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APPLICATIONS AND PERSPECTIVES FOR THE USE OF FIBERS VIA MACHINE LEARNING ASSISTED DATA *MINING - part II*

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Abstract: The use of vegetable fibers in place of synthetic fibers has been valued due to the wide applicability of these materials in the automotive, textile, packaging and construction industries This is due to the fact that they have properties such as: biodegradation, less abrasive, low density and excellent thermal, mechanical and acoustic properties. Thus, this document discusses the use of plant fibers as additives in polymeric matrices from a prospective analysis, via data mining, specific on the use of nanoparticles as additives in plant fibers and their characterizations and applications in the last 10 years (2011 to 2021) based on 3,000 articles made available in the SCOPUS and SCIENCE DIRECT databases. For this, an artificial intelligence algorithm, based on *machine learning, implemented in* the *Vosviewer software was used*. With it, it was observed the advance of the use of fibers of synthetic and vegetable origin, in recent years, focused on the field of health.

Keywords: Modification of plant fibers. Machine learning. Nanoscale modification. Data mining. Artificial intelligence.

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1. INTRODUCTION

Due to the costs of producing synthetic fibers, related to reagents and their disposal in nature, studies on the use and application of natural fibers have grown in recent years[6].
Coconut fibers[2], coffee[6] and sisal[4,5], among others, are used for various applications, due to their natural characteristics such as: thermal, mechanical resistance, low cost and density, besides the fact that they are biodegradable. With the studies of these fibers, some deficiencies related to the nature of these materials were observed as loss of their properties by contact with water and by low chemical support with polymeric matrices[4,5,6]. These deficiencies stimulated scientists to improve the biochemical and physicochemical characteristics of these materials. Currently, such fibers can undergo varied modifications in order to ensure new properties to the material. An example for example is the surface modification of these fibers with nanoparticles, potentiating or adding new properties to these materials[3].
The natural fiber market has expanded in recent years to $121.42 billion in 2017, with a trend of reaching $398.00 billion in 2026[1]. Based on this information, a bibliometric survey was carried out based on 3,000 articles associated with plant fibers and nanoparticles, specifically taken from a collection totaling 25,000 articles associated with fibers and nanoparticles.

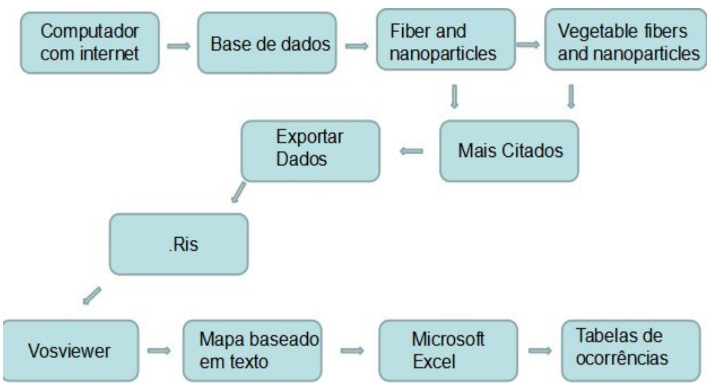
2. MATERIALS AND EQUIPMENT

Computer with internet access, access to *Science Direct and Scopus databases*, via intranet UFRJ / CAFe, Vosviewer Software and Microsoft Excel for table preparation.

1. METHODOLOGY FOR DATA MINING

The articles used were obtained from the Science Direct and Scopus database, following the same methodology performed in part 1 of this article. In this work, the keywords "vegetable fibers and nanoparticles" were used in both databases in order to obtain the maximum number of articles (3,000) related to keywords in the period 2011 to 2021. Thus, it is possible to observe the development of the theme (plant fibers and nanoparticles) more specifically in the last 10 years and thus, to conduct a comparative and prospective study, via data mining, on this theme in addition to performing future projections.

Figure 1 - Steps for data mining.



Source: Prepared by the author.

