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Trends in Coconut Brown Sugar Production – A Review of Health and Future Prospect in the Industry

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ABSTRACT

In recent times, several publications on processing of brown coconut sugar have been carried out, which present an excellent option for health-conscious consumers in the global market. The goal was to discuss and present recent developments in the industry, highlight the numerous health benefits and forecast into the future prospects of the industry. From the discussion, coconut sugar contains all the essential amino acids, various vitamins, minerals, phenolic and antioxidant compounds. These antioxidants are very important in the prevention of heart disease, cancer and inflammatory diseases, whilst the polyphenols inhibited the formation of cancer cells by reducing DNA hypermethylation. Vitamins also play an important role in metabolic reactions by acting as transcription effectors and electron donors. Coconut sugar is also known to prevent kidney stone formation and renal diseases by flushing out formed stones and plays an important role in the revitalization and proper functioning of the kidney due to its high potassium content. With a global trade volume of USD 1.33 billion and a compound annual growth rate (CAGR) of 8%, the industry has great prospects. However, restraints such as high labor intensity, environment-friendly demand, and lack of mechanization require immediate attention to salvage the industry.

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Introduction

Coconut sugar is obtained from the sap of coconut, a sweet, golden brown-colored fluid extracted from the immature inflorescences of the coconut (Nurhadi et al., 2020). The sap is tapped from the immature inflorescences of the coconut that have not yet opened and can be tapped 12 to 15 times a year (Jose, 2013). The main component of coconut sap is sucrose, which accounts for more than 80% of the total solid, followed by a small amount of glucose and fructose of about 2.3% of the total solid (Nurhadi et al., 2018). The extraction of coconut sap production has received popularity in the coconut sector recently (Nurhadi et al., 2020). Coconut sap, like the sap from other palms, is often consumed directly by the population and is highly valued for its nutritional properties (Nurhadi et al., 2018). However, coconut sap is most valued for its conversion into syrup and sugar (Muriel et al., 2019).

Coconut sugar is a natural sweetener obtained through evaporation of coconut sap (Nurhadi et al., 2020). It forms a crystalline sweetener with sugar characteristics, completely natural and highly nutritious, with superior tastes (Abdullah et al., 2014). Conventionally, it is produced by heating the sap until a saturated solution is formed, which crystallizes and forms coconut sugar powder (Nurhadi et al., 2020). Coconut sugar has the potential to be a better substitute for synthetic sugar. It can be used as a sweetener for coffee, tea, chocolate drinks and other baked foods, as well as a cooking ingredient (Asghar, Muhammad T et al., 2020; Hebbar et al., 2015). It has a wider range of applications and is used in various types of traditional cuisine and in beverages as flavor and color enhancer (Karseno et al., 2018). The texture and flavor of coconut sugar are similar to those of brown sugar (Asghar, Muhammad Tuseef, Yus Aniza Yusof, Mohd Noriznan Mokhtar, et al., 2020). Thus, coconut sugar can easily replace regular table sugar. In this paper, we discuss the recent development in the coconut sugar industry, the health benefit of its nutrients and explore its future prospect for the industry. Therefore, the purpose of the review was to discuss and showcase recent developments in the coconut sap brown sugar production, emphasizing the numerous health benefits, and forecast the industry's future possibilities.

Methodology

In the review exercise a narrative review approach was used to provide a broad overview of a topic, drawing from various sources to synthesize knowledge and highlight trends, gaps, and future research directions. In this approach database source such as PubMed, Scopus, Web of Science, ScienceDirect, Francis and Taylor, Wiley's and link springer were used for literature search strategy. For a detailed keywords, phrases and Boolean, words such as coconut sap, nutritional composition, health benefit, glycemic index, and Maillard reaction were used for the review. The criteria used to include or exclude this review studies during informational search included publication date (not more than 20 years) and language (English only). All study design and other related research questions were allowed during the search. For data validity and reliability, the approach of cross-referencing data from multiple sources was applied during the data and information search.

Coconut Sap Production

Coconut sap is tapped from unopened inflorescence, where the heads are sliced and covered with a bowl to collect the sweet fluid sap over time. To stimulate flow of sap, the inflorescences are struck evenly with traditional tools such as wooden ladle to accelerate the flow of sap. The collection of sap as shown in Figure 1, requires time (at least of 8–12 h) and traditionally the surface of the collection bowl is coated to prevent fermentation of sucrose in the sap (Ghosh et al., 2018; Hebbar et al., 2022). Freshly collected sap is sweet, golden brown in color and slightly alkaline (average pH of 7.8) and ferments rapidly within 2-3 h to lower pH under room conditions if not refrigerated or properly preserved.

