

Original Article



The International Natural Product Sciences Taskforce (INPST) and the power of Twitter networking exemplified through #INPST hashtag analysis

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Abbreviations: COVID-19, Coronavirus Disease 2019; DHPSP, Digital Health and Patient Safety Platform; FDA, Food and Drug Administration; HIV/AIDS, Human Immunodeficiency Virus/ Acquired ImmunoDeficiency Syndrome; INPST, International Natural Product Sciences Taskforce; ICNPU-2019, The 4th International Conference on Natural Products Utilization from Plants to Pharmacy Shelf, 2019; LDCs, Least Developed Countries; MDPI, Multidisciplinary Digital Publishing Institute; ROS, Reactive Oxygen Species; SARS-CoV-2, Severe Acute Respiratory Syndrome Coronavirus 2; STEM, Science Technology Engineering and Mathematics.

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ABSTRACT

Background: The development of digital technologies and the evolution of open innovation approaches have enabled the creation of diverse virtual organizations and enterprises coordinating their activities primarily online. The open innovation platform titled “International Natural Product Sciences Taskforce” (INPST) was established in 2018, to bring together in collaborative environment individuals and organizations interested in natural product scientific research, and to empower their interactions by using digital communication tools.

Methods: In this work, we present a general overview of INPST activities and showcase the specific use of Twitter as a powerful networking tool that was used to host a one-week “2021 INPST Twitter Networking Event” (spanning from 31st May 2021 to 6th June 2021) based on the application of the Twitter hashtag #INPST.

Results and Conclusion: The use of this hashtag during the networking event period was analyzed with Symplur Signals (<https://www.symplur.com/>), revealing a total of 6,036 tweets, shared by 686 users, which generated a total of 65,004,773 impressions (views of the respective tweets). This networking event’s achieved high visibility and participation rate showcases a convincing example of how this social media platform can be used as a highly effective tool to host virtual Twitter-based international biomedical research events.

Introduction

Significance of natural products and natural product research

Nature offers multiple solutions to almost all the challenges faced by mankind. In particular, natural products represent a sustainable bio-resource with the potential to treat and manage various diseases and disorders (Durazzo et al., 2018a; Durazzo and Lucarini, 2021, 2019; Ghareeb et al., 2020; Uhrin et al., 2018). Globally, a fast and dynamically growing body of evidence is continuously emerging from computational level to the clinical level, enabling translational aspects and diverse applications of a wide range of bioactive natural products (Apoorva et al., 2021; Bankar et al., 2011; Bansal et al., 2021; Dangar and Patel, 2021; Igoli et al., 2014a, 2014b; Madaan et al., 2022;

Marzocco et al., 2021; Okoh et al., 2021; Singla, 2021; Singla et al., 2021a, 2021b, 2021c; Singla et al., 2021d). Plants, animals, and microbes serve as natural resources and goldmines for therapeutics, supplements, and nutraceuticals discovery (Capó et al., 2021; Dai et al., 2021; Durazzo et al., 2018b, 2020; Mironczuk-Chodakowska et al., 2021; Santini et al., 2018; Santini and Novellino, 2014, 2017, 2018; Santini et al., 2017; Singla and Dubey, 2019; Singla et al., 2019; Wink, 2015; Yang et al., 2019a). Not only do the traditional medicinal systems rely on natural products, but the modern medicinal systems also heavily rely on using multiple natural product scaffolds for drug development, in an unmodified state or for-property optimization achieved by modifying the starting natural product scaffold (Atanasov et al., 2015; Chaturvedi et al., 2020; Ravula et al., 2021; Tewari et al., 2021). For clinical purpose, there are already a lot of highly successful natural

product-based medicines, including but not limited to antibacterials such as streptomycin (Waksman and Schatz, 1945), antifungals such as amphotericin B (Cavassin et al., 2021), antimalarials such as artemisinin (Wang et al., 2019b), anticancer agents such as vinca alkaloids (Ehrhardt et al., 2011), camptothecin (Wang et al., 2021), and paclitaxel (Rowinsky et al., 1995), or antidiabetic agents such as acarbose (Kumar Singla et al., 2016; Tupas et al., 2020). Chemical modification of natural product molecules has also yielded multiple clinically relevant drugs such as caspofungin (Walsh et al., 2004), artemether (Hien et al., 1996), or etoposide (Cragg and Pezzuto, 2016; O'Dwyer et al., 1985). As a reflection of the high significance of natural products for the discovery and development of new pharmaceuticals, a high number of natural products or their derivatives are currently in clinical trials for a range of diverse diseases (Ahmad et al., 2021; Lima et al., 2021; Nile and Kai, 2020; Singla et al., 2022a, 2022b). Moreover, multi-component natural product mixtures are also studied to explore their therapeutic potential and used clinically (Wink, 2015). Examples of botanical drugs based on such complex mixtures of natural products approved by the United States Food and Drug Administration (FDA) include sinecatechins (marketed as Veregen® by Fougere Pharmaceuticals Inc.), an extract of green tea leaves [*Camellia sinensis* (L.) Kuntze] approved for the treatment of genital and anal warts in 2006, and crofelemer (marketed as Mytesi™ by Napo Pharmaceuticals), an oligomeric proanthocyanidin-enriched extract from the latex of the Dragon's blood tree (*Croton lechleri* Müll.Arg.) that was approved for human immunodeficiency virus/ acquired immunodeficiency syndrome (HIV/AIDS)-related diarrhea in 2012 (Chen et al., 2008; Crutchley et al., 2010; Kleindl et al., 2017). Natural products are also been intensively investigated for prevention or treatment of coronavirus disease 2019 (Devpura et al., 2021; Lordan et al., 2021; Silveira et al., 2020; Singla et al., 2021b; Wang et al., 2020b). Aside of medicinal plants, many mushrooms are also exhibiting therapeutic potential, and for example in China numerous medicinal mushrooms have been included in the Chinese Pharmacopoeia (Dai et al., 2021). Along this line, it is important to underline that multiple herbal preparations are used in complementary and alternative medicine around the world. For example, plants with antioxidant phytoconstituents, such as phenolics, carotenoids, allicin, mustard oil and vitamins C and E, are widely employed as phytopharmaceuticals and nutraceuticals and help prevent diseases caused from an overdose of reactive oxygen species (ROS) including cancer, cardiovascular and neurodegenerative health conditions (Wink, 2022). To reduce the financial strain on the public from poorer countries undergoing rapid (economic) development (LDCs), it is essential to focus on such sustainable resources for therapeutic management as they will be cost-effective, accessible, and in most cases safe (Chaturvedi et al., 2018; Heinrich et al., 2021; Singla et al., 2021d; Suryanarayana Raju et al., 2015).

In addition to therapeutic uses, natural products and materials have many other (non-medical) applications in different areas. Cellulose nanofibers with improved photothermal stability, for example, have potential in the fields of coating and packaging (Deng et al., 2022). Rice husk can be applied as a green coagulant (Tan et al., 2022), and hydrophobically modified agarose as hydrogels (Evans et al., 2022). Sweeteners (Pawar et al., 2013; Yeung et al., 2019d), biosurfactants (Liu et al., 2022), bioremediators (Xue et al., 2022), adsorbents (Etim et al., 2016), biofuels (Murillo et al., 2021; Sirigeri et al., 2019), fuel cells (Chen et al., 2018), carbon electrodes (Xi et al., 2021), carbon fertilizers (Xiang et al., 2021), paper industry uses (Haunreiter et al., 2021), cosmetics (Alves et al., 2020), and pesticides (Yang et al., 2021; Zaccardelli et al., 2020) are just a couple of examples out of the broad spectrum applications of various natural products and materials.

Scientific open innovation in the era of digital communications

The traditional approach for the generation of industrial innovation (including the development of new products and services) has been

relying on internal resources and company employees. A newer concept, “open innovation”, moved the focus on a more substantial reliance on innovation generated externally, and its interaction with the company's resources (Chesbrough and Crowther, 2006; Hodson, 2016). The open innovation concept has an advantage that it can tap into newly developed technologies and ideas without the need to entirely depend on own resources and expertise, the maintenance of which is complex and costly. In this model of innovation generation, industrial entities move their priority out of intellectual property protection to pursue external collaboration-oriented strategies, whereby collaborating partners could be other companies, academic units, or the general public as a whole. In analogy to the industrial approach where the concept was first created, the “Open Innovation in Science” approach in academia emerges as a set of practices with the focus shifted to openness and collaborative, interactive, integrated, and often interdisciplinary work involving more vital interaction with external parties from academia, industry, and society (Beck et al., 2020), realized for example by creating collaborative networks and research infrastructures in the perspective of interoperability (Dwyer et al., 2021). In the arena of medical and pharmaceutical research, which is of relevance to the focus of the open innovation platform described in the present manuscript, a recent total-scale literature analysis identified 384 scientific papers dealing with open innovation, with the first publications starting to appear in the literature in the middle of the 2000s (Yeung et al., 2021a). The later analysis also revealed that, so far, most research on open innovation in the arena of medical and pharmaceutical research was done in North America and Europe, and that the pharmaceutical sector was the most active industrial stakeholder.

Digital communication tools have the potential to empower significantly open innovation approaches. Historically, some of the first applications of open innovation took place exactly in the area of information technologies and computer technologies (in addition to the above-mentioned pharmaceutical industry sector) (Chesbrough and Crowther, 2006). With the use of digital communication tools, open innovation practitioners can reach quickly and easily large audiences of relevant stakeholders, which is of high importance for the application of key open innovation techniques such as crowdsourcing (Wazny, 2018). Moreover, digital technologies have enabled the emergence of a variety of virtual organizations that coordinate their activities primarily online, one of which is the International Natural Product Sciences Taskforce (INPST) (Atanasov et al., 2021; Camarinha-Matos and Afsarmanesh, 2005) that we present in detail in the current manuscript.

The International Natural Product Sciences Taskforce (INPST), an open innovation platform to invigorate the natural product research field

The International Natural Product Sciences Taskforce (INPST) was initiated in the early 2018, aiming to bring together in a collaborative environment individuals and organizations interested in natural products science, and empower them through the application of open innovation approaches and digital communication tools (for both networking and dissemination of credible scientific information). Envisaging the diverse applications of natural products in many areas of industry and healthcare, new natural product-related scientific findings could be of high importance in addressing some key societal problems, such as the search for new medicines, the establishment of innovative technologies that are friendlier to the environment, and the development of better food and dietary supplements. Along this line, both the continuous exploration of the existing natural biodiversity is of benefit, but also cultivated biodiversity, involving improvements mediated through modern genetic techniques, which allow to specifically increase the content of substances of high nutritional and even pharmaceutical interest (Sabbadini et al., 2021).

As the major entry point for accessing INPST-curated content, INPST website (<https://inpst.net/>) has been established. The INPST platform integrates several social media channels (Table 1) and presents in

Table 1
Major INPST social media channels.

Social media	Audience (as of April 2021)- Pre INPST Networking Event	Audience (as of January 2022) Post INPST Networking Event	Web address
Facebook	7672	8171	https://www.facebook.com/INPST/
Twitter	3113	4084	https://twitter.com/_INPST
ResearchGate	561	889	https://www.researchgate.net/project/International-Natural-Product-Sciences-Taskforce-INPST
LinkedIn	573	725	https://www.linkedin.com/company/international-natural-product-sciences-taskforce/

diverse subsections, contents that might be of interest to the visitors, including links to relevant conferences, job offers, publications, funding opportunities, and special issues of scientific journals. The INPST has attracted strong attention, and over 1500 people from more than 50 countries have joined the platform as members or email subscribers as of April 2021. In addition, large audiences have followed the major INPST social media channels (Facebook, Twitter, ResearchGate, and LinkedIn), as detailed in Table 1.

