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Global trends in scientific production in enology and viticulture in selected emerging economies (BRIC)

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Abstract The aim of this study was to analyse the scientific productivity of the BRIC countries (Brazil, Russia, India and China) in viticulture and oenology through bibliometric analyses of articles in the Science Citation Index Expanded database for the period 1993–2012. A total of 1067 research articles were published in 363 domestic and international journals. We highlight important growth during the mentioned period in the published research papers, particularly in China and Brazil over the last 5 years. Papers have been published in numerous journals in a number of subject areas, such as *Revista Brasileira de Fruticultura* and *Pesquisa Agropecuaria Brasileira*, which are the most productive among the BRIC countries. A social network analysis of collaboration between each of the four BRIC countries was also performed.

Keywords Scientific productivity and collaboration · Network analysis · Viticulture and oenology · BRIC countries

Introduction

The BRIC acronym was created in 2001 from the initial letters of Brazil, Russia, India and China by the Goldman Sachs experts. It is an economic concept that groups together four emerging economies that have attributes in common. These countries have high economic

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potential and are becoming important world economic players. In the first decade of the twenty-first century, all of these countries grew economically, and it is assumed that they will overtake the EU by the year 2020 and dominate the world economy by 2030. BRIC occupy 26 % of the world's land coverage, with 2860 million inhabitants in total (45 % of the world's population); among these inhabitants, 1430 million are considered economically active population, 44 % of the global labour force (Slobodniková and Nagyová 2011).

The global influence of the BRIC countries has been notable for many years. According to data from the World Bank (2011), the BRICs' share of the global GDP was nearly 20 %, whereas China accounted for one-tenth. The highest per capita GDP value of these countries was reached by Russia (15,900 USD), followed by Brazil (10,900 USD) and China (7400 USD), with India the lowest (3400 USD). However, it is necessary to realise that both China and India have the highest number of inhabitants in the world (1.33 billion and 1.18 billion, respectively); thus, their GDPs per capita will be lower than those of Russia and Brazil (CIA World Factbook 2011).

All of the BRIC countries produce wine, and all are important future sources of wine. As these economies grow, their expanding middle classes will be increasingly attractive target markets for the world's wine makers, and their wines will begin to appear on our local shelves. China was the 6th largest wine producer in the world according to the Organisation of Vine and Wine (OIV 2007). Russia was 11th on the global wine league table, followed by Brazil in 15th place. India does not appear in the OIV wine statistics, indicating that its wine industry is quite small at present. The country is already a major producer of table grapes—only slightly less productive than Chile and the US combined—so it is not unreasonable to suppose that higher levels of wine grape production may follow. India would be on the wine BRIC list for its potential as a wine import market, of course, even if it did not make any wine at all (O'Neill and Stopnytska 2011). The BRIC countries will be important to the future of global wine, even if they are not the solution to current problems, such as surplus production and decreased domestic consumption in wine-producing countries such as Spain.

Papers published in scientific journals are one of the measurable outcomes of research activity and may be analysed using quantitative methods. The quantitative determination is based on measures and indicators derived from the statistical analysis of published scientific literature and included in bibliographic databases (White and McCain 1989). These indicators reflect the scientific activity of researchers and their institutions by listing which papers they have published, the characteristics of the literature and the number of collaborative relationships represented by the papers. Authors confer accreditation to colleagues' publications by citing them, and thus, citation counts reflect the impact of published papers on subsequent publications and their authors (Aleixandre-Benavent et al. 2007).

Scientific collaboration facilitates the flow of information among researchers and allows for cost-sharing and improved efficiency in research (Kretschmer 1994; Newman 2004). One way to determine the level of established cooperation is to count the number of co-authorships in an area of scientific research. The co-authorship relationship occurs when two or more authors or institutions contribute to the same scientific paper (Newman 2004). Using social network analysis (SNA), these interpersonal and inter-institutional collaborations can be represented by graphs that quantify how many members make up a network, the intensity of their relationships and which members are the most relevant (Newman 2004; González-Alcaide et al. 2008a). Researchers with the largest number of

collaborative publications are at the "research front" of that field (González-Alcaide et al. 2008b).

The aim of this study was to analyse the scientific activity of BRIC countries researchers in viticulture and oenology through bibliographic analyses of articles included in the Science Citation Index Expanded (SCIE) database for the period from 1993 to 2012. This length of time allows us to obtain comprehensive information with which to establish research trends in the field. Moreover, the joint analysis of productivity, collaboration and scientific impact provides a global and integrated vision of the countries' research in this area.

Methods and data sources

The articles under analysis were obtained from the Science Citation Index Expanded database, accessed via the Web of Knowledge platform (Thomson Reuters) from terminals at the VLC International Campus of Excellence (Valencia, Spain).

For the SCIE research, we combined the following: a) a search by specific words in title; b) a search by institutional addresses; c) a search in specific viticulture and oenology journals; d) BRIC countries; and e) a period of no more than 20 years (Glänzel and Veugelers 2006; Guilford and Pezzuto 2011; Aleixandre et al. 2012).

(a) For the search in the title field, we used the following specific words linked by the OR operator: grapevin*, wines, "wine grap*", "wine pro*", "red wine*", "white wine*", winemaking, enolog*, viticult*, oenolog*, "wine cell*", "wine yeast*", winery, and wineries. The search was conducted in the title field to achieve greater accuracy in the results (the same search applied in the topic option, which includes the search fields Title, Abstract and Keywords (KW), obtained many not relevant). The terms were truncated using an asterisk to obtain all documents associated with the derived words (e.g., wine* allows for the recovery of items containing the terms wine, wines, winery, wineries, etc.).

(b) For the search in institutional addresses, we used the following words linked by the OR operator: enolog*, viticult*, oenol*.

(c) For the search in specific viticulture and oenology journals, we searched for papers published in the American Journal of Enology and Viticulture, the Australian Journal of Grape and Wine Research, Ciencia e Técnica Vitivinícola, the Journal International des Sciences de la Vigne et du Vin, the South African Journal of Oenology and Viticulture and Vitis.

(d) For the search limited to articles that from the BRIC countries, we used the following: Brazil, Russia, India and China.

Searches a, b and c were combined with the operator of logical sum "or", and the result was combined with the "and" operator with BRIC countries (d) and the period from 1993 to 2012.

