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Global trends in research on wild-simulated ginseng: Quo Vadis?

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Abstract

To the best of our knowledge, no study has systematically reviewed and analyzed the research trends of Wild-simulated ginseng (WSG) used for food or medicinal purposes in many countries. WSG, a non-timber forest product, has been traditionally produced using agroforestry practices, and it has been consumed in various ways for a long time. WSG has a great demand in the market due to its medicinal effects, particularly in improving forest livelihoods and human health. Due to the significance of WSG, we conducted this research to explore the global research trends on WSG using systematic review methodology and keyword analysis. We used two international academic databases, the Web of Science and SCOPUS, to extract 115 peer-reviewed articles published from 1982 to 2020. The research subjects, target countries, and keywords were analyzed. Our results indicate four categories of WSG research subjects, namely growth conditions, components, effects on humans/animals, and the environment of WSG, and the case studies were mainly from the Republic of Korea, China, and the USA. Through topic modelling, research keywords were classified into five groups, namely medicinal effects, metabolite analysis, genetic diversity, cultivation conditions, and bioactive compounds. We observed that the research focus on WSG changed from the biological properties and cultivation conditions of WSG to the precise identification and characterization of bioactive metabolites of WSG. This change indicates an increased academic interest in the value-added utilization of WSG.

Keywords: Wild-simulated ginseng; systematic review; keyword analysis; topic modelling; non-timber forest products (NTFPs); agroforestry

Introduction, scope and main objectives

Ginseng obtained from plant roots has been used as an herbal medicine for thousands of years. Increasing demand for wild ginseng resulted in the overexploitation of wild ginseng to meet the demands of the industrial market. Wild-simulated ginseng (WSG) has been used for food or medicinal purposes in many countries, including the Republic of Korea, China, Japan, Russia, and the USA (Nah 1997). In this study, WSG is defined as the ginseng grown under trees in mountain areas via artificial transplantation of seeds or seedlings.

The active components of WSG can be largely divided into saponins (known as ginsenosides) and non-saponins (polyacetylenes, phenolic compounds, acidic polysaccharides, peptides, alkoxides, and amino acid derivatives) depending on the characteristics of chemical structures. Other components of WSG include volatile oil, sugar, starch, pectin, and minerals (Nam 2002). WSG contains many functional components that exert excellent effects on human health, such as anti-obesity (Mollah et al. 2009), activation of the sympathetic nervous system (Taehan 2009), anti-fatigue (Shin et al. 2019), memory loss improvement (An et al. 2019), spatial cognitive ability improvement (Tu et al. 2017), cancer prevention, anti-cancer activity (Bae et al. 2018), and liver functional resistance (Hu et al. 2019). Since the health effects of WSG are more recognized than those of

cultivated ginseng (Hong et al. 2010), WSG is mostly produced only as a health supplement (Park et al. 2007). Due to the increasing interest and demand for eco-friendly non-timber forest products (NTFPs), WSG has gained attention as a high-value product. Due to the increasing production and demand, especially in the Republic of Korea (Korea Forest Service, 2010), WSG has become a major source of income to forest communities. Thus, it is necessary to build scientific databases and accumulate research data for WSG (Gil et al. 2017).

Due to the greater use of WSG, many studies have been conducted on its growth conditions and characteristics. Many studies have also been conducted on farming locations (Burkhart 2013), harvest, growth (Mcgraw et al. 2005), and identification of genetic traits (Lim et al. 2007) and genome sequences (Kim et al. 2019). Industrialization of WSG requires a scientific and systematic approach considering the environment, location conditions, cultivation technology, efficacy, and environmental impact. Nevertheless, till date, no study has systematically reviewed and analyzed the research trends of WSG. Thus, this study seeks to examine the trends in WSG research using systematic review and topic modelling of which have been widely used to analyze the recent research trends in linguistic, political, medical and biomedical, geographical science, etc. [28]. The study aimed to achieve answers to the following research questions: (1) What are the dominant keywords in the WSG study? (2) What is the main topic of the WSG study? The study findings can contribute to designing future studies on WSG, including the selection of topics.