Aside from the INPST email list and social media channels, another tool for direct communication between INPST members and web visitors was provided through the INPST forum tool (<https://inpst.net/other-topics-and-announcements/>). Representative examples of different INPST-based activities (Table 2) are aligned with the multiple dissemination and outreach activities. INPST-based networking has proven to be an excellent catalyst for new collaborative integrated scientific research (Banach et al., 2018; Horbanczuk et al., 2019; Jozwik et al., 2018; Ruscica et al., 2021; Tancheva et al., 2020; Tewari et al., 2020; Tzvetkov et al., 2019; Yang et al., 2019b; Zhubi-Bakija et al., 2021), including joint work conducting meta-analysis of the published literature (Durazzo et al., 2021a, 2021b; Yeung et al., 2018, 2019a, 2020a; Yeung et al., 2019b, 2020b, 2020c; Yeung et al., 2019c, 2021c, 2019d), and the preparation of scientific collaborative review publications (Khan et al., 2020; Li et al., 2021; Mondal et al., 2021, 2019; Tewari et al., 2018; Vacca et al., 2019; Wang et al., 2022, 2018, 2019a; Wang et al., 2021) utilizing broadly-international collaborative work. In the latest example of collaborative work type, a special mention deserves a 2021 article from *Nature Reviews Drug Discovery* entitled “Natural products in drug discovery: advances and opportunities,” in which the International Natural Product Sciences Taskforce was used for the first time as an author group designation (Atanasov et al., 2021).

Twitter as a tool for science communication and networking

Twitter represents one of the comparably large social media platforms with an estimated more than 300 million monthly active users (<https://www.statista.com/>). The major feature of the platform is that it enables users to share publicly short messages (tweets), with the current characters limit (since 2017) for a single tweet being 280 characters (Boot et al., 2019). Furthermore, tweets can optionally include hyperlinks to other content on the web, photo images, short video clips, and hashtags (broadly used tags in social media used to label and grouping together thematically linked social media posts).

Twitter represents a social media platform widely used by scientists (Soragni and Maitra, 2019) and the general public. It empowers scientists to disseminate their research both to their peers (who are also the users of the platform) and directly to the general public (without the

Table 2
Representative examples of different categories of INPST-based activities.

Category	Example	Weblink
Conference support	ICNPU-2019: The 4th International Conference on Natural Products Utilization from Plants to Pharmacy Shelf, supported by INPST (29 May – 01 June 2019, Albena resort, Bulgaria)	https://inpst.net/4th-international-conference-on-natural-products-utilization-from-plants-to-pharmacy-shelf-supported-by-inpst/
News entries dissemination	INPST collaborative work analyzes about 300,000 scientific papers to outline trends in antioxidants research	https://inpst.net/antioxidant-phytochemicals-takeover-scientific-attention-replacing-antioxidant-vitamins-and-minerals/
Research project features	Multitarget peptide-fragment hybrids for the treatment of neurodegenerative diseases	https://inpst.net/multitarget-peptide-fragment-hybrids-for-the-treatment-of-neurodegenerative-diseases/
Popularization of scientific publications	Marine natural products	https://inpst.net/marine-natural-products/
Funding announcements	Government of Ireland International Education Scholarship Programme	https://inpst.net/government-of-ireland-international-education-scholarship-program/
Online lectures	SARS-CoV-2 and COVID-19: Basic knowledge on a novel pandemic (Special Online Lecture by Prof. Thomas Efferth, on 9th of March 2021)	https://inpst.net/sars-cov-2-and-covid-19-basic-knowledge-on-a-novel-pandemic/
Job offers	Non-academic Executive Director at Natural Product Research center (at Trinity College Dublin, Ireland)	https://inpst.net/non-academic-executive-director-at-natural-product-research-center-at-trinity-college-dublin-ireland/
Collaborative research calls	Collaboration call: Root of <i>Althea officinalis</i> (marsh-mallow)	https://inpst.net/collaboration-call-root-of-althea-officinalis-marsh-mallow/
Award announcements	INPST Young Scientist Award 2019	https://inpst.net/inpst-young-scientist-award-2019/
Blogging	Pomegranate for heart health and the science behind it	https://inpst.net/blog/pomegranate-for-heart-health-and-the-science-behind-it/
Dissemination of journal special issues	Natural Products and Their Applications	https://inpst.net/crbitech-special-issue-natural-products-and-their-applications/

need for involvement of journalists or science communication professionals). Moreover, Twitter represents a fertile ground for networking of professionals and finding new collaboration partners, with multiple examples in the scientific literature of fruitful research partnerships starting through Twitter interactions (Baker, 2015; Doxtader et al., 2019; Guralnick et al., 2016; Lurie et al., 2020).

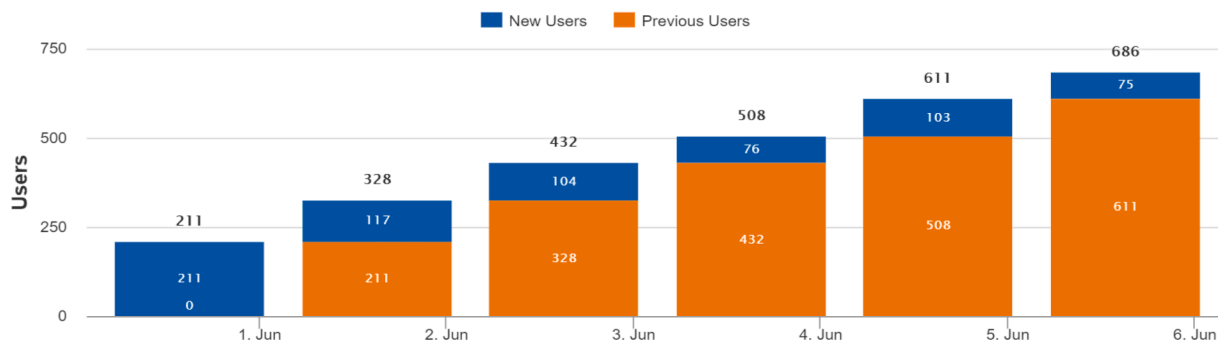
Hashtags, which were mentioned above as one of the commonly used tweet components, are designed as keyword-terms (usually thematically related to the content of the tweet) that are missing spaces (in case the term consists of several words) and have a hash sign (#) in front (particular example: #NaturalProducts). Hashtags afford tagging and thematic grouping of tweets and hashtag analysis has been widely used as a research tool that allows different quantifications (Cheung et al., 2018; Gardhouse et al., 2017; Grabbert et al., 2019; Kudchadkar and Carroll, 2020). In this context, relevant visibility parameters associated with tweets that could be analyzed, include retweets (re-shares) and impressions (views). Consequently, in this work, we aimed to evaluate visibility-associated features of the INPST Twitter networking event 2021 (detailed in the next section) by #INPST Twitter hashtag analysis.

Methodology

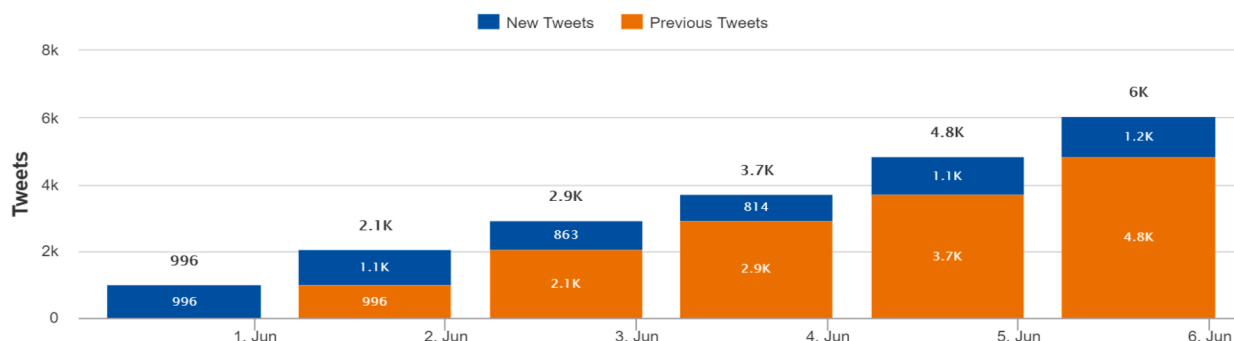
The use of the #INPST hashtag was assessed through a one-week event, highlighted and promoted as “2021 INPST Twitter Networking Event”, which spanned from 31st May 2021 to 6th June 2021. Twitter users were encouraged to use the #INPST hashtag, while doing any relevant scientific communication on Twitter. Contributions that were being encouraged included: showcasing individual research, collaboration calls, job postings, journal special issue announcements,

networking messages, conference announcements, Twitter polls, seminar announcements, links of relevant new publications, and job searches. Readers can refer to <https://inpst.net/inpst-twitter-networking-event-2021/> for more details. Utilization of the hashtag #INPST through the study period was analyzed with the aid of Symplur Signals (<https://www.symplur.com/>).

A



B



C

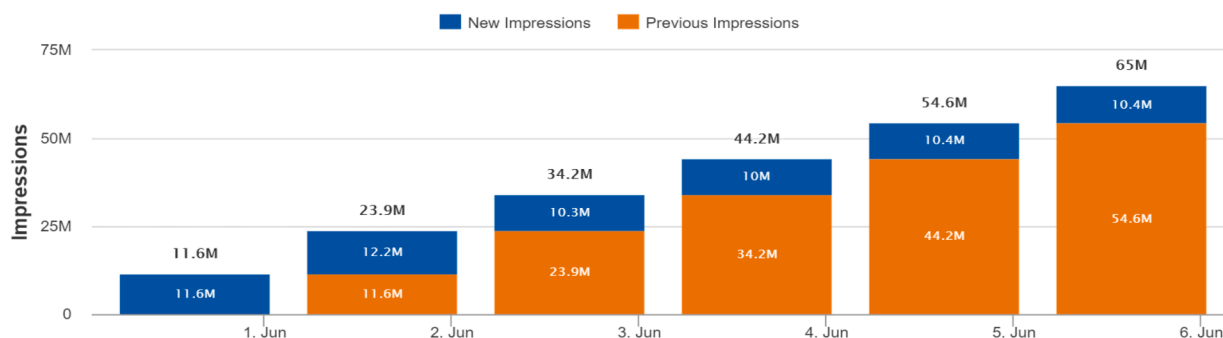


Fig. 1. Cumulative increase in the number of #INPST-posting users (A), #INPST-containing tweets (B), and impressions/views (C) during the networking event timeline (31st May to 6th June 2021).

Results and discussion

A total of 6036 tweets were posted by 686 users in that one-week networking event, generating a total of 65,004,773 impressions (views of the respective tweets). Of these 6036 tweets, 4272 tweets (70.8%) contained links, while only 319 tweets (5.28%) contained different attached images. Strategic usage of links, related hashtags, and images are in general relevant in strengthening tweets' visibility (Mishori et al., 2019). Mishori and the team, in their study published in 2019, have covered seven hashtags such as #ilooklikeasurgeon, #WomenInMedicine, #SheLeads2017, #seetibeit, #BlackMenInMedicine, #QuoteHer, and #diversityinmedicine, and analyzed them for one year. For each tweet, the volume of tweets recorded on a monthly basis (Mishori et al., 2019) was less than the tweets yielded in our one week #INPST campaign. This indicates that the tweets number obtained in the conducted "2021 INPST Twitter Networking Event" was comparably higher than weekly tweets reported in the literature for many other hashtags with biomedical significance.

