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An Overview of the Literature on Drying Processes: Contributions and Trends

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Abstract

Drying is an important industrial process that is highly used in the handling of solids, and its study has increased during the last years due to the upsurge of new technologies. It is necessary to determine the direction of science in the area of drying process to give a valuable research contribution. It was performed a research evolution of drying processes for the period of 2007-2017, using HistCiteTM software. This study evaluated a total of 992 publications related to drying processes which were used to analyze the patterns of publications outputs, main journal, institutions, author, and keywords. The Republic of China, The USA, and Spain were the top 3 most productive countries. The main journals with the highest number of publications were Meat Science followed by Bioresource Technology and Food Chemistry. The most productive institution was Consejo Superior de Investigaciones Científicas (CSIC) followed by the Institute for Research and Technology in Food and Agriculture (IRTA), and the University of Illinois. The most keywords used were dry, followed by process and processing. The most productive authors Vijay Singh from Department of Agricultural and Biological Engineering in the University of Illinois with 21 publications, followed by Fidel Toldrá from CSIC in Spain with 15 publications.

Keywords: Bibliometrics, drying processes, research trends, publications

1. Introduction

Drying process has different zones of drying rates [1] that make difficult the control of the time of drying. Due to the change of porosity of the solids [2], and the many variables involved in transport mechanisms [3], drying becomes one of the most complex operations in a manufacturing process [3]. This phenomenon involves heat, mass and momentum transfer [4] and the percentage contribution of each of then depends on the type of drying being applied, conduction, convection or radiation drying [5]. The process of drying is extremely important because it is a multidisciplinary field which has a very broad application in the food, agriculture, chemical, cosmetic, pharmaceutical, and cement industries.

Considering the application of such an important subject, it is necessary to follow the trend of research in this area so that future projects follow the optimum way to obtain the highest investigative contribution possible.

There have been many publications on this subject around the world that it is very complicated to visualize the participation of authors, journals, and organizations in this field. A simple and practical way to organize all that dense information is using a tool called bibliometric analysis [6] which is a powerful and friendly tool to handle a large number of data. This method of analysis is applied using some computational tools that can quantitatively measure and assess the research impact and evolution of a subject of interest by investigating publication characteristics. The method focuses on identifying research strengths and weaknesses, measuring country, institution, and author contributions, and recognizing the impact of journals [7]. It is an effective way to assess technical innovations that represent progressive development. This kind of structured analysis allows summarizing the global information on drying processes and the appearance of trends on the subject that can be seen as a guide of interest of the future investigations.

To have general information about the research of drying processes, this paper presents a bibliometric analysis developed on scientific publications from 2007 to 2017 with the purpose of revealing the participation of recognized scientific journals and institutions, countries around the world and researchers, in relation to their interest in drying processes determining the direction of science in this area.

2. Methodology

The data were obtained using the software HistCiteTM which is a tool that integrates all the bibliographic production and allows users to evaluate them from different specific indicators. The text file used in the software was provided by the online based scientific citation indexing database Web of Science. All the publications identified in the database were evaluated by the following criteria: year of publication, major journals, most productive countries, most productive institutions, most productive authors, and authors keywords using a program of interactive scientific graphing and data analysis which has a simple interface and

allows to customize the results according to the user criteria. To better visualize the results obtained by HistCiteTM, they were grouped into tables and graphs.

3. Results and Analysis

3.1 Publication outputs

From 2007 to 2017 a total of 992 publications on drying processes were identified. The type of document most frequently used was the article type with a total of 883 publications (89.0%), followed by proceedings papers with 52 publications (5.2%), reviews with 22 publications (2.2%), meetings abstract with 12 publications (1.2%), editorial materials with 10 publications (1.0%), corrections with 8 publication (0.8%), news items with 4 publications (0.4%), and book review with 1 publication (0.1%). Of the 992 publications, 96.8% were written in English (960), followed by German (6), Spanish (5), Japanese (4), Chinese (3), Croatian (2), Czech (2), and Portuguese (2). Figure 1 shows an increase in the number of publications from 2007 to 2017. In fact, it had an average increase of 100% in this period. This trend indicates the importance of drying process in the scientific community. This area is mainly focused on food which is gaining more importance as the global population increases.

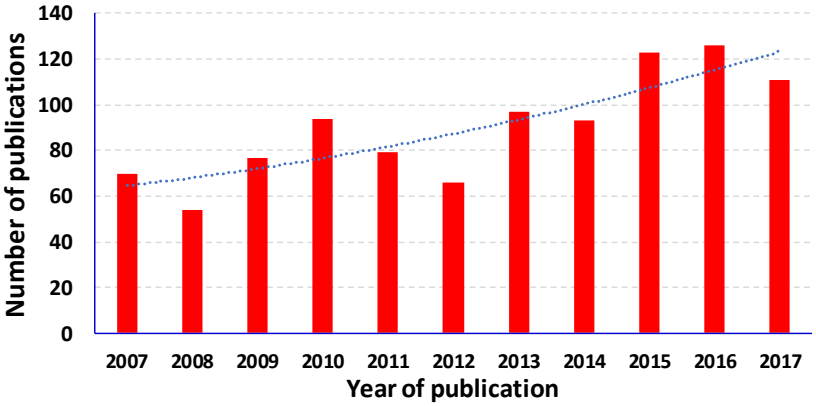

Figure.1 Number of publications from 2007 to 2013.

