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An overview of applications in pineapple agroindustrial residues

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ABSTRACT

Industrial food production causes a high amount of waste. This waste must be taken to a suitable location where it can be further processing. During industrial processing of the pineapple, about 50 % of the mass of the fruit ends up being discarded becoming a residue. Researchers have studied these residues in order to add value to these by-products, to reduce disposal costs and guarantee environmental sustainability. This work investigates the development characteristics of research on agroindustrial residues of pineapple based on bibliometric methods to explore the structure of knowledge in this field over the years, according to the year of publication, periodicals, country, authors, area of knowledge, institutions, keywords, subject type, and citation analysis. In total 927 articles were found and after a careful analysis and selection of papers, 364 articles remained of which 82 % were published only in the last decade. Most studies focused on agricultural and biological sciences. About 1183 authors from 50 different countries contributed to this subject, in which India has the largest number of publications. The results obtained with this study, highlighting the different uses for pineapple residues, can provide valuable information for researchers interested in the field of agroindustrial wastes.

Key words: bibliometric analysis; residues; agroindustrial wastes; pineapple; waste management

IZVLEČEK

PREGLED UPORABE AGROINDUSTRIJSKIH OSTANKOV ANANASA

Industrijska proizvodnja hrane povzroča velike količine odpadkov. Odpadki morajo biti spravljeni na primernem mestu, kjer so lahko nadalje obdelani. Med industrijsko predelavo ananasa postane okrog 50 % mase odpadek. Ti ostanki so bili preučevani z vidika, da bi tem stranskim produktom dodali vrednost, zmanjšali stroške odvoza in zagotovili okoljsko vzdržnost. Prispevek preučuje razvojne značilnosti raziskav, ki se ukvarjajo s preučevanjem agroindustrijskih ostankov ananasa na osnovi bibliometričnih metod z namenom, da se prikaže znanje na tem področju v zadnjih letih glede na leto publikacije, vrsto revij, države, avtorjev, področij znanja, institucijo, ključne besede, tem raziskav in analizo citiranja. Celokupno je bilo najdenih 927 člankov. Po skrbni analizi in izboru objav je ostalo 364 člankov, od katerih je bilo 82 % objavljenih v zadnjem desetletju. Večina raziskav je bila usmerjena v agronomske in biološke vede. Okrog 1183 avtorjev iz 50 držav je prispevalo svoj delež, med njimi ima Indija največje število publikacij. Izsledki, dobljeni v terj raziskavi, osvetljujejo različne rabe ostankov ananasa, kar lahko prispeva pomembne informacije raziskovalcem, ki ji zanima področje agroindustrijskih odpadkov.

Ključne besede: bibliometrična anliza; ostanki; agroindustrijski odpadki; ananas; upravljanje z odpadki

1 INTRODUCTION

Brazil is one of the largest fruit producers in the world. In terms of total volume, pineapple is one of the most important fruit crops (FAO, 2015). The crop represents, according to data from the Brazilian Institute of Geography and Statistics (IBGE, 2017), the third largest fruit product, being surpassed only by oranges and bananas. The total planted area of pineapple in 2016 was 100,238 hectares, of which 67,254 hectares were

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harvested. Production in this same year reached 1,734,627 tons, obtaining an average yield of 25,792 $kg \cdot ha^{-1}$ (IBGE, 2017). Advantages such as geographic location, wide availability of arable land and climatic conditions favor the leading role of pineapple cultivation, ensuring jobs and contributing significantly to the national economy (Brito Neto et al., 2008; Morgado et al., 2004; Silva, 2016).

Industrial food production causes a high amount of waste, such as bagasse, husks and pulp residues of the fruits. This waste must be taken to a suitable location, which in general adds a costly procedure to the industry. In addition to the cost of treating this material, many of which are of low efficiency, there are still risks for the continuity of environmental pollution (Timofiecsyk & Pawlowsky, 2000). Since the residues produced have great potential for reuse, together with the concern for the environment, numerous studies have been carried out with the intention of taking advantage of them (Borges et al., 2004; Ferrari et al., 2004; Zhang et al., 2007). Thus, it is possible to reduce environmental pollution, and increase sustainability, along with obtaining new products with higher added value (Pelizer et al., 2007).

During industrial processing of the pineapple, the crown and stem are cut prior to desquamation. Subsequently, the shell and core are removed, leaving only the pulp. This residue usually corresponds to about 50 % of the fruit mass, representing a growing environmental problem due to microbial deterioration (Ketnawa et al., 2012). The other parts of the plant, such as the stem, roots, and leaves, are generally discarded in the field as agricultural residues, representing high waste since these components also make up the fruit (Fagundes & Fagundes, 2010).

Numerous academic studies are being carried out with the aim of making some use of the agroindustrial residues of pineapple: protein enrichment (Alexandre et al., 2013; Navid et al., 2010; Díaz-Vela et al., 2017), vinegar manufacturing (Madurai et al., 2010; Isitua & Ibeh, 2010), extracting bromelain (Ketnawa et al., 2012; Manosroi et al., 2014) enzyme production (Selvakumar & Sivashanmugam, 2017), preparation of activated carbon nanosheets (Sodtipinta et al., 2017), production of cellulose nanocrystals (CN) (Santos et al., 2013), represent some types of use. These documents summarize ways of taking advantage of agroindustrial residues of pineapples plants from different perspectives, but a bibliometric approach still was not applied. Thus, no study presented a comprehensive picture of this type of exploitation due to its research restrictions.