Methodology/approach

1-Data Collection (Identification)

We used two major databases, SCOPUS and the Web of Science, to search bibliographic information dealing with WSG collected up to October 2020. The first search was done under the title, abstract, and keywords of the paper itself, which includes WSG synonyms. This research follows the preferred reporting items for systematic reviews and meta-analyses (PRISMA) flow diagram (Moher et al. 2010), which has four steps, namely identification, screening, eligibility, and inclusion (Figure 1).

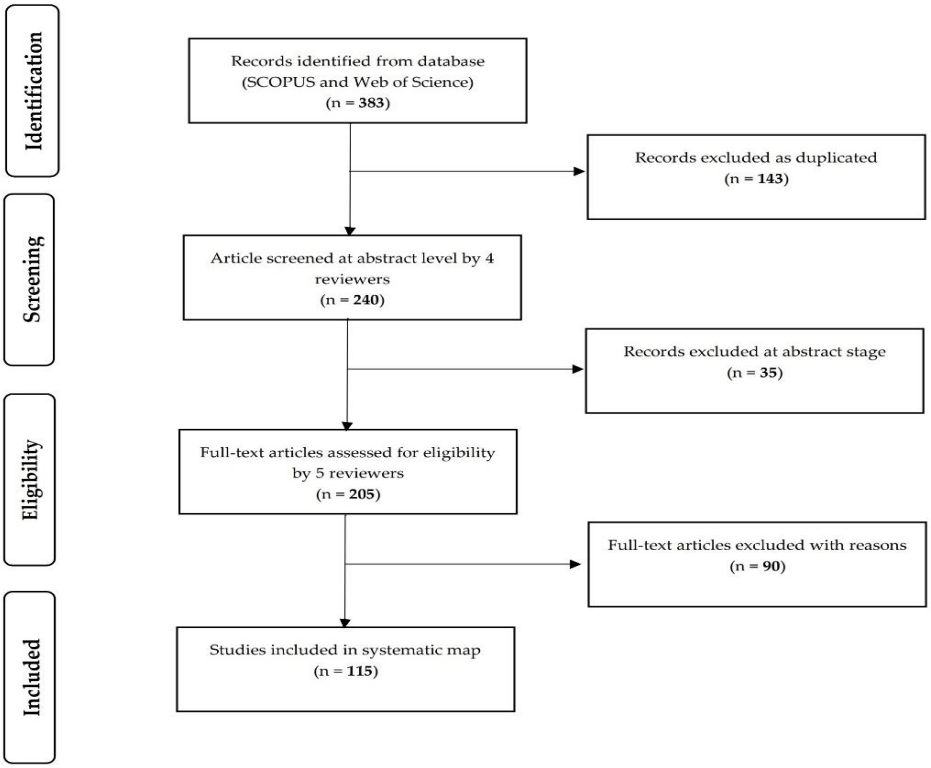

Fig. 1: Preferred reporting items for systematic reviews and meta-analyses flow diagram

2-Article Screening, Eligibility, and Inclusion

Three hundred and eighty-three articles collected from the identification stage were filtered through the next three stages, namely screening, eligibility, and inclusion. The literature search and selection were recorded independently by five coders, who compared the remaining records in each course (Littell et al. 2008). Coders then screened the relevance of articles to WSG by reviewing the full text. Finally, a total of 115 articles of literature were used for the analysis (Figure 1).

