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Consumers' perceptions of dietary supplements before and after the COVID-19 pandemic based on big data

Eunjung Lee [1], **Hyo Sun Jung** [2], **and Jin A Jang** [3]

[1]Food and Nutrition Major, School of Wellness Industry Convergence, Hankyong National University, Anseong 17579, Korea
[2]Center for Converging Humanities, Kyung Hee University, Seoul 02447, Korea
[3]Department of Nutritional Science and Food Management, Ewha Womans University, Seoul 03760, Korea

Correspondence to
Jin A Jang
Department of Nutritional Science and Food Management, Ewha Womans University, 52 Ewhayeodae-gil, Seodaemun-gu, Seoul 03760, Korea.
Tel: +82-2-3277-4427
Email: jja3913@ewha.ac.kr

ORCID iDs
Eunjung Lee
https://orcid.org/0000-0002-6064-7784
Hyo Sun Jung
https://orcid.org/0000-0002-3512-5597
Jin A Jang
https://orcid.org/0000-0002-4318-9355

ABSTRACT

Purpose: This study identified words closely associated with the keyword "dietary supplement" (DS) using big data in Korean social media and investigated consumer perceptions and trends related to DSs before (2019) and after the coronavirus disease 2019 (COVID-19) pandemic (2021).
Methods: A total of 37,313 keywords were found for the 2019 period, and 35,336 keywords were found for the 2021 period using blogs and cafes on *Daum* and *Naver*. Results were derived by text mining, semantic networking, network visualization analysis, and sentiment analysis.
Results: The DS-related keywords that frequently appeared before and after COVID-19 were "recommend", "vitamin", "health", "children", "multiple", and "lactobacillus". "Calcium", "lutein", "skin", and "immunity" also had high frequency-inverse document frequency (TF-IDF) values. These keywords imply a keen interest in DSs among Korean consumers. Big data results also reflected social phenomena related to DSs; for example, "baby" and "pregnant woman" had lower TD-IDF values after the pandemic, suggesting lower marriage and birth rates but higher values for "joint", indicating reduced physical activity. A network centered on vitamins and health care was produced by semantic network analysis in 2019. In 2021, values were highest for deficiency and need, indicating that individuals were searching for DSs after the COVID-19 pandemic due to a lack an awareness of the need for adequate nutrient intake. Before the pandemic, DSs and vitamins were associated with healthcare and life cycle-related topics, such as pregnancy, but after the COVID-19 pandemic, consumer interests changed to disease prevention and treatment.
Conclusion: This study provides meaningful clues regarding consumer perceptions and trends related to DSs before and after the COVID-19 pandemic and fundamental data on the effect of the pandemic on consumer interest in dietary supplements.

Keywords: dietary supplement; social media; big data; COVID-19 pandemic

INTRODUCTION

Coronavirus disease 2019 (COVID-19) has had a huge impact on human health and society as a whole worldwide. Each country has established quarantine policies and guidelines such as lockdowns, social distancing, restrictions on private gatherings, and strict regulations [1]. While these changes have increased negative life patterns related to health, including

reduced physical activity and increased intake of unhealthy foods, they have also increased the awareness of the importance of health and dietary supplements (DSs) for the prevention and recovery from the coronavirus, as well as interest in health maintenance [2,3]. During the COVID-19 pandemic, many people tried to maintain their health by consuming various DSs and functional foods that were expected to have beneficial effects [3]. Sales of DSs, including vitamins, soared as the pandemic grew in several countries, including Korea, the United States, the United Kingdom, and Poland [4-7]. In South Korea, sales of omega-3, vitamin D, krill oil, probiotics, and multivitamins have increased after the COVID-19 pandemic [8]. In addition, sales of red ginseng, known to help strengthen immunity, increased by 92.3% and those of probiotic-related products by 111.5% [9]. This increase was driven by consumer awareness that DSs and functional foods can protect against or mitigate the effects of infections due to the various "immunity-enhancing" claims of these products [5,10]. Indeed, several studies have demonstrated the effectiveness of these nutritional interventions as immune stimulants and protection against viral infections [11]. Vitamin D was associated with lower intubation rates and shorter hospital stays [12], and a large-scale survey of app-based communities in the United Kingdom, United States, and Sweden reported that individuals consuming probiotics, omega-3 fatty acids, multivitamins, and vitamin D had 14%, 12%, and 13% lower risks of contracting COVID-19, respectively [6].

The US Food and Drug Administration (FDA) [13] defines DSs as products that contain specific "dietary ingredients" such as vitamins, herbs, and minerals to "supplement the diet". Accordingly, consumers commonly use DSs not only to strengthen the immune system but also to recover from fatigue, supplement nutrition, and assist in weight gain and loss [14,15]. However, the reasons for consuming DSs are often complex, combining social, psychological, knowledge, and economic factors [16]. Supplement use reportedly increases with age, income, and education, and women are more likely to use supplements than men [17]. In addition, people using DSs are characterized by health-related habits, including better dietary patterns, higher physical activity, maintenance of normal body weight, and tobacco avoidance [17].

Recent consumer-related studies on DSs have mainly focused on DS users and their sociodemographic profiles [17,18], reasons for use [19,20], social-cognitive and psychological factors [21], health awareness and familiarity [22,23], and usage patterns [24]. In addition, studies on the knowledge and attitude regarding DSs among general consumers are being conducted [25-27]. However, consumers' perceptions of DS are believed to have changed amidst individual life, social, and environmental changes since the COVID-19 pandemic. Although consumer studies have been conducted, including those evaluating DS use [2,15] and DS-related behaviors and beliefs [25], they remain insufficient. In particular, few studies have reported on the changes in the perceptions of DS before and after the COVID-19 pandemic. The COVID-19 pandemic and the resulting changes in social trends have drastically altered consumer perceptions and consumption of DS, and we believe that studying their changed perceptions will provide important clues to understanding consumer behavior.

