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## A bibliometric analysis of anaerobic digestion for butanol production research trends

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### Abstract

The technique of anaerobic fermentation for butanol production have arosen increasing attention, since the butanol as regeneration bioenergy is important to solve the world's energy shortage problem. This study uses a bibliometric approach to quantitatively assess current research trends on anaerobic digestion for butanol, by using the data from the Science Citation Index-Expanded database and the Derwent Innovations index of the Web of Science. A metric analysis was made on related literature and patents in these two databases, which was indexed considerably from 2001 to 2011. Results indicated that in recent years there had been a notable growth trend in publication outputs. During this period, USA had the largest number of publications. However, of all the institutes, CHINESE ACAD SCI held primacy over the most publications. The mainstream of anaerobic digestion for butyl alcohol research was in the environmental chemistry, engineering, biochemistry molecular biology related fields. Three journals including Journal of chemical and engineering data, Bioresource Technology, Journal of chromatography, Journal of chemical thermodynamics were the most popular ones in this field. In addition, keyword analysis shows that the process, reactor, pretreatment and co-digestion were the hotpots of the latest 18 years.

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*Keywords:* anaerobic digestion; butanol; research trend; bibliometrics

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### 1. Introduction

Recently years, the energy crisis is more and more serious. There are more and more institutions are exploring new energy material to replace the traditional energy. There were experts believed that although nuclear power and wind power development is still not clear, biomass power generation has

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clearly exceed the sun energy. The wide application of biomass energy may even to be the bringer energy industry [1]. And technology of anaerobic digestion for butanol can deal with waste except for recycling energy. From now on, many material are applied in this the technology. At the same time, The number of relevant science and technology is increased rapidly. Some advanced achievement also be published in <<FEMS Microbiology Ecology>> [2-3] or more authoritative journal. Recently, the number of Citable Documents about anaerobic digestion for butanol is increasing, but few people analysis this technology from the angle of the literature metrology. Literature is the crystallization of the research results. The literature metrological analysis can assess the relative important degree systematically in a field of scientific research results, and indicates the development direction of the field in recently years, and comprehend characterization of the study of the regional distribution [4]. Based on this situation, in order to accurately mastering the present situation and the frontier of research in the field, we make the literature metrological analysis about anaerobic ferment for butanol. It is good for understanding the field research from workers in the whole, knowing the situation of global development, making the future direction of the research clear.

## 2. Data sources and methods

ISI Web of Science is the most comprehensive academic subject information resources in the world. Its reference database SCI (Science Citation Index) which has been a main retrieval tool to statistics and evaluate field. This article's data is based on SCI-Expanded (Science CitationIndex-Expanded) of ISI Web of Science, the data of patents is from Derwent Innovations Index of the Web of Science. We treat “Anaero\*”, “butanol\*”, “butyl alcohol\*” as Subject retrieval words, and choose normal retrieval way, and statistic on the document type, language, document their countries and organizations, the literature of the citation the amount of citations, number of pages, subject classification, publication name and so on. We use the methods of data analysis which has been described by Li et al [5], using a Microsoft Excel 2007 software to deal with the relevant data.

## 3. Results and Discussion

Through analyzing of the data carefully, there are eight kinds of publication type can be included in ISI. Research papers (93.78%) are the most common forms of literature, followed by conference papers (7.36%). Review (1.91%), meeting abstracts (0.88%), research presentations (0.21%), corrections (0.19%), Research Letters (0.07%), Second Edition (0.05%) compared with the other types is less affected. So, research papers are the main types. This article used 6500 papers are analyzed statistically. Though analyzing the language of these papers, there are 97% of the Papers language use English, followed by Portuguese, Japanese, Polish, Korean, Spanish, Chinese, and German. In many areas, in the field of anaerobic fermentation for butanol, English still dominates. the journal of ISI is more likely to use English; expected future English will have a higher penetration rate [6].

