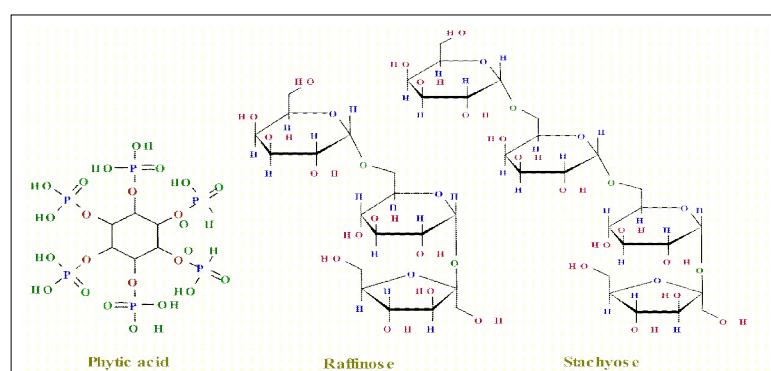


Fig 1: Anti-nutritional factors.

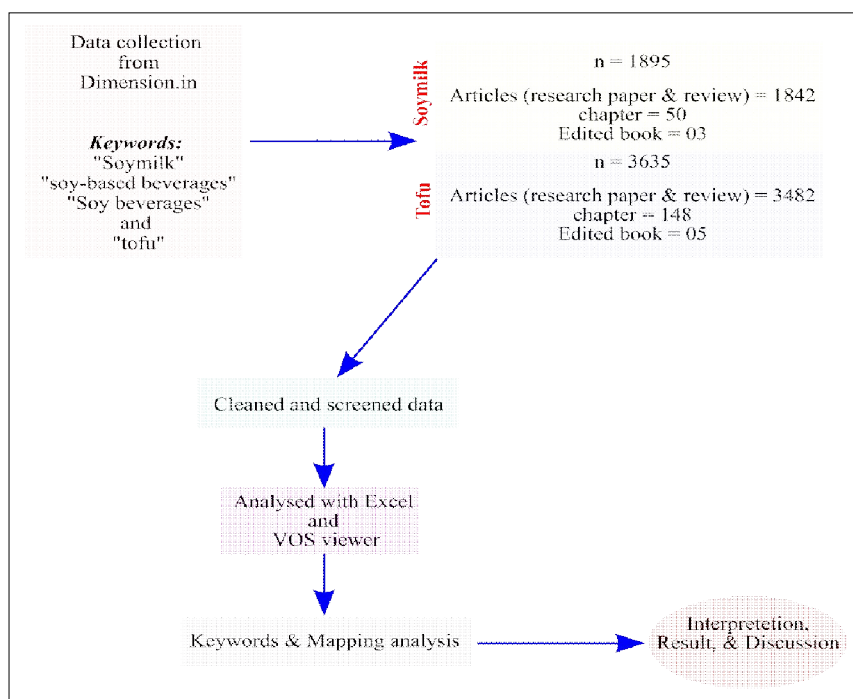


Fig 2: Schematic representation of chosen methodology for bibliometric analysis of scientific literature.

databases since they contain a sizable quantity of verified indexed journals, books and conference proceedings. For data collection, specific search terms “soymilk”, “soy beverages” and “tofu” yielded 1895 and 3635 documents respectively. Then, to create a total of 800 documents, the obtained materials were restricted to articles, edited volumes and chapters. The retrieved data were downloaded in CSV format along with their associated information (keywords, citations, abstract, authors and bibliographical data). All of the bibliometric data gathered was used for additional analysis and result interpretation. The bibliometric network mapping was graphically visualized using the VOS viewer program and other general indicators were visualized using Microsoft Excel. A conceptual illustration of the process is shown in Fig 2.

### Citation and Co-authorship analysis of the documents

Using the authors’ and countries’ input data from the recovered documents, the analysis of co-authorship and citations was completed. This was done to establish networks of engaged collaboration in the soy products industry (Soymilk and tofu).

