Trends on rapid detection technology of food microorganisms based on web of science database

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Abstract. Rapid detection technology of food microorganisms is more and more a hot research topic in the field of agricultural, food safety and environmental sciences. In order to understand the current status of world-wide research on rapid detection technology of food microorganisms, research literature during the period of 1925-2018 was retrieved from the Science Citation Index Expanded (SCIE) database and analyzed using bibliometrics. Results showed that rapid microbial detection has entered the rapid growth phase after its forming phase and the initial phase. America enjoys absolute advantages in this field. China, Germany and Spain are also countries with relatively strong competitiveness. CSIC has the largest number of relevant published papers, while the papers from CNRS and INRA are the most influential ones. International Journal of Food Microbiology is the core journal that published the largest number of relevant papers, while Biosensors & Bioelectronics is the most influential relevant journal. Food Science and Technology is the subject of the most importance in this field. Biotechnology & Applied Microbiology and Microbiology are also significantly relevant. Researches in this field focus the most on relevant technologies on Molecular Biology, second on the technologies on Immune method and biosensors rank second, and the least on the technologies on metabolic methods. Sustainability has been seen in a part of the hot research topics, and new hot topics have also emerged. These results provide important insights to the development of rapid detection technology of food microorganisms in our country.

1. Introduction
According to the WHO statistics, about one-third of people in the developed countries are infected by foodborne diseases every year, and it was even worse in some developing countries, more than half of the food-borne diseases were caused by microorganisms. As a result, pathogenic microorganisms have become one of the main factors affecting food safety, and microbiological testing has become significant with regard to food safety.

Traditional food microbe testing usually adopt AGAR plate culture method, which mainly relies on culture medium for culturing, separating and biochemical identification, and the operation process is complicated and time-consuming, 2~3 days are usually required. A series of domestic and overseas standards based on the traditional detection method has been established, such as ISO international standards, the United States FDA, USDA, AOAC, France AFNOR, Nordic NMKL, Japan’s Ministry of detection methods, as well as our national standards. However, due to the complicated detection procedure and long detection period of the traditional detection methods, the development of rapid, simple and specific detection methods has become a hotspot in the field of microbial detection.
With the same principle of the traditional method of microbial rapid detection, research and development focus on the colour medium technology, carrier technology, analytical chemistry technology, as well as automated microbiological analyzer. By changing the principle of testing to realize the rapid detection of microorganisms, the microorganism was isolated, detected, identified and counted mainly by using the techniques of microbiology, chemistry, biochemistry, biophysics, immunology and serological test. At present, the main microbial rapid detection technologies are based on molecular biology technology gene probe technology, polymerase chain reaction, gene chip technology, latex agglutination based on immune technology, enzyme-linked immunosorbent assay and immune magnetic microsphere technology, ATP bioluminescence, resistance technology, radiation measurement technology based on metabolic technology, Micro-calorimeter technology, as well as immunosensor and gene sensor technology based on biosensors technology and other methods.

Bibliometrics is the interdisciplinary study of quantitative analysis of all knowledge carriers by means of mathematical and statistical methods. Bibliometrics can objectively and quantitatively reflect the macroscopic development trend of a certain discipline, and has been adopted by many disciplines. In the fields of agriculture, forestry, environmental science and new energy utilization, scholars have done plenty bibliometric analysis, and the research methods have been well developed.

In order to clarify the research layout and development trend of food microorganism rapid detection technology in the world, this study is based on the database from Web of Science Citation Index Expanded edition Science platform (Science Citation Index Expanded, SCIE), carries on the metrology statistics of the SCI papers in the field of food microbial rapid detection technology, and probes into the present research status, research emphases and development trend.

2. Data sources and retrieval strategies

The retrieval of sci-tech literature in this study is based on the SCIE database in the Web of Science platform as the data source. This paper makes a logical set of retrieval methods of several technical points of microbial rapid detection technology, and makes a preliminary examination of the documents, adjusts the retrieval and retrieval strategies according to the initial test results, and finally determines the search strategy as shown in table 1.