The records obtained were exported to a relational database in Access (Microsoft) (Redmont, Washington, USA) and were reviewed to ensure their relevance. Then, the information was analysed to identify the journals in which the articles were published, the journals' subject categories (SC), the KWs frequently associated with these areas and the journals and articles that received the most citations. In addition, we used social SNA to identify all combinations of pairs of countries, quantifying the number of different co-occurrences in the set of papers that had been revised. The Pajek software (Ljubljana,

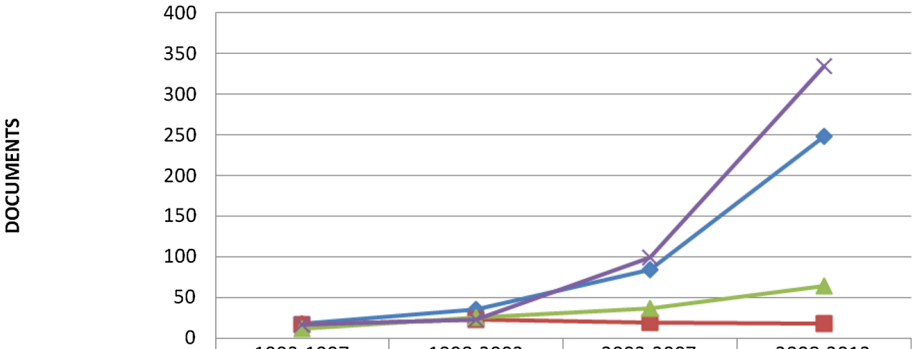
Slovenia) was used for the construction and graphical representation of the networks, and the VOSViewer software (Leiden, The Netherlands) was used to construct the density collaboration map among institutions and countries. The size of the spheres is proportional to the number of articles published by each institution or country, and the thickness of the lines connecting the spheres is proportional to the number of papers published in collaboration. The data on impact factors were extracted from the 2012 edition of the Journal Citation Reports (JCR).

Results

Scientific productivity by country

Over the twenty-year period, 1067 research articles were published, and there was a notable increase in the numbers, from 61 between 1993 and 1997 (5.7 %) to 664 (62.2 %) from 2008 to 2012 (Fig. 1). The countries that published the most articles were China ($n = 472$) and Brazil ($n = 385$). India and Russia were located at a second level, with 137 and 76 papers, respectively. The relative productivity by number of inhabitants and gross domestic product is shown in Table 1. As observed, Brazil has the highest productivity on both indicators, followed by Russia, considering the relative productivity by number of inhabitants, and China, considering the relative productivity by GDP.

The global scientific output in oenology and viticulture in the Web of Science database during the period 1993–2012 using the same search strategy was 22,239 articles. This production increased from 506 articles in 1993 to 1898 in 2012, increasing nearly fourfold between the first and last years. The scientific production of the BRIC countries in oenology and viticulture increased from 13 published articles in 1993 to 160 in 2102, in this case increasing by 12 times between the first and last years. The number of articles on oenology and viticulture in the BRIC countries increased more than the number of articles published in these countries in all other areas; according to data from the Web of Science,



	1993-1997	1998-2002	2003-2007	2008-2012
Brazil	18	35	84	248
Russia	16	23	19	18
India	11	25	37	64
Peoples R China	16	23	99	334

Fig. 1 Number of papers published by BRIC countries (1993–2012)

Table 1 Articles on viticulture and enology in BRIC countries (1993–2012)

Country	1993–1997	1998–2002	2003–2007	2008–2012	Total	Inhabitants[a]	A/I	GDP	A/GDP
Brazil	18	35	84	248	385	198.7	1.9	2253	0.17
Russia	16	23	19	18	76	143.5	0.5	2015	0.03
India	11	25	37	64	137	1237	0.1	1842	0.07
Peoples R China	16	23	99	334	472	1351	0.3	8358	0.05
Total	61	106	239	664	1.070				

Sources: Bulletin de l'OIV (avalaible at: www.oiv.int/oiv/info/frbulletin); World Bank (available at: http://data.worldbank.org/country)

[a] In millions; *A/I* Articles per inhabitant, *GDP* gross domestic product (trillions in current US $), *A/GDP* articles per GDP

the number of articles published in BRIC countries in all areas increased from 48,808 in 1993 to 304,143, that is, sixfold between the first and last years.

Journals of publication

The papers were published in 363 different journals. Table 2 lists the 38 journals that published more than 5 articles distributed by country of publication, number of articles in each BRIC country and impact factor in 2012. *Revista Brasileira de Fruticultura* was the journal that published the most articles ($n = 50$; Brazil), followed by VITIS ($n = 44$; Germany), *Food Chemistry* ($n = 34$; United Kingdom) and the *Journal of Agricultural and Food Chemistry* ($n = 32$; USA). The journals' origins by BRIC country were: 8 Brazilian journals, 2 Chinese, 1 from Russia and no Indian journals. The specific journals that published the most articles (more than 20) were *Revista Brasileira de Fruticultura* ($n = 50$), *Pesquisa Agropecuaria Brasileira* ($n = 27$) and *Spectroscopy and Spectral Analysis* ($n = 24$, China). The specific viticulture and oenology journals that published the most articles were *American Journal of Enology and Viticulture* ($n = 23$; United States), *Journal International des Sciences de la Vigne et du Vin* ($n = 14$; France), *Ciencia e Tecnica Vitivinicola* ($n = 8$; Portugal), *Australian Journal of Grape and Wine Research* ($n = 7$; Australia) and the *South African Journal of Oenology and Viticulture* ($n = 6$; South Africa). Brazil had the most journals ($n = 8$), whereas China published two and Russia published one. The journals with higher impact factors were *Journal of Chromatography A* (IF = 4.612), *Analytica Chimica Acta* (IF = 4.387) and *Analyst* (IF = 3.969). The journals with the highest IFs were generally published in the United Kingdom, the Netherlands and the USA.

