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"NUTRITIONAL AND FUNCTIONAL PROPERTIES OF JACKFRUIT AND COCOA SEED POWDER: A COMPARATIVE REVIEW FOR INDUSTRY APPLICATIONS"

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Abstract : Cocoa and jackfruit seed powder are two plant-based products that have a lot of promise in the food sector. Their nutritional makeup, functional characteristics, and culinary uses are compared in this article. While cocoa powder is renowned for its polyphenol content, antioxidant qualities, and unique chocolate taste, jackfruit seed powder is high in carbs, dietary fibre, and vital minerals. Both components have special functional qualities, such as the ability to absorb water, bind oil, and emulsify, which affect their applicability in a variety of culinary compositions, including dairy substitutes, drinks, confections, and baked goods. Recent studies demonstrate the promise of jackfruit seed powder as an environmentally friendly alternative to cocoa, especially in foods with chocolate flavours. Potential study prospects are explored, as well as sensory acceptance, processing methods, and large-scale implementation. The significance of plant-based components in creating wholesome, affordable, and sustainable food products is emphasised in this study.

Keywords: *Jackfruit, Jackfruit seed powder, Cocoa Beans, Cocoa powder, sustainability, chocolate.*

1. **Introduction:** Jackfruit (*Artocarpus heterophyllus* Lam), it is a large tropical fruit that belongs to Moraceae family. It is native to Indian western Ghats and is cultivated in tropical and subtropical regions [1-4]. It is known for its large size, weighing from 2kg to 36kgs having 100 to 150 seeds per fruit. The seeds constitute about 8-25% of jackfruits weight [2,5]. Jackfruit seeds contain a good amount of carbohydrates (i.e. starch) about 70-85%, they also contain considerable amount of protein (about 6.6-13.5%) and dietary fiber (1-3.19%) [2,3,5]. Jackfruit seeds also have minerals which are essential such as calcium, potassium, iron, zinc, and some amount of vitamins (A, C, B1), along with polyphenols and flavonoids exhibiting antioxidant properties [3-5]. On the other hand, we have cocoa (*Theobroma cacao* L.) seeds, which undergo a distinct profile after being processed into cocoa powder [8,10]. One important method for developing flavour in cocoa beans is traditional fermentation [2,8,10] see *fig.2*. Cocoa beans are known to create flavour precursors and have a higher lipid content than jackfruit seeds [9,11]. Pyrazines are significant markers of flavour quality, and the aroma components in cocoa are well-characterized [2,8]. Cocoa seeds are traditionally used to make chocolate and cocoa drinks, which are highly sought-after due to their distinct flavour [2,10]. The scent profile of cocoa powder, an essential ingredient in many food applications, is used as a standard when assessing possible alternatives, such as roasted jackfruit seed flour [2,8].

Jackfruit seeds are commonly processed into powder by separating, washing, drying (which is frequently preceded by roasting at 160°C to improve nutrient retention and decrease moisture), and milling [3,5,6]. These seeds are typically eaten boiled or roasted [2, 5], the process flow diagram of jackfruit seed processing is given below *fig.1*. Jackfruit seed flour has a wide range of new applications, such as being used to make confections, extruded snacks, and baked goods; it can also be used to extract starch for use in food processing and bioplastics [1, 3, 5]. Notably, when roasted and particularly fermented and acidified, jackfruit seed flour has demonstrated promise as a cocoa alternative since it can acquire a chocolate scent, which has led to its successful application in recipes such as cappuccinos [2].