Table 1. The strategy of related literature retrieval for rapid microbial detection technology.

| No. | Retrieval strategies |
|-----|---------------------|
| #1  | TI=(microorganism or micro-organism or microbial or micro-bial or microbiota* or microbe or bacterium or bacteria or coliform or pathogen* or fungus or fungi or fungal or mould or mold or virus or parasit*) OR AK=(microorganism or micro-organism or microbial or micro-bial or microbiota* or microbe or bacterium or bacteria or coliform or pathogen* or fungus or fungi or fungal or mould or mold or virus or parasit*) OR KP=(microorganism or micro-organism or microbial or micro-bial or microbiota* or microbe or bacterium or bacteria or coliform or pathogen* or fungus or fungi or fungal or mould or mold or virus or parasit*) |
| #2  | TI=(test* or detect* or identif* or inspect* or assay* or diagnos* or estimat* or determinat*) OR AK=(test* or detect* or identif* or inspect* or assay* or diagnos* or estimat* or determinat*) OR KP=(test* or detect* or identif* or inspect* or assay* or diagnos* or estimat* or determinat*) |
| #3  | TS=((microorganism or micro-organism or microbial or micro-bial or microbiota* or microbe or bacterium or bacteria or coliform or pathogen* or fungus or fungi or fungal or mould or mold or virus or parasit*) near/10 (test* or detect* or identif* or inspect* or assay* or diagnos* or estimat* or determinat*)) |
3. Data analysis

3.1. Number of published papers and the analysis of its annual change

The changes over time on the number of papers on rapid microbial detection can reflect the development of relevant research in this sector. Figure 1 illustrates the annual tendency of the number of papers in this sector, which shows that the relevant research on rapid microbial detection can be roughly divided into three phases: 1925 to 1990, the initial phase. During this period, there were only a few papers every year, and the published number per year was no more than 10. There weren’t many changes year by year, nor obvious increase; 1991-2001, a phase with steady growth. During this phase, there were considerably more papers than that in the previous phase, but the development in this period remained relatively steady with relatively small amount of increase. The annual numbers were basically twenty to thirty. There were three small climaxes, namely 1997 (39), 1999 (39) and 2001 (40), which were obviously higher than the average in this phase; since 2002, there have been rapid rises in both the number of published papers and the annual increases. The number exceeded 100 for the first time in the year of 2008, and 200 in the year of 2014, and the annual number has kept soaring ever since (Due to the search time, the data of the published papers in 2018 is not complete, hence just for reference only). These have demonstrated that the technologies of rapid microbial detection are gradually receiving attention, and researchers are increasingly focused on this sector.

![Figure 1. Annual distribution of papers in the field of microbial detection.](image)
3.2. The analysis of scientific articles published by major countries/regions
In this study, the microbial rapid detection of related papers involved in a total of 97 countries/regions. Table 2 shows the number of posts in the top 15 countries/regions and their citation. It shows:

- The United States issued the most (593), the volume is far more than the second-ranked country: mainland China. The published papers from the US were cited 16,155 times, the citations per article is 27.24, significantly higher than the TOP15 country/region average of the citations. It shows that the United States has a strong advantage in the layout of scientific research field and influence in this field.

- China Mainland, although the number of posts has ranked the second (218), the performance of the citations and citations per paper are lower than the average of the TOP15 country/region, which shows that the influence of the research is about to be improved.

- The volume of Denmark (41) and the Netherlands (61) are not much, ranked the 15th and the 13th, but their performance in citations per paper is very eye-catching, 44.71 and 37.77 respectively, ranked the first and the second in the TOP15 countries/regions, indicating that these two countries haven’t done much in terms of the field layout, but their research are very much influential as a result.

Table 2. The volume and citation of papers in TOP15 country/region in the field of microbial testing.

