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Inclinations of Global Research on Saffron as Represented by Science Citation Index-Expanded

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Abstract

Using the Science Citation Index-Expanded of the Web of Science Core Collection, we analyzed global saffron research literature published between 1991 and 2017. The variables examined were research performance of nations, institutions, and authors. The study noted that the distribution of author keywords, citations, and publication patterns of saffron related articles to ascertain the research inclinations. The highly cited articles and author keyword analysis showed that the chemical and biochemical qualities of saffron were of key interest for the researchers.

Keywords: Data Retrieval, Bibliometrics, Research productivity and its assessment, Crocus sativus, Research collaborations, Saffron, Web Of Science.

1. Introduction

Saffron (*Crocus sativus* L.), an Iridaceae herbal geophyte, propagates vegetatively through corms (underground stems); these act as storage and reproductive structures, do not produce seeds or exist as a spontaneous plant (Gresta et al., 2008). A spontaneous plant is that plant which grows and reproduces without human care like weeds. But Saffron is not spontaneous plant as its needs great human care for its production. The spice saffron is the dry, dark red stigma of the flower of *Crocus sativus* (Preview, 2011). On average, each stigma weighs approximately 2 mg and each flower carries three stigmas. To produce 1000 grams (1 kg) of spice one needs to collect at least 1.5 lakh flowers (Pitsikas, 2016). Saffron is the world 's most expensive spice (Fernandez, 2004; Winterhalter and Straubinger, 2000), and named “Red Gold” in Iran (Bathaie & Mousavi, 2010). This “golden” spice is called “Kum Kum” and “Kesar” in Sanskrit, while in Kashmiri it is called “Koung” (Husaini, Hassan, Ghani, Silva, & Kirmani, 2010). It also has uses as a dye, perfume, cosmetic, preservative, antioxidant, and for medicinal purposes (Basker and Negbi, 1983; Bathaie & Mousavi, 2010; Pitsikas, 2016). Ríos, Recio, Giner and Meñez (1996) claim saffron has anticatarrhal, eupeptic, antispasmodic, expectorant, emmenagogue, and sedative properties. Nowadays, the spice’s use is almost exclusively for the coloring and flavoring of food.

Saffron grows primarily in Iran, India, Morocco, Greece, Spain, Italy, China, and Afghanistan. Micro-scale production occurs in France, Switzerland, Turkey, Azerbaijan, Japan, Australia, New Zealand, Argentina, the United States, and elsewhere (De-Los-Mozos-Pascual, Fernández, & Roldán, 2010). The primary purpose of the current study is to present insights into different characteristics of the literature published worldwide about saffron from 1991 to 2017. This study might guide researchers and policy makers in developing methodologies for improved research performance and policy management.

2. Methodology

To understand saffron research trends by countries, institutions, and authors, we explored a bibliometric method for evaluating saffron literature using the Science Citation Index-Expanded (SCI-EXPANDED) database, part of Clarivate Analytics Web of Science Core Collection (WoS). We collected the data from the database using the following search strategy:

TOPIC: ("*Crocus sativus*") OR TOPIC: ("*Saffron crocus*") OR TOPIC: (*Saffron*). Timespan: 1991-2017. Indexes: SCI-EXPANDED.

In total, a 1788 publications were retrieved. We downloaded the complete bibliography and citation records of these publications into spreadsheet software (MS-Excel 2016) for manual coding The source of the impact factor for each journal (IF2017) was Clarivate Analytics Journal Citation Reports (JCR).

The corresponding author labeled as the *"reprint author"* in the SCI-Expanded database of WoS, but the term *"corresponding author"* in place of reprint author has been used in this study. In a *"single author"* article, the single author has been considered both "*first author"* and the "*corresponding author"*. Likewise, for a *"single institution"* article, the institution characterized as the *"first author's institution"* and the *"corresponding author's institution"* (Ho, 2014; Kolle, Shankarappa, Rahimi, & Satish, 2019; Malik, Aftab and Ali, 2019). Articles originating from England, Scotland and Wales were put under the United Kingdom (UK) (Ali, Malik, & Raza, 2018; Fu, Wang, & Ho, 2012).

Publication contributions from various countries and institutions assessed by at least one author's association. The types of cooperation defined by the addresses of the authors, *"single country article"* term given to those articles in which authors addresses are from the same country. The term *"internationally collaborative article"* used for articles co-authored by researchers from several countries. If all researchers are from the same institution, the term *"single institution article"* has been assigned (Wambu, Fu, & Ho, 2017).