Subject areas of publication

Table 3 shows the classification of articles in the SCIE subject areas that exceeded 40 published articles, the three most frequent key words in each area and the three journals that published the most articles in each area. First was the SC food science and technology ($n = 271$), whose most common KWs were grape ($n = 84$), wine ($n = 69$) and red wine

Table 2 Papers in most productive journals published in BRIC countries

Journal	Country of publication of the journal	Brazil	India	Peoples R china	Russia	Articles	% articles	Impact factor
Revista Brasileira De Fruticultura	Brazil	50	–		–	50	4.69	0.296
Vitis	Germany	6	15	23	–	44	4.12	0.859
Food Chemistry	England	12	2	20	–	34	3.19	3.34
Journal of Agricultural and Food Chemistry	United States	11	2	18	1	32	3.00	2.906
Pesquisa Agropecuaria Brasileira	Brazil	27	–	–	–	27	2.53	0.661
Spectroscopy and Spectral Analysis	China	–	–	24	–	24	2.25	0.293
American Journal of Enology and Viticulture	United States	8	1	12	2	23	2.16	1.856
Analytica Chimica Acta	Netherland	7	1	5	7	20	1.87	4.387
Ciencia Rural	Brazil	19	–	–	–	19	1.78	0.383
Journal of the Institute of Brewing	England	2	–	16	–	18	1.69	0.883
Molecules	Switzerland	–	–	15	–	15	1.41	2.428
Journal International des Sciences de la Vigne et du Vin	France	10	–	3	1	14	1.31	0.830
Ciencia e Agrotecnologia	Brazil	13	–	–	–	13	1.22	0.395
Ciencia e Tecnologia de Alimentos	Brazil	13	–	–	–	13	1.22	0.326
Chinese Journal of Analytical Chemistry	China	–	–	12	–	12	1.12	0.769
Applied Biochemistry and Microbiology	Russia	–	–	–	11	11	1.03	0.689
International Journal of Food Science and Technology	England	3	4	3	–	10	0.94	1.240
Quimica Nova	Brazil	10	–	–	–	10	0.94	0.737
Food Research International	United States	4	–	5	–	9	0.84	3.005
Photosynthetica	Czech Republic	–	6	3	–	9	0.84	0.862
Brazilian Archives of Biology and Technology	Brazil	7	1	–	–	8	0.75	0.473
Ciencia e Tecnica Vitivinicola	Portugal	8	–	–	–	8	0.75	0.278
Food Science and Biotechnology	South Korea	1	–	7		8	0.75	0.695
Scientia Horticulturae	Netherlands	–	–	8	–	8	0.75	1.396
Talanta	England	7	–	–	1	8	0.75	3.498

Table 2 continued

Journal	Country of publication of the journal	Brazil	India	Peoples R china	Russia	Articles	% articles	Impact factor
Australian Journal of Grape and Wine Research	Australia	1	–	6	–	7	0.66	2.958
Chromatographia	Germany	1	–	6	–	7	0.66	1.437
European Food Research and Technology	Germany	2	–	5	–	7	0.66	1.436
Journal of Chromatography A	Netherlands	3	2	2	–	7	0.66	4.612
Journal of the Brazilian Chemical Society	Brazil	7	–	–	–	7	0.66	1.283
Analyst	England	5	–	1	–	6	0.56	3.969
Analytical Letters	United States	1	–	5	–	6	0.56	0.965
Journal of Food Science	United States	2	–	4	–	6	0.56	1.775
Journal of Separation Science	Germany	2	–	4	–	6	0.56	2.591
Lebensmittel-Wissenschaft Und-Technologie-Food Science and Technology	Japan	3	–	3	–	6	0.56	0.471
Molecular Biology Reports	Netherlands	–	–	6	–	6	0.56	2.506
South African Journal of Enology and Viticulture	South Africa	–	2	4	–	6	0.56	1.193
World Journal of Microbiology & Biotechnology	Netherlands	1	1	4	–	6	0.56	1.262

($n = 63$). The journals in this SC that published the most articles were *Food Chemistry,* the *Journal of Agricultural and Food Chemistry* and the *American Journal of Enology and Viticulture*. The second SC was horticulture ($n = 172$), whose most frequent KWs were Vitis vinifera ($n = 101$), grape ($n = 78$) and growth ($n = 24$); *Revista Brasileira de Fruticultura*, *Vitis* and the *American Journal of Enology and Viticulture* were the most productive journals. Another with more than one hundred papers published was chemical analytical ($n = 124$), with wine, red wine and phenolic compounds being the most frequent KWs, and *Analytica Chimica Acta*, *Chinese Journal of Analytical Chemistry* and *Talanta* as the journals with more publications. With a total of more than 50 articles, the list was completed by the SCs agriculture, multidisciplinary ($n = 92$), biotechnology and applied microbiology ($n = 89$), chemistry, applied ($n = 88$) and plant sciences ($n = 84$).

Table 3 Papers by main subject areas, key words (KW) and most productive journals

Subject area	*n*	Main key words						Most productive journals
		KW 1	*n*	KW 2	*n*	KW 3	*n*	
Food Science & Technology	271	Grape	84	Wine	69	Red wine	63	Food Chemistry Journal of Agricultural and Food Chemistry American Journal of Enology and Viticulture
Horticulture	172	Vitis vinifera	101	Grape	78	Growth	24	Revista Brasileira de Fruticultura Vitis American Journal of Enology and Viticulture
Chemistry, Analytical	124	Wine	46	Red wine	31	Phenolic compounds	19	Analytica Chimica Acta Chinese Journal of Analytical Chemistry Talanta
Agriculture, Multidisciplinary	92	Vitis vinifera	49	Grape	22	Phenolic compounds	18	Journal of Agricultural and Food Chemistry Pesquisa Agropecuaria Brasileira Ciencia e Agrotecnologia
Biotechnology and Applied Microbiology	89	Saccharomyces cerevisiae	18	Grape	17	Vitis vinifera	16	American Journal of Enology and Viticulture Applied Biochemistry and Microbiology World Journal of Microbiology & Biotechnology
Chemistry, Applied	88	Wine	26	Red wine	26	grape	23	Food chemistry Journal of agricultural and food chemistry Food Additives and Contaminants Part A-Chemistry Analysis Control Exposure & Risk Assessment
Plant Sciences	84	Grape	32	Vitis vinifera	31	Photosystem	20	Photosynthetica Biologia Plantarum Tropical Plant Pathology
Chemistry, Multidisciplinary	45	Wine	13	Red wine	9	Phenolic compounds	5	Quimica Nova Journal of the Brazilian Chemical Society Chemical Journal of Chinese Universities-Chinese

Table 3 continued

Subject area	*n*	Main key words						Most productive journals
		KW 1	*n*	KW 2	*n*	KW 3	*n*	
Nutrition and Dietetics	45	Grape	15	Wine	15	Red wine	14	Food Chemistry Acta Alimentaria Plant Foods for Human Nutrition
Agronomy	42	Grape	19	Vitis vinifera	13	Wine	6	Ciencia Rural European Journal of Plant Pathology Research on Crops
Microbiology	41	Strains	11	Fermentation	9	Yeast	9	Applied Biochemistry and Microbiology International Journal of Food Microbiology Current Microbiology