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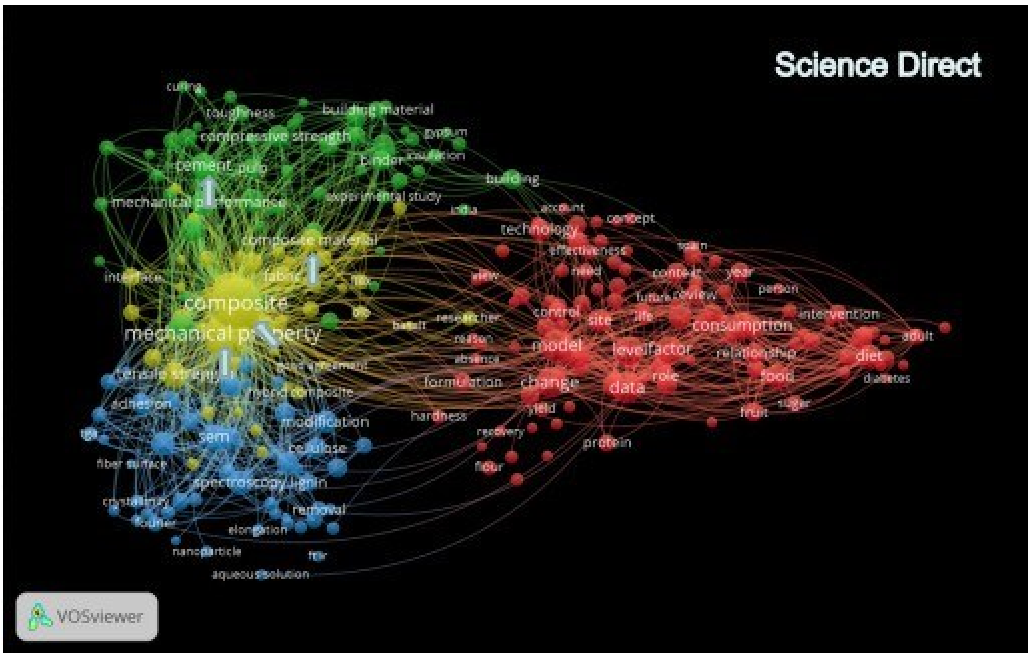
4. RESULTS AND DISCUSSION

Data from 3,000 articles related to "plant fibers and nanoparticles" were accessed. All data (spreadsheets, figures and articles) for this work were organized into folders for further studies. These are available on the google *drive platform*, whose link is found in the bibliographic references.

Figure 2 - Occurrences and links between keywords (vegetable fibers) per cluster between 2011 and 2021.



Source: Prepared by the author.

Figure 2 shows the bibliometric network based on the keyword "vegetable fibers", in the Science Direct database, from 2011 to 2021. A greater interaction was observed between the yellow, blue and green clusters in relation to the red clusters that can be proven from Table 1. The main "nodes" with greater proximity highlight were: "composite x reinforcement", "mechanical property x reinforcement", "mechanical property x model" and "model x data".

Table 1 - Euclidean distance in pixels between the main "nodes" in the period 2011 - 2021 only by the Science Direct database.

Nodes	Composite	Mechanical property	Reinforcement	Model	Data	Cluster
Composite		5701	484	10561	13098	Yellow
Mechanical property			5989	4874	7403	Yellow
Reinforcement				10825	13392	Yellow
Model					2711	Red

Source: Prepared by the author.

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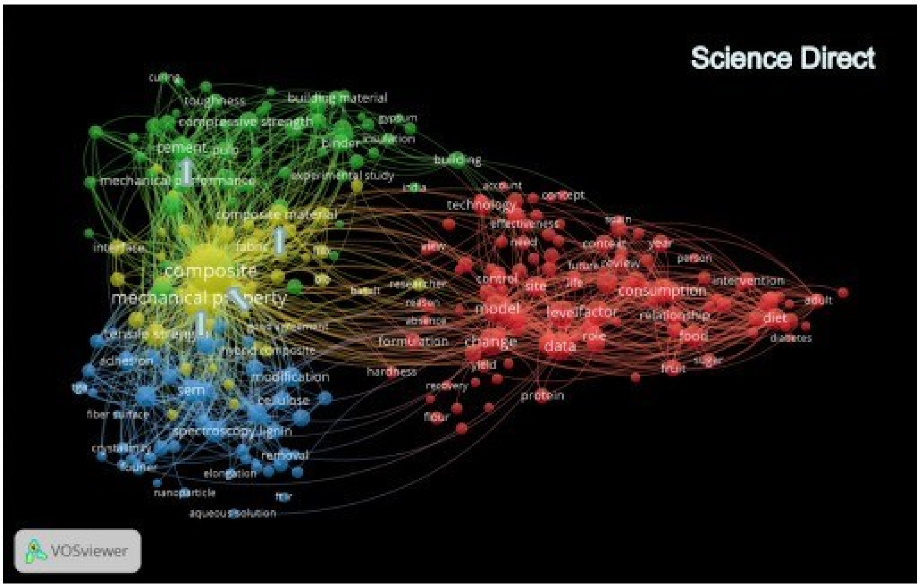
Figure 3 - Most recent occurrences and links between keywords (vegetable fibers) per cluster between 2011 and 2021.