Owing to the recent development of information and communication technology, the use of smartphones has become commonplace, and social media is actively used, creating a vast amount of data [28]. Big data refers to data on an enormous scale, and generally refers to data that are difficult to process with general software technology owing to the large amount of standardized or unstructured data [29]. A technology to analyze very large data has recently been developed, which has enabled data analysis and created new values. Through big data,

it is possible to guess the thoughts of a large number of people by using the keywords of articles distributed online or on SNS or the analysis results of search keywords [30]. Big data has also been used in DS-related studies: Kamiński et al. [31] analyzed the popularity of DSs using Google search rankings, while Hamulka et al. [32] investigated the DS phenomenon during the COVID-19 pandemic using Google Trends analysis. Although big data are used in many research fields as an effective tool to capture meaningful trends and perceptions of the public, it is lacking in DS consumer-related fields. Moreover, big data is considered the best tool for examining consumer perceptions and changes in trends related to DSs before and after the COVID-19 pandemic. Big data analysis, which reflects consumers' opinions in their daily lives, is highly valuable for uncovering new insights and valuable implications that may not be revealed in existing studies utilizing interview or survey techniques [30]. Furthermore, given its ability to rapidly and accurately collect vast amounts of data accumulated from daily life and objectively analyze consumer opinions, we believe that big data on changes in perceptions of DS can provide crucial inspiration for DS consumer research.

This empirical study assessed DS consumer behavior before and after the pandemic as the demand for DSs increases in daily diets. This study aimed to explore consumers' perceptions and trends around DSs before and after the COVID-19 pandemic through the analysis of big data using social networks.

METHODS

Data and summary statistics

This study extracted the main keywords related to DS intake before and after the COVID-19 pandemic using big data retrieved from social media platforms and examined how search words related to DS changed after the onset of the pandemic. As data collection from social media is more generally used to analyze consumer trends, this study focused on social media. For data collection, relevant texts were retrieved from web pages, cafés (open social media communities), news pages, and blogs on social media platforms. This study used two social media platforms, *Naver* and *Daum*, which cover a wide range and volume of data. *Facebook* and *Instagram* were not used because of the difficulty of collecting information, as users often post such that only friends/followers can see. Social media cafés are useful in understanding consumers' ideas and decisions regarding certain issues. Blogs have comparative advantages in that they provide consumers' reviews on products and a glimpse at their consumption habits, which cannot be obtained from other channels because blogs contain all types of content, from users' emotions and information to their opinions on certain issues. Hence, this study extracted data from *Naver* and *Daum,* the most popular online platforms in South Korea in terms of user numbers, with a combined social media share of 80% [33].

This study focused on two 1-year data collection periods: the first period was the year before the coronavirus outbreak, between January 1, 2019, and December 31, 2019. The second period was 1 year after the onset of the COVID-19 pandemic, between January 1, 2021, and December 31, 2021. Data were collected using the keyword "dietary supplement" as a search term.

Methodology

To verify the changes in consumers' perceptions related to DSs before and after the COVID-19 pandemic, this study collected data from social media, cleaned it, and used the data for various analyses. General terms used in the corresponding domains were selected as search

keywords for data extraction. The final data were then selected by considering the relevance of the keywords to the data goals in a discussion with a domain expert. The research data were collected by a South Korean big data analysis company, the IMC Co., Ltd. (Daegu, Korea). In addition to the big data analysis solution TEXTOM developed by this company, Python, Excel, and NodeXL were used as analysis tools.

TEXTOM is a tool that automatically collects data from web portals via channels and conducts a comprehensive process including matrix creation. This tool has been used in multiple diverse studies in recent years. The present study employed the analysis methods of text mining, semantic networking, network visualization analysis, and sentiment analysis. Text mining is a method of extracting information and knowledge from unstructured text data. Using this approach, the researcher identifies core keywords by computing the frequency and the term frequency-inverse to the document frequency (TF-IDF) of the extracted words, and analyzes the meaning of the corresponding keywords. Using a semantic network approach, the interrelationships among the main keywords are analyzed, while checking the connection degree between the words and centrality values. Word groups are formed by clustering, and the network among the groups is visualized. Finally, sentiment analysis, a method of natural language processing, analyzes the subjective data demonstrated in texts, such as people's attitudes, opinions, and dispositions.

RESULTS

Content analysis

We conducted a search using "dietary supplement" as a keyword to understand consumers' perceptions of DS before and after the COVID-19 pandemic. A total of 37,313 keywords were found for the 2019 period (before the COVID-19 pandemic), and 35,336 keywords were found for the 2021 period (after the COVID-19 pandemic) using blogs and cafes on *Daum* and *Naver*. In general, 1,000 cases per channel are deemed sufficient when using TEXTOM, considering the speed of collection accuracy and the potential time problem that can occur in an exhaustive search. In addition, a morpheme analysis was conducted for words with frequencies > 10, with 4,771 and 4,692 words extracted for 2019 and 2021, respectively. For words with frequencies > 15, narrative coding was implemented in four categories (food/intake, needs/goal, sentiment/reaction, and object/association). The four categories were combined into two (needs/goal, sentiment/reaction), centered on the keyword "dietary supplement", and a cluster analysis was conducted for each year using the top 50 words from each category. Visualization was performed by using the top words from each cluster.

Text-mining analysis

Table 1 summarizes the results of the text-mining analysis conducted on data extracted using the keyword "dietary supplement" for 2019. Text mining identifies keywords on a certain issue by computing the term frequency and the TF-IDF of the terms extracted from the collected text data, which is useful for finding contextual meaning. Specifically, term frequency refers to how often a certain word appears in a document, with a higher frequency indicating the significant use of the word in a document. TF-IDF is a statistical value that represents the importance of a word in a certain document among a group of documents. As this value simultaneously accounts for irregularity among documents that contain the identified word together with term frequency, it is appropriate for short- and mid-term trend analyses.