## RESULTS AND DISCUSSION

Online research papers on soyproducts (soymilk and tofu) were carefully examined and it became clear that many different factors were driving researchers to pursue this field worldwide. Products made from soy are a promising source of plant-based nutrition that broadens the range of available foods for vegetarians and offers nutrition. Due to the presence of high protein content in soybean, soy-based foods like tofu and soymilk are also excellent sources of protein.

### Research trends in soymilk and tofu

A useful indicator of the research trend in a particular field of study is the volume of publications that are released on an annual basis. Hence, the analysis of the trend in publication volume can reveal information about the likely direction of future research. To assess the research trend on soymilk, the number of publications and the number of citations were plotted year over year from 2011 to 2022 (Fig 3A). The number of publications increasing from 2011 to till date

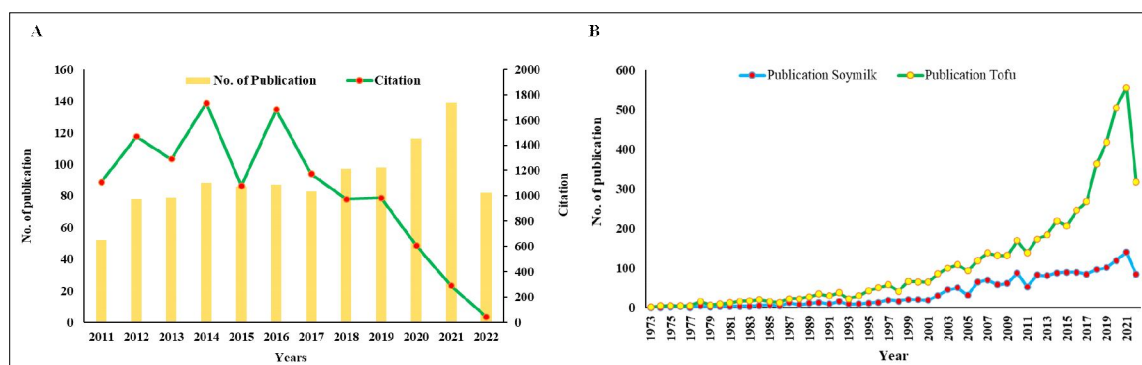
(Aug. 2022) but the citation is declining since 2016. Most articles (139 publications) on soymilk have been published thus far in 2021. Only 82 publications (articles, book chapters and edited books) on soymilk have been identified as of the time this report was being written in 2022. According to the observed pattern in 2021, there is a good chance that there will be more publications in this field of study than there were in 2021. The publication graph also implies that scientists are becoming more interested in these plant-based beverages.

In the case of tofu, the highest number of publications (416) has been published in 2021 and 233 publications were reported in 2022. However, Fig 3B demonstrates that there are far more papers relating to tofu than are relating to soymilk, indicating that tofu was studied by researchers considerably earlier than soymilk. Additionally, the growing popularity of soymilk articles suggested that the scientific community has recently been more interested in plant-based beverages as a result of consumer demand.

### Authorship and citation relationship

Numerous names emerged throughout the analysis of the list of authors who had written about soymilk and tofu and the top five authors with the greatest number of soymilk and tofu-related publications are included in Table 1 below. With 28 publications, the research group of Nagendra Prasad Shah was the leading group in the aforementioned soymilk research section, while the Lorna Woodrow group topped the tofu-related publications with 22 articles (Table 1). It is possible to identify the most active scholars in an area based on how many documents they have published and how many citations they have got. Given that Nagendra, Yu-Fei Hua and Tomotada Ono have the most documents and citations, this may indicate that these three writers are the most active soymilk researchers worldwide.