The search for indicators to quantify scientific activity and technological knowledge has increased over the years. In Brazilian literature, for example, it was mediated by the need for the government and scientific community to have instruments to promote guidelines, incentive programs and evaluation of science and technology development in Brazil (Mugnaini et al., 2004; Allen, 1969). According to Wang et al. (2014), bibliometric is a very useful tool for mapping the literature around a research, using statistical and quantitative analyzes to demonstrate patterns of productivity of articles in a given field of research, institution or country throughout the time. The bibliometric approach has been widely used in several studies, such as the use of nanotechnology in agriculture (Stopar, 2016), the analysis of scientific production related to organic agriculture (Aleixandre et al., 2015), use of energy from biomass and its interaction with the environment (Mao et al., 2018), evaluation of the evolution of the topic of food waste (Chen et al., 2016), verification of publication trends concerning natural fibers (fiber crops or fiber plants) (Bartol & Mackiewicz-Talarczyk, 2015), evaluation of the distribution of research related to rural tourism (Hočevar & Bartol, 2016).

Thus, the purpose of this work was to quantitatively and qualitatively evaluate the scientific literature on the use of agroindustrial residues of pineapples using bibliometric analysis which results provide valuable information to assist researchers in selecting potential research fields, identifying suitable institutions to evolve their studies, and contacting researchers for collaboration filling existing gaps in this field of research.

2 MATERIALS AND METHODS

2.1 Methods

Initially a literature review was carried out on the Scopus database, with the international scientific production on the use of agroindustrial residues of pineapples as its guideline, opting for the search of articles as the only type of document.

In this citation database, the search was used in the section of title, abstract and keywords. The following keywords together with Boolean operators were used as search strategies, only on scientific articles: TITLE-ABS-KEY ((pineapple*) AND (waste* OR residue* OR bagasse* OR skin* OR crown* OR peel* OR core*)) AND (LIMIT-TO (DOCTYPE, "ar")).

After the bibliographic review, the material was analyzed. Once all publications were identified, a pre-selection was made, according to the theme regarding the use of pineapple agroindustrial residue guiding the study, and previously defined inclusion and exclusion criteria. All languages of publication were considered.

The collected data were organized, coded, tabulated and submitted to statistical analysis with the Scopus base itself, and statistics/network using VOSviewer software (Van Eck & Waltman, 2018; Van Eck & Waltman, 2014). For the purpose of analysis, the following variables were chosen: year of publication, periodicals, country, authors, area of knowledge, institutions, keywords, type of subject and citation analysis.

2.2 Review of documents

After searching the Scopus database, 927 articles were found in total. Articles generally provide more original search results and more information about the authors and their affiliations, and only those documents were used in the analysis.

All articles have been evaluated by the titles, abstracts and information contained in the publication. In this phase, the documents that did not correspond specifically to the object of study were identified. This stems from the fact that the use of the keywords results in a general and broad search, covering any kind of subject that contains these questions at random. Thus, scientific documents dealing with pineapple in a general manner were excluded, such as those related to the use of parts of pineapple plant (leaf and stem), pineapple fruit quality, physico-chemical properties, pesticide residues in pineapple and peeling of the fruit.

This filtering process eliminated 563 publications, resulting in 364 articles, which were exported in CSV format for bibliometric analysis.

2.3 Analysis tools

In this study, the Scopus database was used. VOSviewer (Van Eck & Waltman, 2018; Van Eck & Waltman, 2014) was used as tool for analysis and visualization of the network.

Scopus is a global citation database covering science, technology, medicine, social sciences, arts and humanities (Elsevier, 2018). This database has a vast collection of more than 71 million records and 23,700 titles from more than 5,000 international publishers. It also has intelligent tools that allow the tracing, analysis and visualization of searches, which can be done by title of the article, abstract, keywords, authors, affiliation, language, ISSN, DOI, among others (Elsevier, 2018).

VOSviewer is a software used for the creation, visualization and investigation of bibliometric maps from network data using the VOS (Visualization of Similarities) mapping technique. It is possible to use file data from databases such as Web of Science, Scopus, RIS, PubMed, Crossref JSON to build networks. It is worth noting that VOSviewer is not only restricted to the analysis of bibliometric networks, it is possible to expand its use for the elaboration, visualization and analysis of maps made up of any type of network data.

Different publications report applications of VOSviewer, such as in the importance of climate change for the production of tea (verification of the *Camellia sinensis* (L.) Kuntze) (Marx et al., 2017), in the analysis of the research landscape of precision agriculture in Italy (Costa et al., 2017), in the review of publications dealing with climate change and viticulture (Marx et al., 2017), in the verification of publications related to nanocellulose (Milanez et al., 2016).

3 RESULTS AND DISCUSSION

3.1 Publication trend

The trend of publication related to the use of agroindustrial residues of pineapples is shown in Figure 1.