Table 1. Text mining of DS (2019)

Rank	Word	Frequency	TF-IDF
1	dietary supplement	75,735	207.343
2	recommend	11,479	18,064.627
3	vitamin	11,108	18,409.107
4	health	6,386	12,966.012
5	children	4,975	11,846.089
6	feed	4,908	12,028.323
7	multiple	3,967	10,232.022
8	lactobacillus	3,456	8,950.852
9	eyelashes	3,222	11,722.895
10	intake	2,950	8,142.361
11	omega	2,851	8,169.358
12	effect	2,804	7,687.609
13	product	2,630	7,402.186
14	kids	2,575	8,728.438
15	request	2,431	6,994.644
16	day	2,411	6,782.573
17	method	2,305	6,780.577
18	calcium	2,251	7,327.589
19	baby	2,168	7,054.391
20	take	2,110	6,521.873
21	pregnancy	2,110	7,036.388
22	cooked food	2,076	6,448.854
23	lutein	2,072	7,292.119
24	sale	1,913	6,681.296
25	pregnant woman	1,901	6,718.035
26	help	1,855	5,775.720
27	efficacy	1,796	5,820.425
28	need	1,792	5,650.106
29	skin	1,777	6,474.500
30	immunity	1,756	6,055.779
31	gift	1,707	5,904.156
32	tiredness	1,686	6,003.743
33	management	1,672	5,469.734
34	woman	1,665	6,032.654
35	think	1,630	5,209.321
36	husband	1,614	5,560.641
37	hospital	1,604	5,295.576
38	food	1,582	5,272.056
39	ingredient	1,571	5,246.050
40	postscript	1,493	5,071.519
41	purchase	1,491	5,150.721
42	joint	1,467	5,636.729
43	magnesium	1,457	5,456.131
44	degree	1,441	4,760.585
45	nutrition	1,392	4,729.550
46	folic acid	1,335	4,884.750
47	good	1,302	4,476.998
48	use	1,300	4,647.748
49	morning	1,253	4,461.856
50	person	1,239	4,368.364

DS, dietary supplement; TF-IDF, term frequency-inverse document frequency.

The frequency analysis of the main keywords in 2019 extracted using "dietary supplement" as a search term revealed the highest frequency for "dietary supplement" followed by "recommend", "vitamin", "health", "children", "feed", and "multiple". Frequency refers to how often these words appeared in relation to the keyword "dietary supplement" before the COVID-19 pandemic. Therefore, the terms "recommend", "vitamin", "health", and "children" were most significantly used together with the keyword "dietary supplement". In the TF-IDF analysis, the

frequencies for "recommendation", "children", "calcium", "lutein", and "skin" were considerably higher than those for other keywords. Therefore, these words had high scarcity values in documents related to DS and were meaningful terms despite their rare appearances.

Table 2 presents the outcomes in 2021 (after the COVID-19 pandemic). The frequencies of the main keywords were high for "dietary supplement", "vitamin", "recommend", "health",

Table 2. Text mining of DS (2021)

Rank	Word	Frequency	TF-IDF
1	dietary supplement	73,140	138.819
2	vitamin	9,995	17,094.128
3	recommend	9,641	15,951.639
4	health	6,802	13,122.115
5	children	3,896	9,905.170
6	feed	3,394	9,266.295
7	intake	3,358	8,756.982
8	eyelashes	3,318	11,925.803
9	multiple	3,316	8,876.781
10	lactobacillus	3,285	8,690.008
11	omega	3,092	8,544.101
12	effect	2,573	7,203.996
13	product	2,528	7,067.438
14	joint	2,528	8,612.865
15	cooked food	2,246	6,696.479
16	pregnancy	2,230	7,473.507
17	essential	2,204	7,116.910
18	woman	2,184	7,402.041
19	take	2,150	6,563.135
20	help	2,104	6,193.611
21	management	2,078	6,269.955
22	efficacy	1,978	6,126.549
23	request	1,967	5,952.173
24	calcium	1,927	6,436.379
25	day	1,895	5,761.022
26	kids	1,867	6,831.645
27	postscript	1,813	5,706.330
28	think	1,768	5,406.594
29	immunity	1,746	5,969.601
30	need	1,706	5,339.476
31	lutein	1,690	6,011.123
32	method	1,638	5,283.402
33	gift	1,609	5,595.701
34	ingredient	1,593	5,230.509
35	skin	1,571	5,893.096
36	magnesium	1,543	5,582.954
37	purchase	1,513	5,065.710
38	folic acid	1,476	5,257.291
39	prepare	1,431	5,082.811
40	plant	1,417	5,337.785
41	pregnant woman	1,362	5,190.236
42	use	1,361	4,719.566
43	pack	1,356	4,615.251
44	man	1,314	5,106.768
45	because	1,305	4,356.752
46	baby	1,303	4,856.756
47	food	1,291	4,485.052
48	nail	1,262	5,470.611
49	hospital	1,253	4,370.319
50	start	1,231	4,233.525

DS, dietary supplement; TF-IDF, term frequency-inverse document frequency.

"children", "feed". and "multiple" similar to the outcome for 2019. However, the results of the TF-IDF analysis showed relatively higher frequencies for "recommend", "feed", "children", "calcium", "lutein", "skin", "woman", and "husband" than other keywords in 2021. In addition, the TD-IDFs values for "baby" and "pregnant woman" were higher before the COVID-19 pandemic, which may reflect the decreased marriage rate due to the pandemic and decreased birth rate through the pandemic.

Semantic network analysis

A semantic network, often linguistically and analytically called discourse analysis, is a way of understanding the correlations among co-occurring words. The present study used CONvergence of iteration CORrelation (CONCOR) analysis because the location and role of each node can be analyzed based on semantic network indicators. The main themes of a document group can be determined by calculating the degree, and page rank. The degree centrality helps to identify the direction of sharing and dissemination of information, where a higher degree indicates a strong relationship with other variables. A higher page rank value indicates the great popularity of the corresponding variable, meaning that connection lines are concentrated on nodes with important pages or information. Hence, this study conducted a semantic network analysis that combined needs/goals and sentiment/reaction regarding DS intake in 2019 and 2021.

Table 3 summarizes the results of the demand network analysis of the 2019 data that connects the needs and goals using "dietary supplement" as a retrieval keyword. The analysis confirmed that discourses on "need", "health", "gift", "vitamin", "cooked food", and "essential" were based on the degree centrality, and page rank values. The terms "vitamin" and "health" deserve attention, as they demonstrated the highest values in the needs analysis results related to "dietary supplement". Thus, information on "vitamin" and "management" was ranked the most important for the keyword search on "dietary supplement". Other than these terms, searches for information on "gift" and "need" were clearly observed. This result also demonstrated the obvious purpose of searching for "dietary supplements" on web portals. Next, each word group was clustered to visualize the network among the groups (**Fig. 1**). The visualization was categorized into "vitamin" and "management". This means that people who searched for "dietary supplements" in 2019 did so mainly to purchase vitamins among DSs, and that people searched for "dietary supplement" with the aim of health care. In particular, words such as "essential", "pregnancy", "preparation", "age", and "cooked food" were closely connected around "vitamin", indicating that they were related. Moreover, "health", "management", "need", "intake", "gift", etc. were closely connected to "dietary supplement".