The most influential researcher was identified based on the average number of citations per document (CPD). In other words, a higher number of citations would indicate a higher quality paper, which may be determined by computing the average number of citations per document. With 17 papers and 538 citations, Tomotada Ono has an outstanding average of 32 CPD and is linked to 96 other researchers both inside



**Fig 3:** Showing the research trends (A) depicting the number of publications related to soymilk with respective citations from 2011 to 2022, (B) indicating the number of publications related to soymilk and tofu from 1973 to 2021.

and outside of the cluster (Fig 7). This shows that, in comparison to the others, Tomatado Ono's documents had a greater influence because they had an average of over 32 CPD. Distantly present researchers and groups on the network visualization suggested that despite the author's prodigious research output and strong networking and collaboration skills, his findings are not as significant as those of other researchers.

Fig 4 and Fig 6 depict the network map of these 470 researchers (soymilk) and 368 researchers (tofu), with fourteen and sixteen colored clusters indicating various researchers working in small groups, respectively. Nagendra Prasad Shah research team had direct connections to 183 other researchers, formed the largest cluster and was highly networked, indicating that these authors were engaged in collaborative research (Fig 5).

#### Most productive journals in soymilk and tofu research

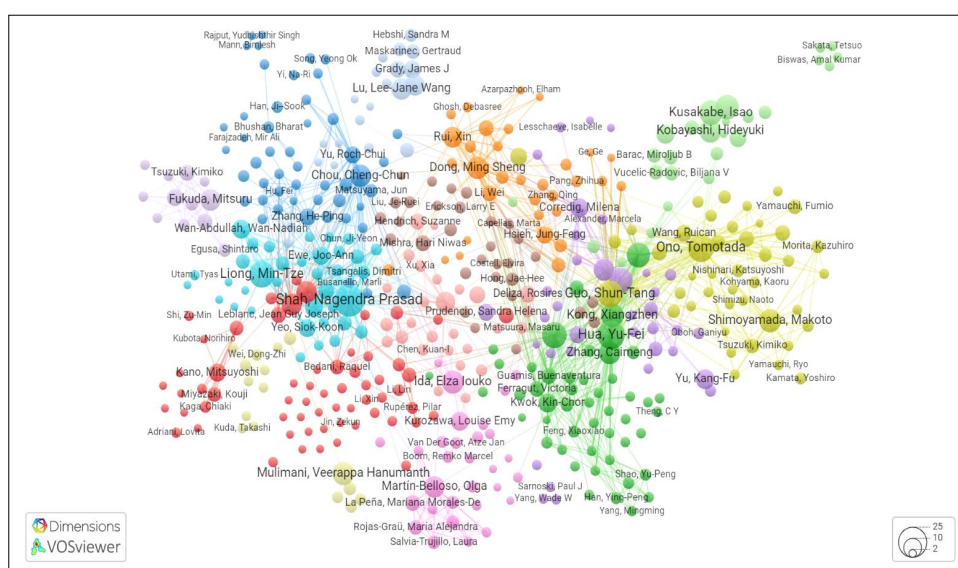
The significant publications where the authors like to publish their findings were identified by the relationship between sources and citations. The top ten journals for soymilk and

tofu-related research articles are listed in Table 2, respectively. The Journal of Food Science received 3606 citations for its 121 soymilk-related studies, making it the most widely used journal. While the IOP Conference Series Earth and Environmental Science was the most popular publication, with 107 tofu-related research and 152 citations.

The complex statistic known as Source Normalized Impact per Paper (SNIP) automatically takes into account the variations in citation styles that exist throughout different fields. This is accomplished by contrasting the average number of citations per publication for each journal with the field's citation potential, which is represented by the total number of articles that cite each journal. The Journal of Agricultural and Food Chemistry and Food Chemistry both have high SNIP scores of 1.4 and 2.2 and high Cite scores of 8.6 and 13.1, respectively, indicating that they are both high-impact journals. As a result, despite having fewer articles, both have high citation per publication (CPP) values of 49 and 34, respectively. While the CPP values for tofu are 49 and 39, respectively, according to the publication.

