THE BRAZILIAN INNOVATION SYSTEM IN LIGNOCELLULOSIC ETHANOL: 
collaborative networks as a measure of the development degree

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The Brazilian Innovation System in lignocellulosic ethanol: collaborative networks as a measure of the development degree

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Márcia Azanha Ferraz Dias de Moraes
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Abstract

Brazil is a larger producer of ethanol (first generation) from sugarcane and therefore have the knowledge, the soil and edaphic-climatic advantages as well, creating a comparative production to produce lignocellulosic ethanol (second-generation). In fact, the competitiveness to obtaining new sources of bioenergy could place the producers in an advantage position, because many capabilities that are used to producing first-generation ethanol could be a first step to produce the second one. Perhaps, Brazil has to compete among countries to achieve the leadership in second-generation innovation (technology development and diffusion). As an Innovation System, does Brazil have the innovative capabilities to take the leadership in production of second-generation ethanol? The evolutionary economic literature guides that there are some network gains between authors through a scientific collaboration. A couple of countries could be in a better position if they can exchange information and knowledge through a scientific collaboration network – the Collaborative Networks (CNs). The aim is to analyze the state-of-art of second-generation ethanol under the formation of CN using international papers database of ISI Web of Science focused on Brazilian relationship. The CNs reveal that Brazil has low international collaboration with focus in a few countries, mainly United States. The researches show that cumulative knowledge in first-generation ethanol is so high that it is difficult to detach lignocellulosic process on the network. Locally, the co-authorship have a focus on a single University. This paper concludes that Brazil must to make a sort of efforts (University-Government-Enterprise) to reach the leadership.

Keywords: ethanol; second-generation; lignocellulosic; networks; innovation

1. Introduction

The projected increase in demand for energy and the mitigation of the effects of climate change, depletion of stocks of carbon-intensive energy, among other factors, stress the need for the use of renewable bioenergy as an alternative to such requirements. The global market considers the lignocellulosic ethanol or "second-generation" ethanol obtained from the biomass converting process as a vital alternative to meeting this demand.

This paper has as a research question: As an Innovation System, does Brazil have the innovative capabilities to take the leadership in production of second-generation ethanol?
The production of ethanol is local-specific, i.e., it uses the raw material available in the installation site of the processing unit. The United States, the largest producer of conventional ethanol, seek mainly to use the straw and corncobs for the production of lignocellulosic ethanol. Brazil, second largest producer of conventional ethanol, aim to use straw and bagasse from disposable sugarcane i.e. not used to produce electricity by burning.

The main requirements for the production of second generation ethanol are: i) high dynamic producers seeking more efficiency and less costly production routes to be commercial feasible, ii) institutional environment that allows the use of bioenergy instead of more pollutants sources, and iii) technology available that is obtained through the research conducted by universities and research centers that culminates in scientific publication and further development and patenting agencies and companies.

The evolutionary economic literature guides that there are some network gains between authors through a scientific collaboration. In an Innovation System (IS) perspective of triple-force - University-Government-Enterprise, the network analysis to scientific international collaboration can deal with one of the triple – University (also public and private institutes of research).

The scientific production belonging the requirements to lignocellulosic ethanol production assume great prominence by allowing greater or lesser interaction between the actors described the triple and so are part of the success or failure of the IS.

The theoretical and methodological approach are structured on the evolutionary concepts underlying the formation of knowledge networks. There is robust evidence showing the scientific collaboration - co-authored publications - and citations - authors that reference other authors in their publications - are positively correlated with the diffusion of scientific knowledge (Wagner and Leydersdorff, 2005).

This article proposes the use of network indicators created from the international scientific publications (ISI Web of Science) and therefore allow to inferring the degree of development of one side of the Brazilian Innovation System (University side) based on the existing relations among authors direct and indirect evolved to second-generation ethanol research. To Brazilian case, at least one of co-authorship must be within a Brazilian researcher.

The next section describes briefly the Innovations Systems literature. The third section reviews the state-of-art in lignocellulosic ethanol. The fourth section shows the methodology of this paper, followed by a
results and discussion in fifth section, covering views on Brazilian collaborative networks by countries, institutions, Keyword Plus and citations. The final section draws conclusions and highlights implications for policy and energy research.

