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Social network analysis of mangosteen technology development cluster in Indonesia based on patent document application

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ABSTRAK

Tren market dan konsumsi pangan fungsional dari hari ke hari semakin besar dan memiliki kapitalisasi yang menjanjikan. Manggis merupakan salah satu komoditas sumber pangan fungsional. Indonesia merupakan salah satu negara pengekspor manggis terbesar di dunia. Sayangnya bentuk ekspor manggis masih dalam kondisi buah segar, bukan bentukan lain yang memiliki nilai tambah. Pemangku kebijakan perlu melakukan identifikasi teknologi kunci dalam pengembangan komoditas manggis. Penelitian ini menggunakan metode analisis dokumen teknologi berbasis paten untuk memetakan potensi teknologi. Data yang digunakan adalah data paten yang terdaftar dalam database WIPO Patentscope dan database Kantor Paten Indonesia. Analisis dilakukan dengan menggunakan metode komputasi yaitu Analisis Jejaring Sosial dengan algoritma Girvan-Newman. Hasil penelitian menggunakan data paten global menunjukkan terdapat tiga klaster teknologi yang dominan diterapkan pada paten manggis: 1) teknologi terkait pengembangan sediaan untuk keperluan medis, gigi, atau kakus (A61K) sebesar 24%, 2) Teknologi terkait makanan dan bahan makanan atau minuman tidak beralkohol (A23L) sebesar 20%. Terakhir, Teknologi terkait sediaan obat (A61P) sebesar 13%, dan sisanya 43% tersebar di banyak kode teknologi IPC lainnya. Hal ini sejalan dengan hasil analisis data paten di Indonesia yang juga menunjukkan bahwa terdapat 3 kelompok teknologi dominan yang diterapkan pada manggis di Indonesia yaitu 1) Teknologi terkait perkembangan teknologi kedokteran gigi dan toilet (A61K) sebesar 47%; 2) Teknologi terkait makanan dan bahan makanan atau minuman tidak beralkohol (A23L) sebesar 18% dan 3) Teknologi terkait sediaan obat (A61P) sebesar 13%, dan sisanya 22% tersebar di beberapa kode teknologi IPC lainnya. Berdasarkan Analisis Jejaring Sosial, dapat diartikan bahwa klaster teknologi yang dominan diterapkan pada manggis secara global adalah teknologi yang terkait dengan pengembangan bahan makanan dan makanan atau minuman non-alkohol (A23L). Klaster teknologi dominan yang dimaksud manggis di Indonesia adalah teknologi yang terkait dengan perkembangan teknologi kedokteran gigi dan toilet (A61K).

ABSTRACT

Functional food consumption is on the rise and has a significant market value. Indonesia is one of the largest mangosteens (a functional food source commodity) exporting countries globally. Unfortunately, the mangosteen export is still in fresh fruit condition, not in other forms that have a higher value. Policymakers need to identify critical technologies in the development of mangosteen commodities. This study uses a patent-based technology document analysis method to map the potential of technology. The data used is patent data that has been registered with the Indonesian Patent Office and the WIPO Patentscope database. The analysis was carried out using computational methods, namely a Social Network Analysis with Girvan-Newman algorithm. According to the study's findings based on global patent data, there are three major technology clusters used in mangosteen patents: 1) 24 percent for technology related to developing preparations for medical, dental, or toilet purposes (A61K). 2) 20% for food and food ingredient technology or non-alcoholic beverages (A23L). The remaining 43 percent is spread across many other IPC technology codes, including technology related to drug preparations (A61P). It is in line with the results of patent data analysis in Indonesia, which also shows that there are three dominant technology groups applied to mangosteen in Indonesia, namely 1) Technology related to the development of medical, dental, and toilet technology (A61K) of 47 percent; 2) Technology related to food and food ingredients or non-alcoholic drinks (A23L) by 18 percent, and 3) Technology related to drug preparations (A61P) by 13 percent and the remaining 22 percent spread over several other IPC technology codes. According to Social Network Analysis, the world's dominant technology cluster for mangosteen is technology related to the development of food and food ingredients or non-alcoholic beverages (A23L). The technology associated with medical, dental, and toilet technology is the most important mangosteen technology cluster in Indonesia (A61K).