3-Topic modelling

For topic modelling, this study utilized a list of keywords selected by researchers for topic modelling. Data preprocessing and cleaning are essential before starting LDA (Maier et al. 2018), as analysis results vary depending on the extracted keywords, or the author may choose unintended keywords, resulting in different results. To minimize the indexing effect of keywords extracted from the morpheme analysis process for data preprocessing, we refined the data by building dictionaries. Particularly, all keywords were reviewed to identify spacing, abbreviations, and word-form unification. For example, as the same words, "WSG" and “wild-cultivated ginseng”, are recognized as designated words with the same meaning were in the same form to prevent them from being treated as different words when analyzing morphemes. Following this, we used term-frequency-inverse document frequency (TF-IDF) to avoid common errors that hinder the independent separation and grouping of keywords (Ramos 2003). By using TF-IDF scores as a baseline, we extracted several words, including ginseng, wild ginseng, wild cultivated ginseng, Panax ginseng, ginsenoside, and antioxidant activities, to increase the independent topic distributions.

The number of topics in modeling is a major issue as it affects data interpretation (Ramos 2003). The number of topics should be determined by focusing on the possibilities of interpretation of the analytical results and research purposes, rather than relying on probability values alone. During analysis, researchers run the LDA process and choose the number of topics, their iterations, α, β, and other values until topics are distinguishably divided. In this regard, the researchers used a social network analysis software, NetMiner 4 (Cyram 2013). For reasonable distributions of topic models, this study chose a set of parameters that affect the structure of word and topic distributions (Maier et al. 2018) with $\alpha = 0.01$, $\beta = 0.001$, and iteration= 10,000 times. After specifying five topics, all words in the papers were automatically calculated and arranged in each topic in descending order of their values, based on the main keyword of each topic with the highest probability. Further, linear regression analysis was conducted to identify the annual research trends in major topics.

Results

1-Article distribution

The results indicate significant differences in the research on WSG, geographical imbalance, and specific period upsurge (Figure 2). First, the trends in publishing reveal three major countries, namely the Republic of Korea (56), China (25), and the USA (15), that have been actively conducting research on WSG. Approximately 73% of the total studies were published in the Republic of Korea and China. On the contrary, other countries such as Russia (3), Canada (2), and New Zealand (1) conducted relatively few studies on WSG. Figure 2 displays the fluctuation in the number of WSG studies since the first publication in 1982. After two reports in the 1980s, no article was published in the 1990s. The articles were published again between 2000 and 2001. The number of published articles increased from 2004. Most articles were published in the last 15 years. More than 50% of the studies were published after 2016, and most studies were published in 2019.