Out of the 686 Twitter users who posted #INPST-containing tweets, 399 (58.2%) made only one tweet during the networking event period; 95 (13.8%) posted two tweets, while 192 (28.0%) users made three or more tweets. This suggested that close to two hundred users have regularly used the hashtag #INPST while promoting their scientific content on Twitter. It has been observed that during the one week of this hashtag networking event, new users kept on joining in the tweeting and sharing (Fig. 1A). On the first day, only 211 Twitter users joined the networking event, and the participant number gradually increased in the next few days, reaching 686 users by the last day of the networking event. During the study period, new tweets number also gradually increased, with daily tweet numbers in the range 814–1200 (Fig. 1B). On the first day of the networking event 996 tweets and 11.6 million impressions were recorded. Each day, there was an increase of around 10 million of new impressions, and by the end of the networking event week, there were more than 65 million impressions (Fig. 1C). For comparison, in a one-year period (from 1st of March 2021 to 1st of March 2022), there have been 49,300 tweets using the hashtag #INPST that have been shared by 4209 users and generated 610,157,622 impressions. Considering that there are around 52 weeks in a year, it becomes obvious that the "2021 INPST Twitter Networking Event" that took place in one single week (from 31st May 2021 to 6th June 2021) generated hugely increased weekly activity reflected in the number of shared tweets (6036 tweets in a single week) participating users (686 users) and generated impressions (65,004,773 impressions). In a previous study, a Twitter campaign focused on the hashtag #DHPSP was executed for five weeks, yielding a total of 151,984,378 impressions (Kletecka-Pulker et al., 2021). Benjamin and Royer in 2018, have performed analytics of a six months-interval to track the significance of the @AACAnatomy Twitter account. Total impressions gained by the posts from that account were calculated to be 60,510 from September 2016 to February 2017 (Benjamin and Royer, 2018). These comparative data illustrate that the #INPST networking event, with its 65,004,773 impressions (views) achieved very high visibility in just one week in comparison to other biomedical Twitter-based campaigns. Similar conclusions can be also reached by comparing to the Spanish pro-vaccine Twitter campaign focused on the hashtag #yomevacuno, which was monitored for two weeks (between 14 December and 28 December 2020) and yielded 915,736 impressions (Herrera-Peco et al., 2021).

Further, as per the user information publicly available on Twitter, the top 5 locations of the users who had used the #INPST hashtag while posted during the one-week networking event was the United States (73 users), India (38), the United Kingdom (22), Canada (18), and Spain (14). Although English remains the most frequently used language with 4068 of the tweets being in English, other languages such as Japanese (26 tweets), Romanian (14), Welsh (10), and Slovenian (6) are also noteworthy. During the one-week #INPST networking event, the most widely shared tweet featured the publication "Big impact of

nanoparticles: analysis of the most cited nanopharmaceuticals and nanonutraceuticals research", and gathered 66 retweets, 6 quoted tweets and 69 likes (Fig. 2). Furthermore, Twitter Analytics revealed that this tweet generated 23,426 impressions and 211 engagements (equaling the total number of times a user has interacted with a Tweet, including all clicks, retweets, replies, follows, and likes). The article featured in this tweet was published in Current Research in Biotechnology (Elsevier) in 2020. As per the Google Scholar record dated January 18 2022, this article has been cited a total of 25 times. Although, the follow-up time was too short to investigate whether the visibility-boost achieved through Twitter during the #INPST networking event might translate into more widespread readership and increasing citation rate for this paper, it is interesting to mention that previous works have indicated that on average widely tweeted manuscripts receive more citations (Luc et al., 2021).

The most frequently used words, which were found in the #INPST tweets shared during the networking event, were also analyzed. The top 10 words were "read", "twitter", "research", "paper", "natural", "event", "analysis", "review", "published", and "networking" (Fig. 3). All of these words have meanings that can be linked to the scope of the #INPST Twitter networking event and scientific research in general. The frequency of these words is quite high, ranging from 200 to more than 400 uses.

As the co-hashtag usage also influences the visibility of tweets, we additionally analyzed the hashtags that were co-occurring with #INPST. The top 10 hashtags that co-occurred with #INPST were also all related and relevant to the focus of the Twitter networking event (Fig. 4). The hashtag #DHPSP (an acronym for Digital Health and Patient Safety Platform) is officially registered with the Symplur Healthcare Hashtag Project and meant to be used with tweets related to "digital health, open innovation, patient safety, personalized medicine" (Kletecka-Pulker et al., 2021). #NPMND is a hashtag officially registered with the Symplur Healthcare Hashtag Project and is meant to be used with tweets related to "cancer, diabetes, metabolic disorders, natural products, neurological disorders, obesity, pain, Parkinson's disease" (Singla, 2021). #AcademicTwitter, is a widely used hashtag to label various academy-related Twitter discussions (Fuller and Potvin, 2020; Gomez-Vasquez and Romero-Hall, 2020). #SciComm hashtag is used with tweets related to "Medical Education, scientific communication, scientific posters" (Kaczmarczyk, 2015). #cancer is broadly used in tweets related to cancer. #AcademicChatter is dedicated to broader academic community chatting (Davies, 2021; Stillwell, 2021). #OpenScience is a hashtag from the accounts @open_science_ and @open-science, and is related to "promoting the discussion/dissemination of open science, equality, inclusivity, and fairness". #womeninstem is a hashtag related to "gender equity, gender parity, STEM, women in healthcare, women in medicine, women in research, women in science" (Woolston, 2015). #meded is linked to medical education (Jaswal et al., 2021), and #STEM is related to science and technology related communications (abbreviation from science, technology, engineering, and mathematics). Thus, all the co-hashtags in the top 10 list were related to science and health.

Special issues in various journals have also been widely promoted during the #INPST networking event. Among the three most shared images (Fig. 5), two illustrations (left and right) are related to journal special issues. At the same time, the third (in the center) presents an overview of a specific drug discovery research project, "Multitarget peptide-fragment hybrids for the treatment of neurodegenerative diseases" lead by Dr. Nikolay T. Tzvetko. The first special issue (the image on the left) is entitled "Plant-Derived Functional Foods, Nutraceuticals, and Cosmeceuticals: From Basic to Applied Science." This special issue is being handled by the guest editor, Dr. Hari Prasad Devkota for the journal, *Applied Sciences*, MDPI publisher. The second special issue was about "Pharmacology of Plant Polyphenols in Human Health and Diseases". This special issue was handled by five guest editors, including Dr. Hari Prasad Devkota, Dr. Atanas G. Atanasov (the founder of INPST and

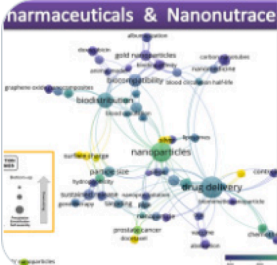


Atanas G. Atanasov
@_atanas_



Big impact of nanoparticles: analysis of the most cited nanopharmaceuticals and nanonutraceuticals research

#INPST #Nanoparticles #Nanopharmaceuticals
#Nanonutraceuticals #scicomm #100DaysOfCode
#globalhealth #nutrition #WomenInSTEM
#OpenScience #STEM



Big impact of nanoparticles: analysis of the most cited nano...
Nanopharmaceuticals and nanonutraceuticals research has been lately receiving a lot of scientific attention. We aimed t...
[sciedirect.com](https://www.sciencedirect.com)

6:58 AM · Jun 5, 2021 · Buffer

66 Retweets 6 Quote Tweets 69 Likes

Fig. 2. The most shared tweet of the #INPST Twitter networking event.

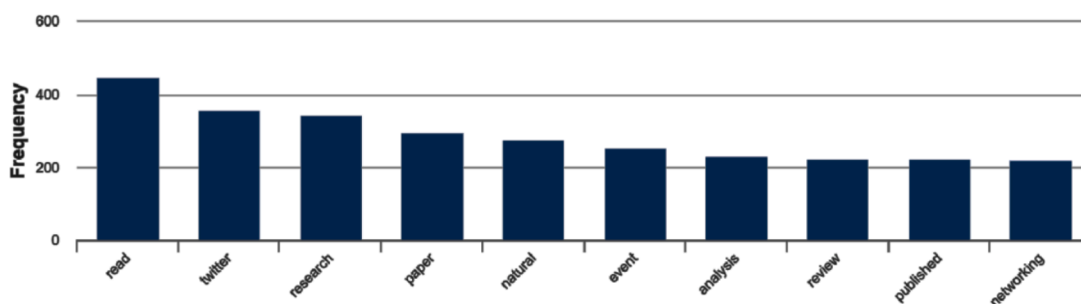


Fig. 3. . Top 10 words of the #INPST tweets posted during the networking event.

the #INPST hashtag), Dr. Keshav Raj Paudel, Dr. Namrita Lall, and Dr. Michał Tomczyk, for the journal *Frontiers in Pharmacology* (Frontiers Publisher).

Other journal special issues promoted during the event (edited by Dr. Anupam Bishayee) were “Molecular Mechanisms Underlying Cancer Prevention and Intervention with Bioactive Food Components” (in *Cancers*), “Molecular insights into natural compounds in oncoprevention and oncotherapy” (in *Pharmacological Research*), and “Molecular pharmacology of anticancer natural products” (in *Phytomedicine*). Additionally, a special collection E-book at the interface of *Frontiers in Plant Science*, *Frontiers in Pharmacology* and *Frontiers in Physiology*, entitled “Lignans: Insights into Their Biosynthesis, Metabolic Engineering,

Analytical Methods and Health Benefits” was published in early 2021. It was edited by Christophe F Hano, Albena T. Dinkova-Kostova, Norman G Lewis, John R Cort, and Laurence B. Davin, and has been viewed more than 18,700 times to date (<https://www.frontiersin.org/research-topics/9159/lignans-insights-into-their-biosynthesis-metabolic-engineering-analytical-methods-and-health-benefit#overview>) (Hano et al., 2021).

In their randomized-controlled trial “Three Facts and a Story”, Tapper and co-workers have also evaluated the use of Twitter for research dissemination, finding a significant increase in engagement for the papers published in the *Journal of Hepatology*, if relevant tweets featuring these papers were posted on Twitter (Tapper et al., 2021).

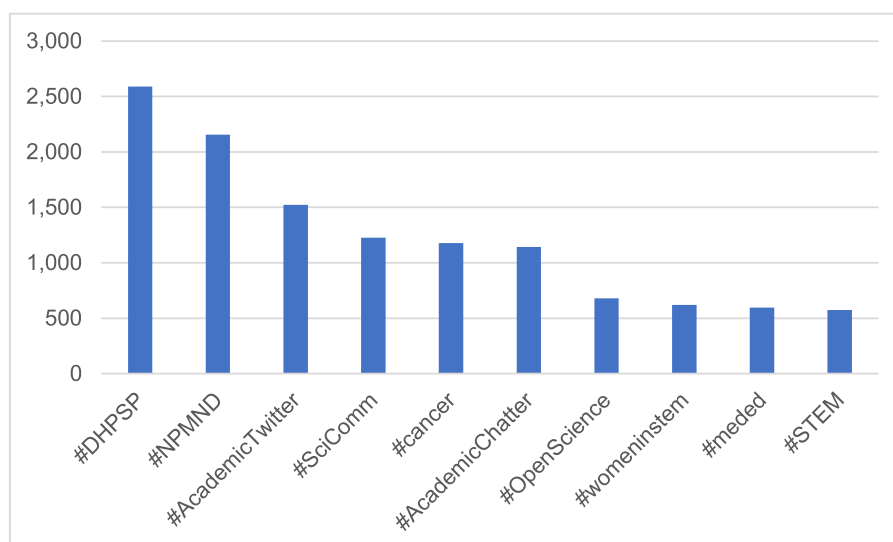


Fig. 4. Top 10 hashtags co-occurring with #INPST.