3. Results and Discussion

3.1 Document Type and Language

A total of 1788 publications were retrieved, including 10 document types (Table 1). Article (1480) has been the most often used type of document consisting 82.77% out of 1788, followed by meetings abstract (138; 7.72%) and review (136; 7.61%). Other document types i.e. Proceeding paper (25), editorial material (11), correction (7), letters (7), notes (6), news item (3), and one book chapter constituted 3.35%. All the articles published in eleven different languages, the main language used was English which contributes 97.77% (1447) articles. The rest 2.23% published in ten other languages that include German 8 (0.54 %), Spanish 6 (0.41 %), Chinese 5 (0.34 %), Portuguese 5 (0.34 %), French 3 (0.2 %) and Italian 2 (0.14 %). Arabic, Polish, Russian and Turkish contributed 1 (.007%) each. We confined further analysis to articles only because they contain a description of complete researches and results.

Table 1. Document type distribution.

Document Types	No. documents	Percentage (%) of Total
Article	1480	82.77
Meeting Abstract	138	7.72
Review	136	7.61
Proceedings Paper	25	1.39
Editorial Material	11	0.62
Correction	7	0.39
Letter	7	0.39
Note	6	0.34
News Item	3	0.17
Book Chapter	1	0.06

3.2 Publication Outputs and Analysis of Citation Trends

Figure 1 shows the yearly publication results and the citations per publication (CPP) for 1991-2017. The number of publications increased from 16 articles in 1991 to 43 articles in 2005. The output increased almost steadily until 2017. We noticed that the maximum CPP of 57 was for articles published in 2003. This was particularly accredited to the highly cited article titled *"Oxidative remodeling of chromoplast carotenoids: Identification of the carotenoid dioxygenase CsCCD and CsZCD genes involved in crocus secondary metabolite biogenesis"* (Bouvier, Suire, Mutterer, & Camara, 2003). And another article titled *"Radical scavenging activity of Crocus sativus L. extract and its bioactive constituents"* attributed to the top CPP of 43 in 2005 (Assimopoulou, Sinakos, & Papageorgiou, 2005). The citation patterns in research articles provide useful information to track down the impression of articles.

Figure 1. Number of articles with average citations per article over time.

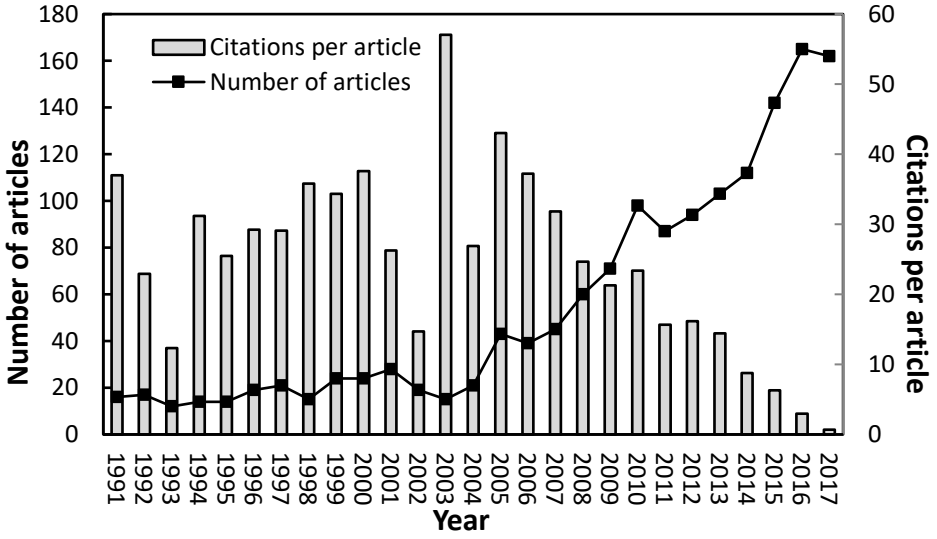

Table 2 presents the saffron research publication results with total publications, authors, references and page numbers. The output of the publication rose from only 16 articles in 1991 to 162 in 2017. During the study period under inquiry, the average annual growth rate (AAGR) of 8.90 percent

papers linked to saffron studies was shown. Of the total articles, 46% produced in the past five years (2013–2017). The average number of authors writing an article is growing; an article is written by four authors on average and the authoring pattern in saffron research is multi-authored. Table 2 shows that the average number of references cited to write the articles increased almost threefold from 14.38 to 42.9, similarly an average page count also shows an increasing trend. All these indicators indicate that saffron research has shown an increasing trend.