Table 1 shows the distribution of the results of 10 main scientific journals. Meat Science was the first in the top with 45 publications corresponding to the 6.5 % of the total number of publications. That journal is followed by Bioresource Technology with 24 publications (2.42%) and Food Chemistry with 19 publications (1.92%). It is interesting to see that the area of the drying process is mainly published in journals focused on food research. It is something somewhat obvious because most of the most important solid products in the world are foods.

The top three journals mentioned before have the top TLCS indicating their high-quality articles. However, when evaluating with another quality parameter such as the ratio TLCS/NP it is obtained that the best journal is Food Chemistry followed by Meat Science and Food Control.

Table 1. Top 10 journals with largest number of publication

#	Journal	NP	NP %	TLCS	TGCS	TLCS/NP
1	Meat science	45	4.54%	52	692	1.156
2	Bioresource technology	24	2.42%	15	367	0.625
3	Food chemistry	19	1.92%	24	193	1.263
4	Powder technology	15	1.51%	1	88	0.067
5	Food research international	12	1.21%	7	132	0.583
6	International journal of advanced manufacturing technology	12	1.21%	1	125	0.083
7	Journal of food engineering	12	1.21%	2	205	0.167
8	Cereal chemistry	11	1.11%	5	183	0.455
9	Food control	11	1.11%	9	115	0.818
10	Drying technology	10	1.01%	2	137	0.200

NP is the number of publications, TLCS is the total local citation score, TGCS is the total global citation score. Table 2 shows the countries that had the highest number of publications, where the Republic of China registered 159 representing the 16.03% of the total NP. That country is followed by the USA with 152 publications (15.32%), Spain with 119 (12.00%), and Japan with 75 (7.56%).

Table 2. Top 10 most productive countries during 2007-2017

#	Journal	NP	NP %	TLCS	TLCS/NP
1	Republic of China	159	16.03%	48	0.302
2	USA	152	15.32%	56	0.368
3	Spain	119	12.00%	96	0.807
4	Japan	75	7.56%	11	0.147
5	South Korea	57	5.75%	14	0.246
6	France	55	5.54%	24	0.436
7	Germany	54	5.44%	11	0.204
8	India	40	4.03%	7	0.175
9	Brazil	39	3.93%	8	0.205
10	Italy	35	3.53%	8	0.229

The majority of the countries in table 2 are developed countries, which is a coherent result with their industrial level. As can be seen, these countries have the highest values of TLCS indicating not only a high number of publications but also a high quality of their papers. However, the country with the highest quality papers is Spain which has the highest ratio TLCS/NP. It can be seen the distribution of the percentage of countries with the highest TLCS in figure 2. It validates that Spain has the highest quality papers followed by the USA and China.

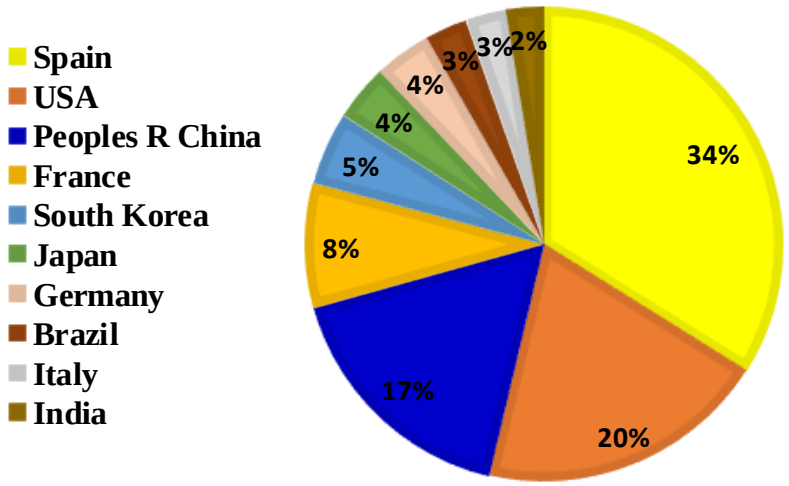

Figure 2. Top 10 countries with the highest percentage of TLCS

Table 3 shows the institutions with the highest number of publications. The institutions with the highest paper production were from Spain, the Consejo Superior de Investigaciones Científicas (CSIC) with 31 publication, and the Institute for Research and Technology in Food and Agriculture (IRTA) with 22 publications followed by the University Illinois from the USA with 18 papers.