Keywords: Functional food; Mangosteen; Patent; Patent cluster; Social network analysis

1. INTRODUCTION

As people nowadays become more and more mindful of their health, they believe that dietary patterns have a synergistic effect on their health (Gherasim et al., 2020), in accordance with the World Health Organization (WHO) statement that considers a healthy and balanced diet is vital for people's health and plays the most crucial role to prevent chronic diseases, such as heart disease, diabetes, and cancer (WHO, 2021). It causes people to pay more attention to functional foods with functional health advantages than foods that merely satisfy their appetites. Because functional food is now seen as a product that may improve one's health and well-being, there is a high market demand for functional food (Ali & Rahut, 2019; Jain et al., 2014), and provides some economic value benefits for the food industry. Some researchers define functional food as food or food ingredients (that have bioactive compounds) that have potential health benefits (Kusumayanti et al., 2016; Banwo et al., 2021). However, because of the variety in interpreting "functional" meaning, until now, there has been a debatable agreement regarding functional food definition for more than 20 years (Alongi & Anese, 2021).

Today, the demand for functional food has changed a lot in recent decades. Consumers are increasingly aware of the importance of health, so they choose functional foods in their diet (Domínguez Díaz et al., 2020). Functional food is one of the sexiest and most dynamically developing food industry segments, with an estimated global value of over 40 billion US dollars and steady annual increases in sales (Bigliardi & Galati, 2013). The rising demand for functional food may be due to several factors, such as rising healthcare expenditures, the increasing elderly population, and many other factors. High market demand for functional food is driving the rapid development of the food industry in several countries. Several factors trigger the development of functional food markets throughout the world due to the increasing number of the elderly population, high health care costs, advances in science that support the role of functional food, the development of food production processes, and industries that are always looking for new opportunities.

The development of functional food in a country not only provides benefits to consumers but provides opportunities for industry and also benefits the government. The functional food market trend seems to be increasing in the long term with large market potential. Dissemination of science and technology related to functional food development is needed to support private investment, consumption decisions, and government regulations (Bigliardi & Galati, 2013). The academic community, government, and the food industry are all involved in the functional food research and development activity to always develop and continue to innovate and create new healthy food products (Betoret et al., 2011). Therefore, exceptional support and efforts from research institutions and universities are needed to provide an overview of future functional food technology trends. This description can be used as a guide for government and industry in developing products and technology in the functional food sector. In those regards, the development of functional foods is quite important and requires detailed knowledge of the variety and balances of nutrients contained in food, so in-depth research on functional food is important to develop innovative functional foods.

One of the food products that are widely used as essential ingredients in functional food development is mangosteen. Mangosteen is one of Indonesia's mainstay export commodities that occupies a strategic position and has high commercial value. In the Statistics of Fruit and Vegetable Plants, Statistics Indonesia (BPS) reported that mangosteen exports reached $ 20.2 million in 2016 (Badan Pusat Statistik, 2016). Three countries were the leading destinations for mangosteen exports, namely Vietnam, Malaysia, and Hong Kong. Xie et al. (2015), in their research, explained that mangosteen has many benefits for human health, including increased antioxidant capacity and possesses anti-inflammatory benefits with no side effects on immune, hepatic, and renal functions for long-term consumption. The health benefits come from the content of the substance xanthones,

which is one of the antioxidants in the fruit and mangosteen peel. Mangosteen fruit allegedly also has activity as a memory protector (neuroprotector).

The large market potential of mangosteen, of course, must be balanced with innovation in this commodity. This is necessary to increase the added value of these commodities. Therefore, efforts are needed to see what research and development are needed for this mangosteen commodity. Research and development of mangosteen commodities as active ingredients in the event of functional food can be traced through patent documents registered in the patent office. A patent is an exclusive right granted by the state to the inventor for the results of his invention in the field of technology, which for a certain period of time carries out the invention itself or gives approval to other parties to implement it (WIPO, 2018). Patent rights are one form of Intellectual Property Rights (IPR). Patents can increase competitive product advantage and also has important significance for guiding the overall industry development (X. Yu & Zhang, 2019).

Patent documents contain technical information related to intellectual property rights and research results (Tseng et al., 2007). A study shows that research using existing patents can shorten research and development (RnD) time and RnD costs (Xu, 2013). Therefore, researchers should be able to utilize the information contained in previously patented scientific research and industrial development for further research activities. In this case, if used correctly, patent information can be one of the main driving factors in technological development.

