Brown Sugarcane as The Forthcoming Innovation for Athlete's Sports Food Product: A Narrative Review

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ABSTRACT

Brown sugarcane is widely known as an additional sweetener in cuisines and beverages. Brown sugarcane has higher contents of carbohydrates, fats, and proteins than brown coconut or palm sap sugar. Athletes usually consume such food before, during, and after a match to restore nutrients. It also benefits as reserves during endurance sports because carbohydrate content can be used to supply energy during the long duration of competition. Simple carbohydrates in brown sugar cane are known to be able to increase blood glucose gradually. This condition provides good benefits for athletes, because the energy source reserves can be stored longer and fatigue can be delayed. Diverse sports food products, such as sports drinks, gels, or bars, could be developed from brown sugarcane. Additional materials are adjusted to the sport of developed food and beverage. Notwithstanding, studies regarding the product development and metabolic effect of brown sugarcane supplementary are needed, particularly during exercise.

Keywords: *Athletes, brown sugarcane, sport food.*

1. Introduction

The study on brown sugarcane have been initiated since 1937, but additional efforts must be made to find it in scientific journals because of the diverse names in each country, including *panela* (Latino America), *jaggery* (South Asia), *kokuto* (Japan), *hakura* (Sri Lanka), *rapadura* (Brazil), *gur* (Pakistan), *tabazard* (Iran), and *gula merah* (Indonesia and Malaysia) (Kouhestani & Honarvar, 2021; Kumar & Singh, 2020). Sucrose is the predominant nutrient in brown sugarcane (Shrivastav et al., 2016; Singh et al., 2015; Singh, 2013).

Saccharum, the scientific name of brown sugarcane meaning "sugar," is in parallel with the main substance of sugarcane juice. Brown sugarcane is a product derived from sugarcane that is evaporated to reduce the water content as much as possible. Brown sugarcane has higher carbohydrate, fat, and protein contents than coconut or palm sap sugar. The micronutrient contents of Ca, Mg, Mn, and Zn, which potentially improve health, are also above these three (Asghar et al., 2020).

Saktibalan et al. (2018) investigated the effect of brown sugarcane supplementation on female college students with iron deficiency anemia (Sakhtibalan et al., 2018). The antioxidant activity of brown sugarcane is 26,400 µmol TE/100 g, which is greater than that of berries but lower than that of cacao. A study by Yukiko et al. in mice showed that antioxidants in brown sugarcane could suppress stress markers after 15 min of consumption (Kinjo et al., 2019). The classification of brown sugarcane in Indonesia has been reported in SNI No. 01-6237-2000 (Badan Standardisasi Nasional (BSN), 2002). Brown sugarcane

(category I) has a 65% sucrose content and varies in color from dark brown to light brown. The most feasible innovation for carbohydrates, its main component, is carbohydrate-rich food, which is essential for sports and exercise.

Endurance exercise requires an additional intake of carbohydrates to supply sufficient energy in addition to the main meal. (Kerksick et al., 2018; Thomas et al., 2016). Sports food is a common term used to describe a supplementary diet to restore nutrients from exercise. Several studies have reported the positive effects of supplementary sports food on athlete performance (AIS, 2019; Kaviani et al., 2019; Martínez-Sanz et al., 2020). Various types of simple sugars are known to be beneficial as energy sources for athletes. However, researchers want to see the benefits of simple sugars in brown sugar cane as an energy source during sports and the potential for product development that can be done.

2. Methods

Articles involved in this review were searched in 2021 – 2024. Searching for the article used Google Schoolar and PubMed. Keywords used for the article were "carbohydrate" "brown sugarcane" "glycemic index" "athlete". The search results were limited to human studies that were written in English. PRISMA flow diagram for article include in this review shown on Figure 1.