$$AAGR = \frac{1}{t} ln\left(\frac{V_f}{V_i}\right)$$

t = Number of times an increase or decrease seen over the time period

ln = Natural log

V_f = Variable under final time period

V_i = Variable under initial time period

Here, t = 26; V_f = 162 and V_i = 16

Table 2. Characteristics of articles published during 1991-2017

Year	TP	%	NA	NA/TP	NR	NR/TP	NP	NP/TP
1991	16	1.08	44	2.75	230	14.38	93	5.81
1992	17	1.15	50	2.94	255	15.00	88	5.18
1993	12	0.81	34	2.83	171	14.25	63	5.25
1994	14	0.95	45	3.21	253	18.07	80	5.71
1995	14	0.95	40	2.86	227	16.21	96	6.86
1996	19	1.28	62	3.26	387	20.37	135	7.11
1997	21	1.42	72	3.43	492	23.43	140	6.67
1998	15	1.01	56	3.73	281	18.73	99	6.60
1999	24	1.62	103	4.29	504	21.00	155	6.46
2000	24	1.62	97	4.04	592	24.67	181	7.54
2001	28	1.89	108	3.86	573	20.46	199	7.11
2002	19	1.28	66	3.47	507	26.68	138	7.26
2003	15	1.01	60	4.00	492	32.80	104	6.93
2004	21	1.42	83	3.95	593	28.24	149	7.09
2005	43	2.91	188	4.37	1278	29.72	305	7.09
2006	39	2.64	188	4.82	1149	29.46	286	7.33
2007	45	3.04	200	4.44	1551	34.47	378	8.40
2008	60	4.05	280	4.67	1855	30.92	467	7.78
2009	71	4.79	319	4.49	2209	31.11	527	7.42
2010	98	6.62	469	4.79	3698	37.73	833	8.50
2011	87	5.88	441	5.07	3058	35.15	657	7.55
2012	94	6.35	468	4.98	3904	41.53	777	8.27
2013	103	6.96	512	4.97	4015	38.98	929	9.02
2014	112	7.57	578	5.16	4370	39.02	937	8.37
2015	142	9.59	711	5.01	5702	40.15	1313	9.25

2016	165	11.15	892	5.41	7368	44.65	1681	10.19
2017	162	10.95	855	5.28	6950	42.90	1517	9.36
Total	1480	100	7021		52664		12327	
Average				4.15		28.52		7.41

TP: Total Publications; ***NA:*** Number of Authors; ***NR:*** Number of Cited References; ***NP:*** Number of Pages; ***NA/TP:*** Number of Authors Per Publication; ***NR/TP:*** Number of Cited References Per Publication, ***PG/TP:*** Number of Pages Per Publication

3.3 Most Productive Journals

Out of 252 WoS subject categories in 2018, we found that 1480 saffron related research articles distributed across 132 subject categories. Among them, Food Science and Technology contributed the most (255 articles), accounting for 17.23% of the total 1480 articles. Then there were 246 (16.62%) and 217 (14.66%) articles related to Pharmacology & Pharmacy and Plant Sciences WoS subject categories respectively. The study further revealed that all 1,480 saffron research related articles published in 667 journals. Table 3 shows the top 12 most prolific journals with total articles and percentage [TP (P)], impact factor according to Journal Citation Report 2017 (IF2017) and WoS categories. These 12 journals contributed 245 (16.55%) articles on the saffron research. Among them the *Food Chemistry* was the most prolific journal with 45 (3.04%) articles, followed by the *Journal of Agricultural and Food Chemistry* contributing 43 (2.91%) articles. The journal *Food Chemistry* is also having the highest IF2017=4.946 among the top 12 productive journals, second highest IF2017=3.849 was of the journal *Industrial Crops and Products*, but it only contributed 12 (0.81%) articles in total. The least IF2017=1.372 among top 12 journals was of *Iranian Journal of Pharmaceutical Research* which published only 12 (0.81%) articles on saffron related research. In addition, the journals with the highest IF2017 was *Circulation* a scientific journal with (IF2017 = 18.880), followed by *GUT Journal* on gastroenterology and hepatology with (IF2017 =17.016), *Journal of Hepatology* with (IF2017 = 14.911), *Journal of the American Chemical Society* with (IF2017 = 14.357), and *Hepatology Journal* with (IF2017 =14.079), each of these journals published one article related to saffron research during the study period.