Previous researchers have conducted several studies on patent issues that have evolved from various perspectives for decades. Previous patent research generally used the bibliometric approach to analyze scientific literature quantitatively (Deliverable et al., 2015; Zhang et al., 2013). Determination of key actors or technology based solely on bibliometric analysis is prone to erroneous conclusions. This is because it is possible that the key/technological actor does not come from the dominant emerging technology (Yaman, 2016a). Lu & Liu (2016) use the concept of edge-betweenness clustering to identify major research themes and development trajectories. Su et al. (2019) use the three-stage analysis model of Integrated Main Path analysis and Patent Family (IMP&PF) to analyze the evolution of science and technology.

Research by Xu (2013) used co-classification analysis and Girvan-Newman algorithm to make cluster analysis, resulting in a network structure of technology. This research identifies critical technologies in a particular field and finds how technologies from different areas can be interrelated and integrated. Patent classification analysis can be used to map the flow of technological developments, past, present, and future predictions, even long before products appear on the market.

This study aims to map functional food clusters based on patent data, especially mangosteen commodities. Patent data uses the patent database of WIPO (World Intellectual Property Organization) and DJKI Kemenkumham (Directorate General of Intellectual Property of the Ministry of Law and Human Rights). This cluster mapping uses IPC (International Patent Classification) analysis to obtain trends and strategic areas for functional food development. This study also tries to analyze the differences in the development of mangosteen commodity technology in Indonesia and global countries in general.

2. LITERATURE REVIEW

2.1 International Patent Classification (IPC)

International Patent Classification (IPC) is an international patent classification system developed by the World Intellectual Property Organization (WIPO). The IPC classification system is the most appropriate way to obtain patent information because of its consistent categorization and indexing. Patents are graded at least by one IPC code to classify all relevant technological features. When there is more than one different technological aspect in a single patent, the patent will have more than one

IPC code (WIPO, 2018). As a result, it can be easy to identify how much technology and technology fields are interrelated in a patent. Patent applications in each field show the accumulation of knowledge and progress on the technological trajectory. The IPC code is a hierarchy that establishes the existence of patents in a category. There are eight sections, 131 classes, 642 subclasses, and 73,915 groups. The 8 IPC Sections consist of: (A) Human Necessities; (B) Operation, Transportation; (C) Chemistry, Metallurgy; (D) Textiles, Paper; (E) Fixed Constructions; (F) Mechanical Engineering, Lighting, Heating, Weapons, Blasting techniques; (G) Physics; (H) Electricity (WIPO, 2018). For example, patent no. CN102275917, with the title "Preparation method of high-specific surface area mangosteen shell active carbon rich in mesopores" have class C01. The definition C01 is "INORGANIC CHEMISTRY". C01 is divided into C01B-C01G, including C01D – "COMPOUNDS OF ALKALI METALS, i.e., LITHIUM, SODIUM, POTASSIUM, RUBIDIUM, CAESIUM, OR FRANCIUM". The researcher used the IPC 2018 version of this study.

2.2 Co-Classification Matrix

The data used in this study uses all data on mangosteen commodity patents registered in the WIPO database (for international patents) and all data on mangosteen commodity patents registered in the DJKI Kemenkumham database (for Indonesian patents). The technology network structure presents data on overall technological development. Patent documents sourced from DJKI provide various information such as patent titles, abstracts, IPC codes, application numbers and dates, status, the period of protection, patent holders, inventors, and so on. The IPC code in the patent document is then extracted and used as a basis for patent classification. Patent classification is based on the IPC class, which is then represented in an IPC code matrix.

The technology classification of a patent document has been regulated by the examiner of the patent office. The examiner has certain rules and technical rules that have been mutually agreed upon when classifying findings in patent documents. Information from co-classification can be used to identify the relationship between technologies because the same document can be classified into several classes (Lv et al., 2018).

2.3 Social Network Analysis

Social Network Analysis (SNA) is a method for analyzing the relationships between objects in a social system (C. Prell, 2012). Using the SNA, the IPC code network structure can be described, and the IPC code that is central to the social technology system can be found. Also, the reciprocal relationship between IPC codes is well understood.