Source: Prepared by the author.

Figure 3 shows the bibliometric network by temporal mean (overlay) showing the most recent words in the period from 2011 to 2021 in the Science Direct database, indicating a trend towards materials applied in the construction industry.

Figure 4 - Occurrences and links between keywords (vegetable fibers) per cluster between 2011 and 2021.
Source: Prepared by the author.

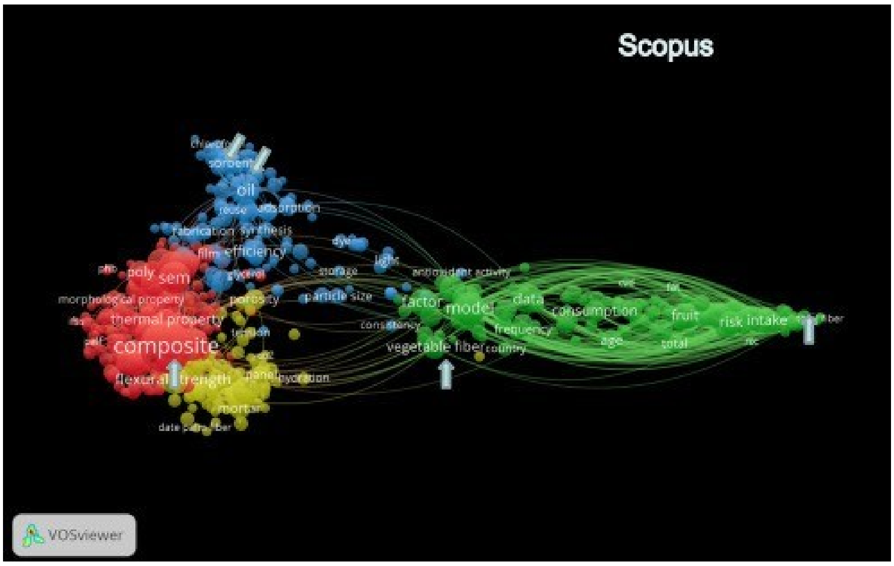


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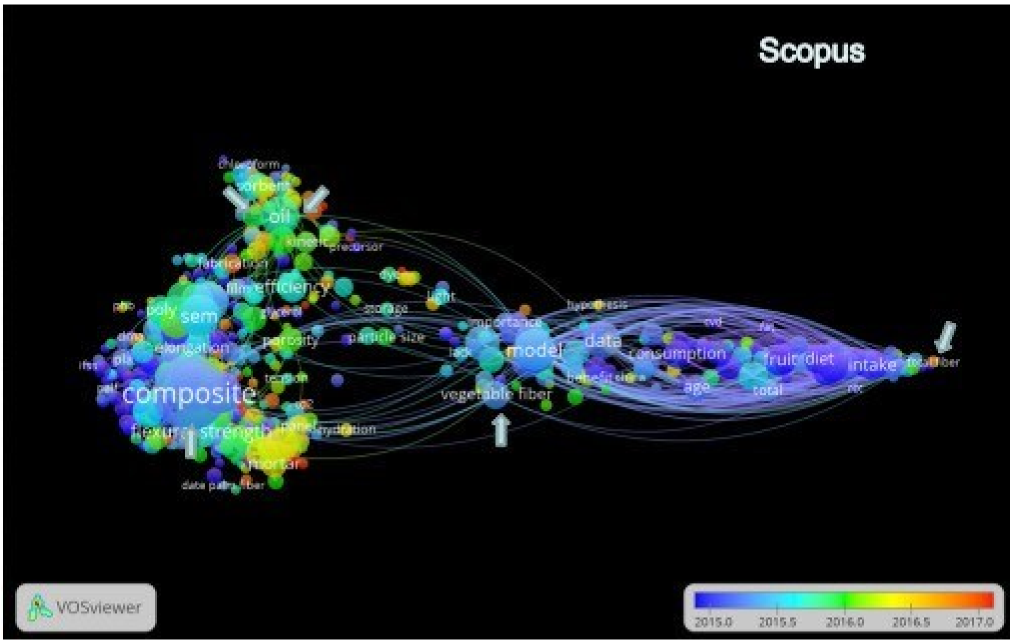
Figure 4 shows the bibliometric network obtained from the keyword "vegetable fibers" in the Scopus database from 2011 to 2021. It was possible to observe that the search for composite materials, their characterizations associated with thermal, morphological and SEM properties were stimulated mainly for the formation of absorbent materials with strong interaction with oil. Table 2 shows the Euclidean distance between the main "nodes" in this period studied, based on the Scopus database.