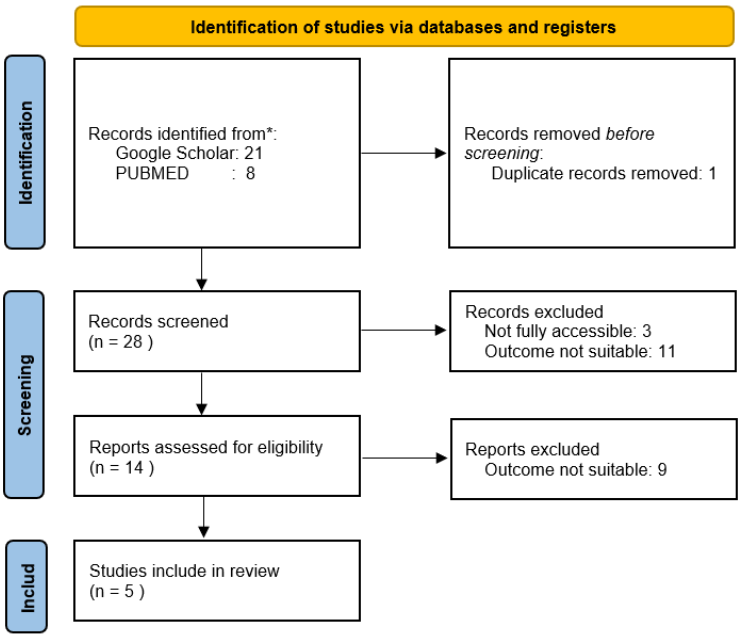

Figure 1. PRISMA Flow Diagram for Article Search

3. Results and Discussion

3.1 Type of Brown Sugar

Brown sugarcane marketed in Indonesia is made from a variety of ingredients, including sugarcane, coconut sap, and palm sap. It was obtained from *Coconus nucifer* L. and *Borassus flabellifer* Linn trees. Sap was obtained from the tree's hilt (Asghar et al., 2020). Each coconut tree produces no less than 3 L of sap every day, collected twice in the morning and afternoon. The harvested sap was placed in a plastic container or bamboo and then stored

overnight for 8–12 h. Subsequently, it was enhanced with lemon to prevent fermentation before evaporation (Wrage et al., 2019).

The brown sugarcane process begins with heating the sap until it is caramelized to a certain tier, which is later called "sugar gel." Afterward, the sugar gel was placed in a bamboo container or other molds and then set aside until solidification (Saputro et al., 2019). A previous study revealed that the glycemic index of brown coconut sap sugar is 35. The nutritional content of brown coconut sap sugar is shown in Table 1.

Table 1. Nutritional Content of Brown Coconut Sap Sugar

Nutritional Contents	Quantity (%)
Total carbohydrates	23.27 – 71.89
Sucrose	59.15 – 84.37
Reducing sugar	3.54 – 23.94
Fructose	4.44 – 23.55
Glucose	4.01 – 24.13

Source: (Naknean & Meenune, 2011)

Devi et al. (2015) showed that brown coconut sap sugar contains various micronutrients, including iron, zinc, calcium, sodium, potassium, dietary fiber, inulin, polyphenols, flavonoids, and antioxidants (Devi et al., 2015). Ascorbic acids and inhibitors, such as acarbose, miglitol, and vaglinose, are also found in brown coconut sap sugars. These contents hinder carbohydrate and glucose absorption, and hence are unfit for the main ingredient innovation of sports food.

Brown palm sap sugar originates from *Arenga pinnata* or palm, renowned as *Enau* or *Aren* trees in Indonesia. The manufacturing process did not differ from the previous process for brown coconut sap sugar. To start, the sap was heated at 127 ℃ for 157 min, set aside for < 5 min, and then stirred manually when the dough reached 93 ℃ until the sugar granules appeared (Victor & Orsat, 2018).

Victor & Orsat (2018) stated that brown palm sap sugar has a phenolic antioxidant content of 2432 + 32 µg/g, which is below that of brown sugarcane (3837 µg/g). Brown sugarcane is extracted from *Saccharum officinarum* Linn or sugarcane, widely known as *Tebu* tree in Indonesia, is extracted from *Saccharum officinarum* Linn. or sugarcane (Kouhestani & Honarvar, 2021).

Saccharum, which means "sugar," contains sucrose as its major component. Brown sugarcane is a product derived from the evaporation of sugarcane juice, which reduces the water content as much as possible. The majority of marketed brown sugarcane is compact in shape and darker in color among the three types mentioned above because of the non-enzymatic browning process of fructose and glucose with the amino acids (Asikin et al., 2014).

Asghar et al. (2020) revealed that brown sugarcane has a greater number of carbohydrates, fats, and proteins than brown coconut or palm sap sugar. The mineral contents of Ca, Mg, Mn, and Zn were also substantially above these three. In this analysis, product development for sports food focuses on brown sugarcane. Brown coconut and palm sap sugars are suitable

alternatives for bakery development. This finding is in accordance with the study by Srikaeo that brown coconut and palm sap sugar are finer than brown sugarcane in flour-based foods (Srikaeo & Thongta, 2015).