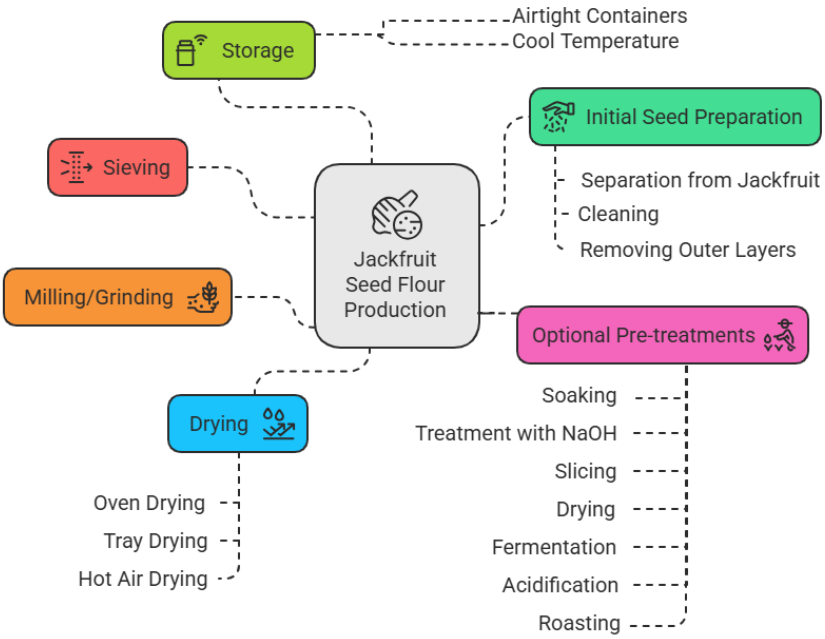

Figure 1. shows the production of jackfruit seed flour

Similar to the pre-treatment of jackfruit seeds, the fermentation of cocoa beans is essential to the creation of its distinctive flavour [2,8].

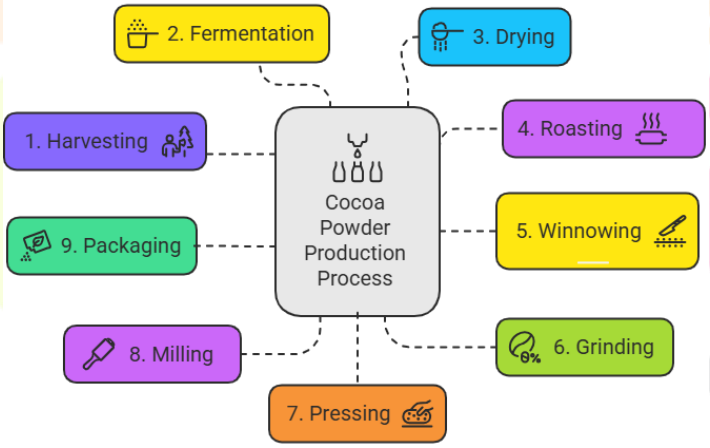

Figure 2. shows the production of cocoa powder from cocoa pods

In light of their high nutritional content and possible health advantages, plant-based components are becoming more and more important in food applications [1,5]. Particularly in areas where nutrient intake may be insufficient, these ingredients like jackfruit seed flour offer important proteins, carbs, dietary fiber, vitamins, minerals, and bioactive compounds that can help fight malnutrition and encourage healthy diets [1,5]. Underutilized and more nutrient-dense plant-based flours are increasingly being used in traditional cuisines as a result of increased awareness of the connection between nutrition and illness [1]. In addition to their nutritional worth, plant-based components have a variety of functional qualities that can greatly affect the texture, flavour, and general quality of food items. These qualities include bulk density, swelling power, emulsifying capabilities, and the ability to hold water and oil [1,7,12]. Additionally, using plant-based by-products like jackfruit seeds is in line with sustainability and waste reduction principles, providing affordable substitutes as well as chances to create novel and nutrient-dense food items like meat alternatives and cocoa substitutes [1, 2, 5, 7, 13]. Plant-based components can

be used in a variety of ways, such as creating gluten-free recipes and improving the physicochemical and sensory qualities of a broad range of foods [1,14]. Additionally, plant-based components' functional and sensory qualities can be altered and improved by processing methods like fermentation and roasting, creating new opportunities for their application in the food business [1, 2, 7, 15].

