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A bibliometric analysis of coconut sap research

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ABSTRACT

Introduction: Coconut sap is a sweet, fragrant liquid obtained from the inflorescence of coconut tree. In this study, a literature search was conducted using the Scopus database to study the trends of coconut sap research. **Methods:** Data extracted from the Scopus database were analysed and visualised using VOSviewer to determine top authors, papers, countries, collaborations, and research areas. A total of 76 publications up to year 2021 were identified and refined using keywords of "coconut sap", "coconut sugar", "coconut inflorescence", "coconut inflorescence sap", "coconut neera", and "*Cocos nucifera*". **Results:** Based on the analysis, research on coconut sap started in 1984, with a total of 53 authors, nine countries, and 12 sources that had published more than two documents. The analysis of countries and sources revealed that India and IOP Conference Series: Earth and Environmental Science (EES) were the most prolific country and sources, respectively. The most influential document was on the chemical compositions and bacteriology of coconut sap. The results also showed that research on coconut sap was in the field of food processing during the early years, followed by fermentation, agriculture, and bacteriology of coconut sap. Research on coconut sap's bacteriology started in 1986 and became a major interest, especially among high impact journals. **Conclusion:** Overall, coconut sap is a potential target for the development of nutraceutical products, especially in the food and beverage industry.

Keywords: bibliometric, coconut sap, nutraceutical

INTRODUCTION

Coconut, *Cocos nucifera* L., is native to tropical countries such as Malaysia, Indonesia, Africa, South America, Australia, and other tropical regions (Lima *et al.*, 2015). In the flowering phase, coconut sap is collected from the unblossomed coconut tree's spadix, which produces inflorescence throughout the year (Ghosh *et al.*, 2018). Locals have been harvesting coconut sap as a nourishing drink which can be consumed in two forms: non-fermented and fermented sap. The non-fermented

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sap is called neera, while the fermented sap is called toddy, with 5-8% of alcohol content (Chinnamma *et al.*, 2019). It has high market value either as fermented or non-fermented products such as sweetener, reducing agent, natural preservative, broiler diets, vinegar, yoghurt, as well as alcoholic, sport and probiotic drinks (Asghar *et al.*, 2020; Joseph *et al.*, 2021; Rajesh *et al.*, 2020; Srikaeo & Thongta, 2015; Ravindran *et al.*, 1984).

Coconut sap is a highly nutritious drink that is rich in minerals (potassium, sodium, magnesium, phosphorus, calcium, ferum, zinc, iron), vitamins (A, B1, B2, B3, B6, B10, C), sugar (sucrose, glucose, fructose), amino acid (aspartic acid, glutamic acid, histidine, leucine, threonine, methionine, valine, alanine, cysteine, isoleucine, tyrosine, arginine), protein, carbohydrates and fats (Jose *et al.*, 2018; Chinnamma *et al.*, 2019; Asghar *et al.*, 2020; Hebbar *et al.*, 2020). Despite the rapid increase in the number of published studies and profound findings on coconut sap, no quantitative analysis has been done on its research trends to identify key research issues, active researchers, research gaps, and future prospects. Hence, this review aims to provide valuable insight into the trend of coconut sap research and its market opportunities.

MATERIALS AND METHODS

Data collection

Five main search keywords were used, namely "coconut sap", "coconut sugar", "coconut inflorescence", "coconut inflorescence sap", and "coconut neera", together with the scientific name of coconut (*Cocos nucifera*). Titles containing these keywords were selected. The papers were retrieved up to 31st December 2021.

Data analysis and visualization

Data from Scopus were analysed and visualized using VOSviewer 1.6.17 according to Fadhlina *et al.* (2023). The analyses consisted areas on authorship, countries, keywords, and terms co-occurrence. The author's credit for publications in this study was based on "complete count". Each occurrence of an author was counted regardless of appearance sequence. Network and overlay visualization were used to present the data.

Selection criteria

The 168 articles identified from the database were subjected to inclusion and exclusion criteria according to Sheikh *et al.* (2022). Titles that contained no abstract and review papers were first removed followed by articles not related to coconut inflorescence sap. These irrelevant articles included articles on coconut husk, coconut inflorescence fibril, coconut water, coconut-associated insects and others. A total of 76 articles were selected for this bibliometric analysis.