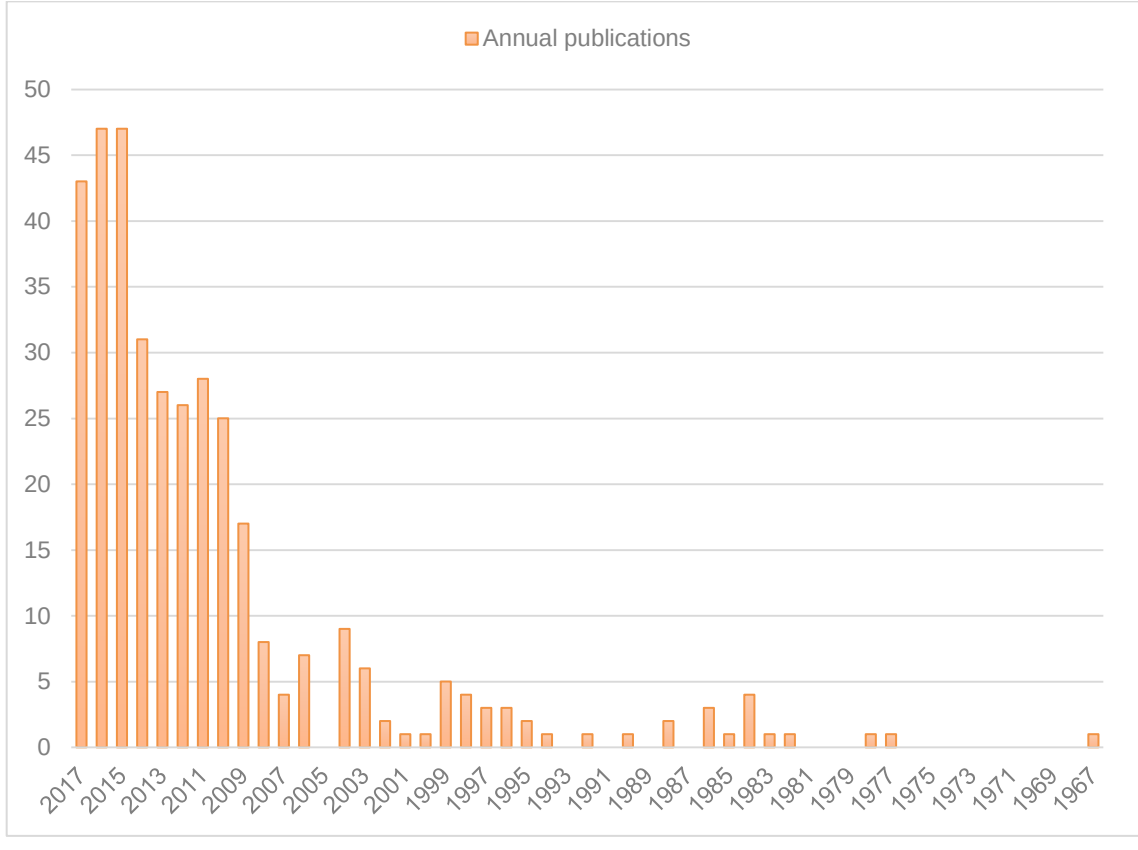

Figure 1: Trends of publications

The first publication occurred in 1967 with the work of Richardson (1967) dealing with the production of vinegar. During 1967-2007, there were few publications, followed by an increase in 2008. Publications in the last 10 years (299) represent more than 82 % of the total. It should be noted that the study in question did not cover all the publications made in the year 2017, since when the research was carried out, publication data for 2017 were not complete. Thus, the observation of the results allows inferring that the annual publications have presented an increasing and constant trend during the last decade. This result can be explained by growing global concern about environmental issues, aiming at sustainable production.

3.2 Areas of activity

The studies that contributed to this research theme involved 21 different academic areas, as shown in Figure 2.

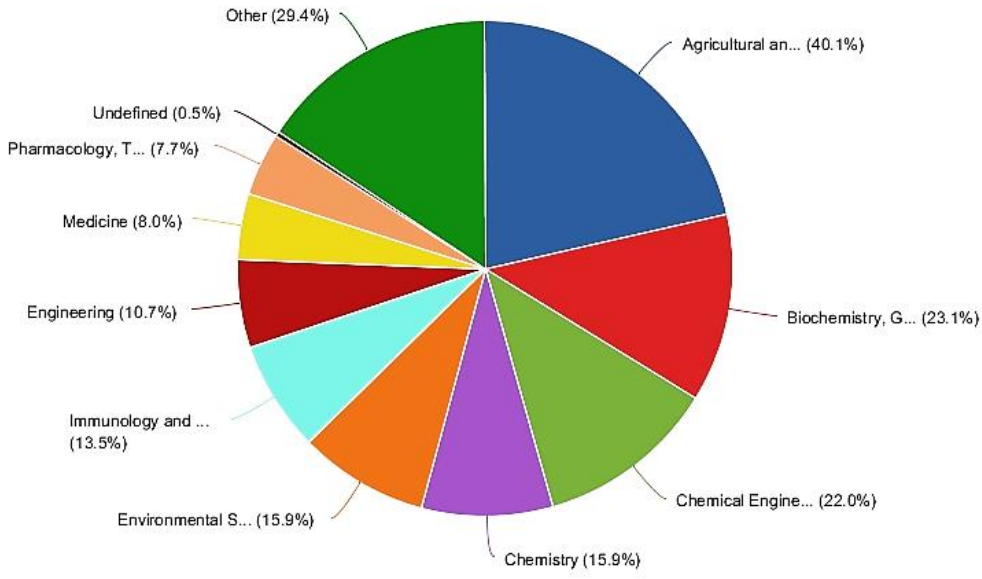

Figure 2: Areas involved in research

Among the areas (Figure 2), agricultural and biological sciences are highlighted as number 1, with 146 publications (40.1 %), followed by biochemistry and genetics (23.1 %) and chemical engineering (22.0 %). Publications involved in environmental sciences, chemistry, immunology, engineering, medicine and pharmacology also contributed to the development of the theme of agroindustrial residues of pineapple, while other areas contributed to the remaining 29.4 %.

3.3 Journals

The 364 articles selected were published in 158 different journals, but most of these journals (55.7 %) published only one article related to the use of agroindustrial residues of pineapples. Table 1 lists the top ten journals with the largest number of publications. In general, citation times for an article might reflect its influence, though the wrong citations might occur. Thus, total citations (TC) and the average number of citations per document of a journal (TC/P) in the period are also shown in Table 1.

Table 1: Periodicals with more publications

#	Periodic	Publications	%	TC[a]	TC/P[b]
1	Bioresource Technology	13	3.57	457	35.15
2	Chemical Engineering Transactions	8	2.19	15	1.87
3	Process Biochemistry	5	1.37	246	49.20
4	Journal of Food Science and Technology	5	1.37	14	2.80
5	International Food Research Journal	5	1.37	5	1.00
6	Carbohydrate Polymers	4	1.09	128	32.00
7	International Biodeterioration And Biodegradation	4	1.09	33	8.25
8	RSC Advances	4	1.09	29	7.25
9	International Journal of Chemtech Research	4	1.09	20	5.00
10	Revista Brasileira de Zootecnia	4	1.09	20	5.00

[a] Total Citations of the document.
[b] Average Citations per published document.