**Table 1:** Top five authors who published the highest number of documents related to “tofu” and “soymilk”.

Author name	Organization and country	Publications	Citation	CPD
<b>Soymilk</b>				
Nagendra Prasad Shah	University of Hong Kong, China	28	1207	43
Yu-Fei Hua	Jiangnan University, China	23	250	11
Tomotada Ono	Iwate University, Japan	21	628	30
Min-Tze Liong	Universiti Sains Malaysia, Malaysia	20	433	22
Shun-Tang Guo	China agricultural University, China	20	499	25
<b>Tofu</b>				
Lorna Woodrow	Agriculture and agriculture-food Canada, Canada	22	293	13
Vaino W Poysa	Agriculture and agriculture-food Canada, Canada	20	502	25
Kang-Fu Yu	Agriculture and agriculture-food Canada, Canada	19	159	8
Tomotada Ono	Iwate University, Japan	17	538	32
Neni Sintawardani	Indonesian Institute of Sciences, Indonesia	15	42	25



**Fig 4:** Soymilk publication (470 researchers, 8635 citation links, 20568 total citations and 14 clusters).



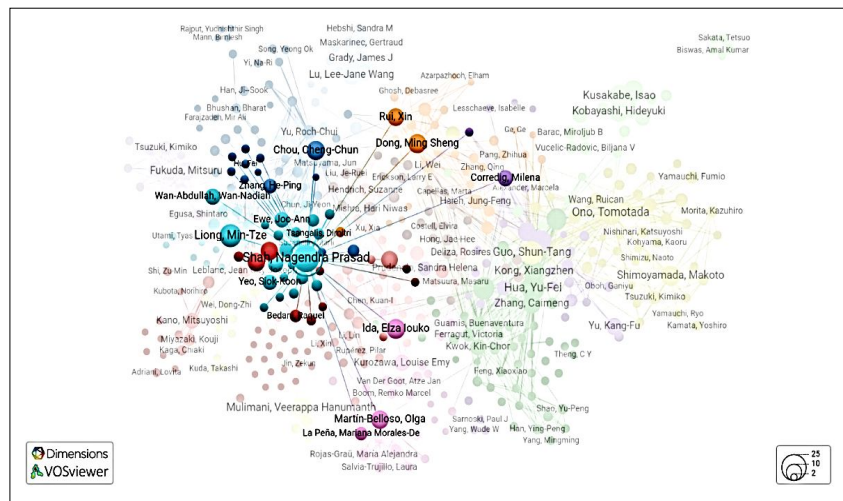


Fig 5: Highlighting the key author (Nagendra Prasad Shah) in soymilk-related publications with 183 citation links, 857 total citations and 28 publications.

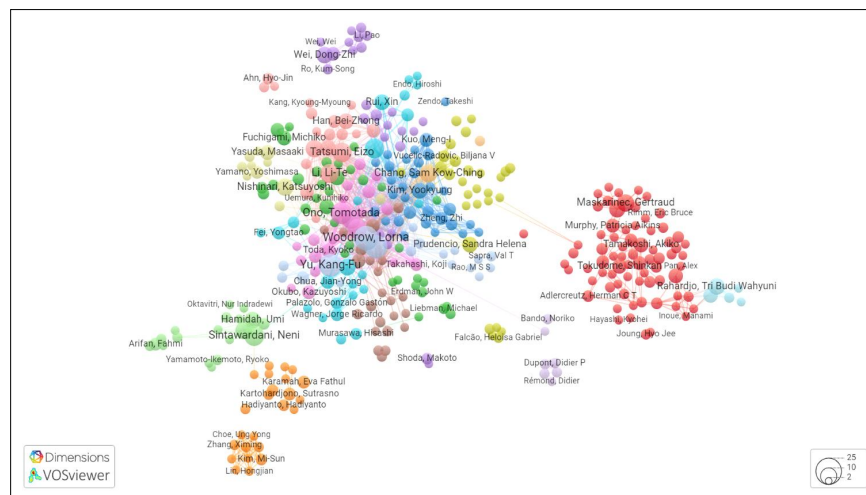


Fig 6: Citation network related to Tofu indicating 368 researchers, 4274 citation links, 9921 total citations, 16 clusters).