### 3.1 Trend of literature

The rapid development of the anaerobic fermentation of butanol in the 21st century.2001 - 2010, the amount of Total issued a document jumped from 3252 to 5672. From the fig 1, the world anaerobic fermentation of butanol research progress is relatively slow before 2004. The amount of paper is below 3500. After that, the number of papers for anaerobic fermentation of butanol increases at high speed. As the number of organic waste grows fast and the urgent needs of human energy, anaerobic fermentation of

butanol has become a hotspot in the world. Relatively large increase during 2001-20011, also showed that the attention of people on the anaerobic fermentation of butanol is increased gradually.

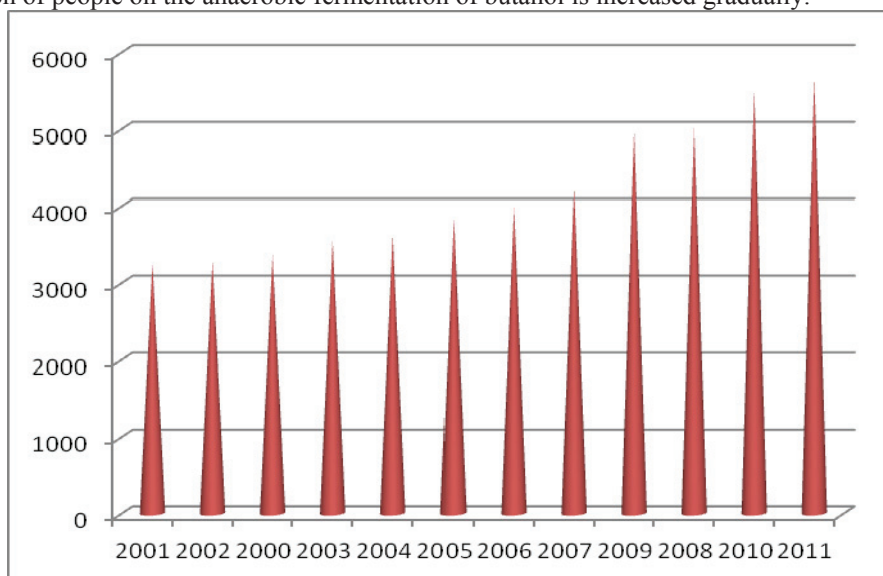


Fig. 1. The literature trends during 2001-2011

2001-2011, the anaerobic fermentation of butanol during the years issued document basic information shown in Table 1. From the table1, in the articles, the number of average citations increased from 27 (2005) to 58 (2011), an increase of approximately 100%; the average number of authors during the same period increases from 4.3 persons 9 persons, an increase of 83%. Paper length remained stable, the average length of 8.0. It suggested that all countries and their research institutions to further deepen the exploration of the field of anaerobic fermentation of butanol; the study has attracted attention globally.

Table 1. Tthe basic characteristics of years from 2005 to 2011

Year	TP	AU	AU/TP	NR	NR/TP	PG	PG/TP
2005	628	2738	4.359873	17550	27.94586	4739	7.546178
2006	716	3144	5.006369	19809	31.54299	5334	8.493631
2007	780	3379	5.380573	22439	35.73089	5776	9.197452
2008	905	3977	6.332803	26757	42.60669	6829	10.8742
2009	892	4006	6.378981	27701	44.10987	6828	10.87261
2010	1067	4688	7.464968	33987	54.11943	8236	13.11465
2011	1123	4977	7.925159	36809	58.61306	8895	14.16401

(TP: the amount of total issued; AU / TP: Average number of authors; PG / TP: articles pages; NR / TP: citation amount)