Table 3. Core saffron research journals with ten or more articles between 1991 and 2017

Journals	**TP (P)**	**IF2017**	**Web of Science category**
Food Chemistry	45 (3.04)	4.946	Chemistry, Applied; Food Science & Technology; Nutrition & Dietetics
Journal Of Agricultural And Food Chemistry	43 (2.91)	3.412	Agriculture, Multidisciplinary; Chemistry, Applied; Food Science & Technology
Iranian Journal Of Basic Medical Sciences	28 (1.89)	1.514	Medicine, Research & Experimental; Pharmacology & Pharmacy
Phytotherapy Research	22 (1.49)	3.349	Chemistry, Medicinal; Pharmacology & Pharmacy
Phytomedicine	18 (1.22)	3.610	Plant Sciences; Chemistry, Medicinal; Integrative & Complementary Medicine; Pharmacology & Pharmacy

Planta Medica	16 (1.08)	2.494	Plant Sciences; Chemistry, Medicinal; Integrative & Complementary Medicine; Pharmacology & Pharmacy
Scientia Horticulturae	15 (1.01)	1.760	Horticulture
Journal Of Ethnopharmacology	14 (0.95)	3.115	Plant Sciences; Chemistry, Medicinal; Integrative & Complementary Medicine; Pharmacology & Pharmacy
Iranian Journal Of Pharmaceutical Research	12 (0.81)	1.372	Pharmacology & Pharmacy
Industrial Crops And Products	12 (0.81)	3.849	Agricultural Engineering; Agronomy
Journal Of Chromatography A	10 (0.68)	3.716	Biochemical Research Methods; Chemistry, Analytical
Molecules	10 (0.68)	3.098	Biochemistry & Molecular Biology; Chemistry, Multidisciplinary

***TP*:** Total articles ***P*:** the percentage of total articles; ***IF2017*:** impact factor in 2017

3.4 Performance of countries and research institutions

Analyzing the country and institution level performances helps to reveal the mainstream participants and collaborators in research area under study. Out of the total articles 1475 articles were found with address information in WoS data related to saffron research. All these articles contributed by 71 countries. Out of the 1475 articles, 1218 were "*single country articles"* produced by 52 countries rest 257 were "*internationally collaborative articles"* produced by 61 countries. Articles with reprint address were 1474 contributed by 59 countries.

Table 4 represents the characteristics of countries with TP ≥ 40. The table shows the research productivity of countries ranked by the total output of articles with five indicators those are: TP, SP, CP, FP and RP (Table 4). It was found that out of 1475 articles, 82.57% originating from single country research, while as only 17.42% accounted for international collaborations. Iran contributed 27.46% out of 1475 and got rank 1st in terms of TP, SP, FP and RP, followed by Spain (10.71%), China (9.08%) and India (8.68%). It was further revealed that USA produced most internationally collaborative articles. The top ten saffron research countries were mostly European (5) and Asian (4) countries.

Table 4. Ten countries that are most productive

Country	**TP**	**TP R (P)**	**SP R (P)**	**CP R (P)**	**FP R (P)**	**RP R (P)**
Iran	405	1 (27.46)	1 (29.89)	5 (15.95)	1 (26.51)	1 (26.57)
Spain	158	2 (10.71)	4 (8.37)	2 (21.79)	2 (9.29)	2 (9.19)
Peoples R China	134	3 (9.08)	2 (9.19)	6 (8.56)	3 (8.47)	3 (8.58)
India	128	4 (8.68)	3 (8.95)	10 (7.39)	4 (8.20)	4 (8.04)
Italy	113	5 (7.66)	6 (5.75)	3 (16.73)	5 (6.51)	5 (6.74)
Greece	108	6 (7.32)	7 (5.34)	3 (16.73)	6 (5.9)	7 (5.52)
USA	105	7 (7.12)	8 (3.61)	1 (23.74)	8 (4.14)	8 (4.36)
Japan	93	8 (6.31)	5 (6.08)	10 (7.39)	7 (5.63)	6 (5.72)

France	56	9 (3.79)	10 (2.87)	8 (8.17)	9 (2.78)	9 (2.66)
Turkey	41	10 (2.78)	9 (3.04)	24 (1.56)	10 (2.58)	10 (2.52)

TP: total articles; ***TPR (P):*** Total Articles Rank and Percentage; ***SPR (P):*** Single Author Articles Rank and percentage; ***CPR (P):*** internationally collaborative articles rank and percentage; ***FPR (P):*** first-author articles rank and percentage; ***RPR (P):*** corresponding-authored articles rank and percentage

3.5 Institutions

It was found that out of 1480 articles five were without author address information in SCI-EXPANDED. Therefore, institution level analysis, confined to 1475 articles, out of which 610 were single-institution articles. Table 5 revealed that the top prolific institutions with (TP ≥ 20) were mainly from Iran (6), Greece (2) and both Spain and Japan were represented by one institution. It was also revealed that all these prolific institutions were found among the list of top ten countries. The table further revealed that the distribution of FP and RP were almost same in terms of rank and percentage, this probably indicates that the *"first author"* and the *"corresponding author"* belongs to the same institution. In terms TP, SP, FP, and RP the Mashhad University of Medical Sciences of Iran ranked first. The high level percentage of SP of Mashhad University indicating its great independent research level. The University of Castilla–La Mancha of Spain ranked 2nd in terms of TP, FP and RP, but in terms of CP it got rank first.