| Ranking | Country                  | Volume | %    | Citations | Citations per paper |
|---------|--------------------------|--------|------|-----------|---------------------|
| 1       | USA                      | 593    | 25.23% | 16,155    | 27.24               |
| 2       | China Mainland           | 218    | 9.28% | 1,635     | 7.50                |
| 3       | Spain                    | 153    | 6.51% | 3,569     | 23.33               |
| 4       | Germany(FED REP GER)     | 152    | 6.47% | 3,716     | 24.45               |
| 5       | United Kingdom           | 136    | 5.79% | 3,712     | 27.29               |
| 6       | Italy                    | 128    | 5.45% | 2,630     | 20.55               |
| 7       | Japan                    | 122    | 5.19% | 1,602     | 13.13               |
| 8       | France                   | 118    | 5.02% | 2,189     | 18.55               |
| 9       | England                  | 118    | 5.02% | 3,175     | 26.91               |
| 10      | South Korea              | 117    | 4.98% | 1,086     | 9.28                |
| 11      | Canada                   | 114    | 4.85% | 2,878     | 25.25               |
| 12      | India                    | 65     | 2.77% | 1,077     | 16.57               |
| 13      | Netherlands              | 61     | 2.60% | 2,304     | 37.77               |
| 14      | Brazil                   | 51     | 2.17% | 678       | 13.29               |
| 15      | Denmark                  | 41     | 1.74% | 1,833     | 44.71               |
| TOP15 Average |                      | 145.8  | 6.20% | 3215.93   | 22.39               |

3.3. Analysis on the published quantity and article citation of key organizations
More than 1000 organizations have published articles relating rapid detection of microorganism. Table 3 lists the volume of the top 11 organizations and their citations. It indicates:
Among the top 11 institutions, there are 5 United States agencies, 3 Spanish institutions, 2 French institutions, 2 Dutch institutions, 2 Danish institutions, 1 Belgian institution, 1 German institution, 1 Canadian institution and 1 Italian institution.

Consejo Superior de Investigaciones Científicas (CSIC) although has the largest number of articles published (48), but its citations per paper is 23.90, ranked eleventh only, at the middle level; Purdue University issued a volume (39) ranked the second, the citations per paper is 26.64, ranked the sixth.

Wageningen University & Research Center’s published articles number (26) only ranked the fourth, but their papers are the most influential, the articles are cited as high as 42.04 times per paper; Netherlands National Institute for Public Health & the Environment published paper (16) although not much with ranking the tenth only, its thesis influence is ranked the second, the articles’ citation per paper is 40.38.

From the point of view of the proportion of the paper citation, papers from University of Copenhagen were all cited by the follow-up study in relevant fields, indicating that the study has follow-ups; papers from Purdue University and North Carolina State University were also with very high proportion of citation, 97.44% and 95.83% respectively, it shows that the research results are count for much as reference of follow-up studies.

| No. | Rank | Organizations                                                   | Volume | Citations | Citations per paper | Proportion |
|-----|------|-----------------------------------------------------------------|--------|-----------|---------------------|------------|
| 1   | 1    | Consejo Superior de Investigaciones Científicas (CSIC)         | 48     | 1147      | 23.90               | 93.75%     |
| 2   | 2    | Purdue University                                             | 39     | 1039      | 26.64               | 97.44%     |
| 3   | 2    | Institut National de la Recherche Agronomique (INRA)           | 39     | 801       | 20.54               | 94.87%     |
| 4   | 3    | Centre National de la Recherche Scientifique (CNRS)           | 34     | 714       | 21.00               | 85.29%     |
| 5   | 4    | Wageningen University & Research Center                       | 26     | 1093      | 42.04               | 88.46%     |
| 6   | 5    | North Carolina State University                               | 24     | 804       | 33.50               | 95.83%     |
| 7   | 6    | Consiglio Nazionale delle Ricerche (CNR)                      | 23     | 492       | 21.39               | 86.96%     |
| 8   | 7    | Ghent University                                              | 22     | 559       | 25.41               | 77.27%     |
| 9   | 8    | University of Arkansas Fayetteville                          | 19     | 385       | 20.26               | 84.21%     |
| 10  | 9    | University of Guelph                                          | 18     | 394       | 21.89               | 83.33%     |
| 11  | 9    | Technical University of Munich                               | 18     | 336       | 18.67               | 88.89%     |
| 12  | 10   | University of Georgia                                         | 16     | 413       | 25.81               | 87.50%     |
| 13  | 10   | Netherlands National Institute for Public Health & the Environment | 16   | 646       | 40.38               | 87.50%     |
| 14  | 11   | Technical University of Denmark                               | 15     | 386       | 25.73               | 86.67%     |
| 15  | 11   | University of Copenhagen                                     | 15     | 460       | 30.67               | 100%       |
3.4. Analysis of core periodicals

According to the Bradford's law, most of the papers in a subject or field are concentrated in a few professional journals. Table 4 lists the top 20 journals published in the field of microbial rapid detection, which can be regarded as core periodicals in this field. From this we can find out that INTERNATIONAL JOURNAL of FOOD MICROBIOLOGY is the most important periodical in the field of microbial rapid detection, which publishes 125 related papers, accounts for the 5.32%; JOURNAL OF FOOD PROTECTION ranked second, published 110 papers in the field of microbial rapid detection, take 4.68% of the total volume of published papers in this field.