In terms of journals performance, Bioresource Technology was the most productive with 13 articles, followed by Chemical Engineering Transactions (8 articles). Bioresource Technology also presented the highest number of citations (457), followed by Process Biochemistry (246) and Carbohydrate Polymers (128). Process Biochemistry had the highest TC/P score, followed by Bioresource Technology and Carbohydrate Polymers. It is interesting to note that despite being in second place in the publications, Chemical Engineering Transactions presents TC/P well below the last three mentioned.

Figure 3 illustrates the performance of journals on the use of agroindustrial residues of pineapples.

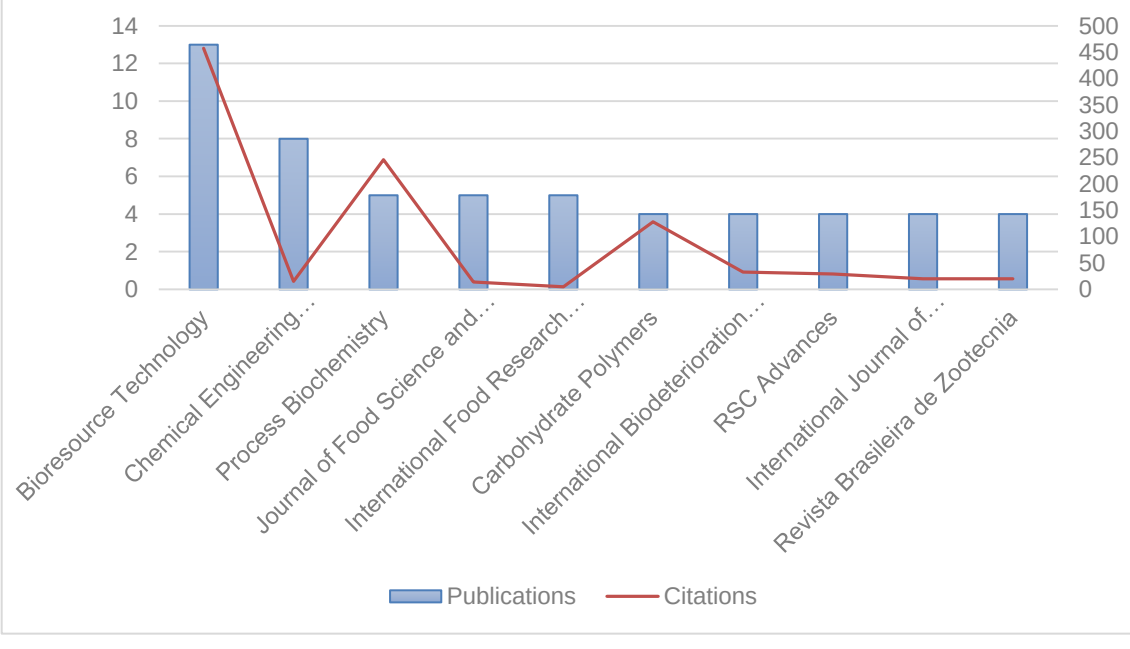

Figure 3: Number of publications and citations in periodicals

The results imply that Bioresource Technology, Process Biochemistry and Carbohydrate Polymers are the leading journals in this area. Other major journals include International Biodeterioration and Biodegradation, RSC Advances, International Journal of Chemtech Research and the Revista Brasileira de Zootecnia.

3.4 Country

From the point of view of the countries, institutions from 50 countries were responsible for the publication of the 364 articles related to the use of agroindustrial residues of pineapples. Of the total countries, 40 % contributed with only one document. Table 2 lists the ten most productive countries.

Table 2: Publications by country, and collaboration between countries

#	Country	n.p.[a]	%	coll[b]	Country 1	Country 2	n.p.[a]
1	India	78	19.38	9	Thailand	Japan	5
2	Brazil	59	16.28	4	India	South Korea	4
3	Malaysia	49	15.12	6	India	United States	3
4	Thailand	40	12.40	15	Malaysia	Australia	3
5	China	19	6.20	2	Thailand	South Korea	3
6	Nigeria	18	5.81	2	Thailand	United States	3
7	United States	17	5.43	20	Brazil	United States	2
8	Mexico	14	3.88	1	Thailand	France	2
9	Japan	13	3.49	8	United States	France	2
10	Australia	11	3.49	4	United States	South Korea	2

[a] Publications number
[b] Collaboration

From Table 2, it can be seen that the ten most productive are responsible for 87.6 % of all publications, with 63.18 % being distributed among the first four. India has more publications in this area, followed by Brazil, Malaysia and Thailand. In this way, it is understood that the main countries of the researchers related to the residues are also the main producers of the fruit. These countries are emerging economies with favorable climates for the cultivation of pineapples, and the use of waste can represent an important economic activity.

Table 2 also shows the main collaborations between countries. Although the United States (USA) is not ranked among the five most productive countries, it is the most active country for international collaboration in this field with 20 collaborations.

Countries collaborating with the USA include India, Thailand, Brazil, France and South Korea. The USA has collaborated with many countries. On the other hand, India, Brazil and Malaysia, although with more publications, have few collaborations with other countries. It has been found that thirteen nations (such as Portugal, Taiwan, Indonesia, among others) have not collaborated with other countries in their publications.

