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Viticulture and oenology scientific research: The Old World versus the New World wine-producing countries

José Luis Aleixandre[a,*], José Luis Aleixandre-Tudó[a,1], Máxima Bolaños-Pizarro[b,2], Rafael Aleixandre-Benavent[c,3]

[a] Instituto de Ingeniería de Alimentos para el Desarrollo, Departamento de Tecnología de Alimentos, Universidad Politécnica de Valencia, Camino de Vera, s/n, 46022 Valencia, Spain
[b] Laboratorio de Estudios Métricos de Información (LEMI), Departamento de Bibliotecomía y Documentación, Universidad Carlos III, Avenida de la Universidad, 30, 28911 Leganes, Madrid, Spain
[c] Instituo de Gestión de la Información y del Conocimiento (CSIC—Universidad Politécnica de Valencia), UISYS (Universidad de Valencia), Plaza Cisneros, 4, 46003 Valencia, Spain

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ABSTRACT

The main aim of this study was to analyze the scientific productivity and collaboration between Old World wine-producing countries (Austria, Bulgaria, France, Germany, Greece, Hungary, Italy, Portugal, Romania, Spain, Switzerland) and New World wine-producing countries (Argentina, Australia, Brazil, Canada, Chile, Mexico, New Zealand, Peru, South Africa, United Sates, Uruguay) in viticulture and oenology through bibliometric analyses of articles included in the Science Citation Index Expanded database for the period 1994–2013. A number of 1527 research articles were published in 563 journals. The results highlight an important growth in the collaboration between countries during the second decade (2004–2013). Papers have been published in numerous journals belonging to several subject areas. *Food Science and Technology*, *Horticulture and Biotechnology* and *Applied Microbiology* appeared as the most productive research areas. A social network analysis of collaboration between these countries was also performed in order to analyze the most powerful scientific cooperation.

1. Introduction

The wines elaborated in the Old World are those produced in regions with a long documented history of wine production. These wines are considered to be from different European and Mediterranean regions. These regions include: Austria, Bulgaria, Spain, France, Greece, Hungary, Italy, Portugal, Romania and Switzerland as the most important countries. On the other hand the New World wines are those coming from countries outside Europe, such as: Argentina, Chile, USA, Mexico, Peru, Canada, Australia, New Zealand, South Africa, Brazil and Uruguay (Anderson, 2003; Robinson, 2006).

Noticeable differences, different from the long tradition of the wine production, between Old World wines and New World wines exist. Differences in terroir, varieties, winemakers, brand policies and designations of origin have been widely identified (Lao, 2009). New World wines are appreciated by different attributes than those found in the wines produced in the Old World wine producing countries. Moreover, Old and New World wine countries consumers seem to have evaluated wines differently (Lecocq & Visser, 2006; Schamel, 2006; Benfratello, Piacenza, & Sacchettos, 2009; Carew & Florkowski, 2010; Parcero & Villanueva, 2011; Yoo, Florkowski, & Crew, 2011).

Throughout the past three decades, the global pattern of wine production has undergone fundamental changes, most notably the emergence of New World producers. Over time only a few New World wine producers developed trade and scientific collaboration networks that resemble those of traditional Old World producers. Also the structures of trade and scientific collaboration networks are more established for Old World producing countries than in New World producers, which suggests that it is particularly the first ones who may have mainly benefited from participation in

* Corresponding author. Fax: +34 963877369.
E-mail addresses: jaleixan@tal.upv.es (J.L. Aleixandre), joaltu@upvnet.upv.es (J.L. Aleixandre-Tudó), mabopi@gmail.com (M. Bolaños-Pizarro), rafael.aleixandre@uv.es (R. Aleixandre-Benavent).
[1] Fax: +34 963877369.
[2] Fax: +34 916249597.
[3] Fax: +34 963919691.

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international scientific collaboration (Aylward, 2003; Brown et al., 2010; Cassi, Morrison, & Rabellotti, 2011).

Wine is an integral part of the so-called Old World nations, amalgamating with the local history and landscape, and providing a powerful "origin branding". To date, however, these dimensions have been discussed to a very limited extent in emerging New World wine regions where the lack of a traditional heritage of wine making presents special challenges in terms of origin branding (Gil & Sánchez, 1997; Beverland, 2006; Bramley & Kirsten, 2007; Perrouty, dí'Hauteville, & Lockshin, 2007; Duarte & Northcote, 2009).