Wide variation in sap yields has been reported in many literature ranging from 0.2 – 1.5 L/ palm day, which is attributed to coconut variety (or genomes), length of internodes, size of inflorescence sheaths, season and time, age of plant and inflorescence and agronomical practices. Magat (1996) found a positive correlation between higher fruit set and plant age and higher sap production. However, younger and well-maintained plants produce high-quality sap for sugar production (Asha et al., 2019). Borin and Preston (1995) also noted that sap flow varies with time and reported a higher sap flow during the night compared to the day.

Sap nutritional composition

Coconut sap is highly rich in nutrients, and its nutritional composition and quality varies with location, time and tapping duration (Xia et al., 2011). Because of its nutritional properties, some researchers have often proposed the use of coconut sap for babies whose mothers are unable to produce breast milk. As a result of high sugar content (15%), coconut sap is susceptible to spontaneous fermentation by lactic acid bacteria, which reduces the sugar to 5% hence initiating the preservation mechanism. The sap also contains amino acids, organic acids, vitamins (Hebbar et al., 2020; TOMOMATSU et al., 1996; Xia et al., 2011), protein, phenolics, antioxidants (Devi et al., 2015) and minerals (Flores-Gallegos et al., 2019).

The sugar composition identified in coconut sap is sucrose, fructose and glucose and there is a general agreement in the literature that sucrose accounts for a high percentage of the identified sugar in the sap. However, the percentage reported for each type of sugar differs from one study to another. For example, Asghar, Muhammad Tuseef, Yus Aniza Yusof, Mohd Noriznan Mokhtar, et al. (2020) reported 6.91%, 3.48%, and 2.53%, while Somawiharja et al. (2018) observed 5.76%, 3.23%, and 2.25% for sucrose, fructose and glucose, respectively. In the work published by Veena et al. (2018), 13.8% sucrose was detected in coconut sap whilst fructose and glucose were not detected in the sap. Previously, sucrose content of 17.78% was reported in coconut sap (Nurhadi et al., 2018), and these variations are ascribed to coconut varieties, time and method of tapping and plant maturity. Other sugars such as mannose and glycerol were also discovered in minute qualities by Ysidor et al. (2014).

So far, 16 amino acids have been detected in coconut sap (Flores-Gallegos et al., 2019; Magat, 1996; Xia et al., 2011), but only 12 of them were identified by Chinnamma et al. (2019). The most interesting aspect of the amino acid constituents in coconut sap is the presence of all the essential amino acids required for human growth, which is why it is recommended by many for infants. Chinnamma et al. (2019) reported higher content of histidine, cystine, arginine and tyrosine in coconut sap, whereas Purnomo (2007) observed glutamic acid, aspartic acid, threonine and serine as prominent amino acids in fresh sap.

Figure 1: Traditional method used to collect coconut sap in Ghana

Eleven (11) water-soluble vitamins were detected in coconut sap, with vitamin C (116 mg/L) showing the highest value, while B7 also known as biotin was found to be only 0.0017 mg/L (Asghar, Muhammad Tuseef, Yus Aniza Yusof, Mohd Noriznan Mokhtar, et al., 2020; Sudha et al., 2019). The other water-soluble vitamins identified are B1, B2, B3, B4 B6, B8, B9, B10 and B12. Ghosh et al. (2018) detected vitamin E and associated coconut sap consumption with an increase in normal liver function. In addition to the water-soluble vitamin, Hebbar et al. (2020) also observed fat-soluble-vitamins such as ergocalciferol, tocopherol, cholecalciferol, vitamin K1, and K2. Coconut sap contains many phenolic compounds, of which Borse et al. (2007) identified and quantified twenty-one (21). Among the identified volatile compounds discovered by gas chromatographic–mass spectrometric analysis, palmitic acid was most dominant volatile phenolic compound, reaching 2.024 mg/100 g with a retention time of 88.68 min. In addition to palmitic acid, other dominant volatile compound constituents include 3-hydroxy-2-pentanone, ethyl lactate, ethyl lactate, phenylethyl alcohol, tetradecanone, farnesol and 2-methyl tetrahydrofuran (Hebbar et al., 2018). Interestingly, more phenolic compounds are detected when coconut sap is fermented or converted to sugar through Maillard reaction.