Table 2 - Euclidean distance in pixels between the main "nodes" in the period 2011 - 2021 only by the Scopus database.

Nodes	Composite	Tensile trength	Modulus	Model	Without	Cluster
Composite		1402	1759	12354	2768	Red
Tensile Strength			962	12128	1368	Red
Modulus				11166	1551	Red
Model					11960	Green

Source: Prepared by the author.

Figure 5 - Most recent occurrences and links between keywords (vegetable fibers) per cluster between 2011 and 2021.



Source: Prepared by the author.

Figure 5 shows the bibliometric network by temporal mean (overlay) obtained from the keyword "vegetable fibers" in the SCOPUS database. It was observed that the use of fibers for the formation of oil-absorbing composite materials was something widespread and possibly is in a new stage, the manufacturing.

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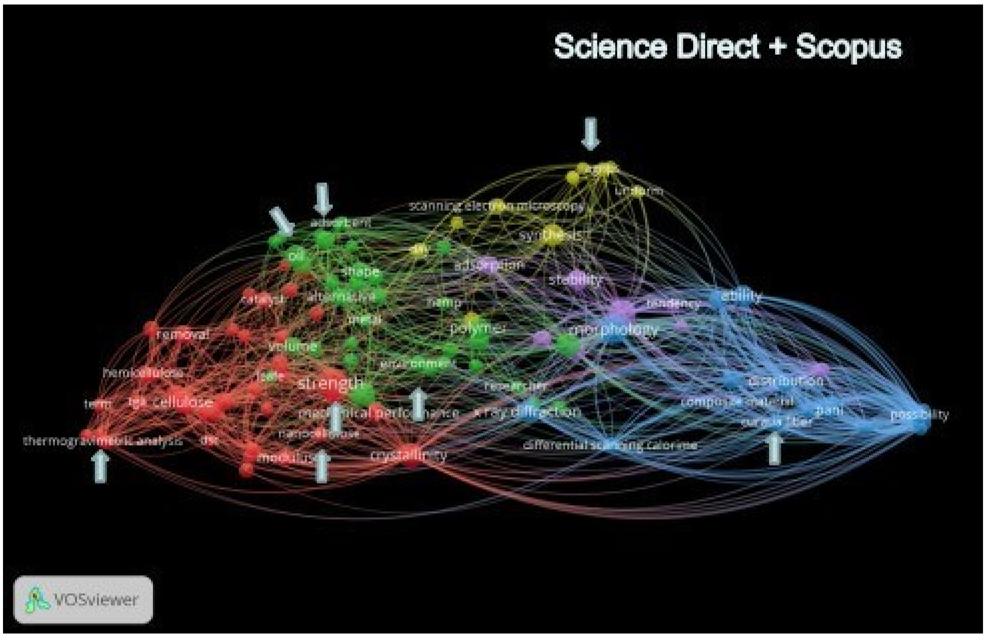
Figure 6 - Occurrences and links between keywords (vegetable fibers and nanoparticles) per cluster between 2011 and 2021.