On the other hand the impact of globalization on the wine industry is characterized by: rapidly growing and evolving international markets, the expansion of New World wines on international markets, and the response of Old World competitors to New World competition (Anderson, Norman, & Wittwer, 2003; Campbell & Guibert, 2006; Archibugi, 2007).

Scientific collaboration facilitates the flow of information among researchers and also allows for cost-sharing and improved efficiency in research (Katz & Martin, 1997; 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, 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; Gonzalez-Alcaide, Aleixandre-Benavent, Navarro Molina, & Valderrama-Zurián, 2008). Researchers with the largest number of collaborative publications are at the "research front" of that field (Gonzalez-Alcaide, Alonso Arroyo et al., 2008).

The aim of this study was thus to analyze the collaborative research between Old World and New World researchers in viticulture and oenology through bibliographic analyses of articles in the Science Citation Index Expanded (SCI-E) database for the 1994–2013 period. The length to this time period allows us to obtain comprehensive information with which establish trends in the research fields. Moreover, the combined analysis of productivity, collaboration and scientific impact will provide a global and integrated vision of the countries' research in this area.

2. Materials and methods

The articles used for analysis were obtained from the Science Citation Index Expanded (SCIE) database, which was accessed via the Web of Knowledge platform. Only papers categorized as articles or reviews were considered; sources such as letters, editorial material, book reviews, proceedings, reprints, news and bibliographic articles were excluded.

To research publications in the field of 'wine research', we used a strategy consisting of several components (Glänzel & Veugelers, 2006; Aleixandre, Aleixandre-Tudó, Bolaños-Pizarro, & Aleixandre-Benavent, 2013): (a) searches by specific words, (b) searches by institutional addresses, (c) searches in specific viticulture and enology journals, (d) searches involving Old World countries and New World countries, (e) searches limited to a 20-year period.

a) For the searches involving specific words, we used the following terms:

TS = (grapevin* or wines or "wine grap*" or "wine pro*" or "red wine*" or "white wine*" or winemaking or enolog* or viticult* or oenolog* or "wine cell*" or "wine yeast*" or winery or wineries). TS means the label for the field "topic", and records are retrieved if the above terms are included in the titles, keywords or abstracts of articles. Some roots were cut with an asterisk to obtain all of the documents associated with the derived words (e.g., by searching for enolog*, the SCIE database finds enology, enologist, enological, etc.).

b) For the searches for institutional addresses, we used the following terms:

AD = (enolog* or viticult* or oenol*), where AD is the label for the institutional addresses of the authors.

c) For the searches in specific viticulture and enology journals, we used:

SO = *American Journal of Enology and Viticulture* or *Australian Journal of Grape and Wine Research* or *Ciencia e Técnica Vitivinícola* or *Journal International des Sciences de la Vigne et du Vin* or *South African Journal of Enology and Viticulture* or *VITIS*. SO is the label for the name of the journal.

d) For the search limited to articles that were authored in Old World and New World countries, we used the following:

CU = (Austria, Bulgaria, France, Germany, Greece, Hungary, Italy, Portugal, Romania, Spain, Switzerland) and CU = (Argentina, Australia, Brazil, Canada, Chile, Mexico, New Zealand, Peru, South Africa, United Sates, Uruguay). CU is the label for the name of the country.

e) Finally, the analysis was limited to a 20-year period, 1994–2013.

The searches using specific words, institutions and journals (a–c) were combined with the logical operator "or". These results were combined with countries (d) and time period (e) using the "and" operator. Searches were performed on 1/04/2014.

The records obtained were exported to a relational database in Microsoft Access. The information was analyzed to obtain bibliometric indicators of scientific productivity, patterns of collaboration, number of citations and impact. A social network analysis was also carried out to identify the number of co-occurrences between countries, i.e., all combinations of pairs of countries on each paper. The software Pajek was used to construct and graphically represent the research groups and to visualize the collaboration networks. Pajek software was used instead of other software options (e.g., VOSviewer) because it allows studying and visualizing more in detail the relationships between research agents. On the contrary VOSviewer only provides a map of clusters based on the elements similarities, but does not show their relationship and frequency. Data on impact factor were extracted from the 2012 edition of the Journal Citation Reports (JCR).

3. Results

During the two decades (1994–2013) 1527 papers in collaboration, 1433 (94%) articles and 94 reviews (6%) were published. The number of published articles has increased steadily from 1994, when 22 articles (1.4%) were published, until 2013 with 164 (10.7%) published articles. Moreover most of the articles were published in the second decade (74% versus 26%) (Fig. 1).