3.2 Shape of Brown Sugarcane

Brown sugarcane is classified into three types according to its shape: liquid, granular, and solid. This variability lies in the manufacturing process of using the same sugarcane juice. First, liquid brown sugarcane begins by heating sugarcane juice to minimize water components continuously until a condensed-like syrup (liquid and thick) is obtained. The quality depends on the sugarcane, additional ingredients (typically precipitating agents), and temperature during the process (Singh, 2013).

The heating process ceases at 103 – 106 ℃ to obtain the maximum product. Additional ingredients, such as 0.4% (400 mg/kg) nitrate acid, prevented crystallization and improved color. Benzoic acid maintains the quality of liquid brown sugarcane during its shelf life (Singh, 2013).

Liquid brown sugarcane was stored for 8–10 days at room temperature. It was then filtered and packaged before being distributed in the market. The nutritional contents in a 100 mL liquid are 30%–35% water, 40%–60% sucrose, 15%–25% reducing sugar, 0.3% calcium, 8.5–10 mg iron, and 0.5 mg phosphor (Singh, 2013).

Second, granular brown sugarcane, the initial process of manufacturing granular brown sugarcane, is indistinguishable from liquid brown sugarcane. Before heating the sugarcane juice, a higher temperature were set for granules at 120 ℃. Precipitates appeared when temperature was attained. They were then scratched or sieved to obtain the granules (Kumar & Singh, 2020). Other food additives, such as lemon, were poured to achieve an optimal pH of 6–6.2, during heating. The finished granules were approximately 3 mm in diameter. Thereafter, they were reheated in the sun until the optimal moisture was reached and wrapped. The polyethylene-based wrapper preserves the quality of the granules for up to two years. The nutrient content of granular brown sugarcane for every 100 g is 88.6% sucrose with expected moisture of 1.65%, 5–9 g reducing sugar, 9 mg calcium, and 12 mg iron (Kumar & Singh, 2020).

Third, in solid brown sugarcane, this variation is manufactured to acquire a product with the least water component. Additional ingredients, such as extract deola, are added for refining sugarcane juice at a ratio of 45 g for every 100 kg juice. It strives for a brighter color because refinement separates the precipitates beneath (Kumar & Singh, 2020). Asikin et al. revealed that solid brown sugarcane is safely preserved in storage for up to one year (Asikin et al., 2014). The color variance of sugarcane is a result of the non-enzymatic browning process. It might become darker by 12.5% because of the interaction between complex amino acids and reducing sugars. However, the sucrose content was highly similar to the shelf life.

3.3 Nutrition Aspects of Brown Sugarcane

Brown sugarcane has a constructive impact on health and multiple studies have proven its efficacy (Jaffe, 2012; Kinjo et al., 2019; Kumar & Singh, 2020). In brief, these two

essential components of brown sugarcane positively improve the wellness. Sugar components comprise the majority of brown sugarcane components, with 88– 93% sucrose, but another derived sugarcane product, granulated white sugar, possesses up to 99% sucrose. Another study reported that brown sugarcane contains 50% sucrose and 20% reducing sugars. The chemical structures of brown and white sugars vary. Brown sugarcane comprises long-chain sucrose, which is predicted to cause slower digestion (Kumar & Singh, 2020). In regard to the facts, sucrose from brown sugarcane can be utilized as a reserve for the body. Endurance athletes can use brown sugarcane as the main carbohydrate source during endurance competitions.

Minerals (potassium and iron) are more predominant than other sugars because they contain vitamins and minerals, some of which can be alternatives to attain daily needs (Kumar & Singh, 2020). For instance, every 100 g of brown sugarcane contains 1056 mg of potassium (Kumar & Singh, 2020). The Indonesian Recommended Dietary Allowance of potassium is 4700 mg per day (Kementerian Kesehatan Republik Indonesia, 2019). Hence, the intake of 100 g of brown sugarcane fulfills a quarter of the total potassium needs. Brown sugarcane also comprises 0.2–0.5 mg mangan, which expectedly meets 25% of human needs per day (2.3 mg) (Kumar & Singh, 2020).