2. **Innovation Systems (ISs)**

The approach of Innovation Systems has emerged in the 80's, with their diffusion in England, Denmark and other countries. This theoretical perspective allows a better understanding of how occur the processes of acquisition, use and dissemination of knowledge as well as how productive and innovative capabilities are developed and generated (Lastres, Cassiolato and Arroio, 2005).

Once the innovation process is cumulative, it means, depends on endogenous capacities and tacit knowledge, the innovative capacity of a country or region stems from the relationship between economic, political and social agents.

The IS approach is broader than those addressing industrial districts or clusters, leading to the question of development of focused innovation (industrial and technological development) policies, and this should consider the locational specifics that are inherent in the development process economies (Lastres, Cassiolato and Arroio, 2005).

By learning means the process by which repetition and experimentation enable tasks to be performed better and quickly, and improve the company's ability to identify new opportunities. For innovation means the processes that firms use to introduce and spread new products and processes (Dal Poz, 2006).


Each of described literature that permeate IS have such specific sights, but, they agree of the importance of an interaction of the triple force – University-Government-Enterprise – as a role of the development of a knowledge based economy.
This paper uses a general concept of IS to focus in to University as an important force to determine the success of knowledge-based economy, specifically to bioenergy sector (second-generation ethanol production).

In the next section it shall be discussed the state-of-art of second-generation ethanol that emerges from the discussion of obtaining bioenergy from lignocellulosic materials.

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carlsson &amp; Stankiewicz (1991)</td>
<td>Define the technological system as &quot;a network of agents interacting around a specific technology area under a particular institutional infrastructure specifically for the purpose of generation, dissemination and use of technology&quot;. Consists of the following components: actors (and their skills), can be firms, users, suppliers, or speculative capital, or other organizations, networks that are important channels for the transfer of both tacit and explicit knowledge capital, and institutions that stipulate the norms and rules regulating interactions between actors and the values several basic segments of society.</td>
</tr>
<tr>
<td>Freeman (1995); Freeman &amp; Söete (2008)</td>
<td>Sets the IS as a network of public and private institutions that interact in order to disseminate new technologies. They note the existence of a network of public and private institutions that interact in order to disseminate new technologies.</td>
</tr>
<tr>
<td>Foray &amp; Lundvall (1996)</td>
<td>Highlight two perspectives on what they consider as knowledge-based economy: one that identifies the sector that produces new knowledge or distribute information and other considers the creation and diffusion of knowledge that occurs in routine activities in the economy (learning by doing, learning by using and learning--interacting).</td>
</tr>
<tr>
<td>Patel &amp; Pavitt (1998)</td>
<td>Define the IS in terms of the institutions involved in the generation, commercialization and diffusion of new and improved versions of products, processes and services (i.e., technological change) and the incentive structures and competences of these institutions influence the rate and direction of change. Specialization implies coordination or even integration, so that the most important are the connections in IS (networks) between the agents. The authors warn that ISs are under increasing strain, since there is an increasing imbalance between what science has to offer, and between the technological system demands.</td>
</tr>
<tr>
<td>Mytelka &amp; Farinelli (2000)</td>
<td>Under the approach of ISs resurgent interest in innovation, which does an iterative process characterize, i.e., ceases to be understood only as a process of radical change by major companies, emphasizing in this process, which businesses interact with each other under the actions of institutions and organizations such as industry associations, R&amp;D, technology parks, standardization and certification institutions, universities, and others.</td>
</tr>
<tr>
<td>Edquist (2001)</td>
<td>Considers that there is a need to develop an IS, for the production, diffusion and use of innovations supranational, national and subnational (regional, local) basis, and may acquire a sectorial nature within geographic boundaries. Organizations - firms and not firms - and institutions make up the Innovation System.</td>
</tr>
<tr>
<td>Malerba (2002)</td>
<td>Considers that the officials of IS, sectorial and local are organizations that develop from specific learnings, skills, goals, organizational structures and behaviors.</td>
</tr>
<tr>
<td>Etzkovitz &amp; Leydesdorff (2000)</td>
<td>Authors of Triple-Helix model, describe the innovation model based on the relationship - University-Government-Enterprise. To the author only through interaction between these actors is possible to create a sustainable and durable IS in the era of knowledge economy. Emerged from a theory to a model applied in several countries by encouraging the emergence of cores incubators, innovation centers, technology transfer offices, new laws and support mechanisms.</td>
</tr>
</tbody>
</table>