### 3.2 Analysis of the major countries and research institutions

Through counting the address and units of the authors (at least one), we obtained the volume of the papers in different places. Reclassified from the papers in England, Scotland, Northern Ireland and Wales, attribution for the British; Hong Kong are included in China. ISI Web of Science, Analyzing the 6500

papers and ranking the top ten countries for analysis and statistical total countries. Analyzing the top ten countries and counting the amount, the amount of independent issued and ranking by the percentage (fig 2). The results showed that only the United States issued a document of 1637, exceeding the second country (China 1033). It is suggested that USA in the field of anaerobic fermentation producing the butyl alcohol independent research capabilities is very strong. China still has obvious distance from United States in the butanol areas of research Even though it is ranked at second place. Posting proportion of the field: United States 24.49%, China 9.04%, and Germany 8.39%. The fig 2 shows the top ten countries and their percentage, just as the data shows: the amount of papers from the United States is 1637 and ranked No. 1, China, Germany, followed by Posting respectively 604 and 561.

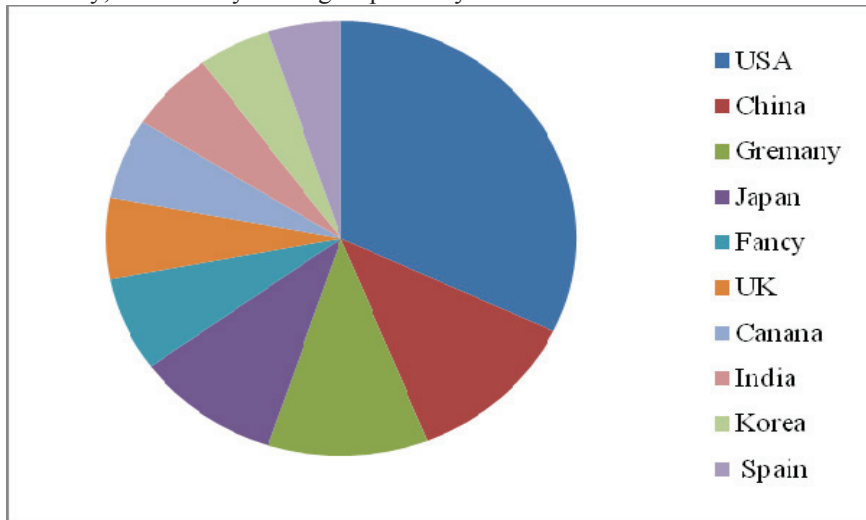


Fig. 2. 2001 -2011 top ten countries

We can see from Table 2, among the top ten research institutions, the United States accounts for 4, respectively, Illinois State University, University of Georgia, University of Wisconsin, and the University of California at Berkeley. Which countries posted more than 1200 papers includes China, Russia, Brazil, Denmark, France, and the Netherlands. The first3, the second and the third are Chinese Academy of Sciences, Russian Academy of Sciences, University of Sao Paulo respectively. Chinese Academy of Sciences and Russian Academy of Sciences issued documents more than 600, from the point of view of the institutional level; the Chinese Academy of Sciences in the field research has achieved gratifying results. Table 3 shows the top seven research institutions of China, we can conclude Tianjin University, China University of Science and Technology, Shandong University and Shanghai Jiao tong University have ranked out of 100 except for Chinese Academy of Sciences.

Table 2. top ten research institutions of 2001-2011

research institutions	tp	r (%)
CHINESE ACAD SCI	650	1.292
RUSSIAN ACAD SCI	618	1.229
UNIV SAO PAULO	404	0.803
INRA	368	0.732

TECH UNIV DENMARK	347	0.69
UNIV ILLINOIS	325	0.646
UNIV GEORGIA	319	0.634
UNIV WISCONSIN	314	0.624
UNIV WAGENINGEN RES CTR	313	0.622
UNIV CALIF BERKELEY	302	0.6

tp: the amount of total issued r: percentage

Table 3. The top 7 research institutions of China 2001-2011

institutions	ranker	percentage
Chinese Academy of Sciences	1	1.292
Zhejiang University	15	0.545
Tongji University	32	0.396
Tianjin University	126	0.201
University of Science and Technology of China	155	0.177
Shanghai Jiao tong University	161	0.175

### 3.3 Analysis of related disciplines and academic journals

Based on the ISI, during the recently seven years, there are 93 disciplines comes to anaerobic digestion for butanol. The top 6 disciplines is environment science(743,16.19%),Application of microbial,technology(663.87,14.45%),Microbiology(662.86,14.43%),EnvironmentalEngineering(504.13, 10.97%), Biochemistry molecular biology(347.23,7.55%).