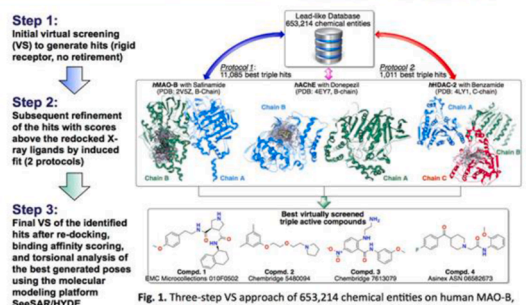


Fig. 1. Three-step VS approach of 653,214 chemical entities on human MAO-B, AChE and HDAC-2 leading to four best scored compounds 1–4.

Drugs	Structure	$K_{i, HYDE}$ ranges		
		MAO-B (PDB: 2V5Z)	AChE (PDB: 4EY7)	HDAC-2 (PDB: 4LY1)
Safinamide (SAF)		4.06 nM < $K_{i, HYDE}$ < 403 nM 5.18 ± 0.04 nM ¹¹	69.0 μ M < $K_{i, HYDE}$ < 403 nM	2209 μ M < $K_{i, HYDE}$ < 22 nM
Compd. 1 EMC Microcollections 010F0502		0.04 nM < $K_{i, HYDE}$ < 4.0 nM	6.89 nM < $K_{i, HYDE}$ < 684 nM	2.36 μ M < $K_{i, HYDE}$ < 234 μ M
Compd. 2 Chembright 5480094		0.23 nM < $K_{i, HYDE}$ < 23.1 nM	81.7 μ M < $K_{i, HYDE}$ < 8.12 nM	1.52 nM < $K_{i, HYDE}$ < 151 nM
Compd. 3 Chembright 7613079		114 nM < $K_{i, HYDE}$ < 11.3 μ M	4.63 μ M < $K_{i, HYDE}$ < 460 μ M	312 nM < $K_{i, HYDE}$ < 30.9 μ M
Compd. 4 Asinex ASN 06582673		947 nM < $K_{i, HYDE}$ < 94.0 μ M	358 nM < $K_{i, HYDE}$ < 35.6 μ M	22.3 nM < $K_{i, HYDE}$ < 2.21 μ M

Table 1. Estimated with HYDE/SeeSAR binding affinity ($K_{i, HYDE}$ ranges) of reference safinamide and compounds 1–4 towards MAO-B, AChE, and HDAC-2 leading to best scored commercially available drugs. ¹¹ Experimental value (Ref. [5]).

Fig. 5. The three most shared images during the #INPST Twitter Networking Event 2021 (with 27, 20, and once again 20 retweets, for the images displayed left, center-bottom, and right, respectively).

Exploring another application of the social media platform, Bennett and co-workers have utilized Twitter to identify COVID-19 vaccine-associated hematological adverse events (Bennett et al., 2022). Further, Eibensteiner and co-workers have utilized the Twitter poll analysis

methodology to assess the people's willingness to vaccinate against COVID-19 (Eibensteiner et al., 2021). As yet another application of Twitter, Lyu et al. have utilized the social media platform to identify topics and perform sentiment analysis in public for COVID-19

vaccine-related discussions (Lyu et al., 2021). Kwok and co-workers did the same but focused only on Australian users and by machine learning analysis (Kwok et al., 2021). As further examples of Twitter hashtag-based studies, Kauffman and colleagues have analyzed the role of Twitter in online radiology education by assessing the hashtag #RadEd (Kauffman et al., 2021), and Robertson et al. have analyzed the hashtags #RadialFirst and #RadialForNeuro on Twitter referring to transradial access for neurointerventional procedures (Robertson et al., 2021). While Twitter-applications have the limitation that they just reach this segment of the population who are users of the platform, the above-described research studies leave no scope for doubting for the value of Twitter use and Twitter-based analysis for the scientific community. Moreover, since social media platforms are a fertile ground for the dissemination of science and health-related misinformation (Yeung et al., 2021b, 2022), scientists-driven activities and events hosted on social media platforms such as Twitter can benefit the general public by providing credible and easy-accessible science-based information. Nevertheless, it should be noted that using specifically Twitter for scientific communication-based initiatives such as the here-described #INPST networking event has one important limitation: Twitter is not popularly used in some countries, which results in excluding a large group of researchers in Asia, particularly in China, who are engaging in natural product research. Envisaging this limitation, it might be recommended that for better international coverage future events from that kind might be executed with the simultaneous use of several diverse social media platforms to better reach and involve scientists located in different countries.

Conclusions

This study demonstrated how Twitter networking event attracted a large number of scientists across the world to showcase their scientific content and gained high visibility for the participants and the INPST platform as a whole, as clearly demonstrated especially by the archived high number (65,004,773) of impressions/views archived in just a single week. This work sets an example of how Twitter can be used as a highly efficient and fascinating channel to host virtual campaigns, disseminate credible scientific information, and host virtual international biomedical research events. Importantly, such digital networking events also provide platform for intensifying of interactions between scientists from different parts of the world, which might potentially yield the formation of new scientific collaborations benefiting future biomedical research. The wider implications of this analysis relate to the potential of better understanding scientific communication both within the scientific community as well as with the wider public enabling a better understanding of science.

CRedit author statement

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and accuracy.

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Availability of data and materials

All the key information is already available in the manuscript; still, the authors are ready to provide any further data if the inquiry will be routed through journal and affiliation authorities, and follow the standard process.

Ethical approval and consent to participate

Not applicable.

Human and animal rights

Not applicable.

Consent for publication

Authors duly provide the consent for publication.

Conflict of Interest

Authors Dr. Rajeev K. Singla and Shailja Singla have an honorary-based associations with the iGlobal Research and Publishing Foundation (iGRPF), New Delhi, India. Dr. Bernd Fiebich is associated with VivaCell Biotechnology GmbH. RKS, SS and BF along with the remaining authors, declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

- Ahmad, R., AlLehaibi, L.H., AlSuwaidan, H.N., Alghiryafi, A.F., Almubarak, L.S., AlKhalifah, K.N., AlMubarak, H.J., Alkhathami, M.A., 2021. Evaluation of clinical trials for natural products used in diabetes. *Medicine (Baltimore)* 100 (16), e25641. <https://doi.org/10.1097/MD.00000000000025641>.
- Alves, A., Sousa, E., Kijjoa, A., Pinto, M., 2020. Marine-derived compounds with potential use as cosmeceuticals and nutricosmetics. *Molecules* 25 (11), 2536. <https://doi.org/10.3390/molecules25112536>.
- Apoorva, M., Pooja, S., G.M, V., 2021. Phytochemical screening for secondary metabolites and nutraceutical value of *Sesbania grandiflora* (L) pers leaf extract. *Indo Glob. J. Pharm. Sci.* 11, 28–32.
- Atanasov, A.G., Waltenberger, B., Pferschy-Wenzig, E.-M., Linder, T., Wawrosch, C., Uhrin, P., Temml, V., Wang, L., Schwaiger, S., Heiss, E.H., Rollinger, J.M., Schuster, D., Breuss, J.M., Bochkov, V., Mihovilovic, M.D., Kopp, B., Bauer, R., Dirsch, V.M., Stuppner, H., 2015. Discovery and resupply of pharmacologically active plant-derived natural products: a review. *Biotechnol. Adv.* 33, 1582–1614.