Brown sugarcane also contains 10–13 mg of iron per 100 g (Kumar & Singh, 2020). Other investigations stated similarly at 12.8+1.2 mg/100 gr (Sulakshana & Udipi, 2017). This number is predicted to comply with 100% iron needs of adult men (9 mg) and up to 55– 70% of the iron needs of adult women (18 mg) per day (Kementerian Kesehatan Republik Indonesia, 2019).

Saktibalan et al. (2018) utilized brown sugarcane for iron supplementation in female college students with iron-deficiency anemia. Brown sugarcane (10 g) was administered daily for 8 weeks consecutively. Every 10 g brown sugarcane comprises 8 mg calcium, 0.3 mg iron, 16 mg magnesium, 13 mg potassium, 9.8 g carbohydrates, and 40 kcal of energy. The results revealed an increase in hemoglobin levels in the subjects. Its application in athletes prevents iron deficiency anemia. Vitamins can also meet daily needs. The daily recommended allowance for niacin (vitamin B3) in adults is 16 mg (Kementerian Kesehatan Republik Indonesia, 2019). Every 100 g of brown sugarcane contains 7 mg niacin (vitamin B3) (Kumar & Singh, 2020). Vitamin B3 is a beneficial coenzyme component of nicotinamide adenine nucleotide (NAD) and nicotinamide adenine nucleotide phosphate (NADP) (Fink & Mikesky, 2015; Penggalih et al., 2019). Niacin also plays a role in mitochondrial energy metabolism in the mitochondria (Fink & Mikesky, 2015).

The antioxidant activity of brown sugarcane (26.400 µmol TE/100 g) is much greater than that of berries. Yukiko et al., asserted that brown sugarcane antioxidants are apt to subdue stress markers 15 minutes after consumption in mice (Kinjo et al., 2019). Five types of antioxidants, p-hydroxybenzaldehyde, p-hydroxy acetophenone, schaftoside, isoschaftoside, and p-coumaric acid, have mechanisms for suppressing stress markers.

p-Hydroxybenzaldehyde is responsive to γ-aminobutyric acid (GABA), a neurotransmitter in the mammalian brain that inhibits the activation of the hypothalamic–pituitary–adrenal (HPA) axis regulation. The stimulated HPA axis (as a result of stress or other actions such as exercise) draws adrenocortical hormones to secrete glucocorticoids. It

triggers cortisol secretion in humans and corticosterone in mice, both of which are stress markers (Kinjo et al., 2019; Vitaminol et al., 2000).

p-Hydroxybenzaldehyde inhibits GABA transaminase enzyme, which degrades the neurotransmitter GABA, thus reducing GABA degradation. The controlled GABA enzyme impedes the HPA axis activity and suppresses stress markers in the body. Yukiko's study is in line with another study that revealed that the p-hydroxybenzaldehyde component is found in another sugarcane juice product, the molasses extract.

3.4 Athletes Sport Food

The Australian Institute of Sport (AIS) (2019) issued a supplemental classification list for athletes. It is categorized into four groups: A, B, C, and D. Group A comprises all supplements consumed by athletes in a particular quantity and time to boost their performance during matches or exercise, some of which are medical supplements, performance supplements, and sports food.

Sports foods are all foods and beverages that contain specific nutrients, usually consumed in unrealistic conditions for eating in normal portions (AIS, 2019). The major nutrients are carbohydrates, electrolytes, and proteins (AIS, 2019; Thomas et al., 2016). Sports food has a main component, in line with its aim and time.

The main goal of sports food consumption is to obtain specific nutrients when unable to consume normal food, such as when athletes require specific nutrients but are in a tight exercise schedule or have extremely short breaks between matches. In 2018, the International Society of Sports Nutrition recommended ingesting 500 mL of liquid, 250–350 mg of sodium, and 30–90 g of carbohydrates during exercise for 1 h (Kerksick et al., 2018).

Sports food is also provided daily as a meal supplement on a day (Comes et al., 2018; Wardenaar et al., 2017). The recommendation for athletes is mainly matched with the duration of games or rehearsal sessions. Figure 2 shows the sports food consumed by athletes during a match.