The United States has the largest cross-country cooperation, maintaining research relationships with 13 countries worldwide by sharing 20 articles, followed by Thailand (6 countries and 15 articles), South Korea (4 countries and 11 articles), India (4 countries and 9 articles), South Africa (9 countries and 9 articles) and Italy (8 countries and 8 articles), while South Africa and Italy, despite high collaboration, share only one article with other countries. Highlight the relationship between Japan and Thailand by cooperating five articles.

In relation to the most productive countries, Malaysia (6 articles) and Brazil (4 articles), although highly productive, maintains collaboration with only four and three countries, respectively, indicating that the research is little diversified and restricted to national researchers, while Nigeria, which despite being among the most productive, shared only two articles.

3.5 Authors

In total, 1,183 authors wrote contributions to this subject, although only 166 authors participated in more than one document. The authors with the highest number of publications are listed in Table 3, including the respective numbers of published documents, h-index, country of origin and collaboration articles. We see Tambourgi E. B. as the most productive author with 9 articles, followed by Huang H. and Vasiljevic T. with 8 and 7 articles, respectively.

Table 3: Main authors and main co-authors

#	Author	n.p.[a]	h-Index	Country	coll[b]	Author 1	Author 2	n.p.[a]
1	Tambourgi, E. B.	9	22	Brazil	39	Tambourgi, E. B.	Silveira, E.	6
2	Huang, H.	8	10	China	17	Carreira, R. L.	Silvestre, M.P.C	6
3	Vasiljevic, T.	7	24	Australia	21	Vasiljevic, T.	Donkor, O. N.	4
4	Silveira, E.	6	6	Brazil	33	Vasiljevic, T.	Sah, B. N. P.	4
5	Carreira, R. L.	6	5	Brazil	28	Vasiljevic, T.	McKechnie, S.	4
6	Silvestre, M.P.C.	6	17	Brazil	28	Huang, H.	Dai, H.	4
7	Zakaria, Z. A.	5	11	Brazil	21	Huang, H.	Hu, X.	4
8	Ahmad, W. A.	5	11	Malaysia	19	Zakaria, Z. A.	Ahmad, W. A.	3
9	Hu, X.	5	4	China	16	Jamal, P.	Alam, M. Z.	3
10	Jamal, P.	5	11	Malaysia	16	Jamal, P.	Saheed, O. K.	3

[a] Publications number
[b] Collaboration

The h-index of each author was obtained from Scopus, being a non-static indicator to measure the author's productivity and the impact of his research. In general, it implies that the total number of articles published by a person is quoted at least h times.

However, regarding the h-index, the number of publications are not proportional to the scores of this indicator. The reason for this can be attributed to the fact that studies related to the use of pineapple residues require the involvement of researchers from different fields, highlighting those that exert a greater influence in their area of research, as is the case of Vasiljevic T. (agricultural and biological sciences).

In order to analyze the collaboration between authors, Table 3 also shows the main authors and main co-authors in this field of research. Interestingly, the authors listed in main authors are also present in main co-authors, indicating knowledge integration of different authors.

Table 3 shows collaboration within a given country, such as Tambourgi, Silveira, Carreira and Silvestre in Brazil; Huang, Dai and Hu in China; Jamal and Alam in Malaysia, and Vasiljevic and Sah in Australia. Therefore, the collaborations among the most productive authors are among authors from the same country.

Looking at Table 3, it is possible to verify that the authors who most shared articles related to the use of agroindustrial residues of pineapples were Tambourgi E.B. and Silveira E., both from the Campinas State University, and Silvestre M.P.C. and Carreira R.L., both from the Federal University of Minas Gerais. This shows that despite the high collaboration observed, the Brazilian scientific production in this field is concentrated among national authors, since Brazil has low international collaboration.

3.6 Institutions

A total of 158 institutions published articles on the use of agroindustrial residues of pineapple, of which 57 (36.1 %) had only one publication. Table 4 lists the ten most productive organizations.

Table 4: Contribution of institutions

#	Institution	Country	Publications
1	Universiti Teknologi Malaysia	Malaysia	19
2	Universidade Estadual de Campinas	Brazil	14
3	Universidade de São Paulo – USP	Brazil	12
4	South China University of Technology	China	10
5	Kasetsart University	Thailand	9
6	Universidade Federal de Minas Gerais	Brazil	9
7	Central Food Technological Research Institute Índia	India	8
8	Victoria University Melbourne	Australia	7
9	Universiti Putra Malaysia	Malaysia	7
10	Universiti Sains Malaysia	Malaysia	6

From Table 4 it can be seen that Malaysia has three of the ten most productive institutions, including Universiti Teknologi Malaysia, which has the largest number of publications. India, although the most productive country, has only one institution (Central Food Technological Research Institute India), indicating a probable production distributed in that country.

Brazil also has three of the ten most productive institutions. The Campinas State University presents greater national production, followed by the University of São Paulo and the Federal University of Minas Gerais. As the second most productive country (section 3.4) and with more than thirty productive organizations, it is concluded that the rest of the Brazilian production is well distributed among the other institutions.

3.7 Keywords

In order to understand a subject during a specific period, it is possible to use keywords which can provide important information. In this sense, the present work extracted 1,061 keywords defined by the authors of the articles, some of them being similar. The most frequently adopted are listed in Table 5.

Table 5: Frequently used keywords

#	Keywords	Frequency
1	Bromelain	33
2	Pineapple	32
3	Pineapple waste	27
4	Pineapple peel	16
5	Fermentation	16
6	Adsorption	12
7	Enzimatic hidrolysis	9
8	Aspergilus niger	8
9	Bioethanol	8
10	Ananas comosus	8

From Table 5 it is concluded that the most used keywords are related to the words bromelain, pineapple and fermentation.