Table 4 Papers by institutions that published more than nine papers, country and citations

Institution	Country	Number of articles	Citations
China Agricultural University	Peoples R China	106	596
Universidade de São Paulo	Brazil	65	695
Embrapa Uva e Vinho	Brazil	64	405
Universidade Federal de Santa Catarina	Brazil	52	253
Northwest A&F University	Peoples R China	50	324
Universidade Federal do Rio Grande do Sul	Brazil	46	177
Zhejiang University	Peoples R China	42	387
Universidade Estadual Paulista (UNESP)	Brazil	27	406
Chinese Academy Of Sciences	Peoples R China	27	180
Universidade Estadual de Campinas	Brazil	26	404
Instituto Agronômico (IAC)	Brazil	25	42
Universidade Federal de Lavras	Brazil	22	110
National Research Centre for Grapes	India	22	103
Fondazione Edmund Mach di San Michele all'Adige	Italy	21	274
Russian Academy of Sciences	Russia	21	126
Universidade Federal de Santa Maria (UFSM)	Brazil	21	90
University of California, Davis	USA	19	256
Jiangnan University	Peoples R China	19	66
Chinese PLA General Hospital	Peoples R China	18	86
Universidade Federal do Paraná	Brazil	17	92
Florida A&M University	USA	16	143
Embrapa Uva Vinho Semi Árido	Brazil	16	58
Government Higher Secondary School	India	15	143
Lomonosov Moscow State University	Russia	14	150
EPAMIG—Empresa de Pesquisa Agropecuária de Minas Gerais	Brazil	14	20
Epagri—Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina	Brazil	13	134
Universidade de Caxias do Sul	Brazil	13	105
Federal University of Bahia (UFBA)	Brazil	12	155
Universite Bordeaux 2	France	11	286
Cornell University	USA	11	185
sri venkateswara university	India	11	57
Shanghai Jiao Tong University	Peoples R China	11	54
Universidade Estadual de Londrina	Brazil	11	33
St Petersburg State University	Russia	10	303
INRA—Institut National de la Recherche Agronomique	France	10	183
Nanjing Agricultural University	Peoples R China	10	69
Shandong Agricultural University	Peoples R China	10	59
Chinese Academy of Agricultural Sciences (CAAS)	Peoples R China	10	25

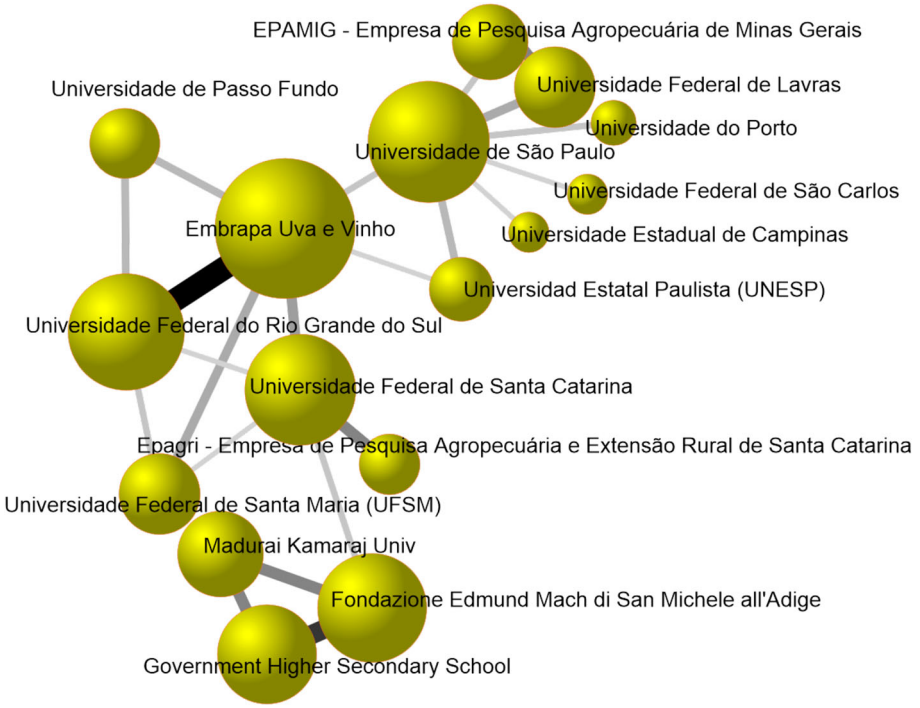


Fig. 2 Network of collaboration between Brazilian institutions

Institutions

The most productive institutions, with more than 50 published articles and citations, were: China Agricultural University (China, $n = 106$), Universidade de São Paulo (Brazil, $n = 65$), Embrapa Uva e Vinho (Brazil, $n = 64$) and Universidade Federal de Santa Catarina (Brazil, $n = 52$) (see Table 4). The first Indian institution was The National Research Centre for Grapes ($n = 22$), and the first Russian institution was the Russian Academy of Science ($n = 21$). The most cited institutions were the Universidade de São Paulo ($n = 695$), followed by the China Agricultural University ($n = 596$), the Universidade Estadual Paulista ($n = 406$), Embrapa ($n = 405$) and the Universidade Estadual de Campinas ($n = 404$).

Networks of collaboration

Figures 2, 3 and 4 show the network of collaboration between institutions. The main network (Fig. 2) comprises Brazilian institutions, particularly the Universidade de Sao Paulo, Universidade Federal do Rio Grande do Soul, Universidade Federal de Santa Catarina, and Embrapa Uva e Vinho. Figure 3 shows the network of Chinese institutions and highlights three groups. The main group has the China Agricultural University as the central institution, Zhejiang University the second, and the Beijing Institute of Technology as the third. Figure 4 shows 10 other collaborations, including collaborations with institutions from non-BRIC countries.