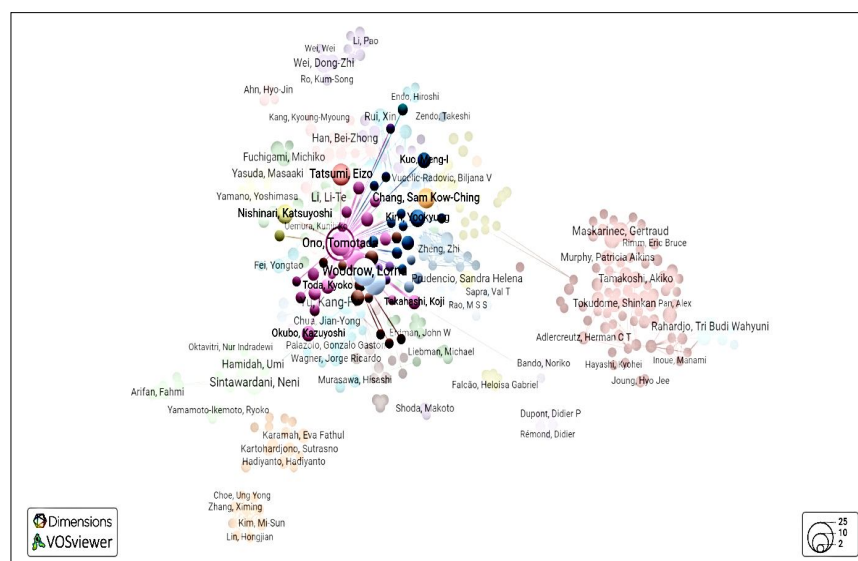


Fig 7: Highlighting the key author (Tomatado ono) in tofu-related publications with a 96-citation link, 538 total citations and 17 publications.

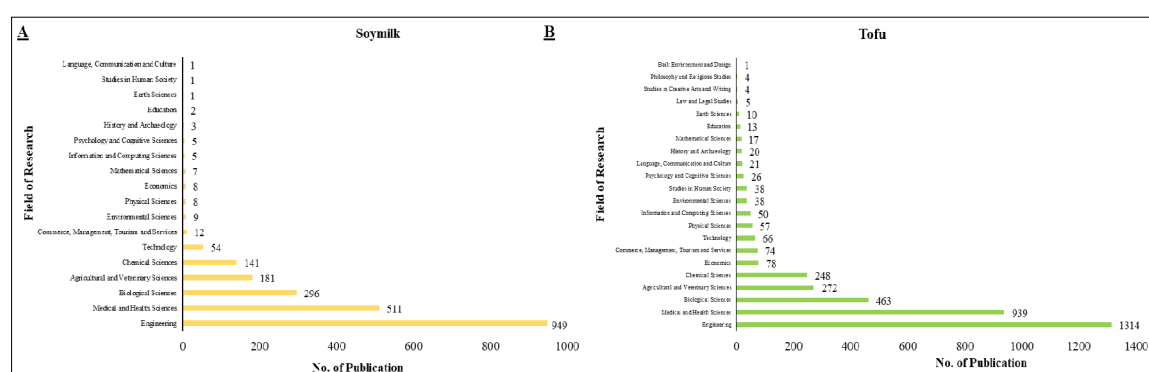


Fig 8: Horizontal bar graph indicating the number of publications in the field of research for (A) soymilk and (B) tofu.