Tab. 1. Main theoretical approaches that permeate the discussion of Innovation Systems.
3. The state-of-art of second-generation ethanol

The process for obtaining ethanol from lignocellulosic comes from the use of lignocellulosic material found in plants and not used before for this purpose. This material can be divided into two major components - carbohydrate polymers such as cellulose and hemicellulose, and - lignin from plant cell wall (Lee, 1997).

Simplifying, the process consists in "break" the lignocellulosic plant material (which may be done physically or through chemical or enzymatic reactions) to obtain the cellulose. In this case sucrose is obtained and having one of the destinations the production of ethanol.

According to Lee (1997), Sun and Cheng (2002) and Rabelo (2010) for the conversion of lignocellulosic materials into other products there is need to perform the following four steps:

i) Begins with the production (and subsequent use in the enzymatic process) of enzymes from microorganisms such as fungi and bacteria. Represents about 50 % of the overall cost of obtaining sugars by enzymatic hydrolysis process;

ii) To a satisfactory result in the conversion of ethanol, there is a need for pretreatment of lignocellulosic material in order to increase the exposure of the pulp fibers, facilitating the action of acids or enzymatic hydrolytic agents;

iii) Conduct the process of breaking the lignocellulosic material, known as hydrolysis, where the delignification and de-polymerization occurs. This process converts the cellulose and hemicellulose in less complex sugars liable to fermentation, usually catalyzed by cellulosic enzymes for be constituted as a promising option in terms of overall cost and the ability to achieve yields of glucose near to the theoretical and possess modern techniques of microbiology and genetic engineering in order to optimize the process steps, and

iv) It ends with a fermentation process of the mixture sugars. The process of fermentation of glucose is already established in the industry with the use of the fungus \textit{Saccharomyces-Cerevisiae} through its intensive used in industrial fermentation, went through a process of natural selection, performing better in converting glucose to ethanol productivity and tolerance alcoholic. The fermentation of pentoses and hexoses are not established as the
previous procedure. Studies have been conducted to find better productivity through the use of yeasts and thermophilic and mesophilic bacteria.

The next section presents the methodological procedures adopted in this article.

4. Method

4.1 Network Analysis

Network analysis emerge from graph theory. A graph (or network) is composed of three basic elements:

i) Nodes - are people or groups of people who come together with a common goal. Visual representation in the units of analysis can be actors, elements, countries, research institutes, companies, friends, papers, etc.;

ii) Edges - indicate the interactions or links between two or more nodes, i.e., connecting two adjacent vertices. In a network with n players, one particular node can have \( n - 1 \) links; and

iii) Flux - indicates the direction of the bond that is with an arrow showing the direction and may be unidirectional, bidirectional or we lose. A network can be constructed from a symmetric relationship between the actors, that is, if falls just a way of information and not the back.

The following presents a hypothetical network (see Fig. 1).

![Fig. 1. Basic elements of a network of interactions.](image-url)
From the networks created with a specific objective, the indicators for the network are follow for further interpretation.

4.2 Network Measures

4.2.1 Average Geodesic Distance

The geodesic distance (or social distance) is an indicator of cohesion of the network. Defined as a minimum number of links (or edges) that separates two distinct actors in a network. That is, given the shortest path between two nodes, the length of this shortcut in number of intermediate links - geodesic distance (Dal Poz, 2006 and Souza, 2013).

The averaging of a geodesic distance undirected network:

$$d_G = \frac{2}{n(n-1)} \sum_{i \neq j}^{n} d_{ij}$$  \hspace{1cm} (1)

where: $i$ and $j$ are two vertices of the network, $n$ is the total number of actors in the network, and $d_{ij}$ is the geodesic distance between $i$ and $j$.