As mentioned in section 3.1, studies on the utilization of agroindustrial pineapple residues can be divided into periods according to annual publications. Thus, the keywords were identified in two periods (1967-2007 and 2008-2017) in order to verify the main research themes. Figures 4 and 5 show the most used keywords and their respective networks during the years 1967-2007 (165 words) and 2008-2017 (947 words), respectively.

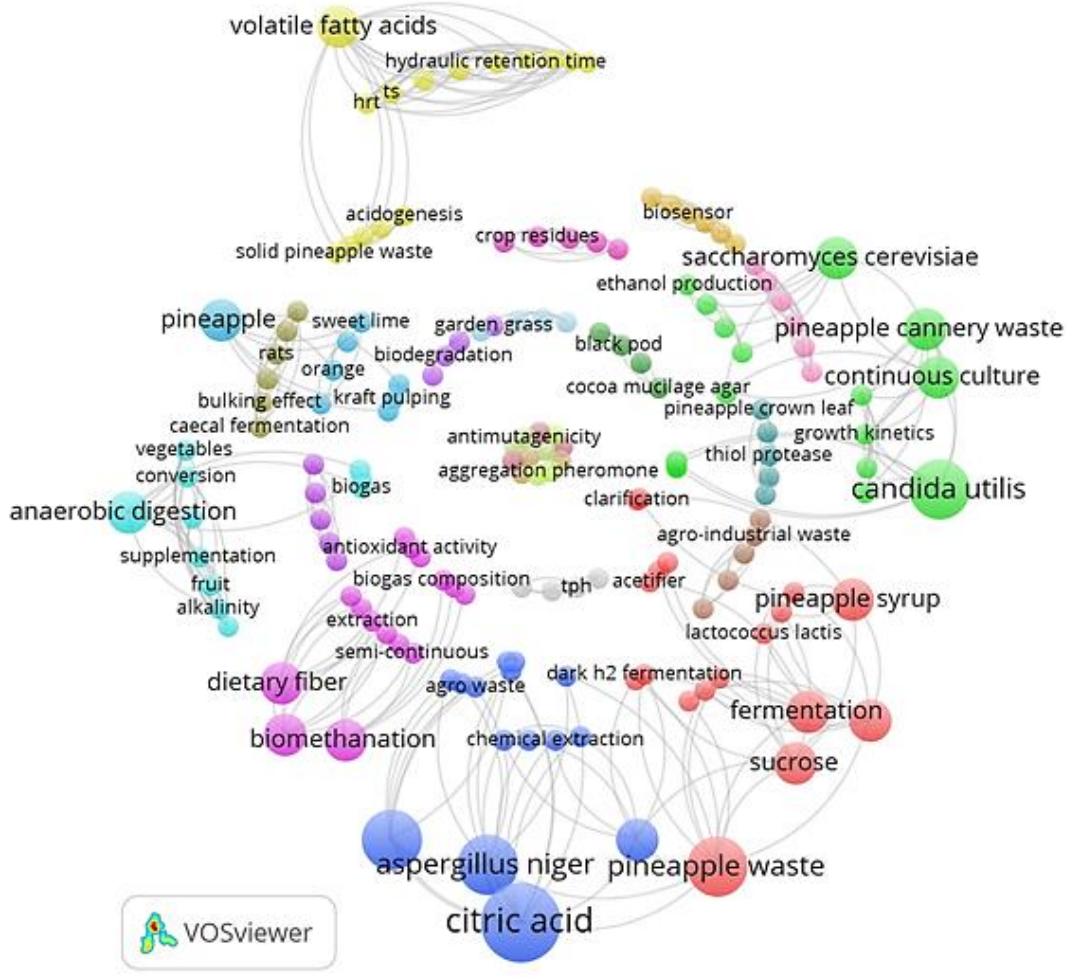

Figure 4: Keywords frequently used in the period 1967-2007

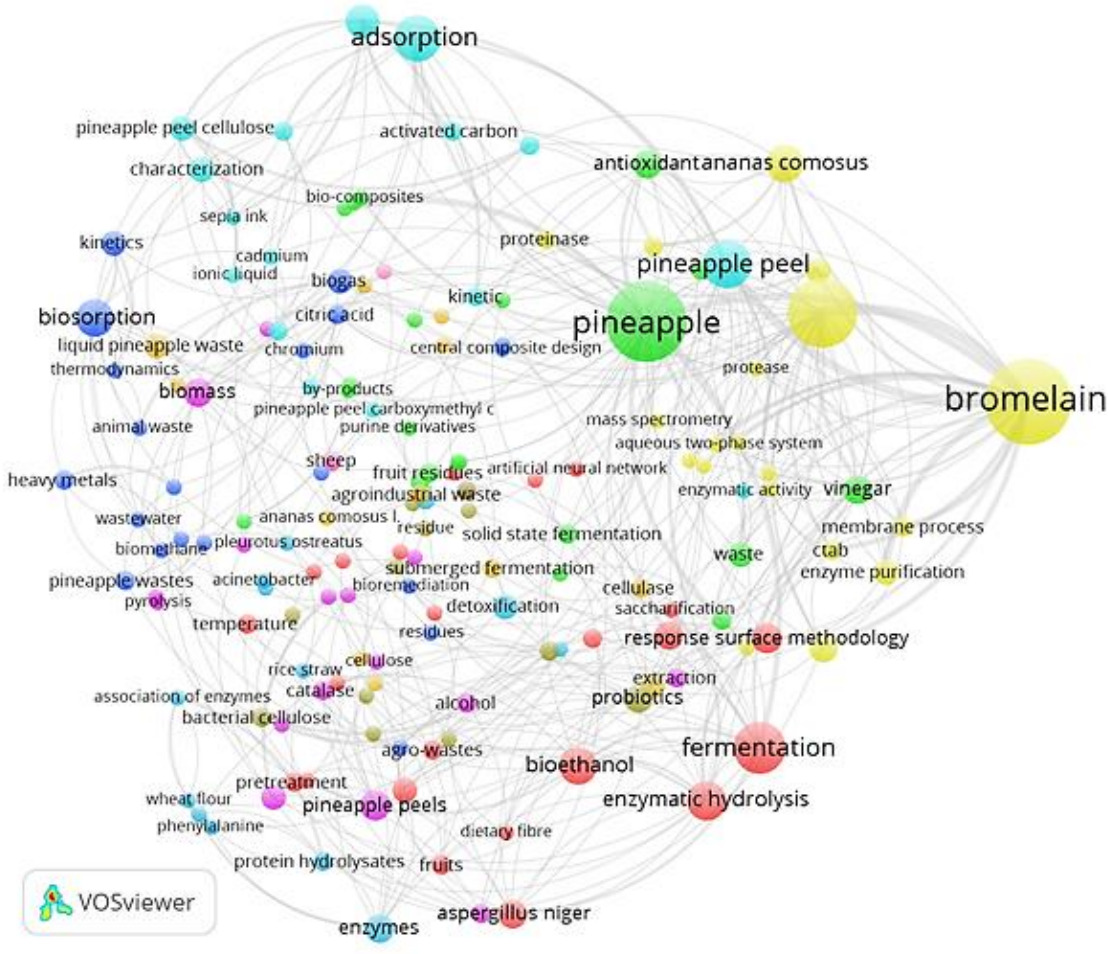

Figure 5: Keywords frequently used in the period 2008-2017

There are circles, in Figures 4 and 5, whose sizes serve to demonstrate the use of the keyword, i.e. the larger the circle size the more often the keyword was used. The lines are used to indicate the number of times that two keywords were used together. From Figure 4, it is concluded that during the first stage (1967-2007), the researchers focused mainly on the contents of pineapple residue, citric acid production and fermenting microorganisms, such as *Candida utilis* (Hennenberg) Lodder & Kreger, *Aspergillus niger* van Tieghem and *Saccharomyces cerevisiae* Meyen ex E.C. Hansen. In the second stage (2008-2017), the topic of residues of pineapple and fermentation remained. In addition, new topics related to bromelain and substance adsorption have become a frequent target of recent research.

In this study, the keywords most frequently used by the authors of the articles, without the use of synonym grouping, were presented, so that the keywords "*Ananas comosus*" and "pineapple" are presented as distinct terms in Figure 5. Nevertheless, these words are related and arranged nearby and connected through the lines by the software.

3.8 Subject Type

The use of agroindustrial residue of pineapple has strong economic appeal, having seen the amount of applications. When conducting an analysis of the summary of the 364 articles selected, it was verified that certain subjects were presented with more frequency. The five main themes studied in the research on the use of agroindustrial residues of pineapples were responsible for accounting for more than half of the publications (204 articles or 56.04 %).

Among the most studied (56.04 %), the highest use of the residue as a protein supplement (14.56 %), source of enzymes (11.54 %), biofuel (10.44 %), bromelain (10.16 %) and use as adsorbent (9.34 %). Other applications involve the production of acids, antioxidant phenols and vinegar / wine.

Protein supplement