Table 5. Ten most productive saffron research institutes (TP ≥ 20)

Institute	**TP**	**TP R (P)**	**SP R (P)**	**CP R (P)**	**FP R (P)**	**RP R (P)**
Mashhad University of Medical Sciences, Iran	115	1 (7.79)	1 (9.51)	2 (6.59)	1 (5.90)	1 (6.67)
University of Castilla–La Mancha, Spain	102	2 (6.92)	3 (3.44)	1 (9.36)	2 (5.49)	2 (5.49)
University of Tehran, Iran	64	3 (4.34)	5 (1.80)	3 (6.13)	3 (2.85)	3 (2.41)
Islamic Azad University, Iran	41	4 (2.78)	5 (1.80)	5 (3.47)	4 (1.76)	5 (1.65)
Agricultural University of Athens, Greece	34	5 (2.31)	18 (0.66)	5 (3.47)	10 (1.22)	11 (0.96)
Tehran University of Medical Sciences, Iran	32	6 (2.17)	82 (0.16)	4 (3.58)	7 (1.29)	7 (1.31)
Tarbiat Modares University, Iran	32	6 (2.17)	11 (1.15)	7 (2.89)	6 (1.42)	6 (1.51)
Aristotle University of Thessaloniki, Greece	32	6 (2.17)	5 (1.80)	8 (2.43)	7 (1.29)	9 (1.09)
Hokkaido Tokai University, Japan	28	9 (1.89)	2 (3.77)	55 (0.58)	4 (1.76)	4 (1.79)
Ferdowsi University of Mashhad, Iran	23	10 (1.56)	8 (1.48)	12 (1.62)	11 (1.15)	9 (1.09)

TP: total articles; ***TPR (P):*** Total Articles Rank and Percentage; ***SPR (P):*** Single institution Articles Rank and percentage; ***CPR (P):*** internationally collaborative articles rank and percentage; ***FPR (P):*** first-author articles rank and percentage; ***RPR (P):*** corresponding-authored articles rank and percentage

3.6 Authorship Analysis

We studied the author performance based on total articles (TP), internationally collaborative articles (CP), first author articles (FP) and corresponding authored articles (RP). While analyzing the author performance it was found that 4744 authors contributed 1480 articles. Authors contributing TP ≥ 21 listed in Table 6. All the productive authors in the table published their work in collaboration. This indicates that saffron related research produced puts emphases on collaborative work rather than on individualistic approach. Hosseinzadeh H from Mashhad University of Medical Sciences of Iran was the most prolific author with 59 articles while Saito K from Hokkaido Tokai University of Japan was the most prolific authors in terms of first authored articles. The table revealed that out of the most productive authors six are from Spain, two each from Iran and Greece and one from Japan.

Table 6. Most productive authors with 21 or more articles

Authors	Institutions	TP	P	CP	FP	RP
Hosseinzadeh H	Mashhad University of Medical Sciences, Iran	59	3.99	59	17	41
Alonso GL	University of Castilla–La Mancha, Spain	47	3.18	47	5	29
Carmona M	University of Castilla–La Mancha, Spain	38	2.57	38	6	4
Saito K	Hokkaido Tokai University, Japan	33	2.23	24	27	31
Gomez-Gomez L	University of Castilla–La Mancha, Spain	26	1.76	26	3	17
Tarantilis PA	Agricultural University of Athens, Greece	26	1.76	26	5	3
Ahrazem O	University of Castilla–La Mancha, Spain	25	1.69	25	9	7
Rubio-Moraga A	University of Castilla–La Mancha, Spain	24	1.62	24	6	2
Polissiou MG	Agricultural University of Athens, Greece	22	1.49	22	0	8
Bathaie SZ	Tarbiat Modares University, Iran	21	1.42	21	0	15
Fernandez JA	University of Castilla–La Mancha, Spain	21	1.42	21	2	8

TP: total articles; ***P:*** Percentage; ***SP:*** Single Author Articles; ***CP:*** internationally collaborative articles; ***FP:*** first-author articles; ***RP:*** corresponding-authored articles