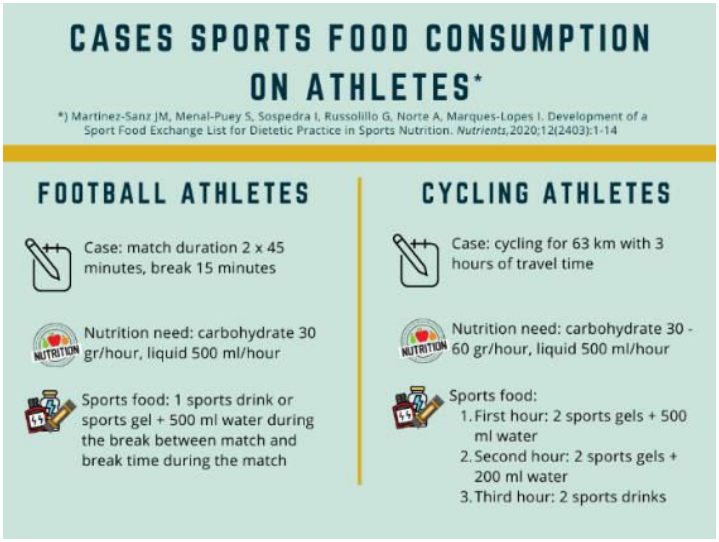

Figure 2. Example of sports food consumption during athlete's match
(Source: Martínez-Sanz et al., 2020)

Endurance sports involve long-duration matches. Performing for a long duration typically causes exhaustion, owing to the depletion of body energy reserves. Sports food consumption is expected to enhance energy consumption during exercise while considering the athlete's preference for a given type, either sports gels or sports drinks. If athletes feel full, sports gel will be the best choice because it has less quantity but contains the complete nutrients needed by athletes during endurance sports (Tharnpichet et al., 2019). Indispensably, it is ingested before, during, and after the exercise.

Peake et al. (2017) stated that sports food consumption before, during, and after exercise helps the immune system because it is related to the reduction in inflammatory cytokines induced by exercise. Sports food ingested before exercise is commonly utilized as a food substitute if athletes are incredibly unable to eat conventional meals. The later consumption of sports food focused on providing energy reserves during recovery (AIS, 2019). During a match, sports food provides carbohydrate storage for the muscles and central nervous system (Burke & Maughan, 2015). Moreover, multiple studies have revealed a positive correlation between sports food and athletes' performance (Pfeiffer et al., 2009; Scott et al., 2015).

Scott et al. (2015) found that rowing athletes perform better when consuming carbohydrate gel than when ingesting protein gel or none. These studies suggest that the development of sports food has a superior impact on athlete performance. The exploration of ingredients for sports food is potentially important to increase the diversity of sports food.

Table 3. Review of Article Summary

Reference	Title	Methods	Results
Jain & Venkatasubramanian, 2017	Sugarcane molasses – A potential dietary supplement in the management of iron deficiency anemia	A review literature study about molasses from sugarcane juice to develop nutraceutical products.	Sugarcane molasses show rich in iron and also contains some of the enhancers of iron absorption. Clinical evidance for sugarcane molasses as nutraceutical product still need development.
Saktibalan et al., 2018	Evaluation of efficacy of jaggery and raisins as supplements in iron deficiency anemia among medical undergraduate students in South India	A prospective interventional clinical endpoint study in tertiary care teaching hospital. Total respondent was 50 female medical undergraduate students between 18 – 25 years old. The oral supplementation was given once a day in the morning, after 3 hour of breakfast for 8 weeks.	The outcome of this study shows effective role for nutritional supplementation in improving hemoglobin. Combination of jaggery with raisins proved as a natural food supplementation.
Solichah et al., 2022	Sparing muscle glycogen in rats with brown sugarcane supplementation	An experimental study with 36 Sprague Dawley rats involved. Supplemention with brown sugarcane given before swimming activity to the rats.	The rats who were given sugarcane supplementation before swimming had a smaller increase in blood glucose. Muscle glycogen levels in the rats given sugarcane supplementation group were higher than in the other group.
Iqbal et al., 2020	Glycemic response of natural sweeteners like sugarcane juice, honey and jaggery in healthy individuals	An experimental study to examine glycemic index of natural sweeteners. 10 respondents were given the product, and test for blood glucose with Accu-check glucometer.	The glycemic response of honey, jaggery and sugarcane juice showed that all had good glycemic response (75.4; 80.7; 74.6).
Pradana et al., 2024	Effects of adding brown sugar in young coconut water post high-intensity interval training on plasma osmolarity, oxygen saturation, and pulse rate	An experimental study with pre and post test control group design. 20 male include in this research and each subject underwent a 30-minute ergo cycle HIIT session.	The results indicated plasma osmolarity levels showed no significant change from pre-HIIT to post-HIIT. Post-hydration shows significant decrease between the group. Oxygen saturation levels remain consistent both pre and post-HIIT. Adding brown sugar to young coconut water resulted in lower pulse rate.