This indicator is used as an indicator of specificity, that is, the farthest two actors are, smaller is the connection between them. In networks with smaller distance between the actors will have greater cohesion, that is, greater the bond strength between the actors, and so quickly the information pass through.

4.2.2 Average Density

The density of the network indicator measures the relative amount of existing connections. Fits as an indicator of cohesion of the network. Networks are dense if there is high amount of links between actors and considered sparse if few links (Souza, 2013).
This indicator is the proportion of ties that occur in relation to all possible links. Allows you to analyze the intensity of relations between actors (weakness / strength) on a network. A fully connected network is called a click and has a specific gravity of 1. If the network has no links, is called empty and its density is zero (Vicente, 2012).

The density calculation from a network:

$$
\rho_G = \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} z_{ij}}{n(n-1)} \quad i \neq j
$$

where: $i$ and $j$ are two non-adjacent vertices, $n$ is the number of actors in the network, and $z_{ij}$ is a binary number and represents a flow between two actors, 0 for no relationship between $i$ and $j$, 1 otherwise.

4.2.3 Average Centrality Degree

The centrality measures assist in verifying the relative importance of a vertex in a network. In this case this indicator is specific and allows verification of the centrality of the actors (Dal Poz, 2006 and Souza, 2013).

The degree of centrality measures the number of actors to which an actor is directly linked. In this case, there is a decision procedure: connect or not an actor.

Thus, the degree of centrality can be analyzed as:

i) In-degree: the sum of the interactions that we have with the other actor (the sum of interactions array to specific column in the actor analysis);

ii) Out-degree: the sum of the interactions that the actor has with others (in the sum matrix interactions to specific line in the actor analysis); and

iii) Degree to a symmetric network: i.e., when the relationship between the different actors is reciprocal, the adjacency matrix is symmetric and therefore the degree of input is equal to output and represents the sum of interactions that actors have with others (the matrix of interactions adds to the row or column specific to the actor in question).
\[ C_{deg}(v) = \frac{\deg(v)}{n-1} \]  

Where: \( \deg(v) \) is the sum of the interactions that the actor \( v \) has with other actors or other actors have with \( v \), \( n \) is the number of actors in the network.

The following are the procedures for constructing the database.

### 4.3 Database

#### 4.3.1 Data Collection

To perform the search databases with greater international integration were adopted. For scientific publications was defined the use of only one database, multidisciplinary base reference, Web of Science, which is integrated to the ISI Web of Knowledge. This database has referential data summaries in all areas of knowledge.

Tab. 2 shows the key question (research parameter) used for searching the ISI WoS. The terms were written in radicals to capture variations in written words.

<table>
<thead>
<tr>
<th>Research Parameter</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>TS=(<em>ethan</em> OR <em>energ</em>) AND TS=(<em>sugar</em> OR <em>cane</em> OR bagas* OR straw* OR cogener*) AND TS=(<em>conversion</em> OR <em>lign</em> OR <em>cellul</em>) AND TS=(<em>hydrolys</em> OR <em>ferment</em> OR <em>enzym</em> OR fung* OR <em>bac</em> OR <em>pressur</em> OR steam* OR chem* OR sacch* OR microb* OR clostrid* OR thermocell* OR <em>spor</em> OR <em>cocc</em> OR erwinia* OR strept* OR sclerot* OR phaneroch* OR trichod* OR asperg* OR schizoph* OR <em>penicill</em> OR SCP OR “Single Cell” OR *xyl&quot;)</td>
<td></td>
</tr>
<tr>
<td>Databases=SCI-EXPANDED, SSCI, A&amp;HCI, CPCI-S, CPCI-SSH Timespan=All Years Lemmatization=On</td>
<td></td>
</tr>
</tbody>
</table>

Tab. 2. Research parameter for scientific publications in selected topics: keyword, title and abstract.  
Source: ISI Web of Science (2012).  
*6,053 papers until 24th october 2012.