RESULTS & DISCUSSION

Co-authorship, sources and countries analyses

A total of 53 authors (out of 265 authors) met the threshold of a minimum of two documents per author, analysed using the network and overlay visualization for co-authorship analysis. Based on the analysed authors, a total of 12 clusters were observed (Figure 1a). However, there was no connection established among the clusters and they were working independently within the same cluster throughout the years. The most prolific author was Hebbar KB (six documents), who conducted research on the nutritional, physicochemical, and microbial studies of coconut sap. Other

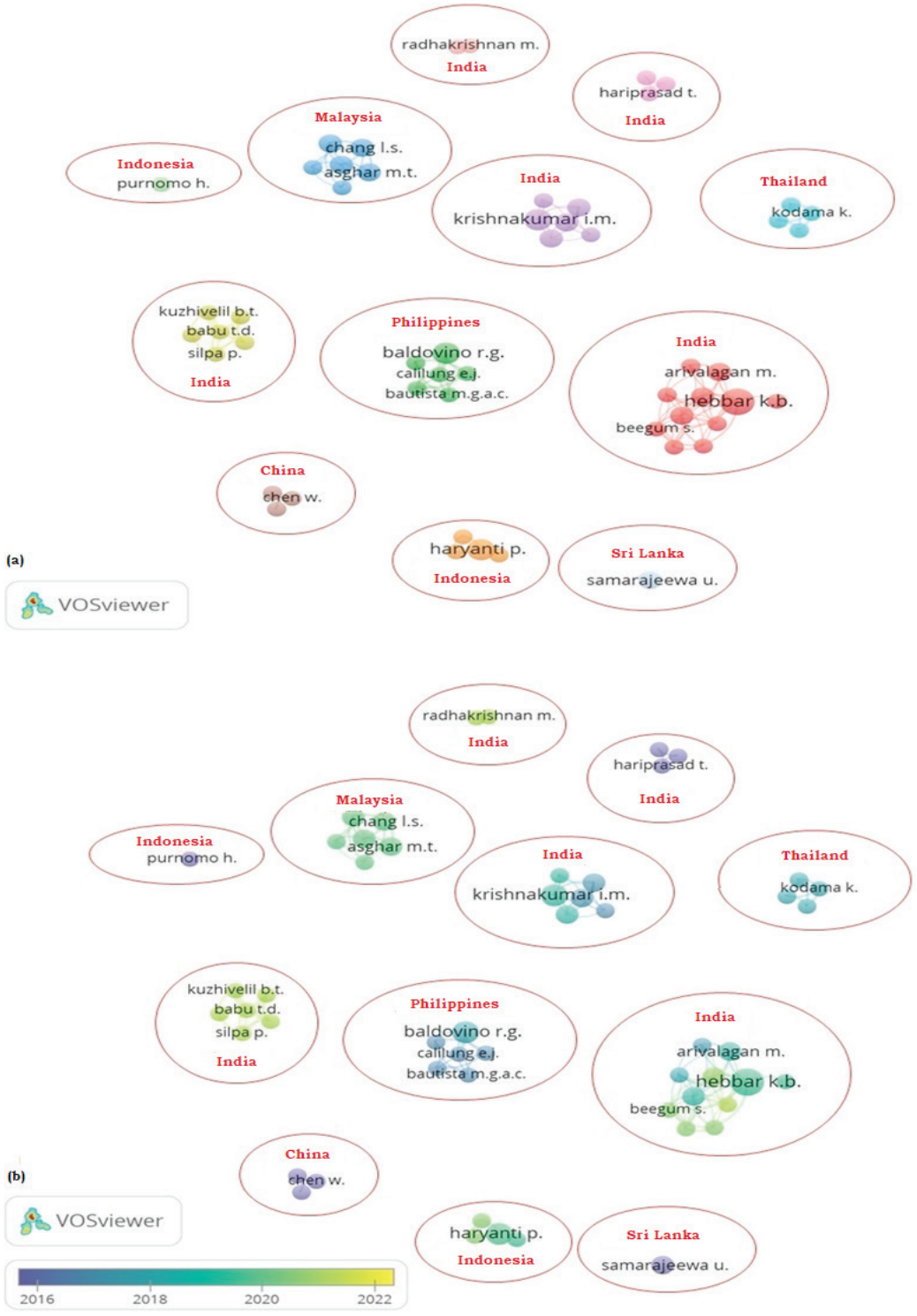

Figure 1. (a) Main authors and their networks (b) Timewise visualization of main authors