In addition, BIOSENSORS & BIOELECTRONICS, FOOD MICROBIOLOGY, APPLIED ENVIRONMENTAL MICROBIOLOGY, FOOD CONTROL, JOURNAL OF APPLIED MICROBIOLOGY, JOURNAL OF MICROBIOLOGICAL METHODS, JOURNAL OF VIROLOGICAL METHODS, LETTERS IN APPLIED MICROBIOLOGY, PLOS ONE all published more papers than other journals in this field.

Among the 20 core periodicals in the field of microbial rapid detection, BIOSENSORS & BIOELECTRONICS are the most influential one, the influence factor is 7.476, and ANALYTICA CHIMICA ACTA (the 15th of the load quantity) and SENSORS AND ACTUATORS B-CHEMICAL (the 19th-ranked) are also very influential, with 5.886 and 4.758 Journal Impact factors respectively.

Table 4. The core periodicals in the field of microbial testing.

| Ranking | Core periodicals                                      | Volume | Proportion | Journal Impact factor |
|---------|-------------------------------------------------------|--------|------------|-----------------------|
| 1       | INTERNATIONAL JOURNAL OF FOOD MICROBIOLOGY           | 125    | 5.32%      | 3.445                 |
| 2       | JOURNAL OF FOOD PROTECTION                           | 110    | 4.68%      | 1.609                 |
| 3       | BIOSENSORS & BIOELECTRONICS                          | 64     | 2.72%      | 7.476                 |
| 4       | FOOD MICROBIOLOGY                                   | 62     | 2.64%      | 3.682                 |
| 5       | APPLIED AND ENVIRONMENTAL MICROBIOLOGY               | 59     | 2.51%      | 3.823                 |
| 6       | FOOD CONTROL                                        | 56     | 2.38%      | 3.388                 |
| 7       | JOURNAL OF APPLIED MICROBIOLOGY                      | 43     | 1.83%      | 2.156                 |
| 8       | JOURNAL OF MICROBIOLOGICAL METHODS                  | 40     | 1.70%      | 1.857                 |
| 9       | JOURNAL OF VIROLOGICAL METHODS                      | 35     | 1.49%      | 1.508                 |
| 10      | LETTERS IN APPLIED MICROBIOLOGY                      | 31     | 1.32%      | 1.579                 |
| 11      | PLOS ONE                                             | 24     | 1.02%      | 3.057                 |
| 12      | JOURNAL OF AGRICULTURAL AND FOOD CHEMISTRY           | 22     | 0.94%      | 2.857                 |
| 13      | JOURNAL OF AOAC INTERNATIONAL                         | 21     | 0.89%      | 0.918                 |
| 14      | JOURNAL OF FOOD SAFETY                               | 20     | 0.85%      | 0.915                 |
3.5. Analysis of research areas

Based on the contents and the inter-citation of the documents in the journals, SCI Database has divided its journals into 177 subject categories. Through analysis, the subjects of papers on rapid microbial detection are categorized as follows: Food Science and Technology has 781 papers in this regard, which is the largest and accounts for 33.23% of the total documents in this sector; Biotechnology & Applied Microbiology and Microbiology also have relatively large number of papers, which are 644 and 624, accounting for 27.4% and 26.55% respectively. Apart from that, Top-10 subjects in terms of relevant papers also include Analytical Chemistry, Biochemical Research Methods, Botanical Science, Nano Science and Nanotechnology, Electrochemistry, Biochemistry and Molecular Biology, and Biophysics.

3.6. Research subject analysis based on author's key words

The research hotspots of the field will be explored by analyzing the high-frequency words of the field. This study classifies the key words in the field of microbial rapid detection into four categories, and they are molecular biology technology, immune technology, metabolic technology, biosensor, etc.