The results of the 2021 analysis (**Table 3**) revealed the formation of discourses regarding "lack", "essential", "cooked food", "omega", "nutrition", "need", "health", "problem", and "mind". In particular, the keywords "lack" and "need" had the highest values in the results of the demand analysis. This means that the insufficient intake of DSs and an awareness of the need to take such supplements were at the base of searching for the keyword "dietary supplement". This was different from the needs/goals of 2019. Furthermore, the results of the demand network visualization indicate that the keywords most frequently linked to "dietary supplement" in 2021 were "lack", "nutrition", and "problem". This confirmed that the demand for "nutrition insufficiency" was driven by concerns about this issue and that users were aware of the problems associated with insufficient nutrition (**Fig. 1**). However, unlike in 2019, words such as "nutrition", "hospital", "treatment", and "prevention" were connected around "vitamin" while words such as "prevention", "health", and "hospital" were closely connected to "dietary supplement".

Table 3. Demand network index of DS in 2019 and 2021

Rank		2019				Rank		2021			
	Word	Degree centrality	Page rank	group	Category		Word	Degree centrality	Page rank	group	Category
1	management	99	1.225	1	demand	1	lack	97	1.159	1	demand
2	need	99	1.225	1	demand	2	essential	97	1.158	1	demand
3	health	99	1.225	1	demand	3	cooked food	97	1.158	1	food/intake
4	dietary supplement	99	1.225	1	food/intake	4	omega	97	1.158	1	food/intake
5	gift	98	1.214	1	demand	5	prepare	95	1.136	1	demand
6	intake	97	1.2	1	food/intake	6	lutein	92	1.105	1	food/intake
7	lack	94	1.169	1	demand	7	gift	94	1.125	1	demand
8	prevention	94	1.168	1	demand	8	recovery	92	1.105	1	demand
9	lactobacillus	96	1.189	1	food/intake	9	supplement	94	1.125	1	demand
10	calcium	94	1.167	1	food/intake	10	magnesium	93	1.114	1	food/intake
11	skin	94	1.167	1	demand	11	maintain	87	1.053	1	demand
12	maintain	86	1.084	1	demand	12	stress	90	1.083	1	demand
13	recovery	94	1.166	1	demand	13	capsule	92	1.102	1	food/intake
14	omega	95	1.176	1	food/intake	14	fatigue	88	1.062	1	demand
15	immunity	92	1.145	1	demand	15	meal	88	1.062	1	food/intake
16	joint	87	1.093	1	demand	16	nutrition	99	1.18	2	demand
17	magnesium	91	1.133	1	food/intake	17	need	99	1.18	2	demand
18	treatment	89	1.112	1	demand	18	health	99	1.18	2	demand
19	problem	87	1.091	1	demand	19	vitamin	99	1.18	2	food/intake
20	supplement	92	1.143	1	demand	20	dietary supplement	99	1.18	2	food/intake
21	vitamin	98	1.212	2	food/intake	21	food	98	1.17	2	food/intake
22	cooked food	97	1.2	2	food/intake	22	prevention	95	1.138	2	demand
23	food	97	1.199	2	food/intake	23	hospital	96	1.147	2	demand
24	essential	95	1.177	2	demand	24	improvement	95	1.136	2	demand
25	hospital	95	1.176	2	demand	25	immunity	95	1.136	2	demand
26	prepare	93	1.155	2	demand	26	dinner	91	1.095	2	food/intake
27	age	93	1.154	2	demand	27	treatment	93	1.115	2	demand
28	mineral	91	1.133	2	food/intake	28	reinforcement	88	1.063	2	demand
29	nutrition	93	1.153	2	demand	29	collagen	88	1.063	2	food/intake
30	herb	89	1.111	2	food/intake	30	nutrient	91	1.092	2	food/intake
31	diet	89	1.11	2	demand	31	problem	91	1.094	3	demand
32	improvement	90	1.12	2	demand	32	mind	95	1.138	3	demand
33	interest	90	1.12	2	demand	33	care	86	1.041	3	demand
34	stress	84	1.057	2	demand	34	childbirth	82	0.999	3	demand
35	health functional food	88	1.099	2	food/intake	35	age	96	1.147	3	demand
36	immune	86	1.077	2	demand	36	management	98	1.17	3	demand
37	lutein	86	1.077	2	food/intake	37	calcium	97	1.158	3	food/intake
38	tiredness	88	1.097	2	demand	38	lactobacillus	97	1.158	3	food/intake
39	pregnancy	86	1.075	2	demand	39	intake	98	1.169	3	food/intake
40	growth	86	1.075	2	demand	40	gum	64	0.808	3	demand

DS, dietary supplement.

The results of the 2019 sentimental network analysis connecting "dietary supplement" and sentiment/reaction (**Table 4**) formed discourses related to "food", "intake", "recommend", "help", "effect", "function", and "precaution". The network visualization results also produced four categories: "food", "dietary supplement effect", "function", and "precaution" (**Fig. 2**). These results indicated that people who searched for "dietary supplements" in 2019 were interested in foods that could replace DSs and wanted recommendations for supplements with stronger efficacy and effects. The individuals were also aware of the relevant concerns.