Table 3 Top 10 most productive institutions during 2007-2017

#	Journal	NP	NP %	TLCS	TGCS	TLCS/NP
1	CSIC	31	3.13%	37	357	1.194
2	IRTA	22	2.22%	29	297	1.318
3	Univ Illinois	21	2.12%	14	180	0.667
4	ARS	15	1.51%	13	187	0.867
5	Chinese Acad Sci	14	1.41%	1	94	0.071
6	INRA	12	1.21%	13	324	1.083
7	Univ Tokyo	12	1.21%	0	56	0.000
8	Donghua Univ	9	0.91%	3	75	0.333
9	Nanjing Agr Univ	9	0.91%	9	58	1.000
10	Univ Fed Lavras	8	0.81%	3	111	0.375

The CSIC state agency has some important scientific-technical areas like Agricultural Sciences, Materials Science and Technology, and Food Science and Technology that research drying processes, mainly the food science and technology. IRTA and CSIC are important centers of research in drying. However, IRTA has the highest quality as can be seen with the ratio TLCS/NP.

Keywords analysis offers insight into research trends, revealing areas of research interest (Wang et al. 2013). Table 4 shows the top keywords appearing in articles

from 2007 to 2017 with a total of 3278 keywords where the most important are dry, process, and processing. It validates that the research trend is specifically focused on the drying process, mainly in food drying.

Table 4 Top 10 authors keyword from 2007-2017

#	Word	NP	TLCS	#	Word	NP	TLCS
1	Dry	926	288	11	Properties	56	10
2	Process	571	144	12	Parameters	54	8
3	Processing	240	106	13	Processed	54	21
4	Processes	136	29	14	Drying	52	8
5	Using	115	19	15	Analysis	51	13
6	Cured	108	105	16	Dryer	51	4
7	Effect	83	34	17	Production	51	14
8	High	74	29	18	Influence	50	15
9	Ham	68	70	19	Effects	44	6
10	Wet	68	8	20	Based	42	7

3.2 Most productive authors

The authors with the highest number of publications were professor Vijay Singh from Department of Agricultural and Biological Engineering in the University of Illinois with 21 publications, followed by professor Fidel Toldrá from CSIC in Spain with 15 publications. Even when Singh has the highest number of records he does not appear among the authors with the highest TLCS. Mora L., Arnau J., Gou P., and Aristoy M., appear in figure 3 a and b indicating a high level of paper quality.

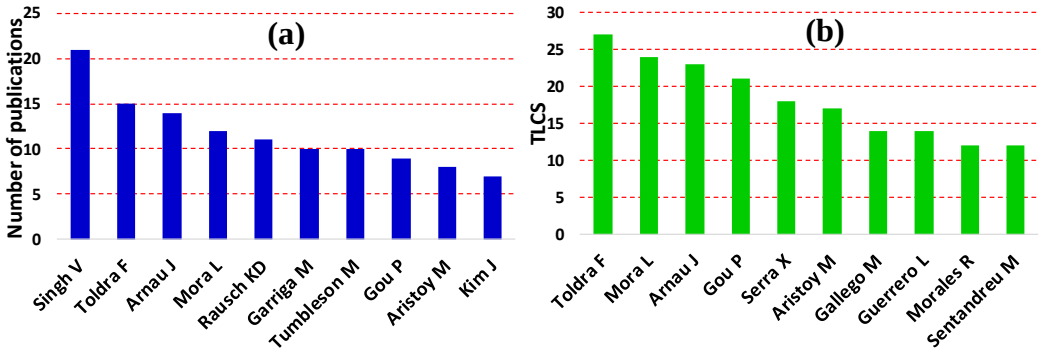

Figure 3. Most productive authors from 2007 to 2017

Most of the researchers presented in figure 3 a and b work in specialized research centers making investigations of high level.

4. Conclusions

A global trend in the research output related to drying processes from 2007 to 2017 was developed considering a bibliometric analysis of the patterns of publications outputs, major journals, international productivity, most productive authors and author keyword using the software HistCiteTM. Most of the researches have been focused on food, and this is related to the growth of global population indicating the highly need to research this area. The number of publication increased approximately a 100% from 2007 to 2017. The country leader in publications was the Republic of China with 159 publications. However, the country with the highest quality papers was Spain with a TLCS of 96 and a ratio of TLCS/NP of 0.807. Spain has two important institutions of research that help in the investigations in this area. These institutions are the Consejo Superior de Investigaciones Científicas (CSIC) and the Institute for Research and Technology in Food and Agriculture (IRTA). These two institutions had the highest number of publications, the highest TLCS and the highest ratio TLCS/NP worldwide indicating their highest level of research. The journals with the highest ratio TLCS/NP were Food Chemistry (1.263), Meat Science (1.156), and Food Control (0.818), all of then related to food.

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