- Atanasov, A.G., Zotchev, S.B., Dirsch, V.M., Supuran, C.T., 2021. Natural products in drug discovery: advances and opportunities. *Nat. Rev. Drug Discov.* 20, 200–216.
- Baker, M., 2015. Social media: a network boost. *Nature* 518, 263–265.
- Banach, M., Patti, A.M., Giglio, R.V., Cicero, A.F.G., Atanasov, A.G., Bajraktari, G., Bruckert, E., Descamps, O., Djuric, D.M., Ezhov, M., Fras, Z., von Haehling, S., Katsiki, N., Langlois, M., Latkovskis, G., Mancini, G.B.J., Mikhailidis, D.P., Mitchenko, O., Moriarty, P.M., Muntner, P., Nikolic, D., Panagiotakos, D.B., Paragh, G., Paulweber, B., Pella, D., Pitsavos, C., Reiner, Z., Rosano, G.M.C., Rosenson, R.S., Rysz, J., Sahebkar, A., Serban, M.-C., Vinereanu, D., Vrablik, M., Watts, G.F., Wong, N.D., Rizzo, M., 2018. The role of nutraceuticals in statin intolerant patients. *J. Am. Coll. Cardiol.* 72, 96–118.
- Bankar, G.R., Nayak, P.G., Bansal, P., Paul, P., Pai, K.S., Singla, R.K., Bhat, V.G., 2011. Vasorelaxant and antihypertensive effect of *Cocos nucifera* Linn. endocarp on isolated rat thoracic aorta and DOCA salt-induced hypertensive rats. *J. Ethnopharmacol.* 134, 50–54.
- Bansal, H., Singla, R.K., Behzad, S., Chopra, H., Grewal, A.S., Shen, B., 2021. Unleashing the potential of microbial natural products in drug discovery: focusing on streptomycetes as antimicrobials goldmine. *Curr. Top. Med. Chem.* 21, 2374–2396.
- Beck, S., Bergenholtz, C., Bogers, M., Brasseur, T.-M., Conradsen, M.L., 2020. The Open Innovation in Science research field: a collaborative conceptualisation approach. *Ind. Innov.* 29 (2), 136–185. <https://doi.org/10.1080/13662716.2020.1792274>.
- Benjamin, H.K., Royer, D.F., 2018. @AACAnatomy twitter account goes live: a sustainable social media model for professional societies. *Clin. Anat.* 31, 566–575.
- Bennett, C.L., Gundabolu, K., Kwak, L.W., Djulbegovic, B., Champigneulle, O., Josephson, B., Martin, L., Rosen, S.T., 2022. Using Twitter for the identification of COVID-19 vaccine-associated hematological adverse events. *Lancet Haematol.* 9, e12–e13.
- Boot, A.B., Tjong Kim Sang, E., Dijkstra, K., Zwaan, R.A., 2019. How character limit affects language usage in tweets. *Palgrave Commun.* 5.
- Camarinha-Matos, L.M., Afsarmanesh, H., 2005. Collaborative networks: a new scientific discipline. *J. Intell. Manuf.* 16, 439–452.
- Capó, X., Martorell, M., Tur, J.A., Sureda, A., Pons, A., 2021. 5-dodecanolide, a compound isolated from pig lard, presents powerful anti-inflammatory properties. *Molecules* 26 (23), 7363. <https://doi.org/10.3390/molecules26237363>.
- Cavassin, F.B., Baú-Carneiro, J.L., Vilas-Boas, R.R., Queiroz-Telles, F., 2021. Sixty years of Amphotericin B: an overview of the main antifungal agent used to treat invasive fungal infections. *Infect. Dis. Ther.* 10, 115–147.
- Chaturvedi, V.K., Agarwal, S., Gupta, K.K., Ranteke, P.W., Singh, M.P., 2018. Medicinal mushroom: boon for therapeutic applications. *3. Biotech* 8 (8), 334. <https://doi.org/10.1007/s13205-018-1358-0>.
- Chaturvedi, V.K., Yadav, N., Rai, N.K., Ellah, N.H.A., Bohara, R.A., Rehan, I.F., Marraiki, N., Batiha, G.E.-S., Hetta, H.F., Singh, M.P., 2020. Pleurotus sajor-caju-mediated synthesis of silver and gold nanoparticles active against colon cancer cell lines: a new era of herbonanocotics. *Molecules* 25 (13), 3091. <https://doi.org/10.3390/molecules25133091>.
- Chen, B.-Y., Liao, J.-H., Hsu, A.-W., Tsai, P.-W., Hsueh, C.-C., 2018. Exploring optimal supplement strategy of medicinal herbs and tea extracts for bioelectricity generation in microbial fuel cells. *Bioresour. Technol.* 256, 95–101.
- Chen, S.T., Dou, J., Temple, R., Agarwal, R., Wu, K.-M., Walker, S., 2008. New therapies from old medicines. *Nat. Biotechnol.* 26, 1077–1083.
- Chesbrough, H., Crowther, A.K., 2006. Beyond high tech: early adopters of open innovation in other industries. *R D Manag.* 36, 229–236.
- Cheung, B., Wong, C.L., Gardhouse, A., Frank, C., Budd, L., 2018. #CGS2015: an evaluation of twitter use at the Canadian Geriatrics Society Annual Scientific Meeting. *Can. Geriatr. J.* 21, 166–172.
- Cragg, G.M., Pezzuto, J.M., 2016. Natural products as a vital source for the discovery of cancer chemotherapeutic and chemopreventive agents. *Med. Princ. Pract.* 25, 41–59.
- Crutchley, R.D., Miller, J., Garey, K.W., 2010. Crofelemer, a novel agent for treatment of secretory diarrhea. *Ann. Pharmacother.* 44, 878–884.
- Dai, R., Liu, M., Nik Nabil, W.N., Xi, Z., Xu, H., 2021. Mycomedicine: a unique class of natural products with potent anti-tumour bioactivities. *Molecules* 26 (4), 1113. <https://doi.org/10.3390/molecules26041113>.
- Dangar, D., Patel, N., 2021. Anti-inflammatory effect of *neuracanthus sphaerostachyus* Dalz. leaves on experimental colitis in rats. *Indo Glob. J. Pharm. Sci.* 11, 07–14.
- Davies, S.R., 2021. Chaos, care, and critique: performing the contemporary academy during the COVID-19 pandemic. *Front. Commun.* 6, 657823. <https://doi.org/10.3389/fcomm.2021.657823>.
- Deng, Y., Li, K., Guan, Q., Hu, T., He, L., 2022. Novel CNFs-based organic UV-adsorber intercalated ZnAl-LDHs composited films with superior photothermal stability and mechanical properties. *Ind. Crops Prod.* 178, 114555. <https://doi.org/10.1016/j.indcrop.2022.114555>.
- Devpura, G., Tomar, B.S., Nathiya, D., Sharma, A., Bhandari, D., Haldar, S., Balkrishna, A., Varshney, A., 2021. Randomized placebo-controlled pilot clinical trial on the efficacy of ayurvedic treatment regime on COVID-19 positive patients. *Phytomedicine* 84, 153494. <https://doi.org/10.1016/j.phymed.2021.153494>.
- Doxtader, E.E., Pijuan, L., Lepe, M., Alex, D., Canepa, M., Deeken, A.H., Gibier, J.B., Jain, D., Janaki, N., Jelinek, A., Kumar, S., Labiano, T., L'Imperio, V., Michael, C., Pagni, F., Panizo, A., Quintana, L.M., Roy-Chowdhuri, S., Sanchez-Font, A., Skipper, D.C., Spruill, L.S., Torous, V., Wu, R.I., Sauter, J.L., Mukhopadhyay, S., 2019. Displaced cartilage within lymph node parenchyma is a novel biopsy site change in resected mediastinal lymph nodes following EBUS-TBNA. *Am. J. Surg. Pathol.* 43, 497–503.
- Durazzo, A., D'Addezio, L., Camilli, E., Piccinelli, R., Turrini, A., Marletta, L., Marconi, S., Lucarini, M., Lisciani, S., Gabrielli, P., Gambelli, P., Aguzzi, A., Sette, S., 2018a. From plant compounds to botanicals and back: a current snapshot. *Molecules* 23 (8), 1844. <https://doi.org/10.3390/molecules23081844>. PMID: 30042375; PMCID: PMC6222869.
- Durazzo, A., Lucarini, M., 2021. Environmental, ecological and food resources in the biodiversity overview: health benefits. *Life* 11 (11), 1228. <https://doi.org/10.3390/life11111228>.
- Durazzo, A., Lucarini, M., Camilli, E., Marconi, S., Gabrielli, P., Lisciani, S., Gambelli, L., Aguzzi, A., Novellino, E., Santini, A., Turrini, A., Marletta, L., 2018b. Dietary lignans: definition, description and research trends in databases development. *Molecules* 23 (12), 3251. <https://doi.org/10.3390/molecules23123251>. PMID: 30544820; PMCID: PMC6321438.
- Durazzo, A., Lucarini, M., Santini, A., 2020. Nutraceuticals in human health. *Foods* 9(3), 370. doi:10.3390/foods9030370.
- Durazzo, A., Lucarini, M., Souto, E.B., Cicala, C., Caiazzo, E., Izzo, A.A., Novellino, E., Santini, A., 2019. Polyphenols: a concise overview on the chemistry, occurrence, and human health. *Phytother. Res.* 33, 2221–2243.
- Durazzo, A., Nazhand, A., Lucarini, M., Delgado, A.M., De Wit, M., Nyam, K.L., Santini, A., Fawzy Ramadan, M., Apetrei, C., 2021a. Occurrence of tocots in foods: an updated shot of current databases. *J. Food Qual.* 2021, 1–7.
- Durazzo, A., Souto, E.B., Lombardi-Boccia, G., Santini, A., Lucarini, M., 2021b. Metrology, agriculture and food: literature quantitative analysis. *Agriculture* 11, 889.
- Dwyer, J., Saldanha, L., Bailen, R., Durazzo, A., Le Donne, C., Piccinelli, R., Andrews, K., Pehrsson, P., Gusev, P., Calvillo, A., Connor, E., Goshorn, J., Sette, S., Lucarini, M., D'Addezio, L., Camilli, E., Marletta, L., Turrini, A., 2021. Commentary: an impossible dream? Integrating dietary supplement label databases: needs, challenges, next steps. *J. Food Compos. Anal.* 102, 103882. <https://doi.org/10.1016/j.jfca.2021.103882>.
- Ehrhardt, H., Schrems, D., Moritz, C., Wachter, F., Haldar, S., Graubner, U., Nathrath, M., Jeremias, I., 2011. Optimized anti-tumor effects of anthracyclines plus Vinca alkaloids using a novel, mechanism-based application schedule. *Blood* 118, 6123–6131.
- Eibensteiner, F., Ritschl, V., Nawaz, F.A., Fazel, S.S., Tsagkaris, C., Kulnik, S.T., Crutzen, R., Klager, E., Völkl-Kernstock, S., Schaden, E., Kletecka-Pulker, M., Willschke, H., Atanasov, A.G., 2021. People's willingness to vaccinate against COVID-19 despite their safety concerns: Twitter poll analysis. *J. Med. Internet Res.* 23 (4), e28973. <https://doi.org/10.2196/28973>.
- Etim, U.J., Umoren, S.A., Eduok, U.M., 2016. Coconut coir dust as a low cost adsorbent for the removal of cationic dye from aqueous solution. *J. Saudi Chem. Soc.* 20, S67–S76.
- Evans, C., Morimitsu, Y., Nishi, R., Yoshida, M., Takei, T., 2022. Novel hydrophobically modified agarose cryogels fabricated using dimethyl sulfoxide. *J. Biosci. Bioeng.* 133 (4), 390–395. <https://doi.org/10.1016/j.jbiosc.2021.12.009>.
- Fuller, D., Potvin, L., 2020. Social media and the Canadian Journal of Public Health. *Can. J. Public Health* 111, 149–150.
- Gardhouse, A.I., Budd, L., Yang, S.Y.C., Wong, C.L., 2017. #GerMedJC: the Twitter complement to the traditional-format geriatric medicine journal club. *J. Am. Geriatr. Soc.* 65, 1347–1351.
- Ghareeb, M.A., Tammam, M.A., El-Demerdash, A., Atanasov, A.G., 2020. Insights about clinically approved and Preclinically investigated marine natural products. *Curr. Res. Biotechnol.* 2, 88–102.
- Gomez-Vasquez, L., Romero-Hall, E., 2020. An Exploration of a Social Media Community: the Case of #AcademicTwitter. *Social Computing and Social Media. Participation, User Experience, Consumer Experience, and Applications of Social Computing. HCII 2020. Lecture Notes in Computer Science*, 12195. Springer, Cham, pp. 526–537.
- Grabbert, M., Khoder, W.Y., Gratzke, C., Paffenholz, P., Salem, J., Bauer, R.M., 2019. Comprehensive analysis of Twitter activity on #Incontinence. *NeuroUrol. Urodyn.* 39, 440–446.
- Guralnick, R., Daume, S., Galaz, V., 2016. Anyone know what species this is?—Twitter conversations as embryonic citizen science communities. *PLoS One* 11 (3), e0151387. <https://doi.org/10.1371/journal.pone.0151387>.
- Hano, C.F., Dinkova-Kostova, A.T., Davin, L.B., Cort, J.R., Lewis, N.G., 2021. Editorial: lignans: insights into their biosynthesis, metabolic engineering, analytical methods and health benefits. *Front. Plant Sci.* 11, 630327. <https://doi.org/10.3389/fpls.2020.630327>.
- Haunreiter, K.J., Dichiaro, A., Gustafson, R., 2021. Structural and chemical characterization of hop bine fibers and their applications in the paper industry. *Ind. Crops Prod.* 174, 114217. <https://doi.org/10.1016/j.indcrop.2021.114217>.
- Heinrich, M., Jiang, H., Scotti, F., Booker, A., Walt, H., Weckerle, C., Maake, C., 2021. Medicinal plants from the Himalayan region for potential novel antimicrobial and anti-inflammatory skin treatments. *J. Pharm. Pharmacol.* 73, 956–967.
- Herrera-Peco, I., Jiménez-Gómez, B., Peña Deudero, J.J., Benítez De Gracia, E., Ruiz-Núñez, C., 2021. Healthcare professionals' role in social media public health campaigns: analysis of Spanish Pro Vaccination Campaign on Twitter. *Healthcare* 9 (6), 662. <https://doi.org/10.3390/healthcare9060662>.
- Hien, T.T., Day, N.P.J., Phu, N.H., Mai, N.T.H., Chau, T.T.H., Loc, P.P., Sinh, D.X., Chuong, L.V., Vinh, H., Waller, D., Peto, T.E.A., White, N.J., 1996. A controlled trial of artemether or quinine in Vietnamese adults with severe falciparum malaria. *N. Engl. J. Med.* 335, 76–83.
- Hodson, R., 2016. Open innovation. *Nature* 533 (7602), S53. <https://doi.org/10.1038/533S53a>.
- Horbaniczuk, O.K., Kurek, M.A., Atanasov, A.G., Brncic, M., Rimac Brncic, S., 2019. The effect of natural antioxidants on quality and shelf life of beef and beef products. *Food Technol. Biotechnol.* 57, 439–447.