Papers have been published in 563 different journals, was the most productive the *Journal of Agricultural and Food Chemistry* ($n = 103$), followed by the *American Journal of Enology and Viticulture* ($n = 71$) and *VITIS* ($n = 48$) (Table 1). Other specific journals in viticulture and enology were: *Australian Journal of Grape and Wine*

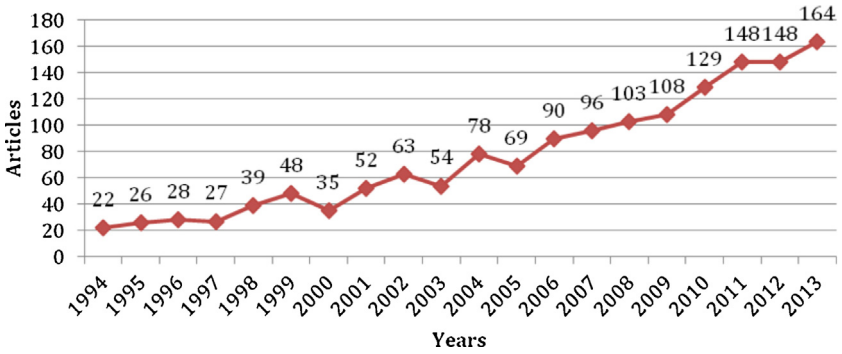

Fig. 1. Annual evolution of papers published in collaboration between Old World and New World.

Table 1
Journals with more than 5 papers published.

Journal	1994–1998	1999–2003	2004–2008	2009–2013	Total
Journal of Agricultural and Food Chemistry	5	25	28	45	103
American Journal of Enology and Viticulture	19	15	25	12	71
VITIS	16	14	10	8	48
Australian Journal of Grape and Wine Research	0	5	5	18	28
Food Chemistry	0	3	4	21	28
Journal International Des Sciences De La Vigne Et Du Vin	0	5	12	9	26
Food Quality and Preference	0	2	8	11	21
Analytica Chimica Acta	1	5	7	5	18
Applied and Environmental Microbiology	1	3	10	3	17
Phytopathology	5	3	6	3	17
BMC Plant Biology	0	0	2	14	16
Journal of Chromatography A	1	4	5	6	16
Food Research International	0	0	0	14	14
Journal of Applied Microbiology	2	2	8	1	13
Theoretical and Applied Genetics	0	4	7	2	13
Water Science and Technology	0	0	11	2	13
International Journal of Food Microbiology	0	1	5	6	12
Journal of the Science of Food and Agriculture	2	2	1	7	12
Plant Disease	3	1	3	5	12
European Food Research and Technology	0	0	3	8	11
Plant Pathology	2	2	1	5	10
PLoS One	0	0	1	9	10
BMC Genomics	0	0	1	8	9
European Journal of Plant Pathology	1	1	3	4	9
Journal of Experimental Botany	0	0	4	5	9
South African Journal of Enology and Viticulture	0	0	2	7	9
Talanta	0	2	2	5	9
World Journal of Microbiology & Biotechnology	0	0	4	5	9
American Journal of Clinical Nutrition	4	1	2	1	8
Archives of Virology	0	2	4	2	8
FEMS Microbiology Letters	1	3	3	1	8
Journal of Cardiovascular Pharmacology	1	3	2	2	8
Agricultural and Forest Meteorology	0	1	2	4	7
Annals of Microbiology	0	0	3	4	7
International Journal of Food Science and Technology	0	2	0	5	7
Letters in Applied Microbiology	1	0	2	4	7
Phytopathologia Mediterranea	0	0	0	7	7
Scientia Horticulturae	1	1	1	4	7
Addiction	0	2	2	2	6
Analytical and Bioanalytical Chemistry	0	1	2	3	6
Analytical Chemistry	1	0	2	3	6
British Journal of Nutrition	0	1	2	3	6
Carbohydrate Polymers	1	4	0	1	6
Food and Chemical Toxicology	0	1	1	4	6
Food Microbiology	1	1	2	2	6
Phytochemistry	1	1	2	2	6
Precision Agriculture	0	0	2	4	6

Research ($n = 28$), *Journal International des Sciences de la Vigne et du Vin* ($n = 26$) and *South African Journal of Enology and Viticulture* ($n = 9$).