Table 5 lists the key keywords and the amount of literature involved in each category. It illustrates that the high frequency words related to the molecular biological methods in microbial detection technology are Polymerase Chain Reaction(PCR), real-time PCR, multiplex PCR, probes, reverse transcription-PCR, quantitative PCR, Molecular detection methods, chip, Real-time qPCR, molecular characterization, oligonucleotide probes, DNA probes, molecular analysis, diagnostic PCR. The high frequency words related to immunological methods in microbial detection techniques are enzyme-linked Immunosorbent assay, immunomagnetic, Immunoassay, immunomagnetic separation, immunosorbent, immunosensor. Bioluminescence, metabolites, ATP bioluminescence and Electrochemical impedance are the main high-frequency words related to metabolic methods in microbial detection technology. The high-frequency words related to biosensor methods in microbial detection technology mainly include biosensor, DNA biosensor, and electrochemical biosensor.

Table 5. Key words classification in the field of rapid microbial detection technology.

| Category                      | Total volume | Key words                           | Volume respectively |
|-------------------------------|--------------|-------------------------------------|----------------------|
| molecular biological methods  | 970          | Polymerase chain reaction            | 673                  |
|                               |              | real-time PCR                        | 287                  |
|                               |              | multiplex PCR                        | 128                  |
|                               |              | reverse transcription-PCR            | 79                   |
|                               |              | quantitative PCR                     | 44                   |
|                               |              | molecular detection methods          | 40                   |
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4. Conclusions and suggestions

The analysis of the scientific research development on rapid microbial detection based on SCI papers indicates that: 1) this field has entered the rapid growth phase after its forming phase and the initial phase; 2) America enjoys absolute advantages in this field. China, Germany and Spain are also countries with relatively strong competitiveness; 3) CSIC has the largest number of relevant published papers, while the papers from CNRS and INRA are the most influential ones; 4) International Journal of Food Microbiology is the core journal that published the largest number of relevant papers, while Biosensors & Bioelectronics is the most influential relevant journal; 5) Food Science and Technology is the subject of the most importance in this field. Biotechnology & Applied Microbiology and Microbiology are also significantly relevant; 6) researches in this field focus the most on relevant technologies on Molecular Biology, second on the technologies on Immune method and biosensors rank second, and the least on the technologies on metabolic methods; 7) sustainability has been seen in a part of the hot research topics, and new hot topics have also emerged.

China has many proper plans on this field and has ranked the second in terms of the number of published papers. However, it underperformed in terms of the total citation and the citation per paper, which are both lower than the average of the Top 15 countries/regions. Hence, China should work on enhancing the quality of papers and the influences of the results.

Wageningen University and Research Centre and RIVM are quite influential in this field though they do not have many research outcomes; the research achievements from institutions like CSIC,
Purdue University, North Carolina State University, CNR, Ghent University, University of Arkansas—Fayetteville, University of Georgia, Technical University of Denmark, University of Copenhagen, University of California—Davis, Complutense University of Madrid, and University of Valencia are above the global average in terms of influences during the same period. Hence, Chinese institutions and scholars can regard them as priorities when considering collaboration, and try to broaden the horizon, elevate the research capability and the significance of the research results through working with them.

International Journal of Food Microbiology and Journal of Food Protection are two of the most important journals, while Biosensors & Bioelectronics, Analytica Chimica Acta and Sensors and Actuators B-Chemical are the most influential ones. Relevant scholars can focus on these journals and pay attention to their development so as to keep their research pertinent to international frontiers and heated topics.

Real-time qPCR, molecular analysis, electrochemical impedance spectroscopy (EIS), diagnostic PCR, DNA biosensor, electrochemical biosensor, multiplex RT-PCR are among the top-10 new heated research topics. Relevant institutions should closely follow their development, figure out the reasons for their popularity, and properly expand the efforts on them; while the popularity on oligonucleotide probes, DNA probes, ATP bioluminescence, targeted oligonucleotide probes, gene probes, RAPD-PCR, and immunofiltration assay, which were hot topics in the past decade, is fading to some extent. Relevant institutions should analyze the reason for this phenomenon, pay attention to their future tendencies, and adjust the research direction appropriately.

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