- Igoli, J.O., Gray, A.I., Clements, C.J., Kantheti, P., Singla, R.K., 2014a. Antitrypanosomal activity & docking studies of isolated constituents from the lichen *Cetraria islandica*: possibly multifunctional scaffolds. *Curr. Top. Med. Chem.* 14, 1014–1021.
- Igoli, N.P., Clements, C.J., Singla, R.K., Igoli, J.O., Uche, N., Gray, A.I., 2014b. Antitrypanosomal activity & docking studies of components of *Crateva adansonii* DC leaves: novel multifunctional scaffolds. *Curr. Top. Med. Chem.* 14, 981–990.
- Jaswal, S., Schooler, G.R., Quirk, C.R., 2021. Introducing @RadG Editor: your new Twitter follow in the era of digital #MedEd. *Radiographics* 41, E196–E197.
- Jozwik, A., Marchewka, J., Strzalkowska, N., Horbanczuk, J.O., Szumacher-Strabel, M., Cieslak, A., Lipinska-Palka, P., Jozefiak, D., Kaminska, A., Atanasov, A.G., 2018. The effect of different levels of Cu, Zn and Mn nanoparticles in Hen Turkey diet on the activity of aminopeptidases. *Molecules* 23 (5), 1150. <https://doi.org/10.3390/molecules23051150>.
- Kaczmarczyk, L.C., 2015. Do you speak #scicomm? *ACM Inroads* 6, 31–32.
- Kauffman, L., Weisberg, E.M., Zember, W.F., Fishman, E.K., 2021. #RadEd: how and why to use Twitter for online radiology education. *Curr. Probl. Diagn. Radiol.* 50, 369–373.
- Khan, H., Pervaiz, A., Intagliata, S., Das, N., Nagulapalli Venkata, K.C., Atanasov, A.G., Najda, A., Nabavi, S.M., Wang, D., Pittala, V., Bishayee, A., 2020. The analgesic potential of glycosides derived from medicinal plants. *Daru* 28, 387–401.
- Kleindl, P.A., Xiong, J., Hewarathna, A., Mozziconacci, O., Nariya, M.K., Fisher, A.C., Deeds, E.J., Joshi, S.B., Middaugh, C.R., Schoneich, C., Volkin, D.B., Forrest, M.L., 2017. The botanical drug substance Crofelemer as a model system for comparative characterization of complex mixture drugs. *J. Pharm. Sci.* 106, 3242–3256.
- Kletecka-Pulker, M., Mondal, H., Wang, D., Parra, R.G., Maigoro, A.Y., Lee, S., Garg, T., Mulholland, E.J., Devkota, H.P., Konwar, B., Patnaik, S.S., Lordan, R., Nawaz, F.A., Tsagaris, C., Rayan, R.A., Louka, A.M., De, R., Badhe, P., Schaden, E., Willschke, H., Maleczek, M., Boyina, H.K., Khalid, G.M., Uddin, M.S., 2021. Impacts of biomedical hashtag-based Twitter campaign: #DHPSP utilization for promotion of open innovation in digital health, patient safety, and personalized medicine. *Curr. Res. Biotechnol.* 3, 146–153.
- Kudchadkar, S.R., Carroll, C.L., 2020. Using social media for rapid information dissemination in a pandemic: #PedsICU and coronavirus disease 2019. *Pediatr. Crit. Care Med.* 21, e538–e546.
- Kumar Singla, R., Singh, R., Kumar Dubey, A., 2016. Important aspects of post-prandial antidiabetic drug, Acarbose. *Curr. Top. Med. Chem.* 16, 2625–2633.
- Kwok, S.W.H., Vadde, S.K., Wang, G., 2021. Tweet topics and sentiments relating to COVID-19 vaccination among Australian Twitter users: machine learning analysis. *J. Med. Internet Res.* 23 (5), e26953 <https://doi.org/10.2196/26953>.
- Li, C., Li, J., Jiang, F., Tzvetkov, N.T., Horbanczuk, J.O., Li, Y., Atanasov, A.G., Wang, D., 2021. Vasculoprotective effects of ginger (*Zingiber officinale* Roscoe) and underlying molecular mechanisms. *Food Funct.* 12, 1897–1913.
- Lima, I.C.G.d.S., de Fátima Souto Maior, L., Gueiros, L.A.M., Leão, J.C., Higino, J.S., Carvalho, A.A.T., 2021. Clinical applicability of natural products for prevention and treatment of oral mucositis: a systematic review and meta-analysis. *Clin. Oral Investig.* 25, 4115–4124.
- Liu, S.-L., Chen, C.-Y., Chen, Y.-S., 2022. Characteristic properties of spray-drying Bifidobacterium adolescentis microcapsules with biosurfactant. *J. Biosci. Bioeng.* 133 (3), 250–257. <https://doi.org/10.1016/j.jbiosc.2021.12.002>.
- Lordan, R., Rando, H.M., Greene, C.S., Gilbert, J.A., 2021. Dietary supplements and nutraceuticals under investigation for COVID-19 prevention and treatment. *mSystems* 6 (3), e00122-21. <https://doi.org/10.1128/mSystems.00122-21>.
- Luc, J.G.Y., Archer, M.A., Arora, R.C., Bender, E.M., Blitz, A., Cooke, D.T., Hlci, T.N., Kidane, B., Ouzounian, M., Varghese, T.K., Antonoff, M.B., 2021. Does Tweeting improve citations? One-year results from the TSSMN prospective randomized trial. *Ann. Thorac. Surg.* 111, 296–300.
- Lurie, D.J., Kessler, D., Bassett, D.S., Betzel, R.F., Breakspear, M., Kheilholz, S., Kucyi, A., Liégeois, R., Lindquist, M.A., McIntosh, A.R., Poldrack, R.A., Shine, J.M., Thompson, W.H., Bielczyk, N.Z., Douw, L., Kraft, D., Miller, R.L., Muthuraman, M., Pasquini, L., Razi, A., Vidaurde, D., Xie, H., Calhoun, V.D., 2020. Questions and controversies in the study of time-varying functional connectivity in resting fMRI. *Netw. Neurosci.* 4, 30–69.
- Lyu, J.C., Han, E.L., Luli, G.K., 2021. COVID-19 vaccine-related discussion on Twitter: topic modeling and sentiment analysis. *J. Med. Internet Res.* 23 (6), e24435 <https://doi.org/10.2196/24435>.
- Madaan, R., Singla, R.K., Kumar, S., Dubey, A.K., Kumar, D., Sharma, P., Bala, R., Singla, S., Shen, B., 2022. Bergenin—a biologically active scaffold: nanotechnological perspectives. *Curr. Top. Med. Chem.* 22 (2), 132–149. <https://doi.org/10.2174/1568026621666211015092654>.
- Marzocco, S., Singla, R.K., Capasso, A., 2021. Multifaceted effects of lycopene: a boulevard to the multitarget-based treatment for cancer. *Molecules* 26 (17), 5333. <https://doi.org/10.3390/molecules26175333>.
- Mironczuk-Chodakowska, I., Kujawowicz, K., Witkowska, A.M., 2021. Beta-glucans from fungi: biological and health-promoting potential in the COVID-19 pandemic era. *Nutrients* 13 (11), 3960. <https://doi.org/10.3390/nu13113960>.
- Mishori, R., Singh, L., Lin, K.W., Wei, Y., 2019. #Diversity: conversations on twitter about women and black men in medicine. *The Journal of the American Board of Family Medicine (Baltimore)*. 32, 28–36.
- Mondal, A., Banerjee, S., Bose, S., Das, P.P., Sandberg, E.N., Atanasov, A.G., Bishayee, A., 2021. Cancer preventive and therapeutic potential of banana and its bioactive constituents: a systematic. *Front. Oncol.* 11, 697143.
- Mondal, A., Gandhi, A., Fimognari, C., Atanasov, A.G., Bishayee, A., 2019. Alkaloids for cancer prevention and therapy: current progress and future perspectives. *Eur. J. Pharmacol.* 858, 172472.
- Murillo, H.A., Díaz-Robles, L.A., Santander, R.E., Cubillos, F.A., 2021. Conversion of residual oat husk and pine sawdust by co-hydrothermal carbonization towards biofuel production for pellet stoves. *Ind. Crops Prod.* 174, 114219 <https://doi.org/10.1016/j.indcrop.2021.114219>.
- Nile, S.H., Kai, G., 2020. Recent clinical trials on natural products and Traditional Chinese Medicine combating the COVID-19. *Indian J. Microbiol.* 61, 10–15.
- O'Dwyer, P.J., Leyland-Jones, B., Alonso, M.T., Marsoni, S., Wittes, R.E., 1985. Etoposide (VP-16–213). *N. Engl. J. Med.* 312, 692–700.
- Okoh, M.P., Singla, R.K., Madu, C., Soremekun, O., Adejoh, J., Alli, L.A., Shen, B., 2021. Phytomedicine in disease management: in-silico analysis of the binding affinity of Artesunate and Azadirachtin for malaria treatment. *Front. Pharmacol.* 12, 751032.
- Pawar, R.S., Krynitsky, A.J., Rader, J.I., 2013. Sweeteners from plants—with emphasis on *Stevia rebaudiana* (Bertoni) and *Siraitia grosvenorii* (Swingle). *Anal. Bioanal. Chem.* 405, 4397–4407.
- Ravula, A.R., Teegala, S.B., Kalakotla, S., Pasangulapati, J.P., Perumal, V., Boyina, H.K., 2021. Fisetin, potential flavonoid with multifarious targets for treating neurological disorders: an updated review. *Eur. J. Pharmacol.* 910, 174492 <https://doi.org/10.1016/j.ejphar.2021.174492>.
- Robertson, F.C., Linzey, J.R., Alotaibi, N.M., Regenhardt, R.W., Harker, P., Vranic, J., Dmytriw, A.A., Koch, M.J., Stapleton, C.J., Leslie-Mazwi, T.M., Patel, A.B., 2021. #RadialFirst and #RadialForNeuro: a descriptive analysis of Twitter conversations regarding transradial access. *Neuroradiol. J.* 34, 494–500.
- Rowinsky, E.K., Wood, A.J.J., Donehower, R.C., 1995. Paclitaxel (Taxol). *N. Engl. J. Med.* 332, 1004–1014.
- Ruscica, M., Penson, P.E., Ferri, N., Sirtori, C.R., Pirro, M., Mancini, G.B.J., Sattar, N., Toth, P.P., Sahebkar, A., Lavie, C.J., Wong, N.D., Banach, M., Acosta, J., Al-Khnifawi, M., Alnouri, F., Amar, F., Atanasov, A.G., Bajraktari, G., Banach, M., Bhaskar, S., Bjelakovic, B., Bruckert, E., Ceska, R., Cicero, A.F.G., Collet, X., Descamps, O., Djuric, D., Durst, R., Ezhov, M.V., Fras, Z., Gaita, D., Hernandez, A.V., Jones, S.R., Jozwiak, J., Kakauidze, N., Kalle, A., Katsiki, N., Khera, A., Kostner, K., Kubilius, R., Latkovskis, G., Mancini, G.B.J., Marais, A.D., Martin, S.S., Martinez, J. A., Mazidi, M., Mikhailidis, D.P., Mirrahimov, E., Miserez, A.R., Mitchenko, O., Mitkovskaya, N.P., Moriarty, P.M., Nabavi, S.M., Nair, D., Panagiotakos, D.B., Paragh, G., Pella, D., Penson, P.E., Petruccioli, Z., Pirro, M., Postadzhiyan, A., Puri, R., Reda, A., Reiner, Z., Radenkovic, D., Rakowski, M., Riaz, J., Richter, D., Rizzo, M., Ruscica, M., Sahebkar, A., Sattar, N., Serban, M.-C., Shehab, A.M.A., Shek, A.B., Sirtori, C.R., Stefanutti, C., Tomasik, T., Toth, P.P., Viigimaa, M., Valdivielso, P., Vinereanu, D., Vohnout, B., von Haehling, S., Vrablik, M., Wong, N. D., Yeh, H.-I., Zhisheing, J., Zirikli, A., 2021. Impact of nutraceuticals on markers of systemic inflammation: potential relevance to cardiovascular diseases—a position paper from the International Lipid Expert Panel (ILEP). *Prog. Cardiovasc. Dis.* 67, 40–52.
- Sabbadini, S., Capocasa, F., Battino, M., Mazzoni, L., Mezzetti, B., 2021. Improved nutritional quality in fruit tree species through traditional and biotechnological approaches. *Trends Food Sci. Technol.* 117, 125–138.
- Santini, A., Cammarata, S.M., Capone, G., Ianaro, A., Tenore, G.C., Pani, L., Novellino, E., 2018. Nutraceuticals: opening the debate for a regulatory framework. *Br. J. Clin. Pharmacol.* 84, 659–672.
- Santini, A., Novellino, E., 2014. Nutraceuticals: beyond the diet before the drugs. *Curr. Bioact. Compd.* 10, 1–12.
- Santini, A., Novellino, E., 2017. To nutraceuticals and back: rethinking a concept. *Foods* 6 (9), 74. <https://doi.org/10.3390/foods6090074>.
- Santini, A., Novellino, E., 2018. Nutraceuticals—shedding light on the grey area between pharmaceuticals and food. *Expert Rev. Clin. Pharmacol.* 11, 545–547.
- Santini, A., Tenore, G.C., Novellino, E., 2017. Nutraceuticals: a paradigm of proactive medicine. *Eur. J. Pharm. Sci.* 96, 53–61.
- Silveira, D., Prieto-Garcia, J.M., Boylan, F., Estrada, O., Fonseca-Bazzo, Y.M., Jamal, C. M., Magalhães, P.O., Pereira, E.O., Tomczyk, M., Heinrich, M., 2020. COVID-19: is there evidence for the use of herbal medicines as adjuvant symptomatic therapy? *Front. Pharmacol.* 11, 581840 <https://doi.org/10.3389/fphar.2020.581840>.
- Singla, R.K., 2021. Secondary metabolites as treatment of choice for metabolic disorders and infectious diseases and their metabolic profiling—part 3. *Curr. Drug Metab.* 22, 412–414.
- Singla, R.K., Behzad, S., Khan, J., Tsagaris, C., Gautam, R.K., Goyal, R., Chopra, H., Shen, B., 2022a. Natural kinase inhibitors for the treatment and management of endometrial/uterine cancer: preclinical to clinical studies. *Front. Pharmacol.* 13, 801733. <https://doi.org/10.3389/fphar.2022.801733>. PMID: 35264951; PMCID: PMC8899191.
- Singla, R.K., Dhir, V., Madaan, R., Kumar, D., Singh Bola, S., Bansal, M., Kumar, S., Dubey, A.K., Singla, S., Shen, B., 2022b. The genus *Alternanthera*: phytochemical and ethnopharmacological perspectives. *Front. Pharmacol.* 13, 769111 <https://doi.org/10.3389/fphar.2022.769111>. PMID: 35479320; PMCID: PMC9036189.
- Singla, R.K., Dubey, A.K., 2019. Molecules and metabolites from natural products as inhibitors of biofilm in *Candida* spp. pathogens. *Curr. Top. Med. Chem.* 19, 2567–2578.
- Singla, R.K., Gupta, R., Joon, S., Gupta, A.K., Shen, B., 2021a. Isolation, docking and in silico ADME-T studies of acacianol: novel antibacterial isoflavone analogue isolated from *Acacia leucophloea* bark. *Curr. Drug Metab.* 22, 893–904.
- Singla, R.K., He, X., Chopra, H., Tsagaris, C., Shen, L., Kamal, M.A., Shen, B., 2021b. Natural products for the prevention and control of the COVID-19 pandemic: sustainable bioresources. *Front. Pharmacol.* 12, 758159.
- Singla, R.K., Kumar, R., Khan, S., Mohit Kumari, K., Garg, A., 2019. Natural products: potential source of DPP-IV inhibitors. *Curr. Protein Pept. Sci.* 20, 1218–1225.
- Singla, R.K., Sai, C.S., Chopra, H., Behzad, S., Bansal, H., Goyal, R., Gautam, R.K., Tsagaris, C., Joon, S., Singla, S., Shen, B., 2021c. Natural products for the management of castration-resistant prostate cancer: special focus on nanoparticles based studies. *Front. Cell Dev. Biol.* 9, 745177.