Table 1. List of top 10 authors, sources, countries and documents

Author	*PC*	*Sources*	*PC*	*Country*	*PC*
Hebbar KB	6	IOP Conference Series: Earth and Environmental Science	7	India	24
Baldovino RG	4	International Food Research Journal	4	Indonesia	18
Haryanti P	4	Food Microbiology	3	Thailand	13
Krishnakumar IM	4	Food Research	3	Philippines	6
Samarajeewa U	3	LWT	3	Malaysia	5
Manikantan MR	3	Frontiers in Microbiology	2	Sri Lanka	5
Asghar MT	3	Journal of Food Biochemistry	2	China	3
Chang LS	3	Journal of Food Science and Technology	2	Pakistan	3
Manaf YN	3	Journal of Food Measurement and Characterization	2	United States	2
Yusof YA	3	ACM International Conference Proceeding Series	2		

Document	*Title*	*Citations*	*Links*
Borse *et al.* (2007)	Chemical composition of volatiles from coconut sap (neera) and effect of processing	63	11
Atputharajah, Widanapathirana & Samarajeewa (1986)	Microbiology and biochemistry of natural fermentation of coconut palm sap.	59	11
Somashekaraiah *et al.* (2019)	Probiotic properties of lactic acid bacteria isolated from neera: A naturally fermenting coconut palm nectar	51	2
Hebbar *et al.* (2015)	Coconut inflorescence sap and its value addition as sugar–collection techniques, yield, properties and market perspective.	34	7
Xia *et al.* (2011)	Chemical composition changes of post-harvest coconut inflorescence sap during natural fermentation.	28	13
Srikaeo & Thongta (2015)	Effects of sugarcane, palm sugar, coconut sugar and sorbitol on starch digestibility and physicochemical properties of wheat-based foods.	28	3
Asghar *et al.* (2020)	Coconut (*Cocos nucifera* L.) sap as a potential source of sugar: Antioxidant and nutritional properties	24	5
Karseno *et al.* (2018)	Effect of pH and temperature on browning intensity of coconut sugar and its antioxidant activity.	24	2
A-Sun *et al.* (2016)	Effect of spray drying conditions on physical characteristics of coconut sugar powder.	21	1
Jirapeangtong, Siriwatanayothin S & Chiewchan (2008)	Effects of coconut sugar and stabilizing agents on stability and apparent viscosity of high-fat coconut milk.	21	0

PC: Publication count

prolific authors included Baldovino RG, Haryanti P, and Krishnakumar IM with four documents (Table 1). Based on the overlay visualization (timewise), authors from India consistently contributed in coconut sap research across the years (Figure 1b), with research mainly focused on the microbial studies of neera/non-fermented coconut inflorescence sap (NFCIS).

A total of nine countries with a minimum of two documents per country were extracted from the country's co-authorship analysis. Based on the network and overlay visualization of analysed countries, Thailand was observed to have collaboration with several countries, such as India, Malaysia and Pakistan, while the rest of the countries, such as Indonesia, Sri Lanka, Philippines and China, worked independently. India and Indonesia were the most prolific countries, followed by Thailand, the Philippines and Malaysia. Indonesia had shown a high number of documents (five) published in the Institute of Physics (IOP) Conference Series: Earth and Environmental Science (EES). In recent years, Pakistan, the United States and Malaysia were observed to have conducted research related to this topic.

Based on the analysis of sources, the highest number of publications was observed for the IOP Conference Series: EES, a Scopus-indexed proceeding with a total of seven publications. All publications between the years 2020-2021 were focused on improving the quality of coconut sap by the use of laru (a natural preservative derived from the bark of certain trees), as well as other chemical agents such as arginine and sodium metabisulfite. In addition, research on the use of chengal wood and the biodiversity of bacteria in coconut sap were also published in the proceeding. Food Microbiology and LWT were among the top five prolific journals whereby research was focused on the microbial studies of coconut sap in the early years (1986-1988), a topic which gained interest again between the years 2020-2021. This may indicate that the microbial studies of coconut sap were among the main interest for publication in high impact journals. Meanwhile, for lower impact journals, the publications were focused on the antioxidant activities, bioactive compounds, and processing of coconut sap, as well as its sugar.