Food Science & Technology (FST) is the subject area with the highest number of published articles ($n = 430$), followed by Horticulture ($n = 222$) and Biotechnology & Applied Microbiology ($n = 208$) (Table 2). The most productive journals in FST have been *Journal of Agricultural and Food Chemistry*, *American Journal of Enology and Viticulture* and *Food Chemistry*. In the subject area of Horticulture journals devoted specifically to enology and viticulture are the most common. In the subject area Biotechnology & Applied Microbiology stands out the *American Journal of Enology and Viticulture* and also specific microbiology journals. The most frequent keywords are related with red wines, *Vitis-vinifera*, identi-

Table 2
Main subject areas, key words, journals and countries.

WOS subject category	Articles	Keywords	Articles	Journals	Articles	Countries and articles[a]
Food Science & Technology	430	Red wines	79	*Journal of Agricultural and Food Chemistry*	103	France (n = 154)
		Vitis-vinifera L.	52	*American Journal of Enology and Viticulture*	71	USA (n = 153)
		Wines	46	*Food Chemistry*	28	Spain (n = 105)
Horticulture	222	*Vitis-vinifera* L.	45	*American Journal of Enology and Viticulture*	71	USA (106)
		Identification	23	*VITIS*	48	France (90)
		Grapevines	19	*Australian Journal of Grape and Wine Research*	28	Italy (57)
Biotechnology & Applied Microbiology	208	Identification	29	*American Journal of Enology and Viticulture*	71	USA (104)
		Saccharomyces-cerevisiae	22	*Applied and Environmental Microbiology*	17	France (64)
		Vitis-vinifera L.	22	*Journal of Applied Microbiology*	13	Spain (62)
Plant Sciences	192	*Vitis-vinifera* L.	41	*Phytopathology*	17	USA (105)
		Arabidopsis-thaliana	26	*BMC Plant Biology*	16	France (67)
		Identification	22	*Theoretical and Applied Genetics*	13	Australia (57)
Chemistry, Applied	166	Red wines	53	*Journal of Agricultural and Food Chemistry*	103	USA (57)
		White wines	22	*Food Chemistry*	28	France (54)
		Identification	21	*Journal of the Science of Food and Agriculture*	12	Spain (44)
Agriculture, Multidisciplinary	144	Red wines	31	*Journal of Agricultural and Food Chemistry*	103	USA (50)
		Identification	18	*Journal of the Science of Food and Agriculture*	12	France (42)
		Wines	14	*Precision Agriculture*	6	Spain (40)
Microbiology	109	Identification	22	*Applied and Environmental Microbiology*	17	USA (43)
		Strains	17	*Journal of Applied Microbiology*	13	Spain (38)
		Fermentations	16	*International Journal of Food Microbiology*	12	Italy (31)
Chemistry, Analytical	90	Wines	23	*American Laboratory*	1	Spain (27)
		Red wines	16	*Analusis*	1	USA (25)
		Identification	10	*Analyst*	3	France (22)
Agronomy	75	*Vitis-vinifera* L.	14	*Theoretical and Applied Genetics*	13	USA (39)
		Identification	11	*Plant Pathology*	10	France (28)
		Grapevines	9	*European Journal of Plant Pathology*	9	Spain (26)
Nutrition & Dietetics	73	Red wines	29	*Food Chemistry*	28	USA (42)
		Risk	9	*American Journal of Clinical Nutrition*	8	Italy (20)
		White wines	8	*British Journal of Nutrition*	6	Spain (16)
Biochemistry & Molecular Biology	72	Red wines	17	*Phytochemistry*	6	USA (50)
		Expression	9	*Plant Science*	5	Italy (28)
		Vitis-vinifera L.	7	*Free Radical Research*	4	France (23)

[a] Countries with most published articles in the subject area.

fication, *Saccharomyces-cerevisae*, *Arabidopsis-thaliana*, strains and fermentations, among others. Regarding the countries leading the publications in each area, USA is the country with the most articles in all areas except FST, where France ranks first, and Applied Chemistry, where this position is occupied by Spain. Other represented countries are Italy and Australia.

Table 3 shows the total number of published papers by each country, the papers written in collaboration between Old World and New World wine-producing countries and the percentage of papers in collaboration. Old World most productive countries were Spain (n = 4786), Italy (n = 3791) and France (n = 3699). New World most productive countries were United States (n = 5837), Australia (n = 1973) and Brazil (n = 1089). Regarding the collaboration, the figures were as follows. The country with which the Old World countries have collaborated the most is United States, highlighting collaborations with Italy (n = 235), France (n = 193), Germany (n = 128) and Spain (n = 117). Other important collaborations were found between Australia and France (n = 98), Australia and Italy (n = 53) and Argentina and Spain (n = 51). The higher percentage of collaborating papers in the Old World countries was found in Hungary (18.4%) followed by Germany (14.4%) and France (14.3%). Percentages of collaboration in New World countries are higher than in Old World countries, highlighting Peru (56.3%), Uruguay (37.6%) and Mexico (35.2%).