#### 4.3.2 Data Procedure

To manipulate the data obtained during the extraction process of the information there is necessary to use a program that can translate data previously extracted in a format (example, format '.txt' with no quotes) and after enables analysis or even export data filtered.
The VantagePoint program allows to import the previously information obtained from the ISI WoS through filters developed by that company. After the importing data, there was a pre-cleaning that aims to extract information and even duplicate the grouping of terms that for some reason the original base was drafted wrong.

With the filtered files you can create subfiles from some criterion (e.g., country, keyword, etc.). In which this new file express only the relations that have this criteria. This is interesting from the moment that there is a general and new base can be generated up to the researcher without the need to return to the original database.

Next are presented the following procedures for the construction of collaborative networks.

4.3.3 Building Networks

For the construction of networks, it is necessary to create the adjacency matrices that express some relation, i.e., from important relationships, build networks analyzable.

For this procedure, three different programs were chosen:

i) Microsoft Excel 2013 - Data tabulation of The VantagePoint and exported to UCINET;

ii) UCINET - import of raster data, graph building, analysis of indicators for networks and nodes and visualization of relationships among key stakeholders; and

iii) Gephi - the graphs created in UCINET were exported in format ‘.net’ (with no quotes, through Pajek program) for import in Gephi. This program allows artistic visualization of networks. A gradual scale in green colored nodes, which is the most intense higher degree of centrality. The size of the node was normalized to the range between 1 and 50 for the maximum degree of centrality. For display was chosen the Fruchterman-Reingold algorithm as best represented the data. In cases where the attractive force creates an agglomeration of the most relevant nodes in the center of the graph, the algorithm was paused and pointed in the extremes of the figure (creating the mandala type figures). In the contrary case, the algorithm was efficient (creating figures of type lotus flower).
With these procedures, it was possible to express the following relationships in Collaborative Networks:

i) Relationship between countries - international collaboration networks (macro);

ii) Partnerships between institutions, i.e., universities, government and businesses - networks of international collaboration (micro);

iii) Relationship between KeyWord Plus - variable created by an algorithm of Thomson Reuters and allowing stress adjacencies between areas of knowledge formed from the second-generation ethanol, is interpreted as an indicator of the amount, or counter clockwise to Search, relating to the initial search but, as was realized again the selection of keywords, i.e., minimizing initial errors of judgment and revealing interesting quirks; and

iv) The co-occurrence networks of authors and publications that appear in the references, indicating that the most relevant authors are the most frequent.

To analyze the Brazilian case it was necessary to isolate the relationship among authors, to show only the papers where at least one author was a researcher from Brazil. The following are the main results from the proposed methodology.

5. Results and Discussion

Analyzing the scientific publications, there is a prominent position by The United States, almost 23% of total papers in second-generation and related areas, followed by China and Brazil (see Tab. 3). There is interesting scene, the range reveals that are countries that want mainly develop new technologies because they are not traditional producers of biofuels (ex. Japan).
Tab. 3. Scientific publications in second-generation ethanol by country (national and in collaboration).

<table>
<thead>
<tr>
<th>Country</th>
<th>Publications</th>
<th>(%) Total</th>
<th>National (%)</th>
<th>Collaboration (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>1,559</td>
<td>22.44</td>
<td>1,190</td>
<td>76.33</td>
</tr>
<tr>
<td>China</td>
<td>684</td>
<td>9.84</td>
<td>505</td>
<td>73.83</td>
</tr>
<tr>
<td>Brazil</td>
<td>347</td>
<td>4.99</td>
<td>257</td>
<td>74.06</td>
</tr>
<tr>
<td>Japan</td>
<td>332</td>
<td>4.78</td>
<td>249</td>
<td>75.00</td>
</tr>
<tr>
<td>India</td>
<td>299</td>
<td>4.30</td>
<td>250</td>
<td>83.61</td>
</tr>
<tr>
<td>Germany</td>
<td>290</td>
<td>4.17</td>
<td>169</td>
<td>58.28</td>
</tr>
<tr>
<td>Canada</td>
<td>275</td>
<td>3.96</td>
<td>178</td>
<td>64.73</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>244</td>
<td>3.51</td>
<td>133</td>
<td>54.51</td>
</tr>
<tr>
<td>Spain</td>
<td>240</td>
<td>3.45</td>
<td>169</td>
<td>70.42</td>
</tr>
<tr>
<td>Sweden</td>
<td>231</td>
<td>3.32</td>
<td>116</td>
<td>50.22</td>
</tr>
</tbody>
</table>