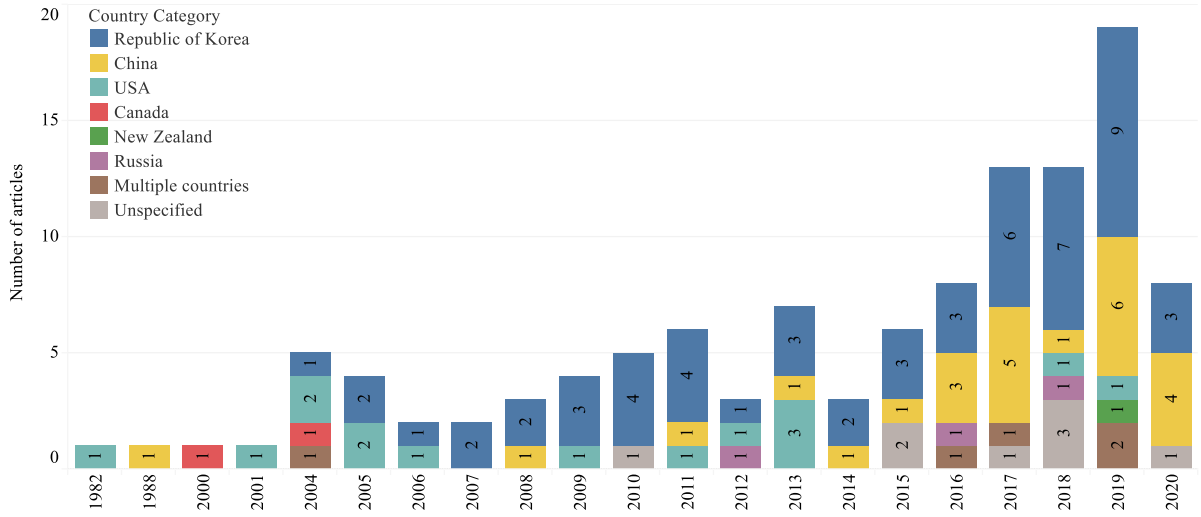

Fig. 2: Distribution of wild-simulated ginseng articles by country and year. The numbers indicate total articles published from January to December. However, the number of articles in 2020 includes articles from January 2020 to October 2020. The category of multiple countries means more than one country and the category of unspecified means no specific country.

2-Keyword frequency

Table 1 shows the frequency of the top 25 keywords out of a total of 481 keywords from the 115 selected articles. The top keywords are mostly ginseng types or species, such as Asian ginseng species, P. ginseng (49). As 11 anti-oxidation studies have been conducted, the relevant keyword, antioxidant activity, was designated with the 5th-highest keyword frequency. However, since frequency analysis alone has limits to discover the relationship between semantic structures and context of WSG research, it is necessary to look at the knowledge structure of the study through topic modelling analysis.

Table 1: Frequency of the top 25 keywords

Rank	Keywords	Frequency
1	Panax ginseng	49
2	wild-simulated ginseng	30
3	ginsenoside	25
4	ginseng	16
5	antioxidant activity	10
6	wild ginseng	10
7	cultivated ginseng	9
8	metabolite	8
9	American ginseng	7
10	genetic diversity	7
11	cytotoxicity	5
12	HPLC	5
13	medicinal plant	5
14	plant conservation	5
15	UPLC-Q-TOF-MS	5
16	soil	4
17	Araliaceae	3

18	bacterial endophyte	3
19	Burkholderia stabilis	3
20	climate change	3
21	ginseng pathogens	3
22	harvest	3
23	identification	3
24	pharmacopuncture	3
25	saponin	3

3-Topic Analysis

As a result of topic modelling, five topics (Table 2) were derived from the large keyword network (Figure 3). The five topics included 336 keywords, excluding keywords with high TF-IDF scores as mentioned in the methods section. Table 2 displays the ranks of keywords according to the topic. Each topic was named depending on the characteristics of extracted keywords. Topic A was named "Medicinal effects", and it included keywords on the medical and pharmacological functions of WSG, such as medicinal plant, insulin, Chinese medicine, Tuina, and chronic fatigue syndrome. The studies related to Topic A indicate the wide use of WSG for various medicinal purposes, and they investigated methodologies to maintain or enhance the medicinal efficacy of WSG (Jiang and Tian 2020; Beon et al 2013). Topic B was named "Metabolite analysis". Included keywords in Topic B are related to the identification and quantification of WSG ingredients. HPLC, UPLC-Q-TOF-MS, and OPLS-DA are analytical techniques and methods to separate, identify, and quantify each component of WSG (Wang et al. 2010). Topic C was "Genetic diversity", which consisted of keywords such as genetic diversity, RAPD, 16S rDNA, UPGMA, genetic differentiation, Illumina MiSeq sequencing, and transcriptome. Topic D was named “Cultivation conditions”. Topic D focused on growth, cultivation, and cultivation environment. The demand for forest products is increasing worldwide (Schippmann et al. 2002), and the harvest pressure on ginseng is also increasing Schmidt (2019). Lastly, Topic E was “Bioactive compounds”, which included various bioactive compounds directly or indirectly related to WSG.