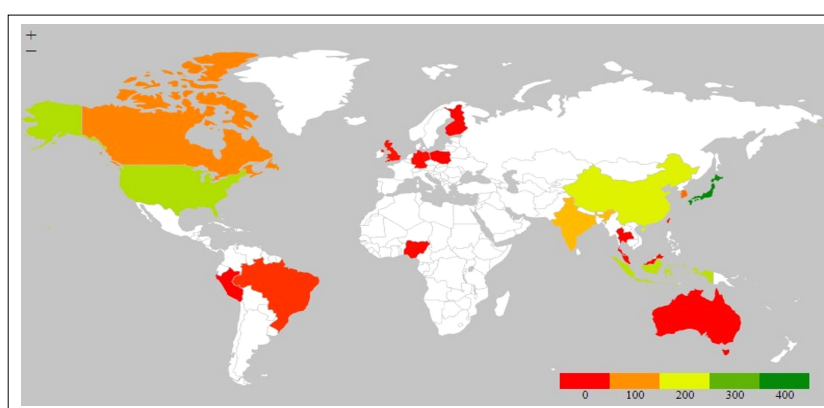


Fig 9: Map of nations where at least ten soy-based (soymilk and tofu) research article has been published.

Table 2: Top ten journals that published research related to soymilk and tofu.

Name	Publications	Citations	CPP	Cite score	SNIP	SJR
<b>Soymilk</b>						
Journal of food science	121	3,606	29.8	5.1	1.064	0.653
Food chemistry	85	2,868	33.74	13.1	2.268	1.489
Journal of food science and technology	72	274	3.81	5.3	1.183	0.64
LWT	61	1,461	23.95	7.3	1.519	1.059
Journal of the science of food and agriculture	48	953	19.85	6.9	1.285	0.705
Food research international	44	1,682	38.23	11.1	1.884	1.248
Journal of agricultural and food chemistry	41	2,007	48.95	8.6	1.404	1.018
Bioscience biotechnology and biochemistry	39	549	14.08	3.3	0.66	0.439
Food science and technology research	30	279	9.3	1.3	0.134	0.138
Journal of food processing and preservation	29	220	7.59	0.3	0.77	0.472
<b>Tofu</b>						
IOP conference series earth and environmental science	107	152	1.42	0.6	0.409	0.202
Journal of food science and technology	96	372	3.88	5.3	1.183	0.64
Journal of food science	61	1701	27.89	5.1	1.064	0.653
LWT	56	1146	20.46	7.3	1.519	1.059
Food chemistry	52	2031	39.06	13.1	2.268	1.489
Journal of agricultural and food chemistry	51	2504	49.1	8.6	1.404	1.018
Bioscience biotechnology and biochemistry	40	735	18.38	3.3	0.66	0.439
Journal of physics conference series	34	43	1.26	0.8	0.395	0.21
IOP conference series materials science and engineering	32	40	1.25	1.1	0.344	0.249
Journal of the Korean Society of Food Science and Nutrition	30	188	6.27	0.9	0.445	0.225

Here: CPP = Citation per publication, SNIP = Source normalized Impact per Paper, SJR = Scimago journal ranking.

### Dominating in the field of research and country

The field of research for soymilk and tofu is represented through horizontal bar graphs in Fig 8. Soymilk and tofu-related scientific documents are mostly published in the engineering category which is 949 and 1314 respectively, followed by medical and health science (511 and 939) and biological sciences (296 and 463). This indicates that processing-related research is dominating in both soymilk and tofu and hence more documents are published in the engineering category. Similarly, health beneficial properties of soymilk and tofu might be the reason for the higher documents published in the medical and health category. In contrast, there are relatively few publications published that discuss soymilk and tofu in the categories of language, communication and culture as well as built environment and design, which is a strong indication of a poor relationship.

Fig 9 showing the leading countries in the field of research related to soy-based foods particularly soymilk and tofu in last decades. Japan, United states, Indonesia, China and India are the top five countries with 363, 237, 230, 204 and 127 publications related to soy-based foods in last decades.

### CONCLUSION

Research on soy-based foods is a new area that aims to produce nutritional, useful and health-improving food products. The results of this bibliometric analysis included lists of the top journals, authors and fields of scientific literature as well as information about the number of citations and collaborations for each. This study also reveals the research trends, top authors and top journals on soy-based foods, particularly soymilk and tofu, which will aid as guidance for the future research, highlighting the contemporary research/issue and correlating with prevailing trend in publications.

**Conflict of Interest:** None.

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