Source: Prepared by the author.

Figure 6 shows the bibliometric network obtained from the keywords "vegetable fibers" and "nanoparticles" in both the SCOPUS and SCIENCE DIRECT databases. It was noticed good interaction between clusters, in addition to fibers used, some properties and formation of absorbent materials associated with oil. Table 3 shows that, in general, the highlighted terms do not present great interaction, indicating a higher level of dissimilarity between them.

Table 3 - Euclidean distance in pixels between the main "nodes" in the period 2011 - 2021 with the union of the Scopus and Science Direct databases.

Nodes	Strength	Morphology	Size	Crystallinity	Development	Cluster
Strength		10334	10723	3859	1204	Red
Morphology			669	8614	9332	Blue
Size				9172	9758	Purple
Crystallinity					2776	Red

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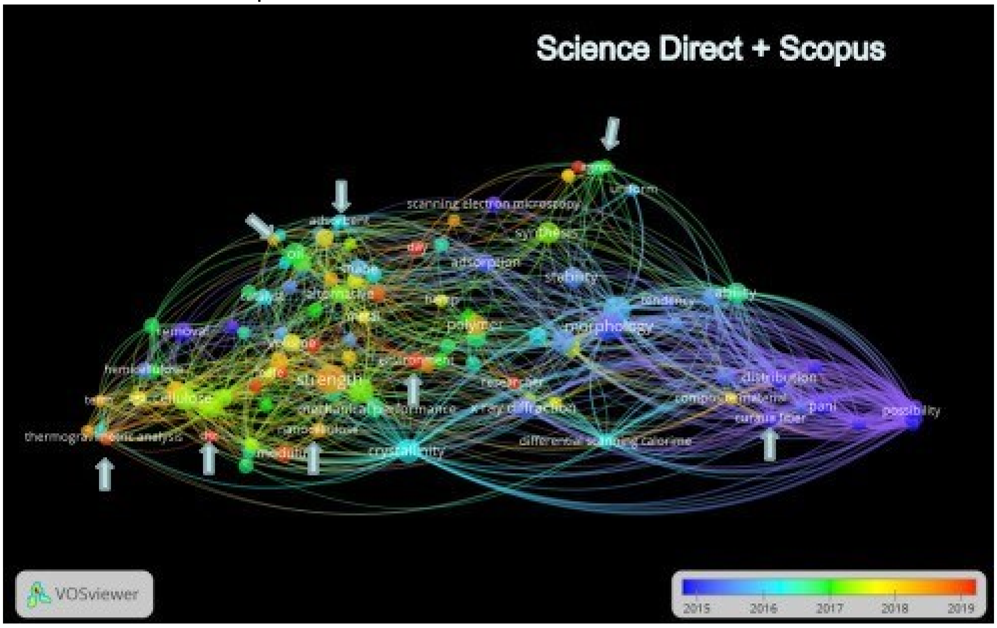
Figure 7 - Most recent occurrences and links between keywords (vegetable fibers and nanoparticles) per cluster between 2011 and 2021.



Source: Prepared by the author.

Figure 7 shows the bibliometric network by temporal mean (overlay) based on the keywords "vegetable fibers" and "nanoparticles", from 2011 to 2021. On average, the study on curauá fibers is well disseminated, but some characterizations of these fibers have been stimulated in recent years, such as thermogravimetric analysis and CSD. In relation to applications, the use for oil absorbing materials remained on average (2017) in this period of time. For better elucidation, tables 4 and 5 were created to show the most current and most frequent "nodes" respectively.

Table 4 - Survey of the 5 most recent words, in the Scopus and Science Direct database, from 2011 to 2021.

Database Scopus	Annual average	Database Science Direct	Annual average
figure	2018,2	**construction industry**	2019,1
water contact angle	2017,7	**metakaolin**	2019
kg m3	2017,5	**ductility**	2018,7
reuse	2017,5	**plaster**	2018,6
particleboard	2017,4	**end**	2018,5

Source: Prepared by the author.