The network of collaboration between the 22 countries is drawn in Fig. 2. The thickness of the spheres is proportional to the number of papers written in collaboration by each country. The thickness of the lines connecting two countries is proportional to the number of papers published in cooperation between the two countries. USA occupies a central position in the network, where also appears highlighted France, Italy, Spain, Germany and Australia.

Fig. 3 correlates the number of published papers and the number of received citations in the two groups of countries. In the New World countries a correlation exists between the total number of scientific papers published by each country and citations in all scientific areas and the number of papers published in viticulture and oenology. The only exception is Canada, with fewer papers in viticulture and oenology than those expected. Regarding Old World countries, there are also correlations between these numbers, with the exception of Germany, a country in which there is no correlation between the total production of scientific papers and the number of papers viticulture and oenology.

Papers with more than 200 citations are shown in Table 4. Two papers are highlighted with more than 2000 citations. The most cited paper, entitled “Cancer chemopreventive activity of resveratrol, a natural product derived from grapes”, was published in 1997 in the journal *Science* and has received 2644 citations. This paper was written in collaboration between three different departments,at the University of Illinois (Chicago, USA) and also with the Universidad Complutense de Madrid (Spain). The second paper, with 2348 citations, entitled “Analysis of total phenols and other oxidation substrates and antioxidants by means of Folin-Ciocalteu reagent”, was published in 1999 in the journal *Oxidants and Antioxidants*. This paper was written in collaboration between institutions from three different countries: University of California (Davis, USA),

Table 3
Papers published in collaboration between Old World and New World wine producing countries.

	New World													
Old Europe	Argentina	Australia	Brazil	Canada	Chile	Mexico	New Zealand	Peru	South Africa	Uruguay	USA	Total collaborations	Total articles	% collaborations
Austria	1	6	4	2	0	2	2	0	0	0	29	46	386	11.9
Bulgaria	0	0	0	0	0	0	0	0	0	0	11	11	117	9.4
France	24	98	40	49	42	28	19	0	25	11	193	529	3699	14.3
Germany	6	46	8	34	10	4	6	1	16	1	128	260	1804	14.4
Greece	0	2	0	14	0	0	0	0	0	0	37	53	651	8.1
Hungary	2	3	1	5	1	0	0	0	3	0	57	72	391	18.4
Italy	18	53	21	25	10	8	12	1	15	7	235	405	3791	10.7
Portugal	2	7	27	3	2	1	0	0	8	1	27	78	1204	6.5
Romania	1	0	1	3	0	0	0	0	1	0	5	11	246	4.5
Spain	51	48	29	12	48	25	6	7	17	12	117	372	4786	7.8
Switzerland	2	12	2	15	0	1	6	0	10	0	67	115	522	22
Total collaborations	107	275	133	162	113	69	51	9	95	32	906			
Total articles	388	1973	1089	876	458	196	366	16	577	85	5837			
% collaborations	30.2	13.9	12.2	18.5	24.7	35.2	13.9	56.3	16.5	37.6	15.5			