Table 4 summarizes the results of the 2021 sentiment network analysis connecting DS and sentiment/reaction. For sentiment regarding the keywords "dietary supplement" in 2021, discourses were formed about "effect", "lactobacillus", "postscript", "efficacy", "help", and
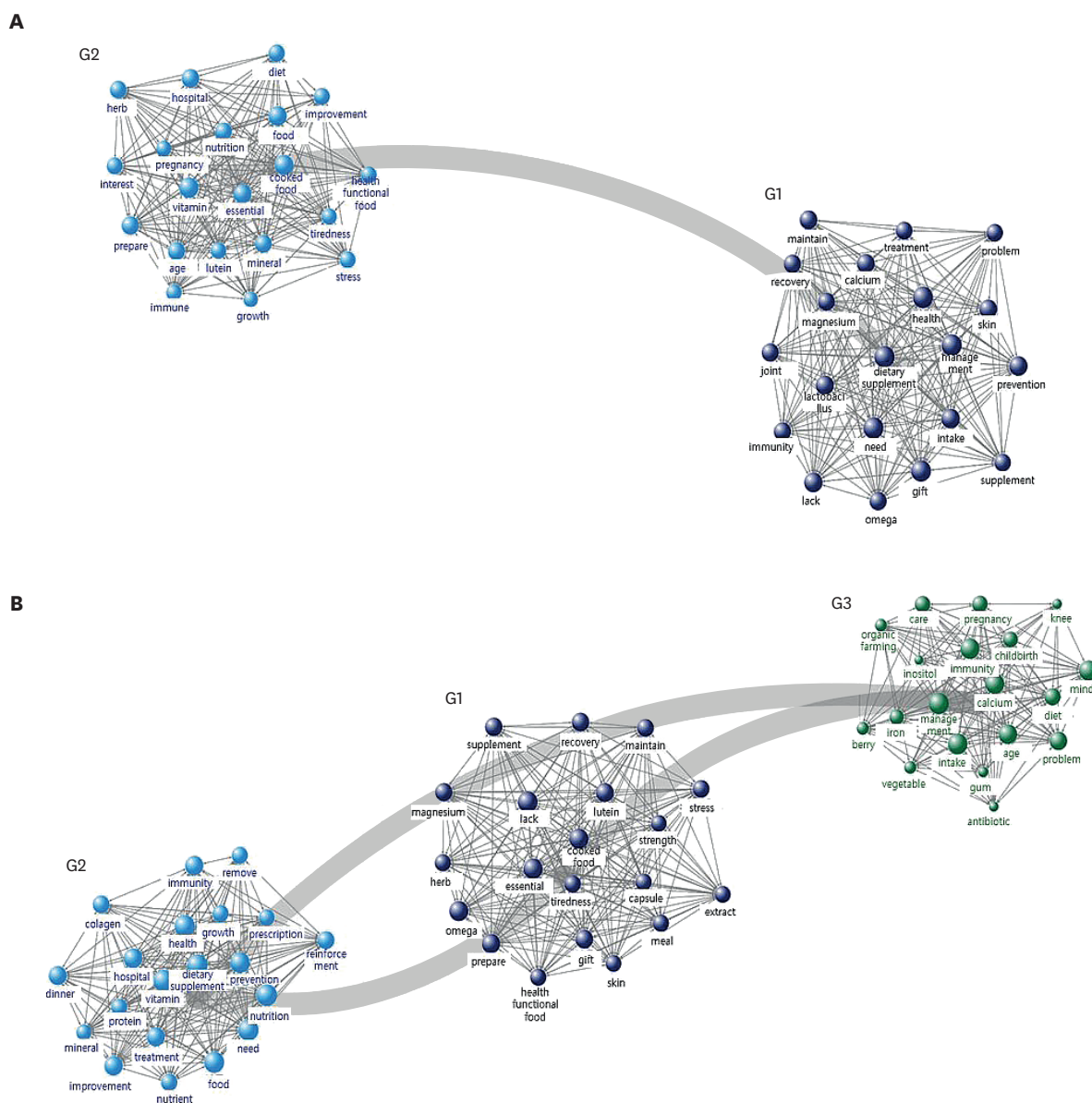
Fig. 1. Demand network visualization of DS in 2019 (A) and 2021 (B).
(A) G1: Management; G2: Vitamin. (B) G1: Lack; G2: Nutrition; G3: Problem.
DS, dietary supplement.

"recommend". The visualization indicated two categories of "postscript" and "help" (**Fig. 2**). Compared to 2019, users were more concerned about "effect", "efficacy", and "side effect".

Semantic network analysis

Positive and negative terms were extracted from the data, and sentiment analysis was conducted using these terms. Comparing 2019 and 2021 in terms of DS, the number of positive words decreased by 0.72% in 2021, and the number of negative words increased by 0.72%. Specifically, sub-emotions from a positive orientation (pleasure) decreased between 2019 and 2021, whereas sub-emotions from a negative orientation (pain, anxiety, and sorrow) increased during the same period.

Table 4. Sentimental network index of DS in 2019 and 2021

Rank		2019				Rank		2021			
	Word	Degree of centrality	Page rank	Group	Category		Word	Degree of centrality	Page rank	Group	Category
1	food	97	1.385	1	food/intake	1	effect	98	1.322	1	sentimental
2	intake	97	1.384	1	food/intake	2	lactobacillus	97	1.309	1	food/intake
3	recommend	97	1.384	1	sentimental	3	postscript	96	1.296	1	sentimental
4	cooked food	96	1.371	1	food/intake	4	efficacy	95	1.283	1	sentimental
5	magnesium	89	1.279	1	food/intake	5	ideal	94	1.272	1	sentimental
6	red ginseng	87	1.251	1	food/intake	6	worry	93	1.26	1	sentimental
7	worry	85	1.225	1	sentimental	7	important	90	1.224	1	sentimental
8	herb	84	1.21	1	food/intake	8	function	91	1.234	1	sentimental
9	lutein	83	1.197	1	food/intake	9	magnesium	91	1.234	1	food/intake
10	folic acid	82	1.184	1	food/intake	10	side effect	90	1.222	1	sentimental
11	mineral	80	1.16	1	food/intake	11	folic acid	89	1.21	1	food/intake
12	iron	76	1.108	1	food/intake	12	herb	86	1.175	1	food/intake
13	nutrient	80	1.155	1	food/intake	13	symptom	88	1.198	1	sentimental
14	protein	75	1.095	1	food/intake	14	lutein	87	1.184	1	food/intake
15	capsule	80	1.155	1	food/intake	15	capsule	82	1.124	1	food/intake
16	famous	74	1.082	1	sentimental	16	health functional food	84	1.147	1	food/intake
17	first	75	1.092	1	sentimental	17	nutrient	82	1.123	1	food/intake
18	propolis	72	1.055	1	food/intake	18	meal	80	1.098	1	food/intake
19	feeling	72	1.055	1	sentimental	19	protein	77	1.063	1	food/intake
20	milk thistle	73	1.067	1	food/intake	20	iron	77	1.063	1	food/intake
21	dietary supplements	99	1.415	2	food/intake	21	help	99	1.337	2	sentimental
22	help	98	1.401	2	sentimental	22	recommend	99	1.337	2	sentimental
23	effect	97	1.387	2	sentimental	23	vitamin	99	1.337	2	food/intake
24	efficacy	96	1.375	2	sentimental	24	dietary supplement	99	1.337	2	food/intake
25	vitamin	98	1.398	2	food/intake	25	intake	98	1.324	2	food/intake
26	lactobacillus	97	1.384	2	food/intake	26	cooked food	96	1.299	2	food/intake
27	calcium	95	1.359	2	food/intake	27	omega	97	1.309	2	food/intake
28	omega	95	1.356	2	food/intake	28	food	96	1.297	2	food/intake
29	ideal	95	1.356	2	sentimental	29	love	84	1.156	2	sentimental
30	side effect	89	1.282	2	sentimental	30	calcium	92	1.245	2	food/intake
31	postscript	92	1.317	2	sentimental	31	concern	89	1.21	2	sentimental
32	important	89	1.28	2	sentimental	32	first	83	1.139	2	sentimental
33	meal	86	1.244	2	food/intake	33	feeling	85	1.161	2	sentimental
34	dinner	81	1.177	2	food/intake	34	thanks	81	1.116	2	sentimental
35	question	81	1.176	2	sentimental	35	dinner	82	1.128	2	food/intake
36	symptom	85	1.223	2	sentimental	36	red ginseng	84	1.149	2	food/intake
37	best	78	1.137	2	sentimental	37	review	86	1.171	2	sentimental
38	love	75	1.101	2	sentimental	38	question	79	1.088	2	sentimental
39	thanks	79	1.148	2	sentimental	39	best	75	1.042	2	sentimental
40	concern	82	1.183	2	sentimental	40	collagen	81	1.11	2	food/intake