Keywords co-occurrence analysis

A total of 143 (after exclusion of 10 keywords: article, non-human, controlled study, unclassified drug, priority journal, male, human, adult, humans, Indonesia) keywords with a minimum of two occurrences of a keyword were analysed. A total of eight clusters were observed in the co-occurrence analysis of keywords with "coconut" as the most frequent keyword (20 occurrences). The use of keywords can be seen moving from "coconut sugar" to "coconut sap" and currently, to the keyword "coconut inflorescence sap" (Figure 2). In terms of research trends, food processing started in the early years of research, followed by the fermentation process and currently, the agriculture and bacteriology of coconut sap. Meanwhile, research on the antioxidant activities and sugar industry of coconut sap was consistently observed throughout the years of research since 2015.

Citation analysis of documents

A total of 47 documents with a minimum of two citations per document were connected and analysed for their network of citations. The most influential documents with the highest citations were authored by Borse BB (63 citations), followed by Atputharajah JD (59 citations), and Somashekaraiah R (51 citations), which focused on

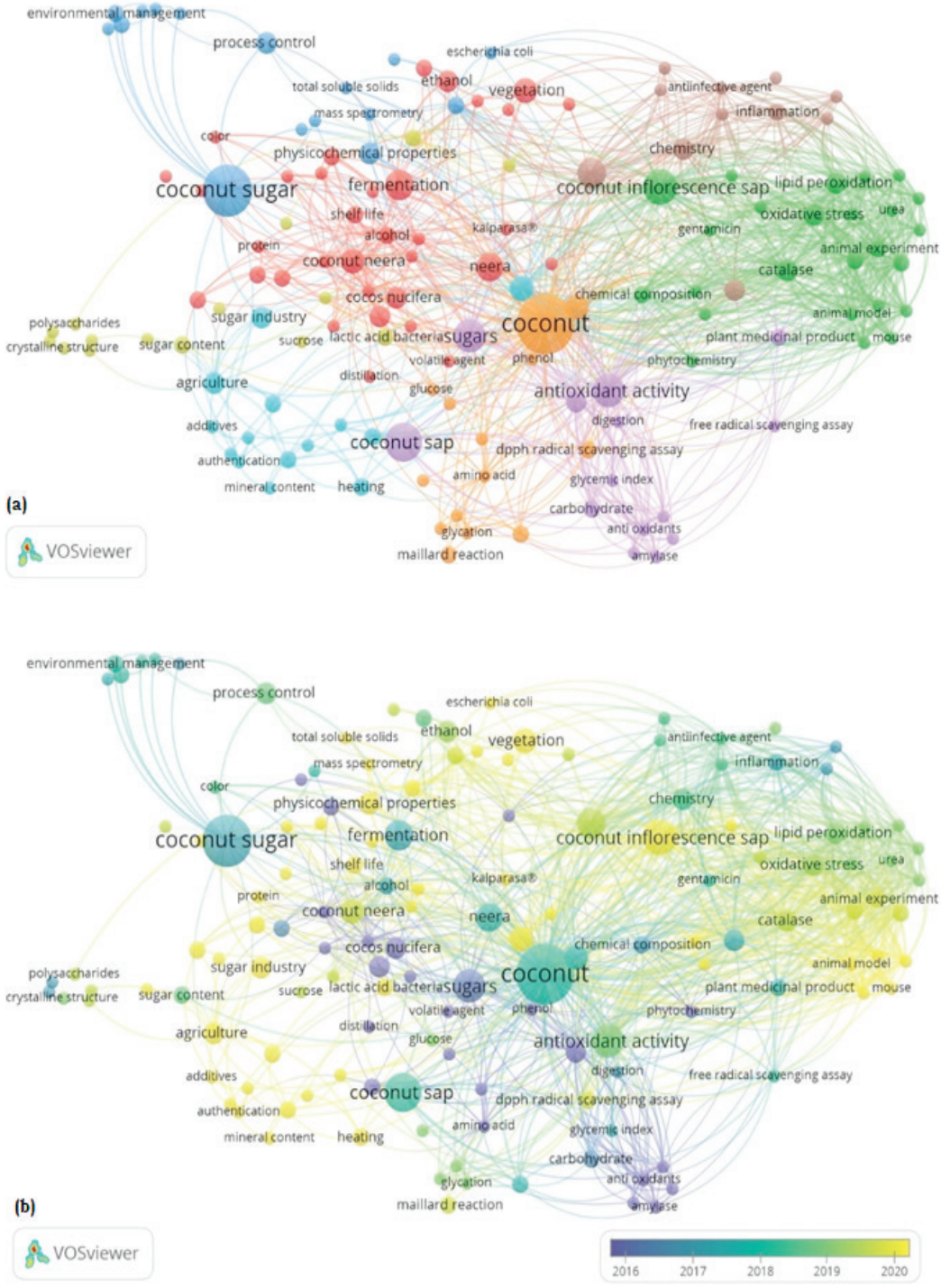

Figure 2. (a) Network visualization of main keywords (b) Timewise visualization of main keywords