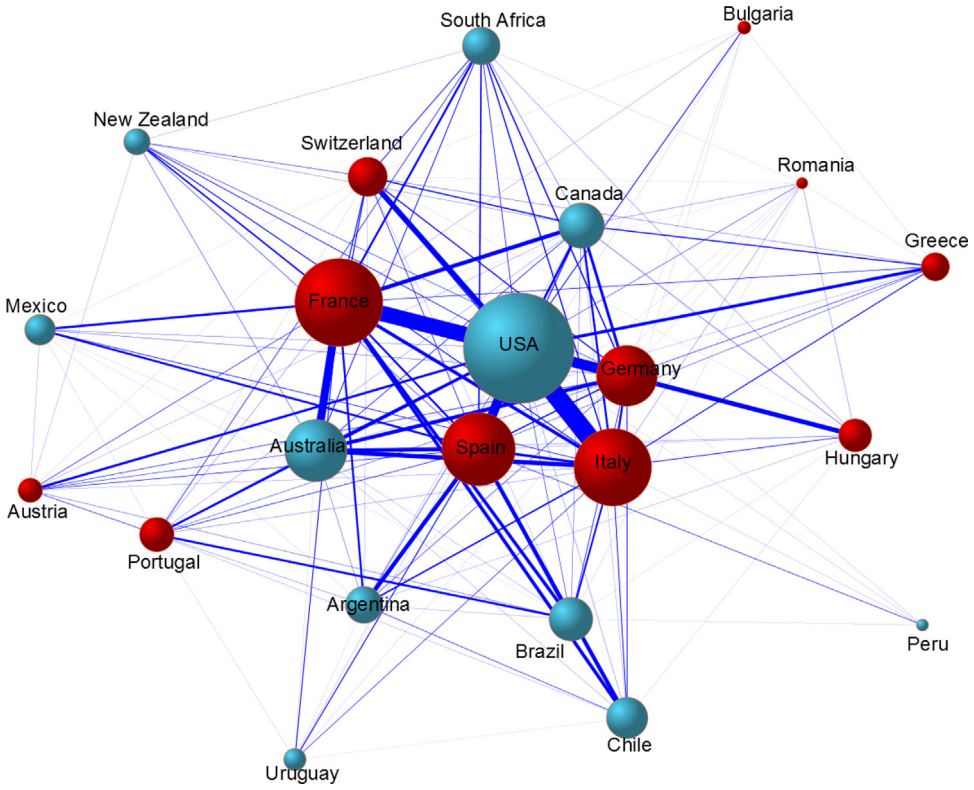

Fig. 2. Collaboration network between countries.

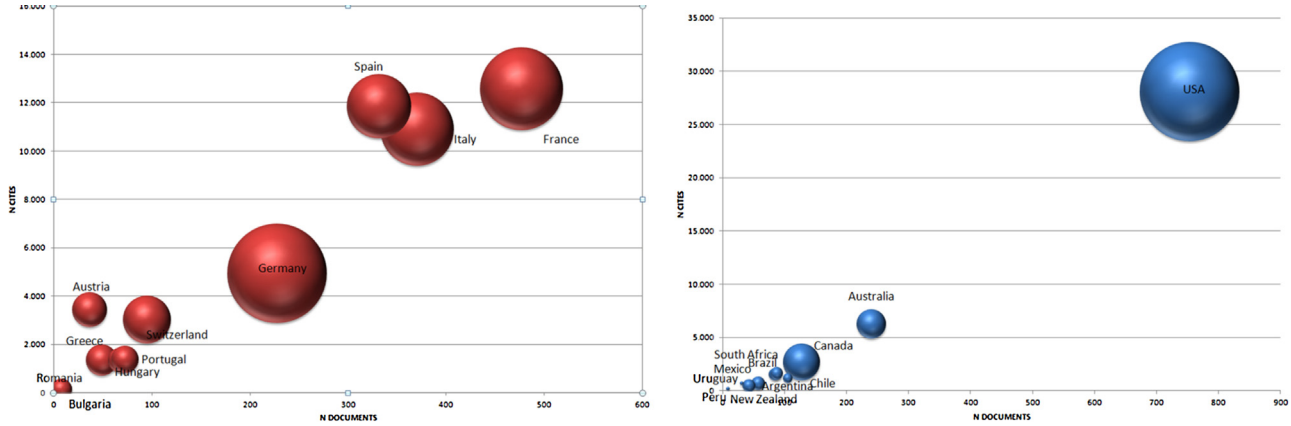

Fig. 3. Correlation between the number of published papers and the number of received citations in the two groups of countries.

Table 4
Most cited papers.