Table 2: Five topic groups related to wild-simulated ginseng

Topic A	Topic B	Topic C	Topic D	Topic E
Medicinal effects	Metabolite analysis	Genetic diversity	Cultivation conditions	Bioactive compounds
medicinal plant	metabolite	cultivated ginseng	American ginseng	ginseng pathogens
cytotoxicity	UPLC-Q-TOF-MS	genetic diversity	plant conservation	*Burkholderia stabilis*
understory ginseng	HPLC	soil	Harvest	bacterial endophyte
fermentation	cultivated ginseng	cytotoxicity	climate change	quercetin
photosynthesis	saponin	leaf litter	medicinal plant	kaempferol
Korea	identification	RAPD	Araliaceae	metabolite
edible plants	phenolic compounds	pharmacopuncture	genetic diversity	bisphenol A
polyacetylene	bioreactor culture	transcriptome	trimethyltin	testicular toxicity
Allium tricoccum	adventitious roots	suitable site	IL-6	ethyl acetate extract
forest inventory	microorganism	calcium oxalate crystal	geoadditive model	biocontrol

		accumulation		
Actaea racemosa	Araliaceae	soil microbial community	open access resource	DPPH radicals

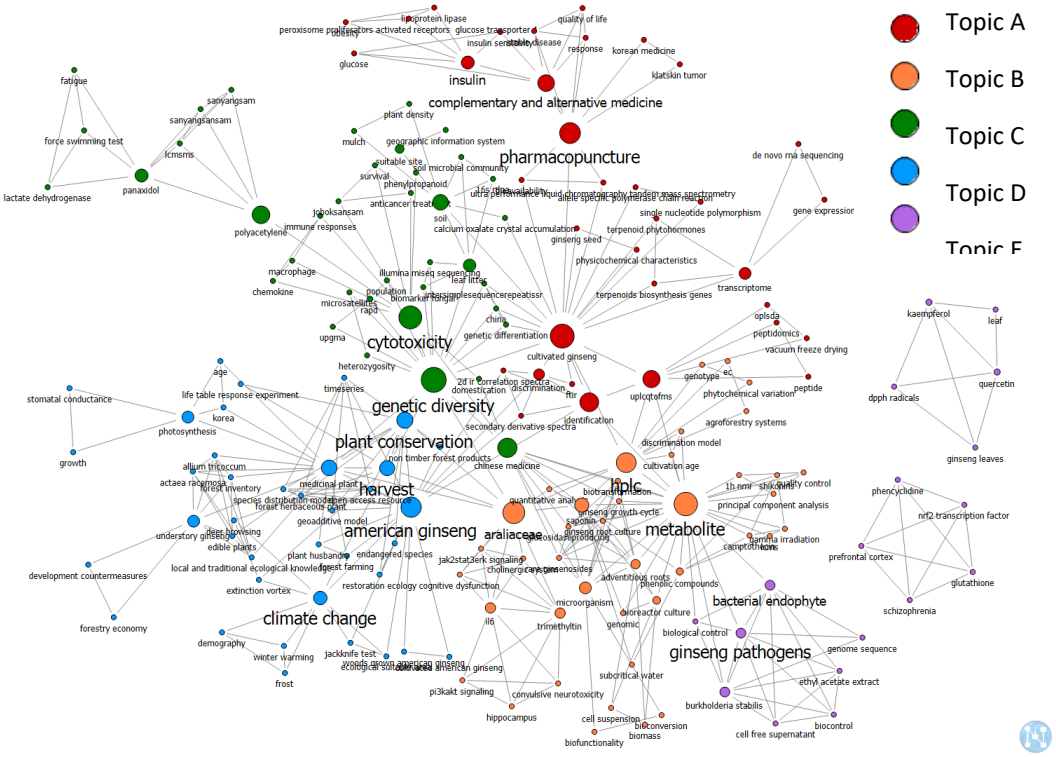

Fig. 3: Clustering of topics related to wild-simulated ginseng. The five resulting clusters are colored by topic group. The size of the nodes is proportional to the sum of the links, called centralities. The bigger size of nodes is, the greater the influence has in the network
* Topic A: Medicinal effects, Topic B: Metabolite analysis, Topic C: Genetic diversity, Topic D: Cultivation conditions, and Topic E: Bioactive compounds

Discussion

1-Studies on Wild-Simulated Ginseng by Country

Studies on WSG were mainly conducted in three countries, namely the Republic of Korea, China, and the USA (Figure 2). WSG studies in the Republic of Korea were evenly distributed into all topics, but studies from China and the USA were conducted on some dominant topics (Figure 3). Chinese researchers have focused more on Topic A, “Medicinal effects”, but less on Topic D, “Cultivation conditions”. On the other hand, the USA shows an opposite pattern, with more studies on Topic D, “Cultivation conditions”.