Several mineral compositions in coconut sap have been reported in literature. For example, Asghar, Muhammad Tuseef, Yus Aniza Yusof, Mohd Noriznan Mokhtar, et al. (2020) observed 8 minerals, namely potassium, calcium, sodium, magnesium, manganese, iron and zinc in varying quantities. However, potassium (960.87 mg/L) dominated in terms of quantities followed by sodium (183.21 mg/L) and magnesium (22.91 mg/L). In addition, phosphorus and copper were also detected in coconut sap, as reported by Sudha et al. (2019). Traces of selenium were also detected and reported Dayrit and Nguyen (2020). Finally, chlorine and bromine were reported to bring the total mineral elements in coconut sap to thirteen (Joelle et al. (2017).

Production of Coconut Brown Sugar

Coconut sap is susceptible to fermentation due to its high sucrose content; hence it is frozen or processed immediately after collection. Coconut sap sugar is one of the secondary processing products. It has a longer shelf life compared to sap. Traditionally, sap is concentrated by applying heat at a temperature of 100-120^{o}C for a period of 3-5 h in an open pan. It is well known that processing conditions such as high temperature and prolonged heating time affect the quality of sugar, so an alternative approach is being sought to improve the chemical and physical properties of the final product (Asghar, Muhammad Tuseef, Yus Aniza Yusof, Mohd Noriznan, et al., 2020). Instead of traditional open-source heating, microwave power has been successfully used to concentrate the sap into syrups and drastically reduce the heating time. In a study by Asghar, Muhammad T et al. (2020), the heating time for the conversion of coconut sap to sugar syrup using open heat or microwaves was significantly reduced from 46.8 min to 9.4 min. However, a microwave cannot be used to form sugar crystals because constant stirring is required.

Another clean and fast heating technique used in the production of coconut sugar is the rotary evaporation technique, which was adopted from the pharmaceutical industry. Rotary evaporation reduces the volume of water in the sap by distributing it in a thin film of a vessel interior at higher temperature and lower pressure. It is based on the principle that when the pressure on the solvent is reduced, evaporation of the analytes occurs as a result of the lower atmospheric pressure. Therefore, with an additional increase in temperature, solvent (water) in the coconut sap evaporates rapidly and concentrates the less volatile substance. The rotary evaporator consists of four main parts, namely water bath, condenser, solvent trap and rotor, which are used to fractionate solvent-phase mixtures to concentrate a particular compound of interest, as shown in Figure 2.

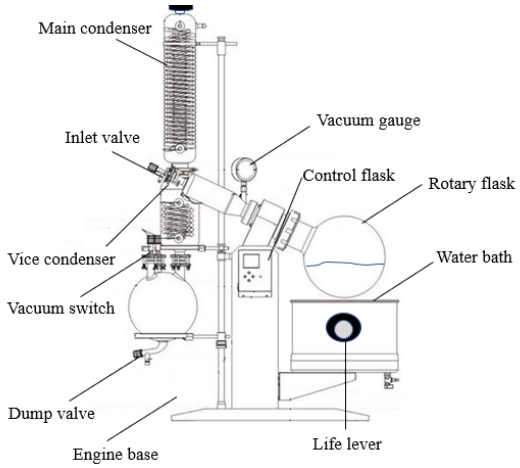

Figure 2. Rotary evaporation mechanism used to evaporate coconut sap

Rotary evaporation technology is quite new in the sugar industry, and therefore few researchers have reported its results in the industry. For example, Asghar, Muhammad T et al. (2020) reported the shortest processing time of 12.2 min for converting coconut sap into syrup compared to microwave (13 min) and open heating system (46.8 min). In addition to saving time, rotary evaporation operates at lower temperatures to reduce the browning reaction to improve the color formation of the final product. In terms of energy consumption, rotary evaporation has an advantage over the open heating system commonly used in the industry. However, a comparative energy analysis revealed that the microwave is the best choice in the coconut sugar industry.

Factors affecting quality aspect of coconut sugar

The quality aspect of coconut sugar in general has been discussed by different authors under two main aspects. These include quality related to the inherent properties of the coconut sap used to produce the sugar and the quality associated with processing, which may reduce its nutritional properties or make it unhealthy for consumption. Therefore, the quality aspect of coconut sugar is divided into two categories, namely inherent/natural factors and processing-related factors.

Natural factors known to affect coconut sugar include seasons, with dry seasons found to produce more nutritious sugar than rainy seasons (Susanti et al., 2021). Other inherent or natural factors that play a critical role in the quality of coconut sugar include soil type, plant variety, inflorescence size, time and age of the plant.