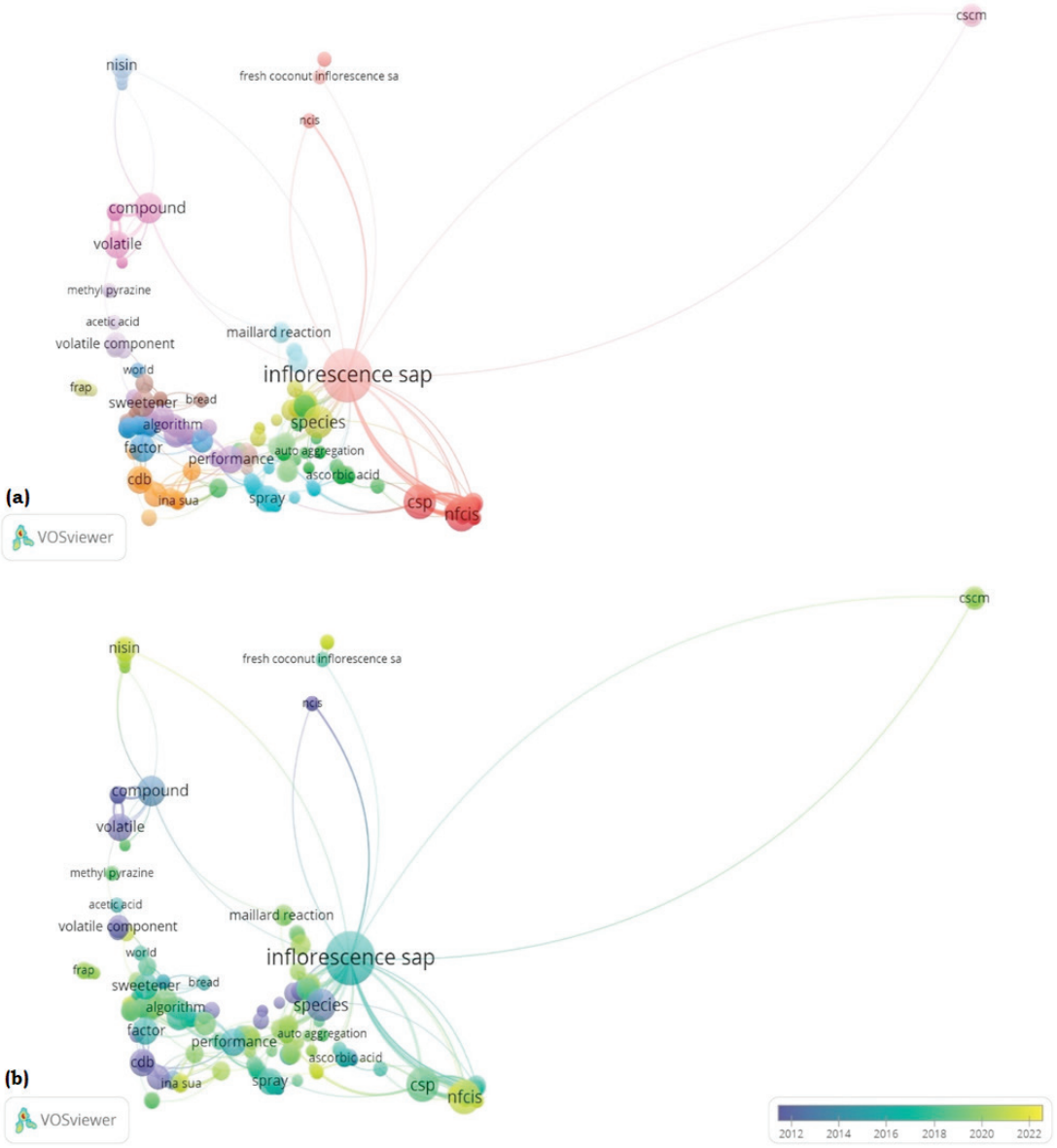

Figure 3. (a) Network visualization of terms co-occurrence (b) Timewise visualization of terms co-occurrence

the study of chemical compositions and bacteriology of coconut sap (Table 1). Research on its bacteriology was observed to have started in the early years (1986) and continued to be of interest. The rest of the research listed in the top ten highest citations focused on food processing and nutraceutical properties of coconut sap.

Co-occurrence of terms in text data

A total of 318 (after exclusion of 36 unrelated terms: volume, higher amount, degree Celsius, percent, minute, g l,

lab, type, ppm, ml 100g fish, g ml, ton, tree day, evening, noon, morning, afternoon, sec, l ml, year, g water, ml kg min, average, w kg b, hour, duration, kind, total, iii, first time, problem, w v, Thailand, Philippine, group, approach) terms with a minimum of two occurrences of a term were analysed. All terms were extracted from the title and abstract of selected documents for the analysis of terms co-occurrence and a total of 18 clusters were observed. From the clusters observation, the highest occurrence (38) term was "inflorescence sap", which was connected to most clusters (Figure 3a). This term was frequently used in research involving animal studies, bioactive compounds, and product innovation of coconut sap. Other frequently used terms were csp and nfcis, which stands for coconut inflorescence sap and non-fermented coconut inflorescence sap, respectively. Timewise, the term nfcis was frequently used in recent years involving its antioxidant studies in comparison to the fermented form, as well as bacteriology of coconut sap (Figure 3b).