The article aims to present a thorough comparison of two plant-based substances that have a lot of promise for use in the food business. The scope would include a thorough examination of the nutritional profiles of cocoa seed powder and jackfruit seed powder, including the amounts of micronutrients (vitamins, minerals) and macronutrients (carbohydrates, protein, fat, and fiber) as well as the presence of bioactive substances like antioxidants and phytonutrients [3,5,14,17,18]. Additionally, a thorough comparison of their functional characteristics such as bulk density, swelling power, solubility, viscosity, water and oil holding capacities, and bulk density—that are essential for food formulation would be included in the review [1, 2, 5, 7, 12]. The scope would probably also include how other processing techniques, such as drying, roasting, fermentation, and acidity, affect these characteristics for both types of seeds [2,5,7]. Examining factors like aroma development (especially chocolate aroma in roasted jackfruit seeds due to pyrazines), sensory acceptability, and suitability for products like bakery items and beverages would be a major focus of research on the potential of jackfruit seed powder as a functional and nutritious substitute for cocoa powder in a

Table 1: Comparison of Nutrient and Mineral properties of Jackfruit and Cocoa Seed Powder.

S.No.	Nutrients and Minerals	Jackfruit seed powder	Cocoa powder	Sources
1	Protein(%)	11.9-13.9(range), 11.85 ± 0.45 (dry weight), 12.25 - 16.80 (range for different processing)	6.80 - 9.55 (range), 17.9 (NCP*), 12-13 (unroasted cocoa beans	[1,12,16,21,24,25]
2	Carbohydrates (%)	76.15, 26.20 ± 0.56 (dry weight)	61.00 - 62.47 (range), 60.0 (NCP*), >32 (unroasted cocoa beans), 16.3 (average)	[1,16,21,24-26]
3	Sugars (g/100g)	0.50 - 2.48 (range for different processing)	Less than 2	[12,26]
4	Fats (%)	1.44, 1 ± 0.006 (dry weight), 0.13 - 0.77 (range for different processing	10.05 - 12.65 (range), 13.6 (Natural Cocoa Liquor – NCL*), 16.1 (average), >40 (unroasted cocoa beans)	[1,12,16 21,24-26]
5	Ash (%)	0.96 ± 0.02, 0.15 ± 0.01 (dry weight)	5.32 - 6.41 (range), 4.63 (NCP), <6 (unroasted cocoa beans)	[1,16,21,24,25]
6	Crude fiber (%)	1.05	1.06 - 2.64 (range), 0.6 (NCP)	[1,21,24]
7	Moisture(%)	6.50 ± 0.07, 61.8 ± 0.09 (fresh weight)	5.12 - 7.10 (range), 6.56 (NCP), 5.95 (unroasted cocoa beans - Ecuador)	[1,16,21,24,25]
8	Zinc(Zn) (mg/100 g)	0.011 ± 0.11 (Volta Region of Ghana), 2.88 ± 0.20 (firm variety, Brazil), 3.44 ± 0.16 (soft variety, Brazil)	99.9 (NCP), 115 (NCL), 106 (ACP)	[1,24]
9	Manganese(Mn) (mg/100 g)	0.104 ± 0.89 (Volta Region of Ghana), 1.02 ± 0.11 (firm variety, Brazil), 1.10 ± 0.10 (soft variety, Brazil	1.93 (NCP), 12 (NCL), 1.18 (ACP)	[1,24]
10	Copper(Cu) (mg/100 g)	1.30 ± 12.37 (Volta Region of Ghana), 1.72 ± 0.13	3.96 (NCP), 2.27(ACP)	[1,24]