Figure 2 presents the Collaborative Network for countries based on Brazilian scientific publications. It appears that in terms of scientific collaboration, Brazil has United States as the country as major partner, because they share the majority of papers whose were made together (the width of each line that connect each node) and at same time the Unite States are the most popular in the network (the bigger name reflects high in-degree).

Tab. 4 shows the indicators of the Collaborative Network to countries based on scientific publications. The average centrality was 0.02538 (2.538%). This value is lower for the network but this case was expected because there is no information that all countries must have a relationship with each one, i.e. a star network. The network shows the central position of Brazil and all relationships acting at same time.

The average density measures the proportion of bonds that occur between countries in relation to all possible links. A fully connected network is called a click and has a specific gravity of 1. In this case, the density was found to be 0.102 that is low, as expected.
**Fig. 2.** Collaborative Network of Brazilian co-authorship through countries in lignocellulosic ethanol.

**Tab. 4.** Measure of Collaborative Network of Brazilian co-authorship through countries in second-generation ethanol.

<table>
<thead>
<tr>
<th>Index</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Centrality Degree</td>
<td>2.538</td>
</tr>
<tr>
<td>Average Density</td>
<td>0.102</td>
</tr>
<tr>
<td>Average Geodesic Distance</td>
<td>1.898</td>
</tr>
</tbody>
</table>
The average geodesic distance is shorter (around 2) because it is expected a small-world effect (it is necessary only a few steps to reach the world) in citations through countries.

Fig. 3 presents the Collaborative Network for the Brazilian relationship through institutions and enterprises based on scientific publications. It appears that in terms of scientific collaboration USP (University of São Paulo) has predominance (huge participation in the network) followed by the UNICAMP (University of Campinas) and UNESP (Univ Estadual Paulista). Actually, there is an integrated graduate program (USP-UNICAMP-UNESP) in Bioenergy to share experiences among them.

Fig. 3. Collaborative Network of Brazilian co-authorship through institutions in lignocellulosic ethanol.
This aspect of the network shows that how the Innovation System is dependent and so on the knowledge have a focus only one institution (USP). There is high probability that to each new paper (from ISI WoS) made by a single Brazilian researcher have a co-authorship shared with a researcher from USP (high preferential attachment).

Tab. 5 shows the indicators of the Collaborative Network for Brazilian institutions based on scientific publications. The average centrality was 0.04024 (4.024%). The value is low because for the network of publications is not expected that all institutions have relationship with all others, i.e., all being central, expected by literature.

**Tab. 5.** Measure of Collaborative Network of Brazilian co-authorship through institutions in second-generation ethanol.

<table>
<thead>
<tr>
<th>Index</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Centrality Degree</td>
<td>4.024</td>
</tr>
<tr>
<td>Average Density</td>
<td>0.024</td>
</tr>
<tr>
<td>Average Geodesic Distance</td>
<td>2.754</td>
</tr>
</tbody>
</table>

The average geodesic distance is shorter (around 3) because it is expected a small-world (it is necessary only a few steps to reach the world) effect in citations through institutions.

Fig. 4 presents the Collaborative Network for Key Words Plus based on Brazilian scientific publications. It appears that in terms of areas of research in second-generation ethanol there especially Fermentation, Ethanol and Ethanol Production. In the background are *Saccharomyces-Cerevisiae* (fungus) and Pretreatment. This information shows that Brazilian Innovation System have so much publications in first-generation ethanol (Fermentation and Ethanol Production) that the share of second-generation in the network is lower.
Fig. 4. Collaborative Network of Brazilian co-authorship through Key Word Plus in lignocellulosic ethanol.

Tab. 6 presents the indicators of the Collaborative Network for Key Word Plus based on Brazilian scientific publications.