Processing factors that affect sugar quality begin with sap extraction, where the tools used have a direct impact on the quality of the sugar produced. During tapping, some practices such as mixing the already tapped sap with the freshly tapped one generally reduce the quality of the sugar. The use of hazardous chemicals such as sodium bisulfite to reduce the enzymatic browning reaction has health implications and thus affects the quality of coconut sugar (Sarpong et al., 2018). Processing temperatures are also directly related to the colour formation of the final products. In this case, higher temperatures lead to a stronger browning reaction as shown by Maillard reactions in Figure 3. To produce Maillard reactions, amino acids and sugars are converted in the presence of heat to 2-furoylmethyl-amino acids (2-FM-AA), which are often used to describe the onset of the Maillard reaction. The 2-FM-AA are measured by high-performance liquid chromatography (HPLC) to determine the degree of Maillard reaction in agricultural products. The 2-FM-AA compound further reacts with amino acids to produce Amadori products to initiate the formation of brown pigmentations (Sarpong et al., 2019)

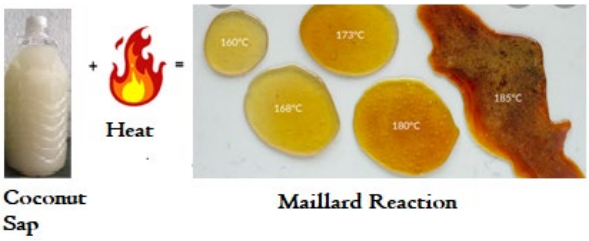

Figure 3. Depiction of temperature effect on Maillard reaction in sugar production

Comparative Nutritional Analysis of Coconut Sap and Sugar

The nutritional composition of brown coconut sugar depends in part on the conditions and method used in processing. Compared to sap, it can be seen that the nutrients in the brown sugar either increase or decrease depending on the processing conditions. In some cases, new phenols and flavors are formed in the brown sugars during processing of the sap to increase the nutrient composition. For instance, Kabir and Lorjaroenphon (2014) discovered nineteen additional volatile compounds compared to coconut sap and concluded that acetic acid is the most abundant compound in coconut sugar. This is attributed to the formation of amino-complex compounds that releases additional aroma-containing volatiles upon heating and continue to increase over time (Reineccius, 1999). However, other heat-sensitive nutrients such as proteins, vitamins, polyphenols, etc., are generally reduced during the conversion of sap to brown sugar.

Health Benefits of Coconut Brown Sugar

The nutritious component of brown coconut sugar is praised by health experts around the world compared to other forms of sugar. This is because coconut sugar contains comparatively high levels of antioxidants, which are known to protect cells from free radicals, preventing heart disorders, cancer, and inflammatory diseases (Jiang & Medicine, 2014). In addition, the polyphenol content of coconut sugar has been found to play an important role in controlling blood pressure by promoting good blood flow (Famurewa & Ejezie, 2018). Famurewa and Ejezie (2018) reported that the polyphenol content of food components has the ability to inhibit cancer cell formation by reducing DNA hypermethylation. Finally, regular consumption of coconut sugar promotes anti-inflammation defense mechanism in humans due to its high polyphenol contents (Sunil et al., 2020)

The numerous vitamins in coconut sugar also play an importance role in metabolic reactions by acting as transcription effectors and electron donors (Gunnar, 2018). In addition to the general well-being of vitamins in the body, individual vitamins have various health roles in the body to ensure the overall functioning of the human system. For example, the metabolic activities of cells and their functions are maximized when B vitamins are present, and coconut sugar in particular contains all the different forms of vitamin B-complex (Rajamohan & Archana, 2018). Thiamine (vitamin B1) in coconut sugar is known to promote the metabolism of fats, proteins, and carbohydrates, whilst riboflavin (vitamin B2) on the other hand, supports the breakdown of steroids, hormones, and drugs. Therefore, people with diabetics condition are recommended to include coconut sugar in their diet to break down sugar and lower sugar levels (Rajamohan & Archana, 2018; Scrob et al., 2022). This is because research by Chen et al. (2017) revealed that thiamine significantly improved insulin levels in patients within six weeks of administration. Finally, thiamine found in coconut sugar plays a vital role in converting food into energy and also helps in the formation of brain cells (Chen et al., 2017). Other B-complex vitamins such as B3 and B6 found in coconut sugar play a significant role in the formation of coenzymes used in digestion and contribute to the proper functioning of the nervous system (Chen et al., 2017).