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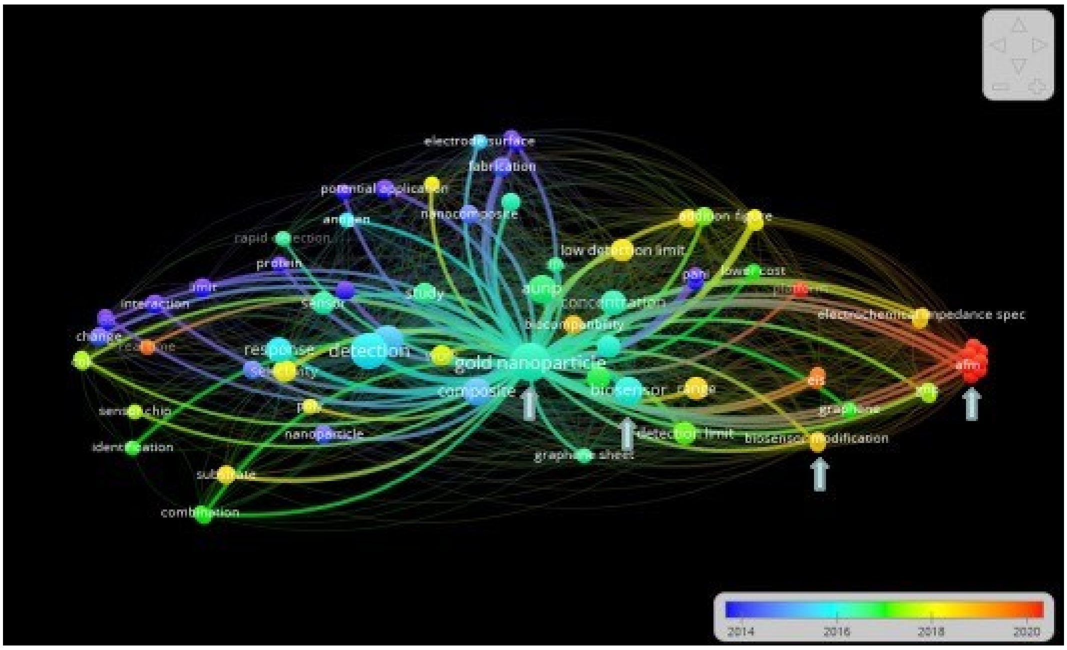
Table 5 - Data collection of the 5 words with the highest number of occurrences between 2011 and 2021.

Fiber and nanoparticles	Occurrences	Vegetable fibers and nanoparticles	Occurrences
gold nanoparticle + aunp	8407	**composite**	254
detection	2601	**mechanical property**	183
composite	1814	**reinforcement**	114
cell	1769	**model**	106
sensor	1561	**data**	100

Source: Prepared by the author.

In order to understand the future perspectives on the theme "fiber and nanoparticles" and "vegetable fibers and nanoparticles", the words with the highest number of occurrences were selected from 2011 to 2021, as shown in Table 5. With this information, keeping the keywords as to the theme in their respective way and indicating the most frequent nanoparticles (gold nanoparticles and nanocellulose) also respectively, another data mining of more specific character was performed. Figures 8 and 9 show the bibliometric networks by temporal mean found.

Figure 8 - Perspectives on the use of fibers and nanoparticles.



Source: Prepared by the author.

Regarding gold nanoparticles, large interactions with other "nodes" can be observed, highlighted by biosensors, biocompatibility and modified sensors, in addition to a great tendency of atomic force characterization (afm).