DS, dietary supplement.

DISCUSSION

This study identified words closely related to the keyword "dietary supplement" based on the analysis of big data from social media and investigated consumers' perceptions and trend changes in DS before and after the COVID-19 pandemic. The main findings of this study are as follows: in 2019, 37,313 DS-related keywords appeared in social media, compared to 35,336 in 2021. The keywords DS-related that frequently appeared in 2019 and 2021 were "recommend", "vitamin", "health", "children", "feed", and "multiple", which indicated the main perceptions that Korean consumers have about DS. These findings suggest people in Korea are generally interested in children's DSs, multiple DSs, vitamins, and *Lactobacillus* and also want to obtain recommendations for DS through social media. In addition, the high TF-IDF values for "calcium", "lutein", "skin", and "immunity" also reveal the main
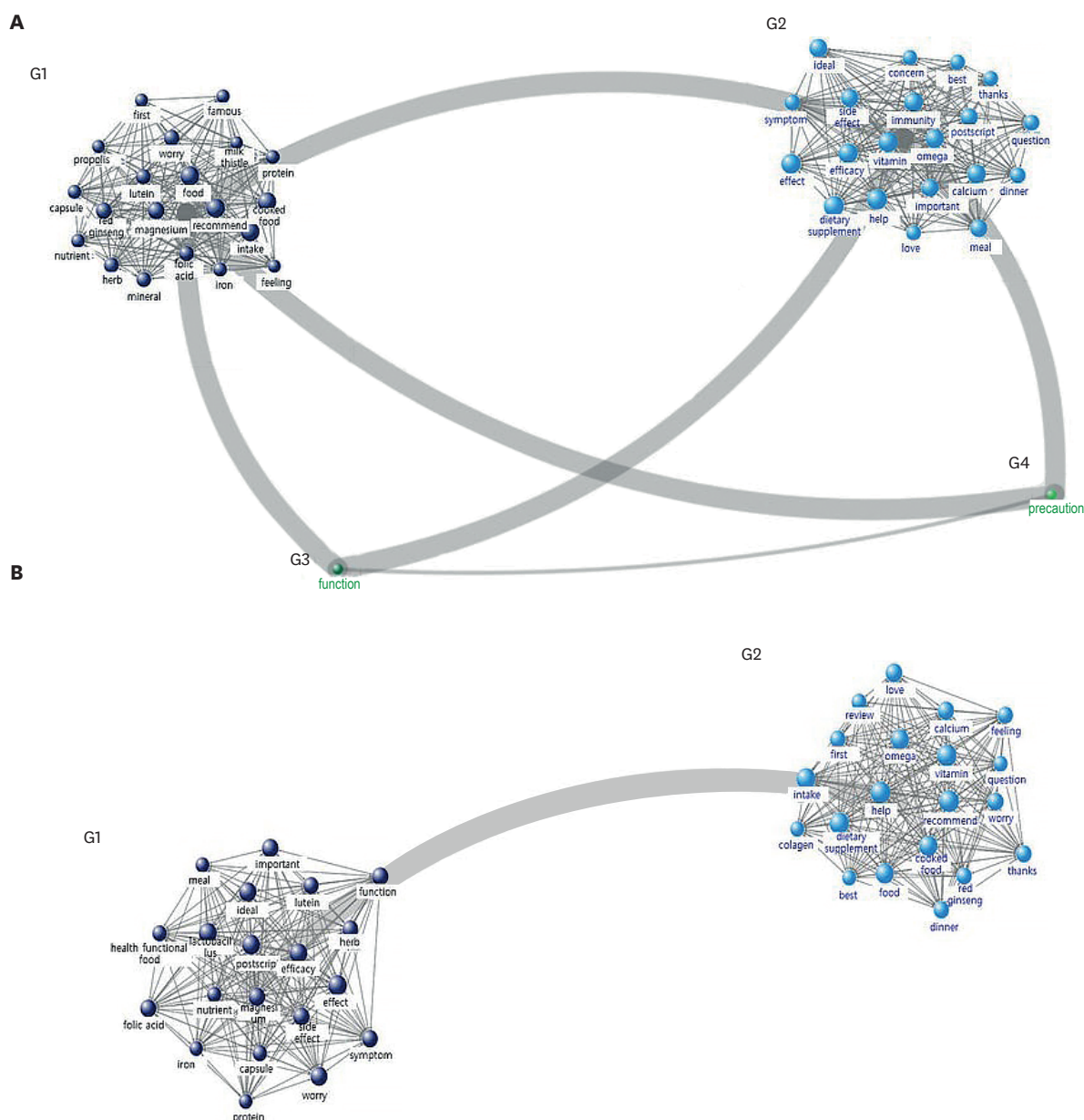
Fig. 2. Sentimental network visualization of DS in 2019 (A) and 2021 (B).
(A) G1: Food, G2: Dietary supplement, G3: Function, G4: Precaution. (B) G1: Postscript, G2: Help.
DS, dietary supplement.