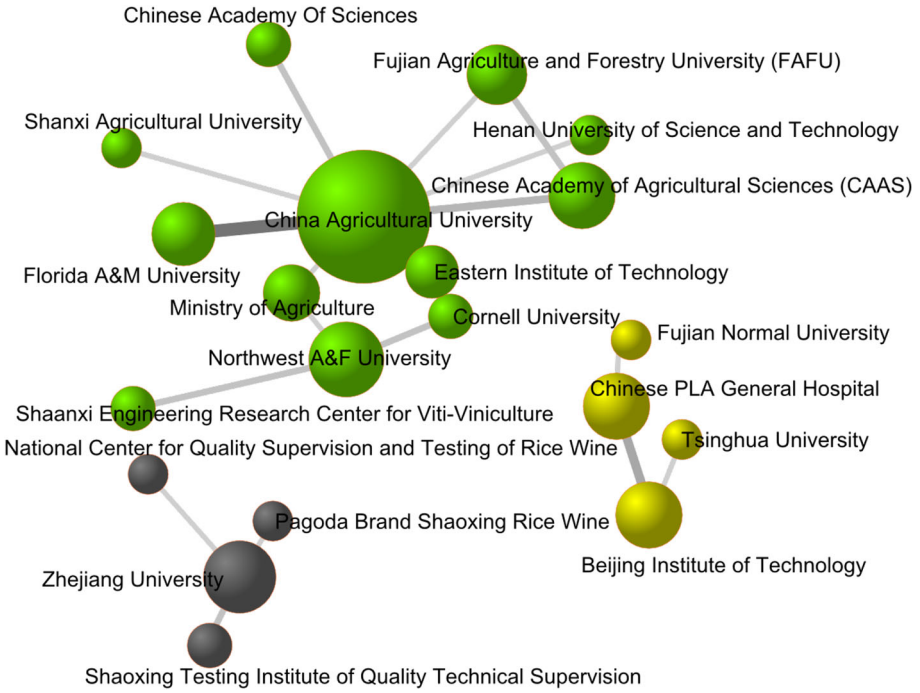


Fig. 3 Network of collaboration between Chinese institutions

Figures 5, 6, 7 and 8 show the collaborations between each BRIC country and other countries. The network of Brazil (Fig. 5) shows the most with the United States, France, Italy, Spain and Portugal. On Russia's map (Fig. 6), there are more collaborations with Italy, the United States and France. India (Fig. 7) collaborated most often with the United States, France, Italy and Spain. China's network (Fig. 8) highlights cooperation with the United States, Japan, France and Australia.

Most cited papers

The 14 papers that received more than 60 citations are presented in Table 5. Six of them were published by Brazilian researchers, five by Chinese researchers, three by Russians and one by an Indian. The most cited article was by Hanquing et al., who were from the University of Science & Technology of China and the Shandong University of China ($n = 198$ citations). The second most-cited article was published by Wu et al. in a collaboration between the New York Medical College (United States) and Nanjing Medical University (China) ($n = 168$ citations). The third, with 121 citations, was a Brazilian paper by Minussi et al., who were affiliated with the Universidade Estadual de Campinas and who collaborated with Consorzio Mario Negri Sud (Italy).

Discussion

This paper has identified some of the characteristics of the research on viticulture and oenology in BRIC countries by analysing the publications included in the WOS, including

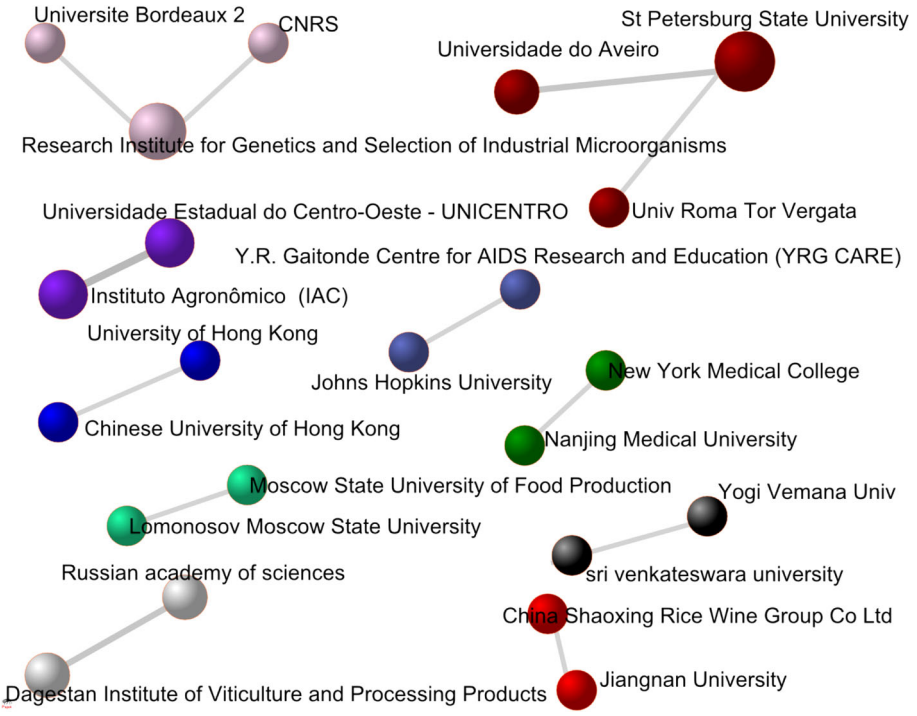


Fig. 4 Other networks of collaboration between institutions

their countries of origin, the journals and subject areas with more papers published, and both the collaborations between institutions and countries and the papers that had the most impact.

There was a progressive increase in the number of papers published by two countries, China and Brazil, which have grown in importance over the last decade. This growth is in accordance with other economic and social indicators. Beginning in the 1990 s, new policies for funding research were implemented in these countries, increasing their significance in many areas (Babini 2011; Albornoz 2014). A previous study that compared the trajectories in the wine sector between Italy and two emerging countries concluded that emerging countries with diverse institutional models and innovation strategies have actively participated in the process of technological modernisation and product standardisation, aligning emerging scientific approaches with successful marketing strategies (Cusmano et al. 2010).