Table 4. The top ten discipline of anaerobic digestion for butanol

discipline	tp	r
environment science	743.966034	16.196
Application of microbial technology	663.870501	14.452
Microbiology	662.865882	14.431
Environmental Engineering	504.13608	10.975
Biochemistry, molecular biology	347.232858	7.559
water resource	344.858304	7.508
chemical engineering	311.249232	6.776
Physical and chemical	263.02752	5.726
Energy fuel school	239.647296	5.217
Sports Science	212.157267	4.619

( note tp: the total amount r: the percentage )

Besides, according to the amount and the percentage of the papers from the journals about anaerobic digestion for butanol, we obtain the top ten journals (the table5), they account for 13.51%. At the first place is CHEMICAL AND ENGINEERING DATA

Table5 . The top ten journal of anaerobic digestion for butanol

rank	Journal	the amount	Percentage
1	JOURNAL OF CHEMICAL AND ENGINEERING DATA	266	3.271
2	FLUID PHASE EQUILIBRIA	117	1.439
3	JOURNAL OF CHROMATOGRAPHY A	116	1.426
4	JOURNAL OF CHEMICAL THERMODYNAMICS	108	1.328
5	INDUSTRIAL ENGINEERING CHEMISTRY RESEARCH	93	1.144
6	JOURNAL OF ETHNOPHARMACOLOGY	93	1.144
7	JOURNAL OF AGRICULTURAL AND FOOD CHEMISTRY	90	1.107
8	FOOD CHEMISTRY	84	1.033
9	JOURNAL OF PHYSICAL CHEMISTRY B	69	0.848
10	JOURNAL OF MOLECULAR CATALYSIS A CHEMICAL	63	0.775

#### 4. Conclusion

Through analyzing database of Science Citation Index-Expanded, Derwent Innovations Index of the Web of Science, we knew trends of anaerobic digestion for butanol production research. Result is that the study of the anaerobic fermentation of butanol has attracted worldwide attention. During the 2001-2010, USA is at the first place, following by China and Germany. Environmental science, chemical, biological, energy-related disciplines is the main areas of the anaerobic fermentation of butanol. JOURNAL OF CHEMICAL AND ENGINEERING DATA is the first academic journals. The analysis of keywords is showed by table 6, anaerobic fermentation, butanol, pretreatment, mixed fermentation become the research focus recently.

Table 6. The top 15 keywords of 2001-2011

key words	tp	Ranker (percentage)	key words	tp	Ranker (percentage)
Anaerobic digestion	654	1(21.24)	fermentation	85	8 (2.76)
Butanol	426	2(13.8)	Archaea	85	9 (2.76)
Biodegradation	422	3(13.71)	Reactor	82	10 (2.66)
Pretreatment	389	4(12.63)	Volatile fatty acids	77	11 (2.50)
Butyl alcohol	364	5(11.82)	Acetate	71	12 (2.30)
Hydrogen	208	6 (6.75)	Thermophilic	63	13 (2.04)
Anaerobic degradation	89	7 (2.8)	Hydrolysis	63	14 (2.04)

Recent years, China has a good upward trend about anaerobic digestion for butanol. But it still can not keep pace with the developed countries. As the leader in the field of Natural Science in China, Chinese Academy of Sciences has played a leading vanguard role, made a great contribution to Chinese butyl alcohol research. Various research institutions on butyl alcohol are extremely unbalanced, lack of cooperation and communication, and present a situation of do-it-yourself alone, so scientific research institutions should intensify cooperation efforts in our country.

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