perceptions related to DS. In this study, immunity improvement can be interpreted as a strong expectation of Korean consumers for DS before and after the COVID-19 pandemic. Global studies after the COVID-19 pandemic also reported similar trends [34]. In addition, "lutein" reflects an increased interest in eye health owing to the recent surge in smartphone use. In particular, as the prevalence of myopia increases worldwide due to decreased outdoor time and increased screen time after the COVID-19 pandemic, interest in and demand for lutein are also expected to increase [35]. According to the Korea Health Supplements Association, the lutein DS market grew by 67.8% in 2020 compared to 2019 [36]. Meanwhile, the big data results also reflected social phenomena related to DSs. Among the low TD-IDF values after the COVID-19 pandemic, "baby" and "pregnant woman" stand out. This is

attributable to the decreased marriage and birth rates after the pandemic and situations in which marriage and childbirth were postponed due to anxiety caused by the virus, as well as the effects of economic recessions not only in Korea but also in other countries [37]. One of the keywords with greatly increased TD-IDF values after the COVID-19 pandemic was "joint". A study that investigated changes in menopausal symptoms during the COVID-19 pandemic among middle-aged Korean women [38] reported that the participants had more severe symptoms than before the pandemic, especially bone and joint pain. A study in Japan that analyzed the contents of newspaper advertisements about DSs before and after the COVID-19 pandemic [39] reported significantly higher joint improvement-related content after the pandemic compared to before, and the difference was highest in ranking. The authors of both studies speculated that these observations had occurred due to decreased physical activity because of restrictions on going out due to the risk of COVID-19 infection. Another notable DS-related search term was "feed". The pet industry in Korea has grown rapidly, with 30% of the population raising companion animals. In addition, the industry has grown by 78% in 6 years, from 1.9 trillion won in 2015 to 3.4 trillion won in 2021 and is expected to reach 6 trillion won in 2027 [40]. In the case of overseas direct purchase shopping malls for domestic DSs, sales of DSs for companion animals have increased by more than 67% in the 2 years since 2019 [41]. Various product groups related to joint and bone health, oral, intestinal, eye, and skin health, including omega-3, are gaining popularity as DSs for companion animals [42].

The result of the semantic network analysis connecting demand/purpose with DS as keywords in 2019 showed a network centered on "vitamin" and "health management". This can be interpreted to mean that consumers who searched for DSs were mainly seeking vitamins, with high demands for DSs for healthcare. In contrast, in 2021, the values were highest for deficiency and need, in which the purpose of searching for DSs was a lack of nutrient intake and awareness of the need. In addition, before the COVID-19 pandemic, DS and vitamins were recognized as a need or purpose for health care in the life cycle, such as pregnancy. However, after the pandemic, the perception has changed to disease prevention and treatment. Mohsen et al. [3] reported that the pandemic significantly changed participants' attitudes toward DSs, perceiving that DSs supported health and strengthened immunity due to the belief that these nutrients are immune-boosting and have antiviral, antioxidant, and anti-inflammatory effects [11]. Because of these consumer perceptions, DS usage has increased since the COVID-19 pandemic and Korea's DS and health functional food market increased from 4.7 trillion won in 2019 to 5 trillion won in 2021. In the case of iHerb, a global health shopping mall specializing in DS, sales in the Korean market in 2021 increased by 22% compared to the previous year [42,43]. The top four products in sales that led to this increase were probiotics and vitamins. Probiotics showed a steep growth trend across all nutritional product groups, with probiotics increasing by 24.3% and multivitamins by 55.7% compared to the previous year [43]. Louca et al. [6] reported that during the lockdown in the United Kingdom in March 2020, vitamin C and multivitamins sales increased by 110% and 93%, respectively, resulting in a 19.5% increase in the DS market, while the US reported a 415% increase in sales during the 7 days of the peak of the COVID-19 pandemic. Hamulka et al. [32] performed a Google Trend analysis and cross-sectional study during the pandemic and reported increased consumption of vitamins C and D, zinc, omega-3, garlic, ginger, and turmeric during the March 2020 COVID-19 outbreak. A similar trend was also reported by Aysin and Urhan [34].

The results of the semantic network analysis connecting emotion/response to DSs before the COVID-19 pandemic revealed that consumers searching for DSs were thinking about food

replacements and wanted to obtain recommendations with high efficacy or effects. They also showed feelings of worry and concern about it. Meanwhile, after the COVID-19 pandemic, consumers were more concerned about functions and side effects in terms of effects and efficacy compared to before. Accordingly, positive keywords related to DS decreased by 0.72% after COVID-19, while negative keywords increased by 0.72%, leading to a decrease in the sub-emotions (joy) of the positive category and an increase in the sub-emotions (pain, fear, and sadness) of the negative category. In this study, the concerns about the function and side effects of DSs after the COVID-19 pandemic and the increased use of negative words can be interpreted in connection with the changes in needs and purposes described above. In other words, as the purpose of DS has changed to infectious disease prevention and treatment, consumers want to obtain information about the effect and efficacy of individual DSs in the COVID-19 pandemic. However, it is difficult to obtain sufficiently reliable information. Thus, negative emotions such as worry and fear increased. In addition, concerns and fear of COVID-19 may have led to the use of DSs. In a situation where a COVID-19 vaccine has already been developed but is not widely used, DSs were commonly used as one way to protect their health during the COVID-19 pandemic. This was linked to an interest in alternative therapies. For example, a study in Saudi Arabia highlighted the growing popularity of ginger, onion, and garlic among the Saudi population because of the belief that they can boost immunity and mitigate the possibility of developing COVID-19 [44]. Moreover, feelings of worry, panic, and anxiety in the medical emergency of the COVID-19 pandemic can lead to a heavy reliance on alternative therapies such as medicinal plants when drug treatment is not yet available [44]. Meanwhile, despite the popularity of DSs in the context of COVID-19, information on their effects and efficacy is insufficient. The Internet plays a pivotal role in health education [45]. The Web provides instant access to a variety of sources and interactions with other users. According to Ayer and Celep [15], who evaluated the use of DSs by Turkish people during the COVID-19 pandemic, 23.4% of respondents said that consumers used social media and the Internet as information sources about DS during the pandemic. Moreover, 90% of young French people perceived the Internet as a reliable source of health-related knowledge [46]. However, while the information consumers obtain leads to the purchase and consumption of DS products, information on social media can be misleading and is sometimes used for business purposes rather than for health promotion communication. Although DSs should be used only after receiving doctor's advice, Mohsen et al. [3] reported that only 24.8% of the participants took DSs according to the doctor's prescription. DS misuse and abuse can cause side effects. According to the US Drug-Induced Liver Injury Network, more than 20% of cases of liver damage are reportedly caused by herbs and DSs [47].