- Singla, R.K., Sharma, P., Dubey, A.K., Gundamaraju, R., Kumar, D., Kumar, S., Madaan, R., Shri, R., Tsagkaris, C., Parisi, S., Joon, S., Singla, S., Kamal, M.A., Shen, B., 2021d. Natural product-based studies for the management of castration-resistant prostate cancer: computational to clinical studies. *Front. Pharmacol.* 12, 732266.
- Sirigeri, S., Vadiraj, K.T., Belagali, S.L., 2019. *Tabebuia rosea*: a prospective non-edible biodiesel feedstock. *Biofuels* 13, 17–19.
- Soragni, A., Maitra, A., 2019. Of scientists and tweets. *Nat. Rev. Cancer* 19, 479–480.
- Stillwell, A.S., 2021. What the science and engineering world needs now is Twitter. *J. Sustain. Water Built Environ.* 7 (1), 01820001 <https://doi.org/10.1061/JSWBAY.0000927>.
- Suryanarayana Raju, D., Kumar, T.N.V.G., Mathew, J., Jeyaprakash, Kandale, A., Singla, R.K., 2015. Synthesis & biological evaluation of 1, 3, 4-oxadiazoles as anticancer agents. *Indo Glob. J. Pharm. Sci.* 05, 01–05.
- Tan, K.L., Lim, K.Y., Chow, Y.N., Foo, K.Y., Liew, Y.S., Desa, S.M., Yahaya, N.K.E.M., Noh, M.N.M., 2022. Facile preparation of rice husk-derived green coagulant via water-based heatless and salt-free technique for the effective treatment of urban and agricultural runoffs. *Ind. Crops Prod.* 178, 114547 <https://doi.org/10.1016/j.indcrop.2022.114547>.
- Tancheva, L.P., Lazarova, M.I., Alexandrova, A.V., Dragomanova, S.T., Nicoletti, F., Tzvetanova, E.R., Hodzhev, Y.K., Kalfin, R.E., Miteva, S.A., Mazzon, E., Tzvetkov, N. T., Atanasov, A.G., 2020. Neuroprotective mechanisms of three natural antioxidants on a rat model of Parkinson's disease: a comparative study. *Antioxidants* 9 (1), 49. <https://doi.org/10.3390/antiox9010049>.
- Tapper, E.B., Mirabella, R., Walicki, J.J., Banales, J.M., 2021. Optimizing the use of twitter for research dissemination: the “Three Facts and a Story” randomized-controlled trial. *J. Hepatol.* 75, 271–274.
- Tewari, D., Atanasov, A.G., Semwal, P., Wang, D., 2021. Natural products and their applications. *Curr. Res. Biotechnol.* 3, 82–83.
- Tewari, D., Jozwik, A., Lysek-Gladysinska, M., Grzybek, W., Adamus-Bialek, W., Bicki, J., Strzałkowska, N., Kaminska, A., Horbańczuk, O.K., Atanasov, A.G., 2020. Fenugreek (*Trigonella foenum-graecum* L.) seeds dietary supplementation regulates liver antioxidant defense systems in aging mice. *Nutrients* 12 (9), 2552. <https://doi.org/10.3390/nu12092552>.
- Tewari, D., Stankiewicz, A.M., Mocan, A., Sah, A.N., Tzvetkov, N.T., Huminiński, L., Horbańczuk, J.O., Atanasov, A.G., 2018. Ethnopharmacological approaches for dementia therapy and significance of natural products and herbal drugs. *Front. Aging Neurosci.* 10, 3.
- Tupas, G.D., Otero, M.C., Ebhohimen, I.E., Egbuna, C., Aslam, M., 2020. Antidiabetic lead compounds and targets for drug development. In: Egbuna, C., Kumar, S., Ifemeje, J.C., Ezzat, S.M., Kaliyaperumal, S. (Eds.), *Phytochemicals as Lead Compounds for New Drug Discovery*. Elsevier, pp. 127–141.
- Tzvetkov, N.T., Stammer, H.G., Georgieva, M.G., Russo, D., Faraone, I., Balacheva, A.A., Hristova, S., Atanasov, A.G., Milella, L., Antonov, L., Gastreich, M., 2019. Carboxamides vs. methanimines: crystal structures, binding interactions, photophysical studies, and biological evaluation of (indazole-5-yl)methanimines as monoamine oxidase B and acetylcholinesterase inhibitors. *Eur. J. Med. Chem.* 179, 404–422.
- Uhrin, P., Wang, D., Mocan, A., Waltenberger, B., Breuss, J.M., Tewari, D., Mihaly-Bison, J., Huminiński, L., Starzynski, R.R., Tzvetkov, N.T., Horbańczuk, J., Atanasov, A.G., 2018. Vascular smooth muscle cell proliferation as a therapeutic target. Part 2: natural products inhibiting proliferation. *Biotechnol. Adv.* 36, 1608–1621.
- Vacca, R.A., Bavari, S., Valenti, D., Tewari, D., Nabavi, S.F., Shirooie, S., Sah, A.N., Volpicella, M., Braidly, N., Nabavi, S.M., 2019. Down syndrome: neurobiological alterations and therapeutic targets. *Neurosci. Biobehav. Rev.* 98, 234–255.
- Waksman, S.A., Schatz, A., 1945. Streptomycin—origin, nature, and properties*[†]Journal series paper of the department of microbiology of the New Jersey agricultural experiment station, Rutgers University. *J. Am. Pharm. Assoc.* 34, 273–291.
- Walsh, T.J., Teppler, H., Donowitz, G.R., Maertens, J.A., Baden, L.R., Dmoszynska, A., Cornely, O.A., Bourque, M.R., Lupinacci, R.J., Sable, C.A., dePauw, B.E., 2004. Caspofungin versus Liposomal Amphotericin B for empirical antifungal therapy in patients with persistent fever and neutropenia. *N. Engl. J. Med.* 351, 1391–1402.
- Wang, D., Huang, J., Gui, T., Yang, Y., Feng, T., Tzvetkov, N.T., Xu, T., Gai, Z., Zhou, Y., Zhang, J., Atanasov, A.G., 2022. SR-BI as a target of natural products and its significance in cancer. *Semin. Cancer Biol.* 80, 18–38. <https://doi.org/10.1016/j.semcancer.2019.12.025>. Epub 2020 Jan 11. PMID: 31935456.
- Wang, D., Huang, J., Yeung, A.W.K., Tzvetkov, N.T., Horbańczuk, J.O., Willschke, H., Gai, Z., Atanasov, A.G., 2020b. The significance of natural product derivatives and traditional medicine for COVID-19. *Processes* 8.
- Wang, D., Ozen, C., Abu-Reidah, I.M., Chigurupati, S., Patra, J.K., Horbańczuk, J.O., Jozwik, A., Tzvetkov, N.T., Uhrin, P., Atanasov, A.G., 2018. Vasculoprotective effects of pomegranate (*Punica granatum* L.). *Front. Pharmacol.* 9, 544.
- Wang, D., Yang, Y., Lei, Y., Tzvetkov, N.T., Liu, X., Yeung, A.W.K., Xu, S., Atanasov, A.G., 2019a. Targeting foam cell formation in atherosclerosis: therapeutic potential of natural products. *Pharmacol. Rev.* 71, 596–670.
- Wang, D., Zhang, L., Huang, J., Himabindu, K., Tewari, D., Horbańczuk, J.O., Xu, S., Chen, Z., Atanasov, A.G., 2021. Cardiovascular protective effect of black pepper (*Piper nigrum* L.) and its major bioactive constituent piperine. *Trends Food Sci. Technol.* 117, 34–45. <https://doi.org/10.1016/j.tifs.2020.11.024>. ISSN 0924-2244.
- Wang, J., Xu, C., Wong, Y.K., Li, Y., Liao, F., Jiang, T., Tu, Y., 2019b. Artemisinin, the magic drug discovered from Traditional Chinese Medicine. *Engineering* 5, 32–39.
- Wang, Z., Little, N., Chen, J., Lambesis, K.T., Le, K.T., Han, W., Scott, A.J., Lu, J., 2021. Immunogenic camptothecin nanovesicles comprising sphingomyelin-derived camptothecin bilayers for safe and synergistic cancer immunotherapy. *Nat. Nanotechnol.* 16, 1130–1140.
- Wazny, K., 2018. Applications of crowdsourcing in health: an overview. *J. Glob. Health* 8 (1), 010502. <https://doi.org/10.7189/jogh.08.010502>.
- Wink, M., 2015. Modes of action of herbal medicines and plant secondary metabolites. *Medicines* 2, 251–286.
- Wink, M., 2022. Current understanding of modes of action of multicomponent bioactive phytochemicals: potential for nutraceuticals and antimicrobials. *Annu. Rev. Food Sci. Technol.* 13, 337–359. <https://doi.org/10.1146/annurev-food-052720-100326>, 6.1-6.23.
- Woolston, C., 2015. Scientists share inspiration on Twitter with #IAMAScientistBecause and #BeyondMarieCurie. *Nature* 520, 267.
- Xi, Y., Liu, X., Xiong, W., Wang, H., Ji, X., Kong, F., Yang, G., Xu, J., 2021. Converting amorphous kraft lignin to hollow carbon shell frameworks as electrode materials for lithium-ion batteries and supercapacitors. *Ind. Crops Prod.* 174, 114184 <https://doi.org/10.1016/j.indcrop.2021.114184>.
- Xiang, A., Gao, Z., Zhang, K., Jiang, E., Ren, Y., Wang, M., 2021. Study on the Cd (II) adsorption of biochar based carbon fertilizer. *Ind. Crops Prod.* 174, 114213 <https://doi.org/10.1016/j.indcrop.2021.114213>.
- Xue, J., Liu, Y., Shi, K., Qiao, Y., Cheng, D., Bai, Y., Shen, C., Jiang, Q., 2022. Responses of seawater bacteria in the bioremediation process of petroleum contamination by immobilized bacteria. *J. Environ. Chem. Eng.* 10 (2), 107133 <https://doi.org/10.1016/j.jece.2022.107133>.
- Yang, D., Zhou, Z., Zhang, L., 2019. An overview of fungal glycan-based therapeutics, Glycans and Glycosaminoglycans as Clinical Biomarkers and Therapeutics, Part B, pp. 135–163, doi:10.1016/bs.pmbts.2019.02.001.
- Yang, R., Ma, M., Lv, M., Zhang, S., Xu, H., 2021. Non-food bioactive products for pesticides candidates (III): agricultural properties of isoxazole esters from the plant product podophyllotoxin as botanical pesticides. *Ind. Crops Prod.* 174, 114181 <https://doi.org/10.1016/j.indcrop.2021.114181>.
- Yang, Y., Kanev, D., Nedeva, R., Jozwik, A., Rollinger, J.M., Grzybek, W., Pyzel, B., Yeung, A.W.K., Uhrin, P., Breuss, J.M., Horbańczuk, J.O., Malainer, C., Xu, T., Wang, D., Atanasov, A.G., 2019b. Black pepper dietary supplementation increases high-density lipoprotein (HDL) levels in pigs. *Curr. Res. Biotechnol.* 1, 28–33.
- Yeung, A.W.K., Aggarwal, B.B., Barreca, D., Battino, M., Belwal, T., Horbańczuk, O.K., Berindan-Neagoe, I., Bishayee, A., Daglia, M., Devkota, H.P., Echeverría, J., El-Demerdash, A., Orhan, I.E., Godfrey, K.M., Gupta, V.K., Horbańczuk, J.O., Modliński, J.A., Huber, L.A., Huminiński, L., Jóźwik, A., Marchewka, J., Miller, M.J.S., Mocan, A., Mozos, I., Nabavi, S.F., Nabavi, S.M., Pieczyńska, M.D., Pittalà, V., Rengasamy, K.R.R., Sanches, A., Silva, A.S., Sheridan, H., Stankiewicz, A.M., Strzałkowska, N., Sureda, A., Tewari, D., Weissig, V., Zengin, G., Atanasov, A.G., 2018. Dietary natural products and their potential to influence health and disease including animal model studies. *Anim. Sci. Pap. Rep.* 36 (4), 345–358.
- Yeung, A.W.K., Aggarwal, B.B., Orhan, I.E., Horbańczuk, O.K., Barreca, D., Battino, M., Belwal, T., Bishayee, A., Daglia, M., Devkota, H.P., Echeverría, J., El-Demerdash, A., Balacheva, A., Georgieva, M., Godfrey, K., Gupta, V.K., Horbańczuk, J.O., Huminiński, L., Jóźwik, A., Strzałkowska, N., Mocan, A., Mozos, I., Nabavi, S.M., Pajpanova, T., Pittalà, V., Feder-Kubis, J., Sampino, S., Silva, A.S., Sheridan, H., Sureda, A., Tewari, D., Wang, D., Weissig, V., Yang, Y., Zengin, G., Shanker, K., Moosavi, M.A., Shah, M.A., Kozuharova, E., Al-Rimawi, F., Durazzo, A., Lucarini, M., Souto, E.B., Santini, A., Malainer, C., Djilianov, D., Tancheva, L.P., Li, H.-B., Gan, R.-Y., Tzvetkov, N.T., Atanasov, A.G., 2019a. Resveratrol, a popular dietary supplement for human and animal health: quantitative research literature analysis—a review. *Anim. Sci. Pap. Rep.* 37, 103–118.
- Yeung, A.W.K., Atanasov, A.G., Sheridan, H., Klager, E., Eibensteiner, F., Völkl-Kernstock, S., Kletecka-Pulker, M., Willschke, H., Schaden, E., 2021a. Open innovation in medical and pharmaceutical research: a literature landscape analysis. *Front. Pharmacol.* 11, 587526 <https://doi.org/10.3389/fphar.2020.587526>. PMID: 33519448; PMCID: PMC7840485.
- Yeung, A.W.K., Heinrich, M., Kijjoo, A., Tzvetkov, N.T., Atanasov, A.G., 2020a. The ethnopharmacological literature: an analysis of the scientific landscape. *J. Ethnopharmacol.* 250, 112414.
- Yeung, A.W.K., Horbańczuk, M., Tzvetkov, N.T., Mocan, A., Carradori, S., Maggi, F., Marchewka, J., Sut, S., Dall'Acqua, S., Gan, R.Y., Tancheva, L.P., Polgar, T., Berindan-Neagoe, I., Pirgozliev, V., Šmejkal, K., Atanasov, A.G., 2019b. Curcumin: total-scale analysis of the scientific literature. *Molecules* 24 (7), 1393. <https://doi.org/10.3390/molecules24071393>. PMID: 30970601; PMCID: PMC6480685.
- Yeung, A.W.K., Kletecka-Pulker, M., Eibensteiner, F., Plunger, P., Völkl-Kernstock, S., Willschke, H., Atanasov, A.G., 2021b. Implications of Twitter in health-related research: a landscape analysis of the scientific literature. *Front. Public Health* 9, 654481. <https://doi.org/10.3389/fpubh.2021.654481>. PMID: 34307273; PMCID: PMC8299201.
- Yeung, A.W.K., Souto, E.B., Durazzo, A., Lucarini, M., Novellino, E., Tewari, D., Wang, D., Atanasov, A.G., Santini, A., 2020b. Big impact of nanoparticles: analysis of the most cited nanopharmaceuticals and nonnutraceuticals research. *Curr. Res. Biotechnol.* 2, 53–63.
- Yeung, A.W.K., Tosevska, A., Klager, E., Eibensteiner, F., Tsagkaris, C., Parvanov, E.D., Nawaz, F.A., Völkl-Kernstock, S., Schaden, E., Kletecka-Pulker, M., Willschke, H., Atanasov, A.G., 2022. Medical and health-related misinformation on social media: bibliometric study of the scientific literature. *J. Med. Internet Res.* 24 (1), e28152 <https://doi.org/10.2196/28152>.
- Yeung, A.W.K., Tzvetkov, N.T., Durazzo, A., Lucarini, M., Souto, E.B., Santini, A., Gan, R. Y., Jozwik, A., Grzybek, W., Horbańczuk, J.O., Mocan, A., Echeverría, J., Wang, D., Atanasov, A.G., 2020c. Natural products in diabetes research: quantitative literature analysis. *Nat. Prod. Res.* 35 (24), 5813–5827. <https://doi.org/10.1080/14786419.2020.1821019>. Epub 2020 Oct 7. PMID: 33025819.