3.7 Most cited articles

Highly cited articles are especially relevant since a large number of citations for a particular research article show a positive influence or significance in the research groups (Wohlin, 2007). These articles offers a valuable understanding about the influence of authors and subjects in a field of research over time (Smith, 2008). Nevertheless, the citations to an article have changed overtime (Ho, 2012). There are studies related to thermodynamics (Fu & Ho, 2015) and material science research (Ho, 2014) which revealed that publications gained more citations with the passage of time from the date of their publishing, but suddenly received less attention after a particular period of time. The articles with highest citation count from its publication date to the end of 2017 considered as the top article. The top articles with total citations till 2017 (TC2017) might be a reliable sign to assist researchers to find the research field's most influential publications. The 10 articles (TC2017 ≥ 145) with high impact till 2017 revealed in Table 7. Of the 10 articles, 2 published in *Cancer Letters* with (IF2017 = 6.491), 1 each in *Molecular Nutrition & Food Research* (IF2017 = 5.151), *Plant Cell* (IF2017 = 2.004), *Journal of Chromatography A* (IF2017 = 3.716), *Nutrition And Cancer-an International Journal* with (IF2017 = 2.261), *Phytotherapy*

Research (IF2017 = 3.349), *Journal of Agricultural and Food Chemistry* (IF2017 = 3.412), *Spectrochimica Acta Part A-Molecular and Biomolecular Spectroscop* (IF2017 = 2.880) and *Journal of Food Science* (IF2017 = 2.018). In general, papers published in high IF journals are likely to have high citations.

Table 7. Table 4 Top 10 articles (TC2017 SE 145)

R (TC2017)	R (C2017)	R (C0)	R (TCPY)	Title	Authors	Journal	Year
1 (209)	11 (19)	341 (0)	28 (9.50)	Crocin, safranal and picrocrocin from saffron (*Crocus sativus* L) inhibit the growth of human cancer cells in vitro	Escribano, J; Alonso, GL; CocaPrados, M; Fernandez, JA	Cancer Letters	1996
2 (196)	14 (18)	122 (1)	2 (16.33)	Total antioxidant capacity of spices, dried fruits, nuts, pulses, cereals and sweets consumed in Italy assessed by three different in vitro assays	Pellegrini, Nicoletta; Serafini, Mauro; Salvatore, Sara; Del Rio, Daniele; Bianchi, Marta; Brighenti, Furio	Molecular Nutrition & Food Research	2006
3 (185)	390 (3)	4 (6)	9 (12.33)	Oxidative remodeling of chromoplast carotenoids: Identification of the carotenoid dioxygenase CsCCD and CsZCD genes involved in crocus secondary metabolite biogenesis	Bouvier, F; Suire, C; Mutterer, J; Camara, B	Plant Cell	2003
4 (182)	84 (9)	341 (0)	54 (7.91)	Determination Of Saffron (*Crocus-Sativus* L) Components In Crude Plant-Extract Using High-Performance Liquid-Chromatography UV-Visible Photodiode-Array Detection-Mass Spectrometry	Tarantilis, PA; Tsoupras, G; Polissiou, M	Journal of Chromatography A	1995
5 (181)	84 (9)	122 (1)	85 (6.70)	Inhibitory Effects Of Nigella-Sativa and Saffron (*Crocus-Sativus*) On Chemical Carcinogenesis In Mice	Salomi, MJ; Nair, SC; Panikkar, KR	Nutrition and Cancer-an International Journal	1991
6 (179)	16 (17)	341 (0)	5 (13.77)	Radical scavenging activity of *Crocus sativus* L. extract and its bioactive constituents	Assimopoulou, AN; Sinakos, Z; Papageorgiou, VP	Phytotherapy Research	2005
7 (165)	113 (8)	341 (0)	39 (8.68)	Flavonols from saffron flower: Tyrosinase inhibitory activity and inhibition mechanism	Kubo, I; Kinst-Hori, I	Journal of Agricultural and Food Chemistry	1999
8 (148)	32 (14)	341 (0)	25 (9.87)	Raman spectra of carotenoids in natural products	Withnall, R; Chowdhry, BZ; Silver, J; Edwards, HGM; de Oliveira, LFC	Spectrochimica Acta Part A-Molecular and Biomolecular Spectroscopy	2003

9 (148)	300 (4)	122 (1)	131 (5.48)	Antitumor-Activity of Saffron (*Crocus-Sativus*)	Nair, SC; Pannikar, B; Panikkar, KR	Cancer Letters	1991
10 (145)	1 (51)	341 (0)	1 (24.17)	Development and Application of a Database of Food Ingredient Fraud and Economically Motivated Adulteration from 1980 to 2010	Moore, Jeffrey C.; Spink, John; Lipp, Markus	Journal of Food Science	2012

TC2017: number of citations until 2017; ***C2017:*** number of citations in 2017; ***C0:*** number of citations in publication year; ***TCPY:*** TC2017 per year

It is evident from the Table 7 that among the highly cited articles five articles published in1990s, followed by four in the 2000s and one in the 2010s. Among these highly cited articles a substantial disparity in the values of total number of citations received from its published year to 2017 (TC2017), total number of citation in 2017 (C2017), total number of citations in publication year (C0) and total number of citations per year (TCPY) without any specific pattern. Out of these ten articles, six articles not cited in their year of publication (C0=0), but became the classic saffron articles.

