Patents

https://doi.org/10.1038/s41587-024-02410-0

The global patent landscape of functional food innovation

An analysis of patent documents reveals a trend of increasing interest in functional food innovations that may aid future decision-making in research, business and policymaking.

Functional foods are broadly defined as food products that contain specific ingredients providing health benefits that go beyond mere nutritive value, with polyunsaturated fatty acids (for example, omega-3 fatty acids), antioxidants, and probiotics, prebiotics and synbiotics being several of the best-known examples[1]. In the European Union, a specific prominent example of a functional food approved by the European Food Safety Agency (EFSA) as a cardioprotective agent is a tomato extract that reduces platelet aggregation and has a similar effect, although different pathway activity, to acetylsalicylic acid[2,3].

Technogenic environmental pollution, changes in nutritional structure and quality, decreased human motor activity, obesity, widespread chronic diseases and population aging collectively pose an increased burden for the functioning of many body systems. In this context, it is possible for individuals to improve their quality of life by improving nutrition and consuming products with functional health-enhancing purposes[4]. Nutrition in general is one of the most important components of a lifestyle and is known to have great impact on a person's health. The consumption of functional foods can help solve many problems—substantially reducing the incidence of disease due to their preventive effects; accelerating recovery from serious diseases due to their balanced composition; providing healthy nutrition for people with insufficient quantity or quality of traditional products available; enriching the habitual diet of all segments of the population with vitamins, minerals and other nutrients; increasing mental and physical endurance; and helping the population to cope with stress and possible psychological disorders[5].

Patents are granted by governments to inventors to provide legal protection of their intellectual property (that is, developed inventions or innovations). They disclose details about the respective invention or innovation, which are often made public in patents before being published in academic articles[6] on the subject or even are never published as such (as companies involved in inventions sometimes encourage their employees to exclusively

Table 1 | Number of patent documents labeled with the diverse functional food CPC codes

CPC code	Definition	Patent document number
*A23V 2200/30	Foods, ingredients or supplements having a functional effect on health	8,412
**A23V 2200/302	...having a modulating effect on age	1,820
**A23V 2200/304	...having a modulation effect on allergy and risk of allergy	1,088
**A23V 2200/306	...having an effect on bone mass, for example, osteoporosis prevention	2,098
**A23V 2200/308	...having an effect on cancer prevention	4,027
**A23V 2200/31	...having an effect on comfort perception and well-being	1,071
**A23V 2200/312	...having an effect on dental health	640
**A23V 2200/314	...having an effect on lung or respiratory system	1,138
**A23V 2200/316	...having an effect on regeneration or building of ligaments or muscles	1,517
**A23V 2200/318	...having an effect on skin health and hair or coat	5,826
**A23V 2200/32	...having an effect on the health of the digestive tract	3,139
***A23V 2200/3202	...Prebiotics, ingredients fermented in the gastrointestinal tract by beneficial microflora	942
***A23V 2200/3204	...Probiotics, living bacteria to be ingested for action in the digestive tract	1,721
**A23V 2200/322	...having an effect on the health of the nervous system or on mental function	5,320
**A23V 2200/324	...having an effect on the immune system	5,829
**A23V 2200/326	...having effect on cardiovascular health	2,575
**A23V 2200/3262	...having an effect on blood cholesterol	2,167
**A23V 2200/328	...having effect on glycemic control and diabetes	4,111
**A23V 2200/33	...High-energy foods and drinks, sports drinks	531
**A23V 2200/332	...Promoters of weight control and weight loss	4,264
***A23V 2200/3322	...Low carb—reduced carbohydrate content	226
***A23V 2200/3324	...Low fat—reduced fat content	297
**A23V 2200/334	...treating the effects of consuming alcohol, narcotics or other addictive behavior, for example, treating hangover or reducing blood alcohol levels	1,392