Girvan-Newman algorithm is the method in SNA that could detect communities in complex systems (Despalatovic et al., 2014). Based on the idea of edge betweenness and iterative edge removal with a high degree of betweenness. The edge betweenness of an edge is defined as "the number of geodesic paths (shortest) between pairs of points on a network that are along the edge." According to the Girvan-Newman algorithm, edge betweenness on all inner edges in the network is calculated, and the edge with the highest betweenness is deleted. Furthermore, the betweenness of all edges is recalculated in the remaining network, and the above process is repeated to get the final result (Despalatovic et al., 2014).

There are at least three indicators to measure the network of linkages between technologies, namely the degree of centrality, betweenness, and closeness. The degree of centrality (see equation 1) in the discussion of technology social network analysis basically measures the technology that is most often applied in the development of mangosteen commodities (Yaman, 2017). The betweenness indicator (see equation 2) can be used to identify which technologies are often the trigger in connecting between technologies. A technology that becomes an intermediary between

two or more technologies in a technology network is considered to have a greater role in a network. This is because this intermediary technology may be a controlling technology so that collaboration occurs among technologies (Salamati & Soheili, 2016; Yaman, 2016). The last indicator is closeness (equation 3). If it is discussed in a technology network analysis, it can be interpreted as a measure of the closeness of the relationship between different technologies.

Degree of node:

Let $A \in R^{n\times n}$ be the adjacency matrix of an undirected graph.

Let $k \in R^n$ be the degree vector. Let $e \in R^n$ be the all-one vector. Then

$$k = Ae \tag{1}$$

Betweenness centrality:

$$Betwenness\ (v) = \sum_{s\neq v\neq t\in V} \frac{\sigma_{st}(v)}{\sigma_{st}} \tag{2}$$

where σ_{st} is the total number of shortest paths from node s to node t and $\sigma_{st}(v)$ is the number of those paths that pass-through v

Closeness centrality:

$$closeness\ (v) = \frac{1}{\sum_{i\neq v} d_{vi}} \tag{3}$$

For comparison purposes, we can standardize the closeness by dividing by the maximum possible value $1/(n-1)$. If there is no (directed) path between vertex v and i, then the total number of vertices is used in the formula instead of the path length.

3. METHOD

The data used in this study are metadata of patent documents contained in the WIPO (international patent) and DJKI (national patent) databases. The word used to filter the database is 'mangosteen.' data were analyzed from 2003-2016. Social Network Analysis (SNA) was used in determining the key to technology for mangosteen development. Data processing is to be carried out using NetDraw software. SNA was carried out using the following stages (Yaman, 2016a):

1. Scraping the metadata of patent documents from both WIPO (international patent) and DJKI (national patent).
2. Use descriptive analysis to determine the dominant technology in a set of patent documents. This stage is carried out in parallel for both the patents contained in the WIPO database and the DJKI database. This stage is intended to see the differences in technological characteristics descriptively in the development of mangosteen in the world generally and in Indonesia.
3. Create a relationship matrix between the two technologies (Co-classification). If two technology classes occur in the same patent document, then the cell between the two technologies is assigned a value by the frequencies. On the other hand, if there is no relationship between technology classes, it is given a value of zero. For deriving the weights of the evaluation criteria, the co-classification frequency matrix was constructed.
4. Describe the network relationship between technology classes.
5. Measure the size of centrality (degree, betweenness, and closeness) in each technology class that is displayed on the technology network image.

4. RESULTS & DISCUSSION

4.1 The trend (Descriptive Analytics) of Mangosteen Commodity Technology Development (Indonesia vs Global)

The distribution of technology development in mangosteen commodities is presented in Figure 1 (global development) and Figure 2 (Indonesia development). The distribution shows the trend of developing mangosteen commodity technology in each section of IPC. It is shown in the picture that cumulatively, the direction of technology development for mangosteen both in the world and in Indonesia has the same development tendency. There are three dominant technology groups in the elaboration of mangosteen commodity technology in the world, namely (1) Technology related to the development of medical, dental, and toilet technology (A61K) by 24%; (2) Technology related to food and food ingredients or non-alcoholic drinks (A23L) by 20%; and (3) Technology related to drug preparations (A61P) by 13%; the remaining 43% is spread over many other IPC technology codes (Figure 1). In line with the distribution of technological developments in the world, there are three dominant technology groups in the event of mangosteen commodity technology in Indonesia. 1) Technology related to the evolution of medical, dental, and toilet technology (A61K) by 47%. 2) Technology related to food and food ingredients or non-alcoholic drinks (A23L) by 18%. 3) Technology affiliated to drug preparations (A61P) by 13% and the remaining 22% spread over several other IPC technology codes.