While the global DS market is growing significantly as interest in health has increased owing to the recent threat of infectious diseases, the COVID-19 pandemic has led to changes in consumer perception and consumption of DSs. In this context, the present study explored DS-related perception changes and trends before and after the COVID-19 pandemic. These study findings suggest the following industrial and academic implications. First, the big data in this study presented important keywords related to COVID-19 and DS, caused by recent social changes. Behind each of these words is the meaning of implied social change, and it will be necessary for product development and marketing approaches to grasp this closely. For example, in the case of joints, due to reduced physical activity caused by the COVID-19 pandemic, joint diseases in middle-aged and elderly people have worsened, resulting in a demand for nutrients that are good for joints. Lutein is associated with an increased prevalence of myopia owing to decreased outdoor activity and increased screen

time after the COVID-19 pandemic. In addition, keywords such as "eyelashes", "skin", and "nail" among the results of this study represent DS trends related to beauty. One major recent health-related trend in Korea is the so-called Healthy Pleasure phenomenon. In other words, while the reason for using DSs in the past was 'to avoid getting sick,' today's younger generations use it to 'be satisfied with their physical condition' [48]. They take various DSs such as solid stamina, skin beauty, and hair loss prevention; while taking them, they feel satisfied that they are managing themselves. The COVID-19 pandemic and these social trend shifts rapidly changed consumer perceptions and consumption of DSs; therefore, product development and marketing efforts in line with these changes are needed. Since non-face-to-face consumption has been strengthened due to the COVID-19 pandemic and with this change in consumption patterns expected to continue even after the end of the pandemic, the importance of online as a channel for consumers to acquire DS information and purchase will increase [49]. In addition, well-being influencers have recently shared their daily supplement regimens through social media, and followers' purchases of DSs through their sales channels are also increasing [50]. However, since the type and amount of DSs required differ depending on the individual's condition, and excessive intake or the combination of certain medications can cause serious side effects, it is necessary to consult a doctor when using DSs [3]. Concerns about DS function and side effects after the COVID-19 pandemic may be an indication of feelings amid heightened DS use. Therefore, according to the recent DS information acquisition and purchasing environment, the government should support online platforms for easy and accurate access to relevant information on DSs and campaigns to prevent the indiscriminate consumption of DSs.

Unlike previous studies that have conducted empirical research with a limited sample, this study utilized a large amount of big data to compare consumer perceptions of dietary supplements before and after COVID-19 to identify direct changes brought about by the pandemic. This provides inspiration for future research on DS-related consumer behavior after the pandemic. For example, it will be possible to study the differences in changed consumer behaviors between the middle-aged and younger generations seeking 'healthy pleasure' DSs after the COVID-19 pandemic, as well as how consumers' DS-related perceptions have changed between before and after the pandemic and after escaping the threat of COVID-19. As an increasing number of consumers are looking for healthy functional foods given individual health conditions, the DS market is also rapidly changing, with the emergence of a customized health functional food market based on genetic test results and technologies, such as artificial intelligence (AI) and big data. Therefore, further research is needed on consumers' perceptions of self-care and self-treatment using DS. In such research, big data is a good tool to identify changes and trends in consumer perceptions in an objective and comprehensive context, and we believe this paper can provide a good guide.

This study has several limitations. First, this study investigated consumers' DS-related perceptions before and after the COVID-19 pandemic. As this topic is rarely reported, it is difficult to discuss in depth due to the lack of related studies. Second, the big data in this study was extracted from portal site data that is widely used in Korea. Therefore, the results of this study are mainly related to the Korean market as the main consumer base is Korean-speaking consumers. Therefore, based on these limitations, follow-up studies should be conducted by applying relevant data in each country. Even if the targets and research methods used in this study are applied to other countries, different significant results can be drawn only in that country. Third, this study analyzed big data with a rather comprehensive keyword of DSs and it is difficult to understand in detail consumers' perceptions of individual DSs

such as vitamins and probiotics. This topic warrants further investigation through additional big data analyses or qualitative research on individual nutritional supplements.

This study empirically examined consumers' perceptions and trends in DSs before and after the COVID-19 pandemic through an analysis of big data. Our results provide meaningful clues regarding the DS industry and social changes. Moreover, our findings provide important basic data for understanding consumers after the COVID-19 pandemic in DS consumer-related research fields and industries.

SUMMARY

This study identified words closely associated with the keyword DS based on big data in Korean social media and investigated consumers' perceptions and trends related to DSs before (2019) and after the COVID-19 pandemic (2021). The results were derived through analysis methods such as text mining, semantic networking, network visualization analysis, and sentiment analysis. The DS-related keywords that frequently appeared before and after COVID-19 were "recommend", "vitamin", "health", "children", "multiple", and "lactobacillus". Keywords "calcium", "lutein", "skin", and "immunity" also showed high TF-IDF values. These keywords implied a main interest in DSs among Korean consumers in recent years. The big data results also reflected social phenomena related to DSs; for example, "baby" and "pregnant woman" showed lower TD-IDF values after the pandemic, suggesting lower marriage and birth rates, whereas the higher values for "joint" indicated reduced physical activity due to the COVID-19 pandemic. The semantic network analysis in 2019 formed a network centered on vitamins and health care. However, in 2021, the values were highest for deficiency and need, indicating that individuals were searching for DSs after the COVID-19 pandemic due to a lack of nutrient intake and an awareness of the need. Before the pandemic, DSs and vitamins were related to health care in the life cycle, such as pregnancy; however, after the COVID-19 pandemic, the results of this study confirmed the changed perception has changed to disease prevention and treatment. This study identified meaningful clues regarding consumer perceptions and trends related to DSs before and after COVID-19, providing fundamental data to understand consumers' post-pandemic in DS consumer-related research fields and industries.

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