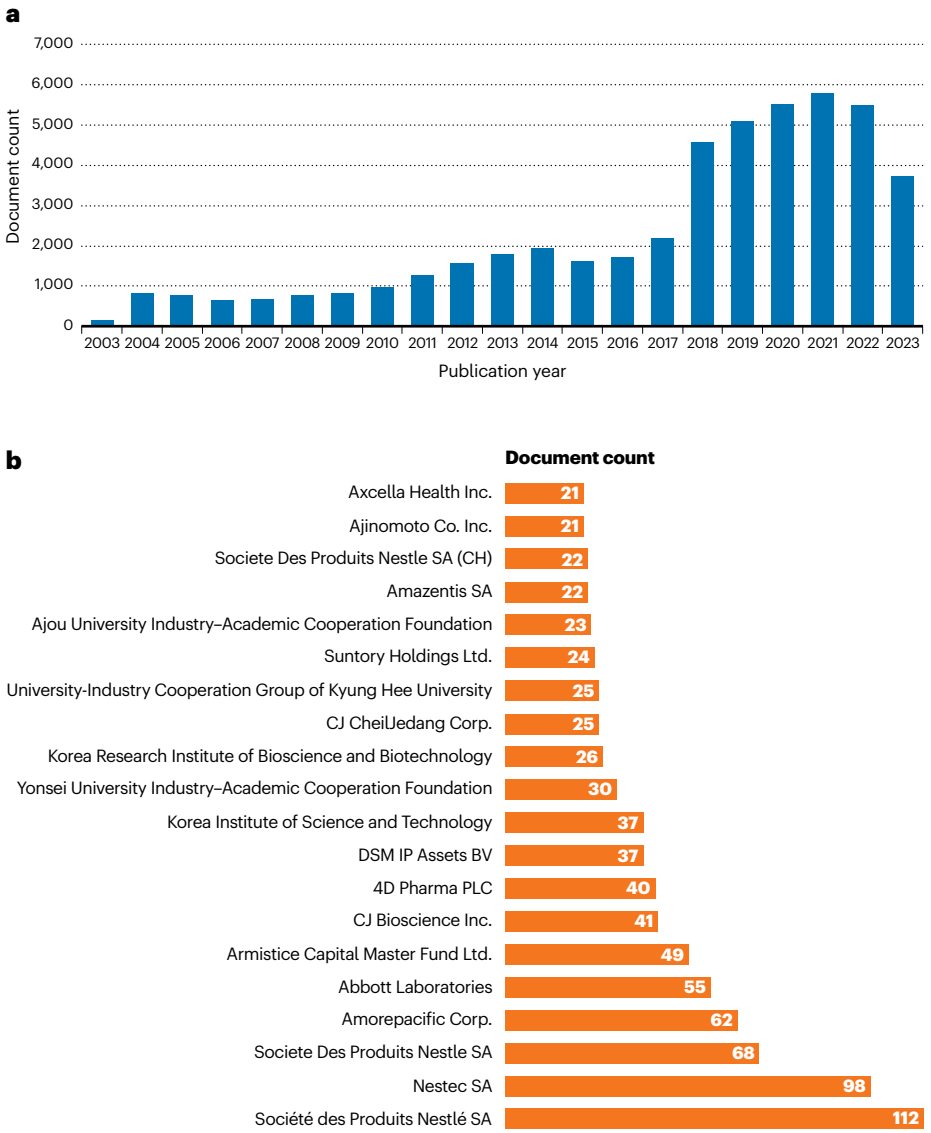

Fig. 1 | Annual publication numbers and top patent owners of the functional food patent documents. a,b, Patent publication counts per year (**a**) and the top 20 patent owners (**b**) of the functional food patent documents from the past 20 years. In **a**, the annual counts for 2003 and 2023 are artificially low because of the timing of the covered period (from 1 October 2003 to 1 October 2023). "Societe Des Produits Nestle SA" is an earlier version of the business name "Société des Produits Nestlé SA."

pursue intellectual property protection and not scientific publications).

Patent classification codes are used to organize and categorize patents on the basis of the type of invention or innovation involved. The Cooperative Patent Classification (CPC) represents an extension of the International Patent Classification that is jointly managed by the United States Patent and Trademark Office and the European Patent Office (https://www.cooperativepatentclassification.org/home). Importantly, the CPC provides a dedicated general code for functional foods—A23V 2200/30, dedicated to "Foods, ingredients or supplements having a functional effect on health"—as well as 22 subgroups of this code designated for functional foods targeting specific health indications. For example, A23V 2200/302 more specifically covers functional foods with a modulating effect on aging. In general, patent protection is granted for a limited time period (usually 20 years) from the date of the application, in order to stimulate further innovation, prevent monopoly and benefit society by making the innovation accessible once the patent expiration date has passed (https://www.wipo.int/).