The Republic of Korea conducted the greatest number of studies on WSG based on a long history of WSG cultivation, since many studies have evaluated the therapeutic potency and cultivation technology of WSG since the first century (Artyukova et al. 2004). The second-largest number of WSG studies was conducted in China. Publications on WSG in China were mainly related to "Medicinal effects" (Topic A) and "Metabolite analysis" (Topic B). Chinese have been consuming ginseng since thousands of years as a traditional herbal

medicine due to its medicinal effects (Fu et al. 2014). Due its high medicinal value (Topic A), ginseng has been cultivated in large areas in China. Many studies have been conducted on its medicinal basis and application (Pan et al. 2013; Chang-Xiao and Pei-Gen 1992). Based on advanced research on the noteworthy medicinal effects of ginseng, such as modulation of immune functions and metabolic processes, anti-stress activity, and improvement of the memory process, various preparations of ginseng have been approved through metabolite analysis (Topic B) for clinical application in China (Chang-Xiao and Pei-Gen 1992). Lastly, the research on WSG in the USA has been shown in Figure 3. A number of studies have been conducted on "Cultivation conditions", classified as Topic D. For nearly 300 years, American ginseng has been harvested in large quantities in eastern and central North America, and it has been exported to China (Van der Voort and McGraw 2006). In 1975, however, American ginseng was listed in the CITES Appendix II (FREY ET AL. 2018). Since American ginseng was listed in Appendix II of CITES, early research on the growth and ecology of ginseng population was promoted, which can be explained as an opportunity to support many studies on WSG cultivation environment in the USA (Lewis 1998).