Authors	Tittle	Source	Times cited
Jang M, Cai L, Udeani GO, Slowing KV, Thomas CF, Beecher CW, Fong HH, Farnsworth NR, Kinghorn AD, Mehta RG, Moon RC, Pezzuto JM	Cancer chemopreventive activity of resveratrol, a natural product derived from grapes	*Science* 1997; 275(5297):218–20	2644
Singleton VL, Orthofer R, Lamuela-Raventos RM	Analysis of total phenols and other oxidation substrates and antioxidants by means of Folin-Ciocalteu reagent	*OXIDANTS AND ANTIOXIDANTS, PT A* 1999; 299:152–178	2348
Gil MI, Tomás-Barberán FA, Hess-Pierce B, Holcroft DM, Kader AA	Antioxidant activity of pomegranate juice and its relationship with phenolic composition and processing	*J Agric Food Chem* 2000; 48(10):4581–9	624
Willett WC, Sacks F, Trichopoulou A, Drescher G, Ferro-Luzzi A, Helsing E, Trichopoulos D	Mediterranean diet pyramid: A cultural model for healthy eating	*Am J Clin Nutr* 1995; 61(6 Suppl.):1402S–1406S	561
Kris-Etherton PM, Hecker KD, Bonanome A et al.	Bioactive compounds in foods: Their role in the prevention of cardiovascular disease and cancer	*American Journal of Medicine* 2002; 113(9b Suppl.):71–88	384
Velasco R, Zharkikh A, Troggio M et al.	A high quality draft consensus sequence of the genome of a heterozygous grapevine variety	*PLoS One* 2007; 19;2(12):e1326	373
Compant S, Duffy B, Nowak J, Clément C, Barka EA	Use of plant growth-promoting bacteria for biocontrol of plant diseases: Principles, mechanisms of action, and future prospects	*Appl Environ Microbiol* 2005; 71(9):4951–9	371
Duran N, Rosa MA, D'Annibale A et al.	Applications of laccases and tyrosinases (phenoloxidases) immobilized on different supports: A review	*Enzyme Microb Technol* 2002; 31(7):907–931	343
Teissedre PL, Frankel EN, Waterhouse AL et al.	Inhibition of in vitro human LDL oxidation by phenolic antioxidants from grapes and wines	*J Sci Food Agric* 1996; 70(1):55–61	326
Yao LH, Jiang YM, Shi J et al.	Flavonoids in food and their health benefits	*Plant Foods Hum Nutr* 2004; 59(3):113–122	287
Ray PS, Maulik G, Cordis GA et al.	The red wine antioxidant resveratrol protects isolated rat hearts from ischemia reperfusion injury	*Free Radic Biol Med* 1999; 27(1–2):160-9	253
Zang M, Xu S, Maitland-Toolan KA et al.	Polyphenols stimulate AMP-activated protein kinase, lower lipids, and inhibit accelerated atherosclerosis in diabetic LDL receptor-deficient mice	*Diabetes* 2006; 55(8):2,180-2,191	241
Tapiero H, Tew KD, Ba GN et al.	Polyphenols: Do they play a role in the prevention of human pathologies?	*Biomed Pharmacother* 2002;56(4):200-7	230
Vogt T, Jones P	Glycosyltransferases in plant natural product synthesis: Characterization of a supergene family	*Trends Plant Sci* 2000;5(9):380-386	226
Lee IM, Bertaccini A, Vibio M et al.	Detection of multiple phytoplasmas in perennial fruit-trees with decline symptoms in Italy	*Phytopathology* 1995; 85(6):728–735	224
German JB, Walzem RL	The health benefits of wine	*Annu Rev Nutr* 2000; 20:561–593	220
Casper RF, Quesne M, Rogers IM et al.	Resveratrol has antagonist activity on the aryl hydrocarbon receptor: Implications for prevention of dioxin toxicity	*Mol Pharmacol* 1999; 56(4):784–90	213
Tomás-Barberán FA, Gil MI, Cremin P et al.	HPLC-DAD-ESIMS analysis of phenolic compounds in nectarines, peaches, and plums	*J Agric Food Chem* 2001; 49(10):4748–60	212

Austrian Institute of Technology (Seibersdorf, Austria) and University of Barcelona (Spain).

4. Discussion

This study provides a bibliometric analysis of collaborative research on wine and grapes by Old World and New World wine-producing countries. This work showed that the scientific collaboration in viticulture and oenology between these countries has been steadily increased during the past 20 years. This growth took place mainly in the decade comprising the years from 2004 to 2013. Increasing number of international collaborations was also observed throughout the study period. These results point out a positive trend, which indicates an increase in the research collaboration in the area. One of the main reasons that explain these findings could be the need for increased international cooperation between countries. Collaboration between countries would be required in order to achieve improved research results. (Katz & Martin, 1997; Newman, 2004). Encouraging the development of research networks which bring together scientists from different countries would thus be a key role strategy for cooperation. These research groups enhance knowledge, improve quality, and increase innovation and competitiveness (Aleixandre-Benavent, Aleixandre-Tudó, Gonzaléz Alcaide, & Aleixandre, 2013).

The research papers have been published in numerous journals specialized in several subject areas such as for example FST. This includes specific journals in the areas of viticulture and enology, horticulture, biotechnology and applied microbiology, plant sci-

ences, etc. This diversity is consistent with the multidisciplinary nature of the subject that favors the existence of extensive collaborations and synergies between viticulture and enology and other disciplines (Glänzel & Veugelers, 2006; Aleixandre et al., 2013).