Figure 1 and Figure 2 clearly show that the proportion of A61K technology development (the most widely developed technology for mangosteen commodities) in Indonesia is more than twice the proportion contained in world patents. This could be an indication that technically the development of mangosteen commodity patents in Indonesia did not occur gradually and naturally but rather modified and updated existing patents globally. Another indication can be seen from the level of diversity in the development of mangosteen technology in Indonesia, which is far less diverse than the mangosteen patents in the world.

The low level of diversity also shows that the development of technology on the mangosteen commodity has actually been carried out by considering the efficiency of research time and costs. These results show that with analysis through patents, we can shorten the time and reduce research and development costs. This is important, especially in Indonesia, where the level of RnD expenditure is still low.

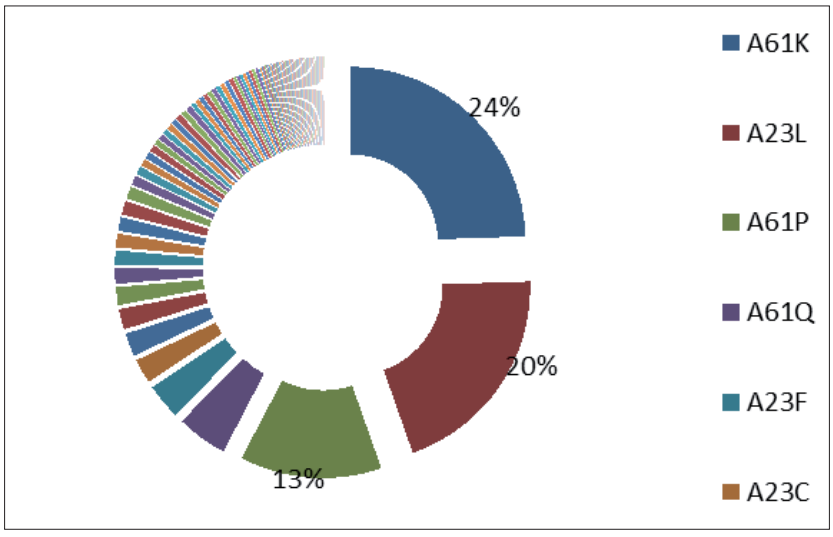

Figure 1. Distribution of Mangosteen Commodity Technology Development in the World
Source: Processed Primary Data, 2021

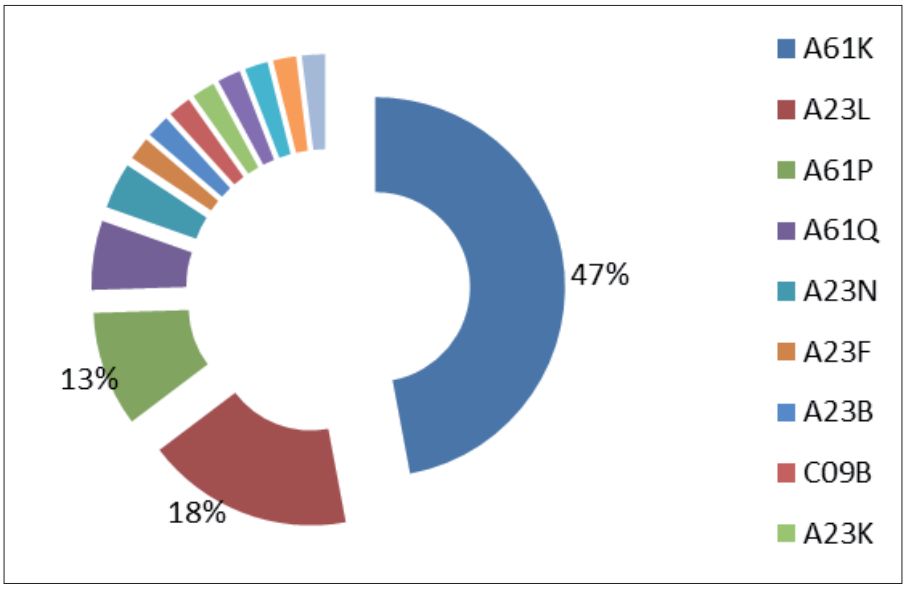

Figure 2. Distribution of Mangosteen Commodity Technology Development in Indonesia
Source: Processed Primary Data, 2021