The size of the global market for functional foods was estimated at $305.4 billion in 2022. According to experts, it is expected to reach approximately $597.1 billion by 2032, expanding at a compound annual growth rate of 6.93% between 2023 and 2032 (https://www.precedenceresearch.com/functional-food-market). Studying the current state, directions and trends in the creation of functional foods on the basis of patent information can help one track advanced achievements in this sphere in

Table 2 | The most cited functional food patent documents

Patent document	Title	Citations
WO 2014/082050 A1	Synergistic bacterial compositions and methods of production and use thereof	131
WO 2007/095638 A2	Boron-containing small molecules as anti-inflammatory agents	125
WO 2011/110918 A1	Composition comprising probiotic bacteria for use in the treatment of immune disorders	106
WO 2014/075745 A1	Use of *Akkermansia* for treating metabolic disorders	104
WO 2010/144508 A1	Glucose-regulating polypeptides and methods of making and using same	86
US 2012/0171166 A1	Synbiotic combination of probiotic and human milk oligosaccharides to promote growth of beneficial microbiota	85
KR 100972116 B1	Method of producing fermentation of herbal medicine, the fermentation produced thereby, and food comprising the fermentation	84
US 2009/0181114 A1	Chia seed beverage and related method	76
WO 2017/148596 A1	Compositions comprising bacterial *Blautia* strains for treating visceral hypersensitivity	71
US 2017/0143774 A1	Compositions comprising bacterial strains	71

order to find business partners, monitor the activities of actual and potential competitors, and find suitable markets. This research not only ensures users a high technical level and competitiveness of products, but also reduces the cost of their creation by eliminating duplication of research and development. Here, we aimed to investigate the patent documents in the Lens patent database that are covered by CPC codes assigned to functional foods from the past 20 years, to gain quantitative insights and characterize the landscape of recent functional food innovations.

Results

We queried the Lens patent database (https://www.lens.org/), which contained 151,313,881 patent documents as of the time of the search, on 7 November 2023 to identify patent records from the last 20 years (from 1 October 2003 to 1 October 2023) tagged with at least one of the 23 CPC codes designated for functional foods (Table 1 and Supplementary Methods). The search yielded 47,996 patent documents. Annual document counts increased over time and ranged between 169 (in 2003) and 5,782 (in 2021) (Fig. 1a). Among the top 20 patent owners (Fig. 1b), the largest number of patents belonged to the Société des Produits Nestlé SA (112 patents), while Axcella Health Inc. was ranked 20th (21 patents).

Analysis of the distribution of patent documents among the 23 functional food CPC codes (Table 1) indicated that the largest number of patent documents (8,412) belonged to A23V 2200/30 (the most general category, "Foods, ingredients or supplements having a functional effect on health") and the lowest number (226) to A23V 2200/3322, which is assigned to reduced-carbohydrate-content products aimed to support weight loss.

The top ten most cited functional food patent documents (Table 2) had between 131 citations (WO 2014/082050 A1, entitled "Synergistic bacterial compositions and methods of production and use thereof") and 71 citations (US 2017/0143774 A1, "Compositions comprising bacterial strains"). The top ten scientific publications most often cited in functional foods patent documents (Table 3) have been cited between 37[7] and 16 times[8].

To identify frequently mentioned diseases and food crops in the titles of the functional food patent documents, the patent document details were extracted, saved in comma-separated value format (.csv) and subjected to further analysis using Python (see Supplementary Methods). The top ten diseases occurring most frequently in the titles of the functional food patent documents were mentioned between 668 ("Obesity") and 201 ("Respiratory disease") times (Fig. 2a), and the top ten most frequently referenced food crops were mentioned between 665 ("Rice") and 87 ("Radish") times (Fig. 2b).

Discussion

In this work, we analyzed the patent documents indexed in the Lens database (with 151,313,881 patent documents as of the time of the search) that were tagged with the 23 CPC codes designated to functional foods in the last 20 years. We identified 47,996 functional food patent documents, which were analyzed for time of publishing, top patent owners, citations, distribution according to CPC code subgroups, most cited academic publications, and most frequently mentioned diseases and food crops in the document titles.

Previous studies with relevance to functional food patents have examined the patent documents associated with specific countries, foods or food groups. At the country-specific level, Wong et al. discussed regulations and features associated with functional food patents in the United States on the background of several high-profile Supreme Court rulings, including *Mayo*, *Myriad* and *Alice*[9]. An examination of the functional food patent application records in Brazil for the period 2008–2020 identified and analyzed 608 patent documents[10], whereas other, even more narrowly focused studies have examined patent applications related to selected functional food products, such as pomegranate juice[11] and plant food supplements with potential benefits in neurodegenerative and metabolic disorders[12]. In contrast to these previous works, the present study was designed to yield quantitative data on the worldwide functional food patenting trends, without limitations imposed by focusing of specific food or food group.