Coconut sugar contains 16 amino acids, including all the essential amino acids used as building blocks for polypeptides and proteins. The health benefits of these amino acids contained in coconut sugar are very important for the formation of neurotransmitter, which is important for digestion and immune response (Asha et al., 2019; Li et al., 2021). Purnomo (2007) discovered histidine, one of the essential amino acids in coconut sugar, which is known to play a vital role in digestion, immune response, sleep-wake cycles, and sexual function. Besides, histidine also functions as a shaping myelin sheath around the central nervous system and serves as a barrier for nerve cells. Another essential amino acid is threonine, which is abundant in coconut sugar and has an important function in the formation of elastin and collagen for healthy skin and connective tissue.

Other amino acids such as glutamine and arginine protect the stomach and gastrointestinal tract and help remove excess ammonia from the body.

Coconut sugar contains important minerals such as potassium, sodium, and magnesium (Asghar, Muhammad Tuseef, Yus Aniza Yusof, Mohd Noriznan Mokhtar, et al., 2020), which regulate body's water content and cell hydration. These minerals also play an important role in many heart, nerve, and muscle functions. Coconut sugar prevents kidney stone formation and renal diseases by flushing out formed stones and plays an important role in the revitalization and proper functioning of the kidney due to its high potassium content (Anwar et al., 2018).

In addition, coconut sugar contains trace elements such as iron, zinc, bromine, and calcium, which are known to strengthen bones (Okoma et al., 2020). The minerals found in coconut sugar, especially potassium and iron, play an important role in maintaining cardiac automatism and promoting digestion and assimilation (Okoma et al., 2020). Coconut sugar is considered a raw food because it is made only from dehydrated coconut sap and thus contains all the beneficial antioxidants such as polyphenols, flavonoids and anthocyanidins of the original source. These antioxidants prevent cell oxidation in the body and thus prevent ageing. Coconut sugar contains polyphenols, dietary fibers and amino acids such as leucine, isoleucine, and arginine, which have the potential to scavenge free radicals and control streptozotocin-induced hyperglycemia (Renjith et al., 2013). Coconut sugar is rich in vitamin C, which supports healthy joints and skin and boosts the immune system. It also contains inulin, which balances blood glucose levels by slowing glucose absorption, preventing colon cancer, and protecting the intestines. Inulin plays an important role in reducing the risk of intestinal diseases such as irritable bowel disease and colon cancer (Shoaib et al., 2016). Inulin stimulates the immune system, which fights harmful substances in the body by identifying and acting on antigens (Shoaib et al., 2016). Coconut sugar also contains dietary fiber, which supports weight loss, improves serum lipoprotein levels, reduces the risk of coronary heart disease, stroke, hypertension, gastrointestinal disease, and obesity, and improves blood glucose control in diabetic patients (Anderson et al., 2009). Coconut sugar contains polyphenols that inhibit lipogenesis, reduce inflammation, and improve weight loss and maintenance (Wang et al., 2014). Flavonoids present in coconut sugar neutralize free radicals and help reduce cancer risk by inhibiting cell growth in tumours (Wang et al., 2014). Flavonoids have been reported to lower blood pressure, reduce platelet activity, modulate enzymes, and promote vascular health (Zhou et al., 2016)

Glycemic Index

Sugar consumption in foods, beverages, and confectionery has recently increased the threat of diabetes, obesity, hypertension, and heart disease in many people worldwide (Chattopadhyay et al., 2014), which is due to their high glycemic index. The glycemic index (GI) is a food classification system based on how a food affects blood glucose levels compared to a standard glucose solution or starchy food (Trinidad et al., 2010). GI is used to categorize carbohydrate-containing foods, as well as their ability to raise blood sugar and how quickly they do so. A glycemic index between 70 and 100 is considered high, between 56 and 69 is considered medium, and from 0 to 55 is considered low (Ghosh et al., 2018). Foods with a low glycemic index contain unrefined and complex carbohydrates that break down slowly into glucose, therefore limiting the release of usable energy and thus controlling blood sugar levels. Coconut sugar has a lower GI of 35 (Asghar, Muhammad Tuseef, Yus Aniza Yusof, Mohd Noriznan Mokhtar, et al., 2020; Trinidad et al., 2010) compared to most commercial sugars such as table sugar, cane sugar, and honey with a glycemic index of 70, 68, and 55, respectively (Ghosh et al., 2018). This implies that coconut sugar has the potential to reduce blood sugar levels, reduce cholesterol and maintain body weight when compared with other forms of sugar. From the perspective of GI, incorporating coconut sugar into the diet has the benefit of reducing the risk of heart disease, preventing type 2 diabetes, curbing appetite to reduce body mass and promoting the general well-being of the body.