As we have observed, five countries are leading publications in all areas: United States, France, Spain, Italy and Australia. United States stands out strikingly on the New World countries due to their greater scientific productivity. Regarding Old World countries the productivity is led by Spain, but closely followed by Italy and France. These findings could be explained by the logical reasoning that is based in the large wine production industry which is accompanied by the subsequent increased research productivity (Aleixandre-Benavent et al., 2013).

The highest percentage of papers published in collaboration corresponds to Latin American New World countries, especially Peru, Uruguay, Mexico and Argentina. For these countries, collaboration with the scientific elite nations such as the United States or the European countries is essential, because this enables researchers, lecturers and students to exchange with their international colleagues the latest scientific developments allowing them to gain access to the best equipment, facilities, and talent, and therefore to participate in large-scale research projects that are beyond the financial capabilities of individual countries (Glänzel & Veugelers, 2006; Glänzel, 2001; Subramanyam, 1983; Luukkonen, Persson, & Sivertsen, 1992). Research-based collaboration includes joint research activities, technology co-development, contract research, and technology exchange. The promotion of these research opportunities in foreign centers is considered critical to the development of the domestic research and toward internationalization.

As has been shown in previous papers (Aleixandre et al., 2013; Aleixandre-Benavent et al., 2013) and in other research areas such us nanobiopharmaceuticals (Qingjun & Jiancheng, 2011) alcoholism and health (Murray, 2011) or biotechnology (Suarez-Villa, 2004) the United States is the chosen country to collaborate with by both the developed and the emerging countries. It is precisely the emerging countries and countries with fewer resources the ones who have a higher percentage of papers published in collaboration, simply because they need to use the available resources present in the more developed countries. When choosing countries with which to establish collaboration there is also an important cultural roots influence. For this reason, Spain has a preference to collaborate with Latin American countries, such us Argentina and Chile, while Portugal does with Brazil.

The information management can be enhanced by the analysis of the research networks. In research collaboration, scientist exchange ideas regarding further experiments, new hypotheses to test, instrumentation to build, relationships between their latest experimental results to theoretical models, and so on. In these and other tasks, members of a research group will not only discuss among themselves but will also seek advice and help from others (and will often offer information in return) (Katz & Martin, 1997). Social network analysis applied to research collaboration can facilitate information management in several ways. First of all, making visible and tangible those institutional elements on the research topics that are normally regarded as invisible and intangible (Cross, Parker & Borgatt, 2002). For example, social network analysis applied to the analysis of co-words allows detecting both the research trending topics as research gaps (i.e., under-researched topics that might need further attention) (Gonzalez-Alcaide, Aleixandre-Benavent et al., 2008). Secondly, using the existing networks for a variety of organizational and network situations (i.e., implementing changes in the research group structure or policy in order to improve its performance) (Cross et al., 2002; Springer & Steiguer, 2011).

With respect to the most cited papers, we highlight the significance of the research on the hypothetical health benefits from wine, especially red wine, attributed to the polyphenols, particularly flavonoids and resveratrol antioxidant and anti-inflammatory effects. These health benefits are related to the prevention of several pathologies as cancer, cardiovascular diseases and atherosclerosis, among others (Aleixandre et al., 2013). It is noteworthy that most of these highly-cited papers have been published in journals of general purpose with high impact factor, such as *Science*, *PLoS One*, as well as biomedical journals and highly-cited specific journals related with food science and technology. Obviously the number of citations in published papers is higher in the early years of the studied period, as they are available longer time to be cited.

This work also has some limitations that should be considered. The SCIE does not contain all of the published scientific papers on viticulture and oenology, so other bibliographic databases could have been used complementarily. Nevertheless, we used the SCIE because it includes the most important journals in the world, which helps emphasis analyses on the most relevant papers. On the other hand, it provides the names of all institutional affiliations of the authors, which allowed us to determine the indicators of collaboration between countries. Moreover, it makes the number of citations that articles have received available, information that does not exist in other databases.

5. Conclusion

This study provides an indication of the state of collaborative research between Old World and New World wine producing countries in the field of viticulture and enology based on the analysis of articles published in journals included in the SCIE. The results highlight the significant growth in the number of research papers published from 1994 to 2013. All countries have USA as the main country with which one collaborates with and, in second place, countries with which they bind through cultural or linguistic ties. Future work could identify the evolution of collaboration over time and new collaborations with other emerging countries such us China, India or Russia.

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