We selected the 20-year time frame to cover patent documentation that is still active, as patent protection is usually granted for 20 years. The annual number of patent documents has significantly increased in the course of the study period, from less than 1,000 published patent documents per year before 2000 to over 5,000 documents per year in the most recent few years (Fig. 1a). This trend is in line with the increasing market demands for foods and nutraceuticals with health-promoting properties, which was further accelerated by the COVID-19 pandemic that caused consumers to seek additional means to improve their health for better protection[13,14].

Regarding the identified top patent owners (Fig. 1b), the top three owners were related to the Switzerland-based corporation Nestlé SA. This finding accords with Nestlé's status as a leading publicly held food company, which is in the *Fortune* Global 500 ranking of the top 500 (by revenue) corporations worldwide (https://fortune.com/ranking/global500/) and has well-established interests[15,16] in functional food developments.

Table 3 | The scientific publications most often cited in the functional foods patent documents

Citations	Title	Authors, journal, volume and pages
37	Dietary modulation of the human colonic microbiota: introducing the concept of prebiotics	Gibson, G. R. & Roberfroid, M. *J. Nutr.* **125**, 1401–1412 (1995)
30	Probiotics: how should they be defined?	Salminen, S. et al. *Trends Food Sci. Technol.* **10**, 107–110 (1999)
22	Molecular-phylogenetic characterization of microbial community imbalances in human inflammatory bowel diseases	Frank, D. N. et al. *Proc. Natl Acad. Sci. USA* **104**, 13780–13785 (2007)
22	Dosage-related bifidogenic effects of galacto- and fructooligosaccharides in formula-fed term infants	Moro, G. et al. *J. Pediatr. Gastroenterol. Nutr.* **34**, 291–295 (2002)
21	Th17 cell induction by adhesion of microbes to intestinal epithelial cells	Atarashi, K. et al. *Cell* **163**, 367–380 (2015)
21	A decrease of the butyrate-producing species *Roseburia hominis* and *Fecalibacterium prausnitzii* defines dysbiosis in patients with ulcerative colitis	Machiels, K. et al. *Gut* **63**, 1275–1283 (2014)
20	Basic laboratory culture methods for anaerobic bacteria	Strobel, H. J. *Methods Mol. Biol.* **581**, 247–261 (2009)
20	Microencapsulation of probiotic bacteria: technology and potential applications	Kailasapathy, K. *Curr. Issues Intest. Microbiol.* **3**, 39–48 (2002)
17	*Eubacterium limosum* ameliorates experimental colitis and metabolite of microbe attenuates colonic inflammatory action with increase of mucosal integrity	Kanauchi, O. et al. *World J. Gastroenterol.* **12**, 1071–1077 (2006)
16	Gut microbe-derived extracellular vesicles induce insulin resistance, thereby impairing glucose metabolism in skeletal muscle	Choi, Y. et al. *Sci. Rep.* **5**, 15878–15878 (2015)

In regard to the disease areas targeted by the patent documents, the analysis of the 23 functional food CPC codes (targeting diverse indications, Table 1) not surprisingly revealed that the highest number of patent documents (8,412) belonged to the most general category code (A23V 2200/30), "Foods, ingredients or supplements having a functional effect on health." This aligns with the rationale that using this code would provide the broadest coverage of diverse disease indications. Further, numerous patent documents were designated for indications such as weight loss (4,264 documents), glycemic control and diabetes (4,111 documents), immunomodulation (5,829), mental health (5,320), health of skin and hair (5,826) and cancer prevention (4,027). These indications mostly align well with the global burden of diseases, with prominent representation of conditions associated with inflammation and metabolism (for example, diabetes, obesity, cardiovascular diseases), cancers and mental-health-related disorders[17], which have both high prevalence and severity. One notable deviation is the high observed number of patent documents for skin and hair health, as skin- and hair-associated conditions are often less severe than the other referenced conditions.

Examination of the top ten most cited patent documents (Table 2) indicates that themes related to bacterial compositions, fermentation and probiotics predominate, but also reveals a diversity of innovations targeting other impactful topics, such as boron-containing anti-inflammatory molecules (WO 2007/095638 A2), glucose-regulating polypeptides (WO 2010/144508 A1) and chia seed beverages (US 2009/0181114 A1). The dominant roles of bacterial compositions, probiotics and prebiotics among the functional food patent documents was even more evident in the top ten list of the most referenced academic papers, as all of them dealt with these themes (Table 3). This trend reflects the growing body of evidence showing the key role of gut microbiota in regulating numerous health conditions[18,19], as well as the possibility of regulating microbial flora through foods or food ingredients[20,21]. In this context, it is also worth noting the comparably high number of patent documents for functional foods with effects on the health of the digestive tract (A23V 2200/32, $n = 3{,}139$; Table 1).