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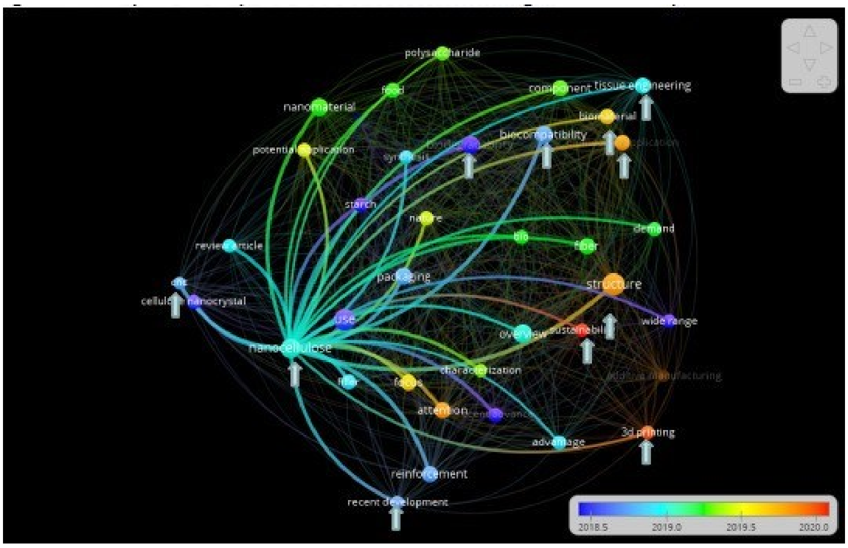
Figure 9 - Perspectives on the use of plant fibers and nanoparticles.



Source: Prepared by the author.

Figure 9 shows the interactions between the highest-occurring nanoparticle (nanocellulose) with other "nodes". It is possible to infer that the use of nanocellulose for tissue engineering was stimulated in the period of 2019, as well as its association with newer words *such as biomaterial, sustainble* and *3d printing*. Indicating a tendency of this nanoparticle to such applications. Thus, a new data mining was made associating, in the same databases, nanocellulose with the most recent theme according to the temporal mean, 3D printing (*3D printing*).

Figure 10 - Perspectives associated with nanocellulose and 3D printing.

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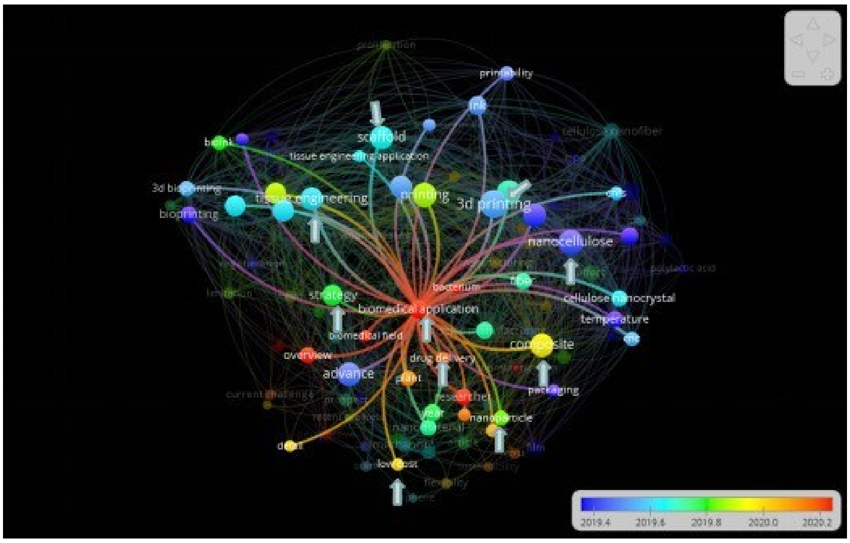

Source: Prepared by the author.

Figure 10 shows perspectives associated with nanocellulose and 3D printing, from a bibliometric network based on temporal mean. It is possible to infer that the use of nanoscale cellulose is a recent technology in some areas such as tissue engineering and 3D printing. Highlight for trend of the use of nanocellulose associated with 3D printing for biomedical applications. So this set of results demonstrates that the main trends in plant fiber modification are in biomedical applications, such as: tissue treatment, 3D printing and as a drug delivery system.

5. CONCLUSION

It was observed, according to a prospective analysis by data mining, that research related to fibers and nanoparticles has been very relevant in recent years. With regard to the use of fibers of plant origin and nanoparticles, the use of nanocellulose seems a viable tendency to form composites for cellular treatment purposes aimed at tissue regeneration. Finally, the use of fibers of plant origin associated with nanoparticle structures or isolated in nanoscale, are presented as a solution and tendency of application in various branches of science and industry.

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