Marketable products of coconut sap

Coconut sap may offer varieties of products to be commercialised owing to its nutritional and health benefits. It has been reported to show numerous bioactivities such as antioxidant (Asghar *et al.*, 2020; Devi *et al.*, 2015), anti-inflammatory (Ratheesh *et al.*, 2017), hepatoprotective, nephroprotective (Jose *et al.*, 2017), antimicrobial, and cytotoxic (Rajesh *et al.*, 2020) activities. It contains a lot of nutritional values such as vitamins, minerals, amino acids, carbohydrates, protein and sugars (Table 2). The diversity of coconut varieties, harvesting (tapping, collecting, processing) methods, geographical locations, and climatic conditions may cause variations in the total and reducing sugar contents of coconut sap (Chinnamma *et al.*, 2019; Sarma *et al.*, 2021). In addition, the concentration of volatile compounds, such as acetic acid, dodecanoic acid, 1,4-dimethyl-6-1 butyl acetate, and 2-methylcyclohexane, had previously been found to decrease from morning to evening tapping of coconut sap (Purnomo, 2007). Once harvested, coconut sap is prone to fermentation, which affects its commercial value. Thus, prevention of the fermentation process to suppress microbial growth by incorporation of limestone, potassium metabisulphite, and citric acid or natural preservatives, such as mangosteen skin, the bark of jack fruit, and chengal wood, have been reported (Chinnamma *et al.*, 2019; Purnomo, 2007; Saidan *et al.*, 2020).