Similarly to the outcomes of the evaluation of functional food CPC codes (Table 1), the analysis of the most frequently mentioned diseases in the titles of functional food patent documents (Fig. 2a) revealed fairly good correlation with the global burden of life-threatening diseases, with a notable exception again being conditions related to skin and hair, in particular "hair loss" (mentioned 342 times, making it the third most frequently mentioned disease condition). Few functional foods have been reported so far in the scientific literature to counteract hair loss. For example, preclinical research with *Equisetum debile* extracts reported a range of activities counteracting hair loss, including inhibition of 5α-reductase and IL-6 secretion, along with antioxidant activity[22], and a pilot clinical study indicated that a kimchi and cheonggukjang probiotic product induce hair growth promotion and reversal of hair loss[23]. Nevertheless, the scarcity of research on the topic and the relatively low severity of the condition (as compared to other diseases in the top ten list, Fig. 2a) make the high prevalence of functional food patent documents targeting hair loss rather unexpected. This finding could be related to the high prevalence of hair loss in the population[24] and the perceived high importance of the condition from a psychological perspective[25].

Rice and soybean were by far the most commonly mentioned food crops in the titles of the functional food patent documents (Fig. 2b). Because rice is one of the most common staple foods worldwide, it comes as no surprise that extensive innovation efforts have been invested to improve its health-promoting properties. A notable example is the "Golden Rice" engineered to produce β-carotene and intended to be delivered to populations deficient in vitamin A[26]. Nevertheless, other prominent staple food crops, such as wheat and corn, were not in the top ten list (Fig. 2b). Instead, garlic was ranked in third place, and potato (another common staple food) was also present, along with turmeric (a spice, also known as curcuma), coffee (reflecting its status as one of the most common beverage commodities) and mulberry (representing a berry

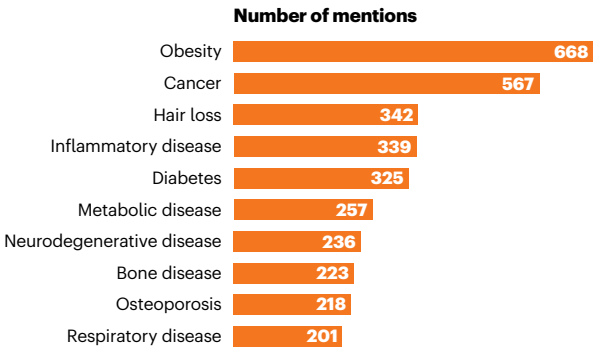

Fig. 2 | Most frequently mentioned diseases and food crops in the titles of the functional food patent documents. a,b, Number of mentions of the top ten diseases (**a**) and the top ten food crops (**b**) in the titles of the functional food patent documents from the past 20 years.

fruit with well-established health-promoting properties[27]), among others (Fig. 2b).

Conclusions

Focusing on the last 20 years, we examined the functional food patent literature for the first time at international scale. Increasing interest in functional food innovations is observed, with fewer than 1,000 documents published annually before the year 2000 and more than 5,000 documents published annually in the past few years. Examination of the 47,996 patent documents identified revealed Nestlé SA to have by far the largest portfolio of functional food patents. Frequently targeted were disease areas with both high worldwide burden and severity (for example, metabolic, inflammatory and respiratory diseases, cancer, neurodegenerative diseases), with hair loss being one notable deviation representing a less severe condition covered by disproportionately large number of patent documents. Probiotics, prebiotics and fermentation represent highly impactful areas covered by functional food innovations, and rice, soybean, garlic, barley, mulberry, bamboo, coffee, turmeric, potato and radish were some of the frequently covered food crops. The insights and the quantitative data provided by this work may be useful to support future research and innovation development, as well as policymaking and business decision-making with relevance to the functional foods area.