The use of agroindustrial residues of pineapple as a supplement usually involves the use of microorganisms for protein enrichment. For example, Mensah and Twumasi (2017) used pineapple residues as a substrate for production of Single Cell Protein (SCP) with yeast *Saccharomyces cerevisiae* as inoculum. According to its results, it was concluded that residues from the food processing industry serve as good substrates for SCP production, which presents high benefit. In this way, protein-rich foods for animals and humans can be produced.

According to Damasceno et al. (2016), the pineapple peel flour is high in fiber and can be introduced into cereal bars as food. In their work, they evaluated the use of this flour in different concentrations in cereal bars, concluding that this material is a good alternative to be introduced in the human diet while minimalizing the environmental impact.

Other work on supplements involves the use of pineapple residues as cattle silage (Yang et al., 2016; Braga et al., 2016), piglet feeding (Ramos et al., 2016) and forage for dairy cows (Kraiprom et al., 2013), presenting an alternative food in periods of scarcity or as food of low cost.

Enzymes

In recent work, Selvakumar and Sivashanmugam (2017) produced lipase from pineapple skin. According to the authors, these enzymes are important because they can be used in the hydrolysis of the acylglycerols present in fatty acids and glycerol. They also investigated its use in the conversion of palm oil into biodiesel, obtaining yield 88.63 %.

Arun and Sivashanmugam (2015) produced different types of enzymes from pre-consumed pineapple residues. These enzymes were used in the treatment of activated sludge, solubilizing insoluble organic compounds in soluble compounds, which can later be treated to produce methane or hydrogen.

Silvestre et al. (2012) performed the extraction of protease from pineapple peels. When evaluating the stability, they verified the maintenance of the initial activity in 60.9 % and 53.7 % for the different pH and temperature conditions, respectively.

Other studies involved, for example, the production of amylase (Orlandelli et al., 2017), xylanase (Harris & Chidambaram, 2015) and cellulase (Kannahi & Elangeswari, 2015).

Biofuel

Shamsul et al. (2017) performed the production of biomethane and biometanol in batch bioreactor using pineapple peels as one of the substrates. They verified ideal temperature, concentration and retention times for production, obtaining 2.49 % methanol with 74.24 % methane.

Ogunleye et al. (2016) used pineapple residues in mixture with animal waste for the production of biomethane. They used 1.5 l anaerobic digesters and incubated for 10 weeks. When using the pineapple residues, they obtained increased yield and shorter start-up time for the generation of biomethane.

Other studies have involved biomethanization of pineapple peels (Aworanti et al., 2017) and bioethanol production (Conesa et al., 2016; Venkateswarulu et al., 2015), contributing as a biotechnological alternative to the use of fossil fuels.