Another work that analysed the scientific production in Latin American countries (Aleixandre et al. 2013) showed that Brazil stands out with the most scientific productivity in the region. Brazil's lead in this area can be explained by the fact that its spending on research and development comprises 60 % of the entire region's spending (Babini 2011). The weight of Brazil and China in terms of scientific productivity is also reflected in the most-cited papers: 11 of the 14 were published by institutions from these countries. Another paper that analysed the scientific production in the same field in South Africa and that used similar methodology identified 406 papers, placing South Africa on a similar level with Brazil and China in terms of research (Aleixandre et al. 2013). Although China

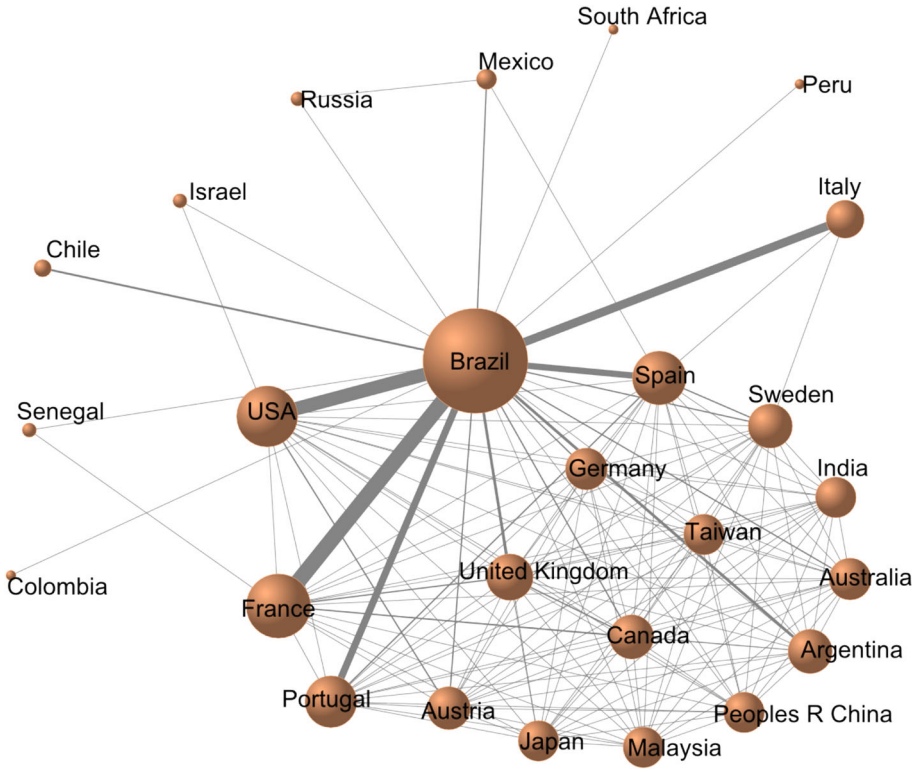


Fig. 5 Network of collaboration between Brazil and other countries

is the country with the most papers published, it should be noted that if the absolute productivity of each country is related to other indicators such as the number of inhabitants and the gross domestic product, Brazil stands as the leader. Brazil's growth has also been observed in other areas, such as ceramics (Rojas-Sola and Jordá-Albiñana 2009), psychology (Sánchez Sosa 2008; Vera-villarroel et al. 2011) and health technology (Pichon-Riviere et al. 2009).

Brazilian journals have published the most articles, with 8 journals with more than 5 items on the topic. The journal with most published articles, *Revista Brasileira de Fruticultura*, is the official publication of the Sociedade Brasileira de Fruticultura. The journal publishes technical scientific papers and scientific communications in the fruit culture area, in Portuguese, Spanish and English. It was added to the WOS in 2007 and received its first IF in 2009. The IF in 2012, the most recently published, was 0.296. The second most productive Brazilian journal is *Pesquisa Agropecuaria Brasileira*, which was added to the WOS in 1981, has an IF of 0.681, and is published monthly by Empresa Brasileira de Pesquisa Agropecuária (Embrapa), which is associated with the Ministério da Agricultura, Pecuária e Abastecimento. *Spectroscopy and Spectral Analysis* is another BRIC country journal, a Chinese journal sponsored by the Chinese Optical Society and published by Peking University Press (IF = 0.293); this is the Chinese journal with the highest productivity. The first Russian journal is *Applied Biochemistry and Microbiology*, edited by the Russian Academy of Sciences (IF = 0.689). The Indian journal that published the most

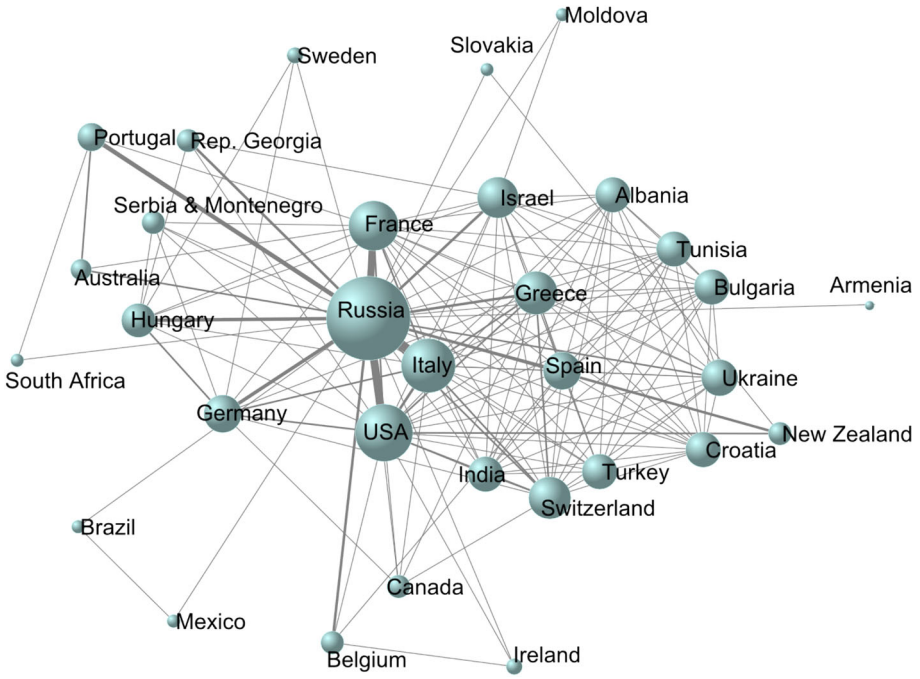


Fig. 6 Network of collaboration between Russia and other countries

articles over the study period was the *Indian Journal of Horticulture* ($n = 5$ papers). Other reasons for this increase could be the increasing number of BRIC-country journals in the SCIE, which increased from 233 journals in 2003 to 481 in 2012. The increase is most evident in Brazil, where the number of journals increased fivefold, from 18 in 2003 to 90 in 2012; in China, the number multiplied by 2.25 (from 67 to 151 in the same period), in India, by 1.95 (from 46 to 90) and in Russia by 1.5 (from 101 to 150).