Maima Matin[1], Dalibor Hrg[2,3], Olena Litvinova[4,5], Małgorzata Łysek-Gładysinska[6], Agnieszka Wierzbicka[1], Jarosław Olav Horbańczuk[1], Artur Jóźwik[1] & Atanas G. Atanasov[1,5]

[1]Institute of Genetics and Animal Biotechnology of the Polish Academy of Sciences, Magdalenka, Poland. [2]Hrg Scientific, Varaždin, Croatia. [3]Artificial Intelligence and Innovation in Healthcare Lab, AI2H Laboratory, Varaždin, Croatia. [4]National University of Pharmacy of the Ministry of Health of Ukraine, Kharkiv, Ukraine. [5]Ludwig Boltzmann Institute Digital Health and Patient Safety, Medical University of Vienna, Vienna, Austria. [6]Division of Medical Biology, Institute of Biology, Jan Kochanowski University, Kielce, Poland.

e-mail: atanas.atanasov@dhps.lbg.ac.at

Published online: 14 October 2024

References

1. Granato, D. et al. *Annu. Rev. Food Sci. Technol.* **11**, 93–118 (2020).
2. European Food Safety Authority. *EFSA J.* https://www.efsa.europa.eu/en/efsajournal/pub/1101 (2009).
3. O'Kennedy, N., Raederstorff, D. & Duttaroy, A. K. *Eur. J. Nutr.* **56**, 461–482 (2017).
4. Tenore, G. C. et al. *Nutrients* **11**, 122–137 (2019).
5. Essa, M. M. et al. *J. Food Sci. Technol.* **60**, 820–834 (2023).
6. Milana, S. *Nat. Commun.* **14**, 1562 (2023).
7. Gibson, G. R. & Roberfroid, M. B. *J. Nutr.* **125**, 1401–1412 (1995).
8. Choi, Y. et al. *Sci. Rep.* **5**, 15878 (2015).
9. Wong, A. Y.-T., Lai, J. M. C. & Chan, A. W.-K. *J. Funct. Foods* **17**, 540–551 (2015).
10. Hilachuk, D. et al. *J. Technol. Manag. Innov.* **16**, 70–81 (2021).
11. Fahmy, H., Hegazi, N., El-Shamy, S. & Farag, M. A. *Food Funct.* **11**, 5768–5781 (2020).
12. Leuci, R. et al. *Recent Pat. Food Nutr. Agric.* **11**, 145–153 (2020).
13. Chopra, A. S. et al. *Pharmacol. Res.* **175**, 106001 (2022).
14. Finnegan, D., Tocmo, R. & Loscher, C. *Nutrients* **15**, 3371 (2023).
15. Guesry, P. R. *Forum Nutr.* **57**, 73–83 (2005).
16. Redgwell, R. J. & Fischer, M. *Mol. Nutr. Food Res.* **49**, 521–535 (2005).
17. GBD 2019 Diseases and Injuries Collaborators. *Lancet* **396**, 1204–1222 (2020).
18. Fan, Y. & Pedersen, O. *Nat. Rev. Microbiol.* **19**, 55–71 (2021).
19. Pieczynska, M. D. et al. *Molecules* **25**, 594 (2020).
20. Marco, M. L. et al. *Curr. Opin. Biotechnol.* **44**, 94–102 (2017).
21. Eid, H. M. et al. *Front. Pharmacol.* **8**, 387 (2017).
22. Chaiyana, W. et al. *Nutrients* **9**, 1105 (2017).
23. Park, D. W., Lee, H. S., Shim, M. S., Yum, K. J. & Seo, J. T. *World J. Mens Health* **38**, 95–102 (2020).
24. Piraccini, B. M. & Alessandrini, A. *G. Ital. Dermatol. Venereol.* **149**, 15–24 (2014).
25. Aukerman, E. L. & Jafferany, M. *J. Cosmet. Dermatol.* **22**, 89–95 (2023).
26. Tang, G., Qin, J., Dolnikowski, G. G., Russell, R. M. & Grusak, M. A. *Am. J. Clin. Nutr.* **89**, 1776–1783 (2009).
27. Zhang, H., Ma, Z. F., Luo, X. & Li, X. *Antioxidants* **7**, 69 (2018).

Author contributions

M.M. and A.G.A. designed the study, conducted the analysis, interpreted the results and wrote the paper. D.H. provided guidance on biomedical natural language processing and a part of analysis. O.L. contributed to defining the scope of the study. M.M., D.H., O.L., M.Ł.-G., A.W., J.O.H., A.J. and A.G.A. commented on the paper draft and approved the submission.

Competing interests

The authors declare no competing interests.

Additional information

Supplementary information The online version contains supplementary material available at https://doi.org/10.1038/s41587-024-02410-0.