In total 1480 articles got 24650 citations till 2017. The ten most cited articles accounted for 1738 (7.05%) citations till 2017 (Table 7). The two most cited article (TC2017 = 225) and (TC2017 = 217) by Goel & Aggarwal, (2010) and Worthen, Ghosheh, & Crooks, (1998), published in Nutrition and Cancer-an International Journal and Anticancer Research Journals respectively. However, these two articles do not fit in saffron science. Because among them the first related to *"Curcuma longa* L.*"* frequently referred to as Indian saffron which actually is turmeric. The second highly cited related to blackseed (*Nigella sativa* L). For the analysis of most cited articles, these two articles were therefore excluded. So, we might say that one can't rely solely on search terms used to search the literature about the field under study. The researchers need to have knowledge about the subject and that the review of highly cited articles is very important to determine whether they belong to the field under study or not.

The article titled *"Crocin, safranal and picrocrocin from saffron (Crocus sativus* L*) inhibit the growth of human cancer cells in vitro"* by Escribano, J; Alonso, GL; CocaPrados, M; Fernandez, JA (1996) had the highest TC2017 while this article got rank 11th on C2017 and 28th on TCPY. In over-all, this article shows a growing trend in citations. In this article authors reported that extracts of saffron have tendency to inhibit the growth of tumor cells. Crocin, picrocrocin and safranal from saffron (*Crocus sativus* L.) inhibit the growth of human cancer cells in vitro. The study concluded that Crocin is the most promising and adhering component confirmed as a cancer therapeautic agent (Escribano, Alonso, Coca-Prados, & Fernández, 1996). The 2nd article among the highly cited articles published in the journal "Molecular Nutrition & Food Research" analyzed the total antioxidant capacity (TAC) of spices, dried fruits, pulses, nuts, cereals and sweets. Among spices, saffron showed the highest antioxidant capacity, whereas in case of dried fruits, prune exhibited the highest value. Thus, it concluded that spices yield good total antioxidant capacity (TAC) as compared to various other spices examined (Pellegrini et al., 2006).

The article with TC2017=185 got highest citations in publication year (C0=6) among the top cited articles in table 7. In this article Bouvier et al. (2003) identified and functionally characterize the Crocus zeaxanthin 7, 8 (7,8)-cleavage dioxygenase gene (CsZCD), which mainly codes for a chromoplast enzyme that initiates or acts as precursor for the biogenesis of these derivatives. Another top cited publication related to saffron research ranked at 4th place laid emphasis on the determination of saffron (*Crocus sativus* L.) components like the determination of picrocrocin, the glycosidic precursor of safranal, safranal and flavonoids in crude plant extract using high-performance liquid chromatography-UV-visible photodiode-array detection-mass spectrometry**.**

The differentiation of *cis* and *trans* isomers of saffron derivatives examined by using such techniques (Tarantilis, Tsoupras, & Polissiou, 1995).

Salomi, Nair, and Panikkar's (1991) study got rank 5th among highly cited article, the study examined the effect of topical application of *Nigella sativa* and *Crocus sativus* extracts. They analyzed that these extracts inhibited two stage initiation as well as promotion of skin carcinogenesis (dimethylbenz[a]anthracene (DMBA)/croton oil) in mice. The 6th ranked article is survey based, the authors of this study surveyed that radical scavenging activity is involved in aging processes, anti-inflammatory, anticancer and wound healing activity. Researchers in this research assumed that a methanol extract of *Crocus sativus* exhibited high antioxidant activity, besides containing several active and inactive constituents. The structure-activity relationship of crocin and safranal estimated in their study. Both these components showed high antioxidant properties which in turn find an application in pharmaceutical and food industry (Assimopoulou, Sinakos, & Papageorgiou, 2005).

Kubo and Kinst-Hori's (1999) experiment to isolate a common flavonol and kaempferol from the fresh flower petals of *Crocus sativus* L. The inhibition kinetics analyzed by a Lineweaver-Burk plot found kaempferol to be a competitive inhibitor, which in turn comes from its ability to chelate copper in the enzyme. This study placed at 7th place among highly cited articles. The 8th ranked study was somewhat different as in this study the Resonance Raman spectra was compared between naturally occurring carotenoids of nautilus, periwinkle with in situ spectra of tomatoes, carrots, saffron and red pepper. The tomatoes, carrots and red peppers gave rise to resonance Raman spectra exhibiting nine conjugated carbon- carbon double bonds in their main chains, whereas the resonance Raman spectrum of saffron showed crocetin, having seven conjugated carbon-carbon double bonds (Withnall, Chowdhry, Silver, Edwards, & de Oliveira, 2003).