4.2 Technology Development Cluster on Mangosteen Commodities

The results of the analysis using Social Network Analysis (SNA) are shown in Figure 3. The results are in the form of a cluster of technological developments in mangosteen commodities. Figure 3. shows the technology development map of the mangosteen commodity in Indonesia. In Figure 3. we can see that there is one dominant cluster formed, which is indicated by a red dot, for identification of other clusters can be seen in Table 1. The clustering in social network analysis is different from traditional clustering (G. Yu, 2007). It requires grouping objects into classes based on their links as well as their attributes. For example, there is a cluster containing sub-class IPC G01R, G06F, and H03K. This means that the three IPC sub-classes have been at least classified in the same patent document. In other words, the three IPC sub-classes interact with each other in the findings of the same technology.

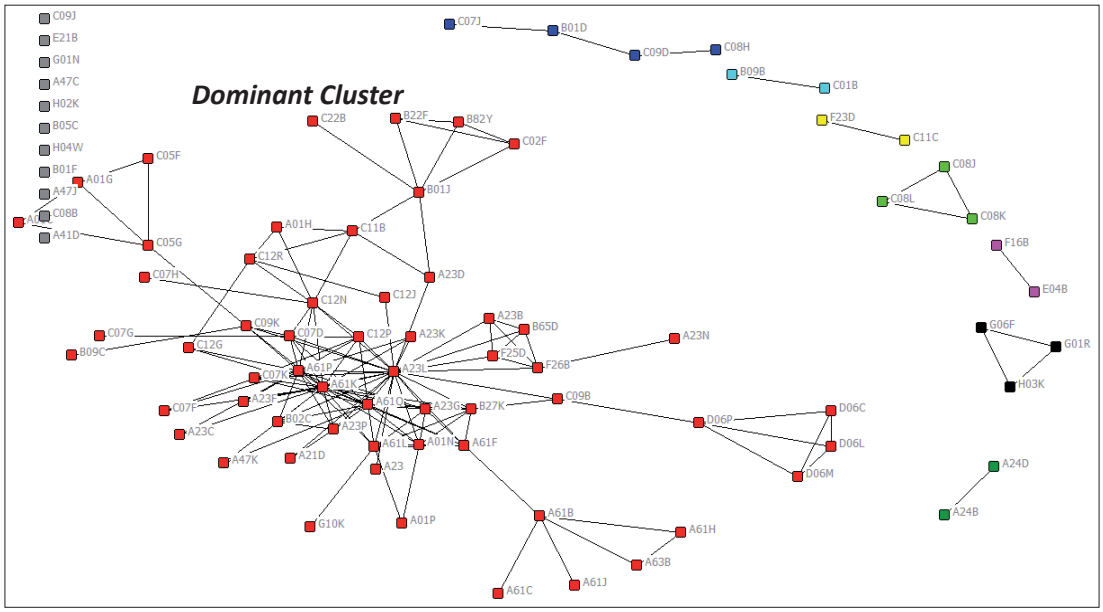

Figure 3. The results of the analysis using Social Network Analysis (SNA)
Source: Processed Primary Data, 2021

Table 1. The Cluster of Mangosteen Technology in Indonesia by Type of IPC

ID	Degree	Betweenness	Closeness	Cluster (Q=-0.04)
A61K	9	25.667	50	1
A23L	7	11.667	52	1
A23B	5	0.667	54	1
B01D	4	0	55	1
B01J	4	0	55	1
A23N	3	0	56	1
A61P	2	0	57	1
A61Q	2	0	58	1
C11D	2	0	58	1
A01N	1	0	61	2
A23K	1	0	59	3

Source: Processed Primary Data, 2021

Furthermore, an in-depth analysis will be carried out regarding the central technology class in this dominant cluster formed in Indonesia. In table 1, we can see that the A61K is an umbilical technology class in the dominant group formed. This phenomenon is because the A61K technology class has the following characteristics: 1. It is the technology class that is most actively collaborating with other technology classes (the largest degree value), 2. It is the technology class that is most often the collaboration bridge with other technology classes (highest betweenness values) and 3. It is a technology class that has the closest collaboration relationship with other technology classes (the smallest closeness value).