Bromelain

Bromelain is a group of proteolytic enzymes found in pineapple tissues. Due to its high activity, it can potentially be used in the cosmetic, pharmaceutical and food industries (Spir et al., 2015).

Chaurasiya et al. (2015) used reverse micelle extraction (RME) for the separation and purification of bromelain from the pineapple nucleus. This bromelain was used in beef softening and compared to commercial bromelain. The results indicated a high recovery of activity (85 %) and a greater reduction of tenacity (52.1 %) compared to commercial bromelain (26.7 %).

Work on the separation, extraction and purification of bromelain from pineapple residues were carried out, for example, by Coêlho et al. (2015), Martins et al. (2014) and Novaes et al. (2013).

Adsorption/Absorption

Solidum (2013) evaluated the ability to remove heavy metals from water by pineapple peels. They analyzed the kinetic parameters of the removal of lead and cadmium in contaminated waters, varying pH, contact time and metal concentration. According to the authors, the use of these residues in the absorption of the metals presents considerable profitability.

Shifera et al. (2017) conducted studies on the removal of lead (II) and chromium (VI) present in water. They concluded that the adsorption on pineapple peels is viable, besides being spontaneous and exothermic.

Gandhi et al. (2012) analyzed the removal of fluoride from water from pineapple peel powder. The results showed that the use of residues as adsorbents are a viable alternative, because they have significant removal capacity and low cost.

Other examples include adsorption of methylene blue (Yamuna & Kamaraj, 2016), nickel (Dotto et al., 2016; Rao & Khan, 2017) and copper (Romero-Cano et al., 2017).

Other applications

Other applications involve the production of different compounds, such as: antioxidant phenols (Nor Halaliza & Zulkifly, 2017; Alias & Abbas, 2017), acids (Tang et al., 2014; Lun et al., 2014), wine/vinegar (Roda et al., 2017; Praveena & Estherlydia, 2014), bacterial cellulose.(Kumbhar et al., 2015), acetone-butanol-ethanol (ABE) using *Clostridium acetobutylicum* McCoy et al. Emend. Keis et al.(Khedkar et al., 2017), hydrogel (Dai & Huang, 2016), phenolic antioxidants using *Rhizopus oligosporus* Saito(Correia et al., 2004), yellowish orange pigment from *Chryseobacterium artocarpi* Venil et al. 2014(Aruldass et al., 2016).

3.9 Citation analysis

Citation analysis is a widely used method for assessing the academic performance of a researcher. When one article is quoted by another, it means that the search results of that article can provide useful information for others, the relevance of which is proportional to the number of quotes.

The simplest way in citation analysis is to count the number of citations received by a document. However, authors can cite their own articles, or some citations can be negative. Thus, total citations do not always indicate the true value of an article (Geng et al., 2017).

Thus, the citation analysis was based on the average number of citations per year after publication (TC/Y), since recently published articles are less likely to be cited. Table 6 shows the top ten articles based on this indicator.

Table 6: Most cited articles by year of publication

#	Author[a]	Periodic	TC/Y[b]	TC[c]
1	Hameed (2009)	Journal of Hazardous Materials	17.3	156
2	De Oliveira (2009)	Food Chemistry	13.4	121
3	Castro (2011)	Carbohydrate Polimers	13.1	92
4	Bansal (2012)	Waste Management	13.0	78
5	Foo (2012)	Microporous and Mesoporous Materials	9.7	58
6	Imandi (2008)	Bioresource Technology	9.4	94
7	Idris (2006)	Process Biochemistry	8.6	103
8	Umesh hebbar (2008)	Bioresource Technology	8.0	80
9	Nanda (2016)	Energy Conversion and Management	8.0	16
10	Mahamad (2015)	International Biodeterioration and Biodegradation	7.3	22

[a] Data referring to the first author.
[b] Annual average citations.
[c] Total citations.

In total, 94 articles (25.8 %) were not cited. Table 6 shows that the work done by Hameed et al. (2009) has a great popularity, being also the one with the highest TC/Y index. Soon this is the most credible study to be quoted. His research explored the use of the waste as a low cost adsorbent of methylene blue aqueous solution, studying adsorption kinetics and isotherms.

Also noteworthy for the studies carried out by Nanda et al. (2016), on supercritical water gasification of pineapple bark for bio-gas production, and by Mahamad et al. (2015), on dye worship, which, although recent and with few quotations, present a high TC/Y value.

4 CONCLUSIONS

Based on the data extracted from the Scopus database, this paper investigated the development characteristics of publications (from 1967 to 2017) on the use of agroindustrial residues of pineapples, using bibliometrics analysis. The studies that contributed to this research theme involve 21 different academic areas, being 40.1 % in the area of agriculture and biological sciences, 23.1 % biochemistry and genetics and 22.0 % in chemical engineering.

Although there have been publications on the subject in the last 40 years, 82 % of these publications have been published in the last decade, which shows a growing trend of research in this area in the last years. The growth can possibly be attributed to the growing environmental concern and high costs of agroindustrial waste disposal.

India, Brazil and Malaysia collaborate weakly with other countries despite producing large number of publications. The United States is the leader in international collaboration. However, Brazil has three of the ten most productive institutions, with Campinas State University being nationally the most prominent. Universiti Teknologi Malaysia is the most productive institution.

Finding ways to reuse waste brings benefit not only to the environment but also to industries. During this work, several studies on the reuse of pineapple residues were found, such as: protein supplement, source of enzymes, biofuel, bromelain, use of adsorbent and production of acids, antioxidant phenols, vinegar and wine. Thus, this study provides a framework and serve as a base for future studies into the identification of influential authors, journals, works, institutions and subjects in the field of agroindustrial residues of pineapple helping new researches and interactions in this area.

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