The article “Antitumor-Activity of Saffron (*Crocus-Sativus*)” with TC2017=148 by Nair, Pannikar, and Panikkar (1991) investigated against intraperitoneally transplanted sarcoma-180 (S-180), Ehrlich ascites Carcinoma (EAC) and Dalton's lymphoma ascites (DLA) tumors in mice by Nair et al., (1991). By analyzing the various dimensions like inhibition of tumor cells, mechanism of action of the extract at the site of DNA synthesis, toxicity studies, biochemical and hematological parameters by saffron extracts indicated the ant cancerous activities of saffron. The last article among highly cited article on saffron research organized a database information (comprehensive compilation) from publicly available articles existing in scholarly journals and general media regarding food ingredient fraud as well as economically manipulated adulteration. The results summarized are a profusely a database that has been published in the US Pharmacopeial Convention's Food Chemicals Codex, 8th edition, and includes 1305 records, with 1000 records with analytical methods collected from 677 references. The database also provides baseline information and data useful to governments, agencies, and individual companies indicating the risks of specific products (Moore, Spink, & Lipp, 2012). Even though this article placed at 10th rank in terms of TC2017 but in terms of C2017 and TCPY it got rank 1st.

The most prominent subject categories were food science and technology (3 articles), oncology (3 articles), followed by Multidisciplinary Agriculture, Biochemistry & Molecular Biology,

Biochemical Research Methods, Cell Biology, Analytical Chemistry, Medicinal Chemistry, Nutrition & Dietetics, Applied Chemistry, Pharmacology & Pharmacy, Plant Sciences and Spectroscopy with one article only, respectively. All the top ten articles refer primarily to the chemical composition of saffron and its antioxidant activities. This asserted that there was a shift from conventional saffron research to the chemical and biochemical qualities of saffron after the year 1990.

3.8 Research tendency and hotspots

Author keyword rankings viewed as per their occurrence, which can help to identify important hot research topics. Sixteen author keywords frequently used by the authors throughout 1991–2017 listed in Table 8. Other than the search keywords Saffron and *Crocus Sativus* it was found that the most often used author keywords were Crocin appeared in 201 articles, followed by Safranal (109 articles), Crocetin (82 articles), and Oxidative Stress (73 articles). These author keyword usages indicate that the components of interest include crocin, safranal and crocetin, all of which have been shown to promote health.

Table 8 Keywords used more than 20 times

Author Keywords	TP	R (%)
Saffron	378	1 (30.46)
Crocin	201	2 (16.20)
Crocus Sativus	187	3 (15.07)
Safranal	109	4 (8.78)
Crocetin	82	5 (6.61)
Oxidative Stress	73	6 (5.88)
Crocus Sativus L.	61	7 (4.92)
Apoptosis	53	8 (4.27)
Antioxidant	44	9 (3.55)
Picrocrocin	39	10 (3.14)
Crocins	31	11 (2.50)
Crocus Sativus L	30	12 (2.42)
Iridaceae	27	13 (2.18)
Cytotoxicity	22	14 (1.77)
Rat	22	14 (1.77)
Carotenoids	21	16 (1.69)

TP: Total articles; ***R:*** rank; ***P:*** percentage out of the total articles

4. Conclusion

The study, examined the world's saffron related literature bibliometrically. We found significant developments related to saffron research between 1991 and 2017. The study revealed that 1788 publications produced during all those years, the prominent contribution was of articles (1480). Out of these articles approximately 97% published in English language. We observed that these research articles published in 667 journals and the *Food Chemistry* was the most productive journal followed by *Journal of Agricultural and Food Chemistry*. The study further revealed that a

progressive trend was found in terms of researchers, institutions and countries involved in saffron research. It has also been verified that the countries like Iran and Spain have a long reputation in the production of saffron. It was found that European countries followed by Asian countries subjugated the output in terms of publication. Iran is primarily concerned with saffron production as well as saffron research. The Mashhad Medical Sciences University in Iran has been the most prolific institution. The examination of the author's keywords indicates that the chemical compounds like crocin, safranal and crocetin isolated from saffron were of key interests among the researchers. The analysis of saffron related literature uncovers trends that might ascertain the track of science as the source for planned research in saffron science in the succeeding study times.

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