Based on the information in Table 1, we can see that among the eleven technology classes, there are three key technologies. These three technologies were chosen as key technologies for developing mangosteen commodities because they have a betweenness level measure compared to the other eight technologies. The three key technologies for mangosteen development in Indonesia are A61K, A23L, and A23B. A61K, according to the WIPO dictionary, is a technology related to Preparations for Medical, Dental, or Toilet Purposes (devices or methods specially adapted for bringing pharmaceutical products into particular physical or administering forms A61J 3/00; chemical aspects of, or use of materials for deodorization of air, for disinfection or sterilization, or for bandages, dressings, absorbent pads, or surgical articles A61L; soap compositions C11D). A23L is a technology related to Foods, Foodstuffs, Or Non-Alcoholic Beverages, Not Covered by Subclasses A21D or A23B-A23J; their Preparation or Treatment, e.g., Cooking, Modification of Nutritive Qualities, Physical Treatment (shaping or working, not fully covered by this subclass, A23P); Preservation of Foods or Foodstuffs, In General. At the same time, A23B is technologies related to Preserving, e.g., BY Canning, Meat, Fish, Eggs, Fruit, Vegetables, Edible Seeds; Chemical Ripening of Fruit or Vegetables; The Preserved, Ripened, or Canned Products.

Theoretically, based on Figure 1., Figure 2., Figure 3., and Table 1. (Descriptive analysis and SNA analysis), we can see coincidentally the dominant technology shown in the descriptive analysis is synchronous with the key technology shown in Figure 3 and Table 1. However, this could be different. A slightly different thing appears that A23B based on SNA is one of the key technologies for developing mangosteen commodity technology. However, this A23B does not appear to be one of the technologies that are categorized as dominant (a lot of them appear). It should be noted that it is not enough for us to analyze using a bibliometric method to show key technologies. But it needs to be combined with other analyzes such as SNA. The combination of these analyzes is needed to increase the level of confidence in the analysis. Often bibliometric results are not in sync with advanced analyzes such as SNA.

If we compare the dominant clusters in patent mapping in the world and Indonesia, there are different technical characteristics. In world patents, Dominant groups that are formed have a collaborative level between high technology classes compared to Indonesia. Also, if it is associated with the theme of functional food, then the emergence of functional food technology in world patents is initiated through food development and then continues to functional food (medical mangosteen technology, A61K). This development is different from the conditions in Indonesia. The emergence of functional food technology for mangosteen commodities in Indonesia indeed has been directed from the beginning to functional food rather than a derivative of other technology classes.

5. CONCLUSION

There are characteristic differences between Indonesia and the world in the development of mangosteen innovation and technology. The first characteristic, dominant technology cluster applied to mangosteen in the world (global development) is technology related to the development of food and food ingredients or non-alcoholic beverages (A23L). Second, the dominant technology cluster referred to as mangosteen in Indonesia is the technology associated with the development of medical, dental, and toilet technology (A61K). In world patents, the dominant cluster formed has a high collaboration level between technology classes compared to Indonesia. If associated with the theme of functional food, then the emergence of functional food technology in the world is initiated through food development and then continues to functional food (mangosteen technology for medical, A61K). This phenomenon is different from the conditions in Indonesia, where the emergence of functional food technology for mangosteen commodities in Indonesia has indeed been directed from the beginning to functional food rather than a derivative of other technology classes.

Currently, the development of mangosteen commodity technology in Indonesia is running on the right track. It can be seen from the level of technological diversity that is low compared to world patents. This can increase cost efficiency and development time.

As a comparison of technology cluster analysis in patent documents, future research may consider modeling topics in patent documents. Further analysis may consider the ‘claim’ section of the patent document. It is expected to see the technology cluster organically.

CREDIT (CONTRIBUTOR ROLES TAXONOMY)

Aris Yaman: Conceptualization, Methodology. **Yulia Aris Kartika**: Data curation, Writing- Original draft preparation. **Silmi Tsurayya**: Visualization, Investigation. **Lindung P. Manik, Zaenal Akbar**: Supervision, Software, Validation. **Adi Ankafia, Ariani Indrawati**: Writing- Reviewing and Editing.

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