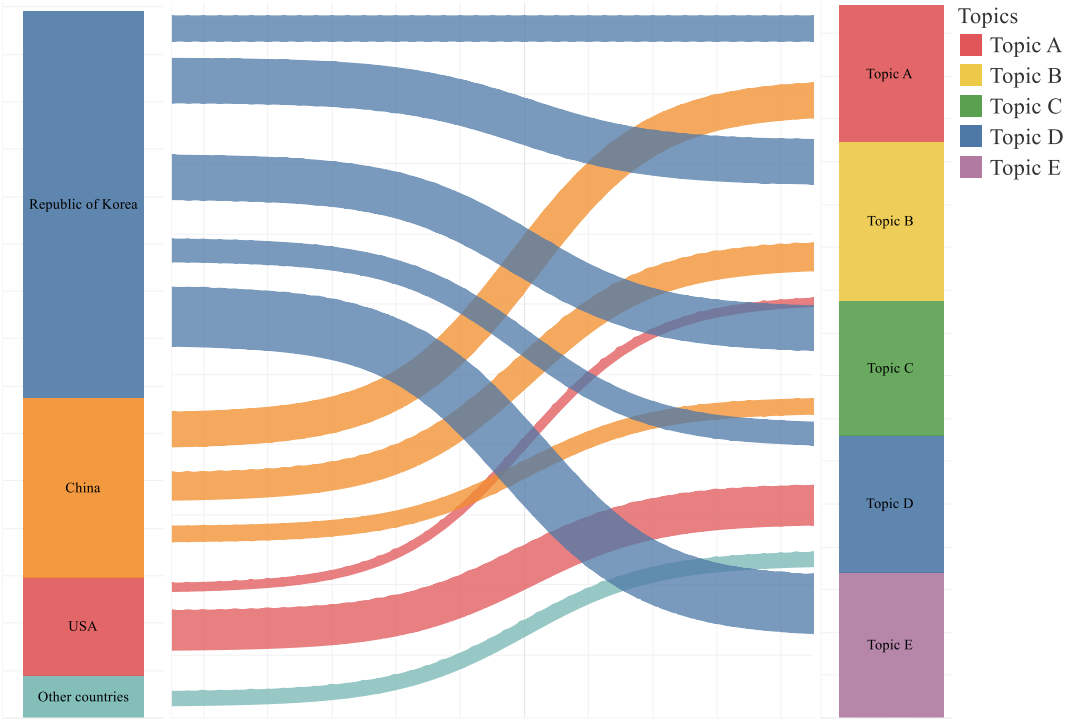

Fig. 3: Sankey diagram on topics of wild-simulated ginseng research. The flow diagram shows the country names on the left and aggregation into the five topics on the right. The dimension of rectangles on the right is proportional to the fields' prevalence. Colors are the same as in Figure 2 and 3.

* Topic A: Medicinal effects, Topic B: Metabolite analysis, Topic C: Genetic diversity, Topic D: Cultivation conditions, and Topic E: Bioactive compounds

2-Changing Topic Trends of Wild-Simulated Ginseng Studies

This study analyzed the changing trends in the share of topics over time by categorizing the results over 5 year-periods (Figure 4). Before 2005 (Period 1), Topic E, "Bioactive compounds", was the least studied topic (11.76%) and other topics had a similar share. In Period 2, however, Topic A, "Medicinal effects", was prominent (30.95%) and Topic C, "Genetic diversity", also received more attention with an increase of more than 6%. However, studies on Topic B, "Metabolite analysis", decreased significantly (9.52%). In Period 3, the proportion of studies on "Cultivation conditions", Topic D, increased by 10% (31.71%). On the other hand, the proportion of studies dealing with Topic A, "Medicinal effects", decreased from 30.95% (Period 2) to 13.41%

(Period 3). Recently, Topic E, “Bioactive compounds”, became the most prominent research area in Period 4 (24.72%), but the proportion of studies on Topic D declined. A decrease in the ratio of topic groups does not indicate a decrease in the number of keywords. Both, the number of articles and keywords on WSG, increased over time (Figure 4). Figure 4 shows changes in the relatively dominant topics of keywords along with the ratio values.

This approach is deeply related to the application of WSG in treating human diseases. It offers evidence of the contribution of WSG to enhance human health. The evidence is closely linked with value addition (Murthy et al. 2014) in the utilization of WSG. As the global interests in ginseng consumption increase in the market of health foods (Baeg and So 2013; Chung et al. 2011), this trend highlights a hidden potential for the expansion of the industrial market of WSG with a focus on bioactive metabolite traits for human well-being.

Period	Year	N
Period 1	~2005	34
Period 2	2006~2010	42
Period 3	2011~2015	82
Period 4	2015~2020	178

Fig. 4: Change in topic share by period

* Topic A: Medicinal effects, Topic B: Metabolite analysis, Topic C: Genetic diversity, Topic D: Cultivation conditions, and Topic E: Bioactive compounds

Conclusions/ wider implications of findings

This study explored WSG research trends using systematic review and topic modelling. The systematic review approach allowed us to examine the existing literature thoroughly with an obvious, repeatable, and minimal bias process to search, identify, select, evaluate, and aggregate research evidence. Topic modelling allows us to analyze what topics have been conducted and how the topic has changed recently. We found that the top keywords were related to anti-oxidation (Table 1), and research trends varied by country (Figure 3) and time period (Figure 4). Moreover, the research focus changed from the biological properties of WSG and its cultivation conditions to the precise identification and characterization of the bioactive metabolites of WSG. This change indicates an increased academic interest in the value-added utilization of WSG. The study offered dominant research keywords and topic categories of WSG studies. These results will contribute to understanding the trend of WSG research and designing future research on WSG.

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