**Tab. 6.** Measure of Collaborative Network of Brazilian co-authorship of Keyword Plus in second-generation ethanol.

<table>
<thead>
<tr>
<th>Index</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Centrality Degree</td>
<td>14.451</td>
</tr>
<tr>
<td>Average Density</td>
<td>0.014</td>
</tr>
<tr>
<td>Average Geodesic Distance</td>
<td>3.081</td>
</tr>
</tbody>
</table>
The average centrality was 0.14451 (14.451%). This value is considered as low-medium for network publications is not expected that all areas of knowledge, sprayed on various subjects, having regard to all the others, but that some is central, i.e., converges to ethanol.

The average density measures the proportion of bonds that occur between countries in relation to all possible links. In this case the density was found to be 0.014, or lower, as expected. The relatively high number of KeyWord Plus make researches in this sphere are not centralized.

The geodesic distance to the value of 3.081 shows that the research areas are on average separated by KeyWords Plus 3, i.e., there is a close proximity of research areas, which are relevant. In a different case, a high distance show that there is no convergence of efforts in second-generation ethanol.

Fig. 5 presents the Collaborative Network for authors through co-occurrence of these in scientific publications. It appears that in terms of scientific collaboration are important as some authors:

i) Ashok Pandey – Professor of Biotechnology Division – CSIR, National Institute for Interdisciplinary Science and Technology - India;

ii) Miller, G L; - paper from 1959 - Use of dinitrosalicylic acid reagent for determination of reducing sugar.

iii) Charles Wyman – Professor of Chemistry and Environmental Engineering – University of California Riverside – United States;

iv) José Goldemberg – Titular Professor of University of São Paulo;


In this perspective, it was achieved that the state of art in second-generation ethanol comes from exclusively American authors.

Tab. 7 shows the indicators of the Collaborative Network for authors based on co-occurrence in Brazilian scientific publications. The average centrality was 0.57999(57.999%). This value is medium for the network of publications because is not expected that all authors have compared with all others, i.e., all being central. Perhaps it appears that some are in a prominent position before the others. These authors are linked directly to the process of converting biomass, specifically hydrolysis and pretreatment. These facts indicate the presence of preferential attachment, i.e., more experienced authors in the area having high number of citations.
The geodesic distance to the value of 3.026 shows that the research areas are on average separated by 3 citations, i.e., there is a close proximity of researchers, which are relevant. This fact is related within small-world effect.
6. Conclusions

The commercial production of lignocellulosic ethanol and new products from this conversion will become a reality in the coming years not only motivated by the need for a replacement for petroleum and its derivatives, but by the productive capacity and opportunities that the second-generation ethanol will bring to the countries with benefits from such technology. However, leadership and productive capacities needed for insertion in this market require that countries increase their competitiveness and deepen investments in innovation to address such advents.

Brazil has a huge experience in ethanol production as well as soil and climatic advantages of the country creates the innovative potential of the Brazilian sugarcane industry. This article aimed to present the methodology of knowledge-based networks – Collaborative Networks – applied to the case of Brazilian bioenergy, in particular, for the production of second-generation ethanol. Once the knowledge is cumulative and dynamic theory of evolutionary economics fits directly on aspects of training focused on the network to reach the-state-of-art in the production of lignocellulosic ethanol.

From the institutional perspective - Universities and Research Centers - Brazil show to be more closed in terms of international partnerships. The University of São Paulo (USP) has a prominent position in the network despite the other Brazilian institutions and abroad. This fact limits the potential of diffusion of knowledge among researchers outside of USP. One of these aspects occurs because sugarcane have a prominent production on São Paulo State and the advances initiate by USP researchers decades ago. Therefore, in Brazil, USP have the leadership in the entire network. Future policies have to introduce this sort of aspects.
There is no alignment of the effort of the researches in Brazil with the technological bottleneck of second-generation ethanol, which is the process of conversion of lignocellulosic material, enzymatic hydrolysis. There are large number of researches on fermentation, more directly linked to the achievement of first generation ethanol process. These characteristics reveal that the IS is not focused on the frontier of technology.

References