As observed, the analysis of the subject categories shows that papers were published in journals from a variety of study areas: food science and technology, horticulture, analytical, applied and multidisciplinary chemistry, agriculture, biotechnology, microbiology, nutrition and dietetics, among others. This is a logical dispersion owing to the variety of disciplines related to the area and the existence of extensive collaborations and synergies between viticulture and oenology researchers, as has already been observed in other studies (Glänzel and Veugelers 2006; Aleixandre-Benavent et al. 2012). However, this diversity of subject areas should alert researchers seeking information on viticulture and oenology to not limit their searches to specific viticulture and oenology journals but to expand their searches to other related journals and even others of general purpose, such as those identified in this study (Aleixandre et al. 2013).

The identified collaboration networks show that the BRIC countries prefer to collaborate most often with the United States and France. The United States is preferred by Brazil, India and China, whereas Russia prefers Italy. Brazil also shows a preference for collaborating with Italy, Spain and Portugal, whereas India collaborates with Italy and Spain and China with Japan and Australia. This preference of BRIC countries to establish their scientific links primarily with the countries of the scientific elite is a fact that is

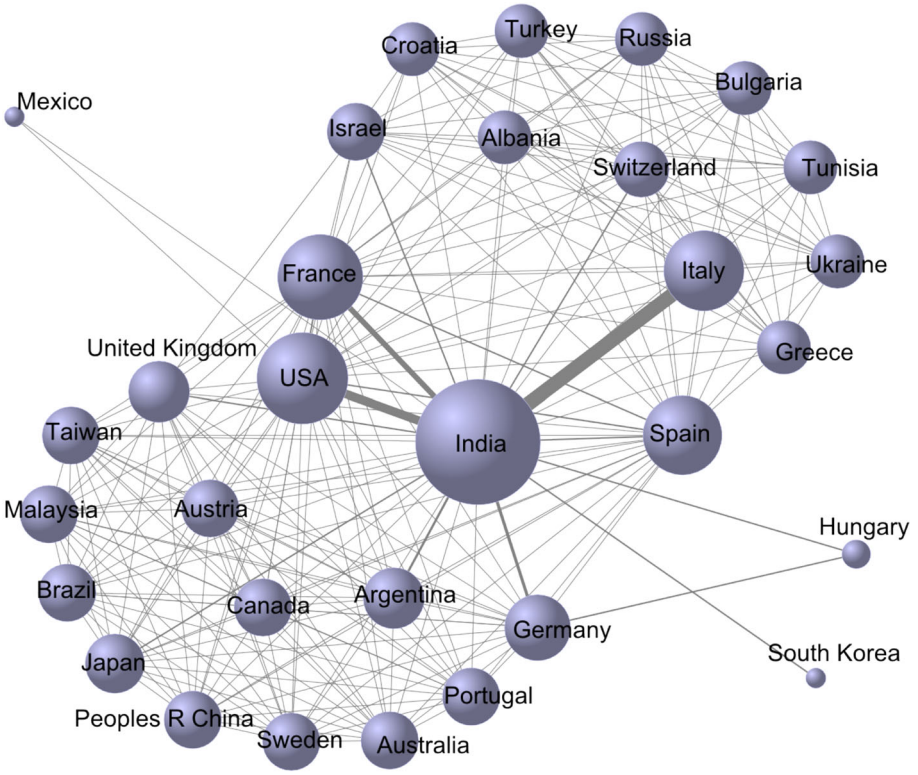


Fig. 7 Network of collaboration between India and other countries

possibly driven by their research policies (Glänzel and Veugelers 2006; Newman 2004). However, cultural roots may also play an important role in countries such as Brazil, whereas China's geographical proximity to Japan and Australia is crucial.

One notable fact is the lack of intensive ongoing cooperation between BRIC countries, which could be attributable to a number of factors. For one, the concept of the BRIC countries is still recent, having been established in 2001, and it may not yet have translated into scientific collaboration. Moreover, this cooperation concerns economic agreements, not agreements aimed at specific research topics. However, given the relationship between economic development and research, it is possible that in the future, this economic union will also lead to greater scientific collaboration. A recent paper that explores the determinants of scientific collaboration between countries on wine-related topics concludes that geography and a common scientific background are significant for international collaboration. The authors' findings suggest that scientific collaboration is generally constrained by geographical and technological distance despite the growth in international trade (Cassi et al. 2014). They also conclude that the international scientific cooperation could facilitate adapting wines to local tastes and therefore may increase when countries have trade relations. Other papers that analyse the geographical interactions among researchers in scientific collaboration networks in Brazil and China have also found that geographical proximity plays an important role in determining inter-regional collaboration because this proximity favours relationships among researchers (Scherngell and Hu 2011;

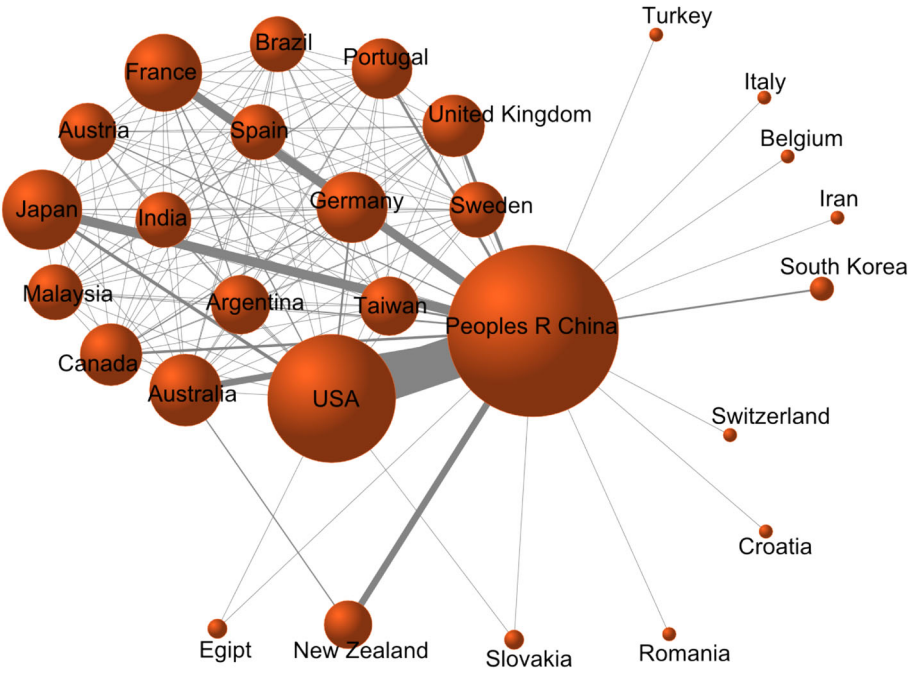


Fig. 8 Network of collaboration between China and other countries

Sidone et al. 2014). Therefore, it should be noted that geographic distance is a major problem that primarily affects Brazil's relationships with the other BRIC countries.