- Yeung, A.W.K., Tzvetkov, N.T., El-Tawil, O.S., Bungău, S.G., Abdel-Daim, M.M., Atanasov, A.G., 2019c. Antioxidants: scientific literature landscape analysis. *Oxid. Med. Cell. Longev.* 2019, 1–11.
- Yeung, A.W.K., Tzvetkov, N.T., Georgieva, M.G., Ognyanov, I.V., Kordos, K., Jozwik, A., Kuhl, T., Perry, G., Petralia, M.C., Mazzon, E., Atanasov, A.G., 2021c. Reactive oxygen species and their impact in neurodegenerative diseases: literature landscape analysis. *Antioxid. Redox Signal.* 34, 402–420.
- Yeung, A.W.K., Tzvetkov, N.T., Gupta, V.K., Gupta, S.C., Orive, G., Bonn, G.K., Fiebich, B., Bishayee, A., Efferth, T., Xiao, J., Silva, A.S., Russo, G.L., Daglia, M., Battino, M., Orhan, I.E., Nicoletti, F., Heinrich, M., Aggarwal, B.B., Diederich, M., Banach, M., Weckwerth, W., Bauer, R., Perry, G., Bayer, E.A., Huber, L.A., Wolfender, J.-L., Verpoorte, R., Macias, F.A., Wink, M., Stadler, M., Gibbons, S., Cifuentes, A., Ibanez, E., Lizard, G., Müller, R., Ristow, M., Atanasov, A.G., 2019d. Current research in biotechnology: exploring the biotech forefront. *Curr. Res. Biotechnol.* 1, 34–40.
- Zaccardelli, M., Pane, C., Caputo, M., Durazzo, A., Lucarini, M., Silva, A.M., Severino, P., Souto, E.B., Santini, A., De Feo, V., 2020. Sage species case study on a spontaneous mediterranean plant to control phytopathogenic fungi and bacteria. *Forests* 11 (6), 704. <https://doi.org/10.3390/f11060704>.
- Zhubi-Bakija, F., Bajraktari, G., Bytyci, I., Mikhailidis, D.P., Henein, M.Y., Latkovskis, G., Rexhaj, Z., Zhubi, E., Banach, M., Alnouri, F., Amar, F., Atanasov, A.G., Bajraktari, G., Banach, M., Bartlomiejezyk, M.A., Bjelakovic, B., Bruckert, E., Cafferata, A., Ceska, R., Cicero, A.F.G., Collet, X., Descamps, O., Djuric, D., Durst, R., Ezhov, M.V., Fras, Z., Gaita, D., Hernandez, A.V., Jones, S.R., Jozwiak, J., Kakauridze, N., Katsiki, N., Khera, A., Kostner, K., Kubilius, R., Latkovskis, G., Mancini, G.B.J., Marais, A.D., Martin, S.S., Martinez, J.A., Mazidi, M., Mikhailidis, D.P., Mirrakhimov, E., Miserez, A.R., Mitchenko, O., Moriarty, P.M., Nabavi, S.M., Nair, D., Panagiotakos, D.B., Paragh, G., Pella, D., Penson, P.E., Petrulioniene, Z., Pirro, M., Postadzhiyan, A., Puri, R., Reda, A., Reiner, Z., Riadh, J., Richter, D., Rizzo, M., Ruscica, M., Sahebkar, A., Sattar, N., Serban, M.-C., Shehab, A.M.A., Shek, A.B., Sirtori, C.R., Stefanutti, C., Tomasik, T., Toth, P.P., Viigimaa, M., Vinereanu, D., Vohnout, B., von Haehling, S., Vrablik, M., Wong, N.D., Yeh, H.-I., Zhisheng, J., Zirluk, A., 2021. The impact of type of dietary protein, animal versus vegetable, in modifying cardiometabolic risk factors: a position paper from the International Lipid Expert Panel (ILEP). *Clin. Nutr.* 40, 255–276.