3.5 Prospective Innovation of Brown Sugarcane for Athletes Sport Food

The classification of brown sugarcane in Indonesia has been reported on SNI No. 01-6237-2000, depicting two standards for brown sugarcane: grades I and II (BSN, 2002). Grade I brown sugarcane has higher sucrose (up to 65%), which is diverse in color from dark to light brown. Color heterogeneity is influenced by the raw material varieties. With regard to the SNI classification, the majority of compounds in brown sugarcane are carbohydrate–sucrose forms.

Carbohydrates are paramount compounds produced during exercise, particularly for long durations (AIS, 2019; Kerksick et al., 2017; Peake et al., 2017; Thomas et al., 2016). The key objective of carbohydrate supplementation during exercise is to supply energy from carbohydrates to the brain, the central nervous system, and muscles. Escalating athletes' performance from befitting carbohydrate exogens for long- or high-intensity sports. The regulation of muscle adaptation during exercise by glycogen is restored in the body directly or indirectly (Thomas et al., 2016).

Previous studies have reported that carbohydrate consumption during long-duration and frequent exercise averts cytokine rise in the blood and redistribution of neutrophils, monocytes, NK cells, and lymphocytes owing to a stable blood glucose level and less unleashed stress hormones, such as catecholamines and glucocorticoids (Peake et al., 2017). Thus, brown sugarcane could potentially be developed as a carbohydrate-rich food for athletes.

Simple carbohydrates in brown sugar cane can increase blood glucose levels gradually (Solichah et al., 2022). Although the increase in blood sugar is not higher than glucose, this condition can prevent the breakdown of muscle glycogen (Solichah et al., 2022). This is possible because the gradual release of simple sugars causes the insulin used to decrease. Decreased insulin use will cause the body to use metabolism through fat oxidation. This causes the substrate derived from carbohydrates (simple sugars and glycogen) to not be used (Kaviani et al., 2020). If this happens, the body has more glycogen reserves, and can delay fatigue during exercise.

Carbohydrate-rich sports foods commonly develop into drinks or gels. The main perks of sports food are easily consumed, absorbed, and carried, while fulfilling athletes' needs from dissolved carbohydrates and electrolytes. The recommended composition for sports gel is 60–70% of the carbohydrate in the total admixture (AIS, 2019). Electrolytes accommodate water retention and regulate thirst in endurance sports (AIS, 2019). Brown sugarcane is presumably the main simple carbohydrate source for sports food.

Brown sugar innovation focuses on three categories: sports drinks, sports gels, and sports bars, as these three are concerned with carbohydrates (Martínez-Sanz et al., 2020). Additional ingredients can be adjusted using a preferable local culture. Sports food is equivalent to the duration of exercise. In reference to AIS, no sports food supplementation is necessary for less than 45 min of short-duration exercise. High-intensity sports lasting approximately 45–75 min require <30 g carbohydrates, whereas those lasting 1–2.5 h require 30–60 g/h. Ultra-endurance sports exceeding 2.5 h are suggested to ingest 90 g/h of carbohydrates (AIS, 2019; Thomas et al., 2016).

This study has potential limitations. The analysis of the articles conducted in this study is still in the review stage of similar articles. Statistical analysis to see the magnitude of the effect or significance has not been done. In the future, this can be developed to deepen the discussion of the article.

4. Conclusion

Brown sugarcane is a derived product, in which sucrose is the predominant simple carbohydrate component. Brown sugarcane contains minerals, vitamins, and antioxidants, which provide health benefits to the body. With carbohydrate as the predominant nutrient, brown sugarcane is potentially an essential ingredient of carbohydrate-rich sports food. Simple carbohydrates in brown sugar cane can increase blood glucose levels gradually and has potential purpose for endurance exercise. Sports food products include supplementary food and beverages to replenish utilized nutrients and provide an energy alternative for athletes during endurance exercises. The uppermost sports food is drinks, gels, and bars. The carbohydrate composition can be established from brown sugarcane. Additional materials were used to develop food and beverages. Nevertheless, studies on the product development and metabolic effects of brown sugarcane supplements are needed, particularly during exercise.

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