Several products have been developed from coconut sap, namely Kalparasa (unfermented drink), Rasgulla (sugar-based dessert), coconut sap yoghurt, and Coconut Sap Powder (CSP). CSP was previously reported to show an ergogenic effect, which may have the potential to be commercialised as an energy drink (Joseph *et al.*, 2021). Meanwhile, coconut sugar has a low glycaemic index (GI) value, which offers promising market as a diabetic sugar and a better replacement for regular refined sugar, as well as muscovado sugar. Besides, it can be used in wheat-based products (e.g., bread with coconut sugar) and produce acceptable bread quality in comparison to conventional bread made using sugarcane (Srikaeo & Thongta, 2015). Coconut sap also had been used in improving the shelf life and sensory attributes of foods such as fermented salted fish (Wattimena, Temartenan & Lesbatta, 2021), acidophilus milk (Jirasatid & Nopharatana, 2020), and animal feeds (Ravindran, Sriskandarjah & Rajaguru, 1984). Lactic acid bacteria (LAB) isolates from neera demonstrated probiotic attributes with antimicrobial activities, therefore exhibiting the

Table 2. Marketable products and nutritional values of coconut sap

Marketable products	*Applications*	*References*
Non-alcoholic products	Unfermented coconut sap drink/ Kalparasa/ Neera, energy drink (CSP)	Hebbar *et. al.*, 2015
Fermented products	Toddy, vinegar, gluten-free soy source alternative	Mesquita *et al.*, 2020
Probiotic drinks	Lactic Acid Bacteria (LAB)	Somashekaraiah *et al.*, 2019
Preservative	Fermented-salted fish	Mahulette *et al.*, 2016
Milk emulsifier	*Acidophilus* milk, high-fat coconut milk	Jirapeangtong Siriwatanayothin S & Chiewchan 2008; Jirasatid & Nopharatana, 2020
Yoghurt	Coconut sap drink yoghurt	Karseno *et al.*, 2021
Sweetener	Syrup (Coconut Nectar, Sucrose heavy dessert e.g., Rasgulla) Coconut Sap Powder (COCOZEN™) Wheat-based foods	Kaur & Goswami, 2021 Srikaeo *et al.*, 2015
Chicken feed	Coconut sap distillery by-products	Ravindran *et. al.*, 1984.
Reducing agent	Synthesis of silver nanoparticles (AgNPs)	Joseph *et. al.*, 2021
Fermentation medium	Levan production	Mummaleti *et al.*, 2020
	Nutritional values	
Proximate composition & minerals: Carbohydrates, Protein, Fats, Sucrose, Glucose, Fructose, Potassium, Magnesium, Selenium, Phosphorous, Sodium, Zinc, Iron, Copper, Manganese, Choline, Nitrate, Calcium (Jose *et al.*, 2017; Jose *et al.*, 2018; Chinnamma *et al.*, 2019)	Amino acids: Aspartic acid, Glutamic acid, Serine, Valine, Alanine, Threonine, Methionine, Leucine, Isoleucine, Histidine, Cysteine, Arginine, Tyrosine (Chinnamma *et al.*, 2019; Hebbar *et al.*, 2020)	Vitamins: Vitamin A, Thiamine (B1), Riboflavin (B2), Niacin (B3), Pyridoxine (B6), Biotin (B7), Folic acid (B9), Adenine (B4), Para-aminobenzoic acid (B10), Vitamin C (Asghar *et al.*, 2020; Chinnamma *et al.*, 2019)

potentiality for use as probiotics in food and feed formulations (Somashekaraiah *et al.*, 2019).

CONCLUSION

Based on the data search in Scopus (1984-2021), there were a total of 76 articles published on coconut sap research. The bibliometric analysis revealed that 53 authors and 12 sources produced more than two documents. Hebbar K.B. from India was the most prolific author, while the most influential publication was authored by Borse B.B., reporting on the effect of processing in bioactive compounds identification (63

citations). Observation of the research trend revealed that the bacteriology of coconut sap was consistently reported from the earliest years to the present. This review also showed that coconut sap has a huge potential in the nutraceutical food and beverage industry and appears to be an emerging product which may penetrate the global market.

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Authors' contributions:

Fadhlina A, led the data analysis and prepared the draft of the manuscript; Sheikh HI, advised on the data analysis and interpretation, and reviewed the manuscript; Nor MM, principal investigator, conceptualised and designed the study; Saidan NH, assisted in drafting the manuscript and reviewed the manuscript; Zainurin NA, assisted in data collection.

Conflict of interest

The authors declare no conflict of interest.

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