Cooperation between countries is a growing need for progress in research (Cunningham and Dillon 1997; Katz and Martin 1997; Newman 2004). The incentive to create networks and groups that bring together scientists and technologists from different countries is a central aspect of their cooperation strategies because these networks offer advanced knowledge, improved quality, and increasing innovation and competitiveness (Cunningham and Dillon 1997; Aleixandre 2013). Similarly, international collaboration is a positive indicator of openness to foreign research, and this collaboration is particularly evident with countries in the scientific elite, such as the United States, the European Union, Japan and Australia. Similar to the results found in other studies (Cassi et al. 2012), the dominance of the Old World wine-producer countries in the production and trade of wine is reflected in the structures of the scientific collaboration networks.

This study has some limitations that should be taken into account when interpreting the results. First, the SCIE does not include all of the published scientific literature on viticulture and oenology, and other bibliographic databases that compile publications from the BRIC countries could have been used. However, we used the SCIE because it is widely used in studies that analyse the scientific activity in science and technology because it includes the highest-impact journals in the world (Rojas-Sola et al. 2009). Additionally, the SCIE tells the number of citations and each journal's impact factor, information that is not available in other databases. Secondly, this study did not allow us to study in depth the BRIC countries' contributions to the progress of scientific knowledge on viticulture and oenology. However, this work can be observed as the starting point for future research under the same theme.

Table 5 Most cited papers (60 citations or more)

Authors	Title	Source	Citations	BRIC country
Hanqing, Yu, Zhenhu, Zhu, Wenrong, Hu, Haisheng, Zhang	Hydrogen production from rice winery wastewater in an upflow anaerobic reactor by using mixed anaerobic cultures	*International Journal of Hydrogen Energy* 2002; 24(11–12): 1359–65	198	Peoples R China
Wu, JM, Wang, ZR, Hsieh, TC, Bruder, JL, Zou, JG, Huang, YZ	Mechanism of cardioprotection by resveratrol, a phenolic antioxidant present in red wine	*Int J Mol Med* 2001;8(1):3–17	168	Peoples R China
Minussi, RC, Rossi, M, Bologna, L, Cordi, L, Rotilio, D, Pastore, GM, et al.	Phenolic compounds and total antioxidant potential of commercial wines	*Food Chemistry* 2003;82(3): 409–416	121	Brazil
Arroyo-García, R, Ruiz-García, L, Bolling, L, Ocete, R, López, MA, Arnold, C, et al.	Multiple origins of cultivated grapevine (*Vitis vinifera* L. ssp sativa) based on chloroplast DNA polymo	*Mol Ecol* 2006;15(12):3707–14	113	India; Russia
Wang, Z, Huang, Y, Zou, J, Cao, K, Xu, Y, Wu, JM.	Effects of red wine and wine polyphenol resveratrol on platelet aggregation in vivo and in vitro	*Int J Mol Med* 2002 Jan;9(1):77–9	113	Peoples R China
Katalinic, V, Milos, M, Modun, D, et al.	Antioxidant effectiveness of selected wines in comparison with (+)-catechin	*Food Chemistry* 2004;86(4):593–600	104	Peoples R China
Legin, A, Rudnitskaya, A, Lvova, L, Vlasov, Y, Di Natale, C, ĎAmico, A	Evaluation of Italian wine by the electronic tongue: recognition, quantitative analysis and correlation with human sensory perception	*Analytica Chimica Acta* 2003;484(1): 33–44	96	Russia
Da, RR, Palacios, V, Combina, M, Fraga, ME, De, OR, Magnoli, CE, Dalcero, AM	Potential ochratoxin A producers from wine grapes in Argentina and Brazil	*Food Addit Contam* 2002;19(4):408–14	89	Brazil
Riul, A; de Sousa, HC; Malmegrim, RR; dos Santos, DS, Carvalho, A; Fonseca, FJ, et al.	Wine classification by taste sensors made from ultra-thin films and using neural networks	*Sens Actuator B-Chem* 2004;98(1): 77–82	81	Brazil
Dalbó, MA, Ye, GN, Weeden, NF, Steinkellner, H, Sefc, KM, Reisch, BI	A gene controlling sex in grapevines placed on a molecular marker-based genetic map	*Genome* 2000;43(2):333–40	79	Brazil

Table 5 continued

Authors	Title	Source	Citations	BRIC country
Tonietto, J, Carbonneau, A	A multicriteria climatic classification system for grape-growing regions worldwide	*Agr Forest Meteorol* 2004;124(1–2): 81–97	78	Brazil
Legin, A, Rudnitskaya, A, Vlasov, Y, Di Natale, C, Mazzone, E, ÓAmico, A	Application of electronic tongue for quantitative analysis of mineral water and wine	*Electroanalysis* 1999;11(10–11): 814–820	73	Russia
Vitrac, X, Bornet, A, Vanderlinde, R, Valls, J, Richard, T, Delaunay, JC et al.	Determination of stilbenes (delta-viniferin, trans-astringin, trans-piceid, *cis*- and *trans*-resveratrol, epsilon-viniferin) in Brazilian wines	*J Agric Food Chem* 2005 13;53(14):5664–9	61	Brazil
Zou, JG, Wang, ZR, Huang, YZ, Cao, KJ, Wu, JM	Effect of red wine and wine polyphenol resveratrol on endothelial function in hypercholesterolemic rabbits	*Int J Mol Med* 2003 Mar;11(3):317–20	60	Peoples R China

Conclusions

This study provides indicators of the research situation in BRIC countries in the field of viticulture and oenology based on the analysis of the articles published in journals that can be found in the SCIE. We highlighted an important increase in the number of = published research papers, especially in China and Brazil in the last 5 years. The BRIC countries are now more specialised in viticulture and oenology than they were 20 years ago; growth in this area has been higher than the growth in any other scientific areas. Papers have been published in numerous journals in multiple subject areas, and *Revista Brasileira de Fruticultura* and *Pesquisa Agropecuaria Brasileira* are the most productive from the BRIC countries. Future work in this area could identify the evolution of the knowledge on this topic in a later time period and on newly emerging collaborations between these countries.

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