Future prospect of the industry

Brown coconut sugar is rapidly becoming a trading commodity among Asian countries such as Indonesia, Philippines and Thailand, which have the potential to catch up in terms of production in the global market. The size of the global market for this commodity was 123,408 metric tons in 2020, valued at USD 1.33 billion, with a compound annual growth rate (CAGR) of 8% (WIRE, 2020). The brown coconut sugar market is very lucrative, as it is a global alternative consumption to white sugar, which is directly correlated with obesity, hypertension and heart disease; and has recently surged. This has attracted wealthy countries to import the commodity in large quantities for their citizens (Figure 4). Currently, China is the leading importer with a market share of 17.29%, whilst Indonesia is the leading exporter of the commodity. The market trend is projected to flourish in the coming days in Europe due to its nutritional benefits as compared to other forms of sugar in the international market. Due to the rising population and health awareness, all the market analysts have predicted lucrative growth of the commodity in the Asia-Pacific and Europe (Tridge, 2022).

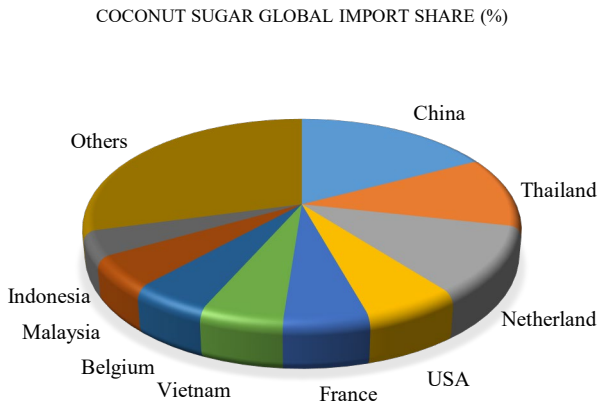

Figure 4. The global import market share of coconut brown sugar. Source (Tridge, 2022)

The commodity can be easily melted and mixed in recipes while creating a caramel-flavoured aroma, which has led to an increase in global demand of the commodity, attracting wider usage (Research, 2022). In addition to the direct consumption of the commodity, coconut sugar has a variety of uses. For instance, coconut sugar is used in the cosmetics and personal care industry for body scrubs, lotions, and creams as it has exfoliating and non-toxic properties, which has contributed to their market growth. The bakery industry has also discovered the product through its use in seasoning, beverages, confectionery, and baking.

Therefore, natural sweeteners such as coconut sugar have received much attention in recent decades as a healthier alternative. Coconut sugar production provides a better opportunity for coconut farmers by generating additional income for their businesses. Asghar, Muhammad Tuseef, Yus Aniza Yusof, Mohd Noriznan Mokhtar, et al. (2020) documented that one hectare of coconut can produce about 19 tons of sugar per year, which is more than sugarcane production (5-10 tons of sugar per year). In addition, the production of coconut sugar provides a great benefit to the environment, consumers, and the local economy (Hebbar et al., 2015).

The commodity market also faces some constraints, such as getting large volumes onto the global market, as processing is very labor-intensive. With the goal of producing environmental-friendly products, the processing of the commodity has further slowed down, which has hindered the release of the product to meet the market demand. Another obstacle in the industry is the cost of production, which is comparatively higher than processing other forms of sugar. To mitigate these challenges, it is proposed to mechanize processing to reduce the labor intensity and shorten production time.

Conclusion

In this paper, we reviewed recent developments in the coconut sugar industry, the health benefits, and future prospects for the industry. It became clear that coconut sugar is superior to sweetener available in the market due to its nutritional properties. It was observed that coconut sugar contains all the essential amino acids, 16 vitamins, numerous identified and quantified phenolic compounds, and several minerals in various proportions. Due to its high susceptibility to fermentation, coconut sap is processed into sugar, with methods such as open heat, microwave, and rotary evaporation. Brown coconut sugar is highly rich in nutrients with accompanying health benefits, and has drawn global attention to the commodity such that production is not able to meet the demand. This is due to some limitations, such as high labor intensity, environmental-friendly demand and lack of mechanization. However, the future prospects for the commodity are promising, as the growing awareness of its health benefits supersedes the available alternatives.

Declarations

Conflict of Interest

The authors report no conflicts of interest.

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