		(firm variety, Brazil), 1.45 ± 0.06 (soft variety, Brazil)		
11	Iron (Fe) (mg/100 g)	30.87 ± 16 (Volta Region of Ghana), 2.55 ± 0.21 (firm variety, Brazil), 2.93 ± 0.18 (soft variety, Brazil), 11.8 - 12 (range)	11 (NCP), 12 (NCL), 10.5 (ACP)	[1,24]
12	Calcium(Ca) (mg/100 g)	33.80 ± 3 (Volta Region of Ghana), 68.22 ± 0.46 (firm variety, Brazil), 88.10 ± 0.33 (soft variety, Brazil)	66.3 (NCP), 5.9 (NCL), 144.7 (ACP)	[1,24]
13	Sodium (Na) (mg/100 g)	147.81 ± 2 (Volta Region of Ghana), 3.07 ± 0.16 (firm variety, Brazil), 4.86 ± 0.24 (soft variety, Brazil)	141.1 (NCP), 16.9 (NCL), 66.3 (ACP)	[1,24]
14	Potassium (K) (mg/100 g)	2 (Volta Region of Ghana), 148.90 ± 0.58 (firm variety, Brazil), 151.09 ± 0.34 (soft variety, Brazil)	87.7 - 99.0 (range), 88.1 (NCP), 79.7 (NCL), 23.5 (ACP)	[1,24]
15	Phosphorus (P) (mg/100 g)	Not detected	696 (NCP), 736 (NCL), 726 (ACP)	[1,24]
16	Magnesium (Mg) (mg/100 g)	0.606 ± 2.01 (Volta Region of Ghana), 249.13 ± 0.21 (firm variety, Brazil), 215.09 ± 0.44 (soft variety, Brazil)	141.1 (NCP), 16.9 (NCL), 66.3 (ACP)	[1,24]

variety of food applications [2,5,7,10]. By examining the relative benefits and drawbacks of each powder, the review will help the food industry make well-informed decisions about their use in creating innovative, wholesome, and sustainable food products. It will also take into account the potential for jackfruit seeds and other underutilized resources to be valorised [1, 5].

2. Discussion

2.2. Nutrition: Jackfruit seed powder's macronutrient composition shows that it is especially high in carbs, mostly starch, with reported percentages ranging from 22% to 79.34% [3,14]. Additionally, it has a significant protein content; several studies have shown values ranging from 6.6% to 13.50% [3,5,14]. Jackfruit seeds typically have a modest fat content, ranging between 0.40 and 1.27% [3,14]. In contrast, the data we studied suggest that the lipid content of cocoa seed powder is higher than that of jackfruit seeds. Although the provided materials do not provide precise numbers for the carbohydrate, protein, and fat content of cocoa seed powder, they do highlight the aroma and the possibility of using roasted jackfruit seeds in place of cocoa [2,8]. Thus, according to studies, cocoa seed powder stands out for having a larger fat content, while jackfruit seed powder is distinguished by having a moderate protein level and a high carbohydrate content with low fat [1,3,5,16].

Numerous nutrients that are vital to human health can be found in significant amounts in jackfruit seed powder *(see Table 1)*. Significant levels of potassium, which is essential for controlling blood pressure [3], have been found in studies [3,5,16,18]. Concentrations as high as 14781 mg/kg [3] have been observed. With levels as high as 3087 mg/kg, calcium is another abundant mineral that is crucial for bone health [3,5,18]. Additionally, iron, which is essential for oxygen transport, is present; one research found 130.74 mg/kg [3]. Jackfruit seeds also include magnesium, phosphorus, sodium, copper, manganese, and zinc, a crucial microelement [1,3,5,14]. The type of jackfruit and its place of origin can affect the precise concentrations of these minerals [1,3,5]. Vitamin C content in jackfruit seeds ranges from 2.10 to 14.0 mg per 100g, according to reports [5,14,18]. Additionally, they contain B-complex vitamins, especially riboflavin and thiamine, which are uncommon in many fruits [3,6,17,18]. Vitamin A may also be present, according to certain publications [3,17,18]. These vitamins function as antioxidants and support a number of metabolic functions [6].

According to reports, the dietary fiber content of jackfruit seed powder ranges from 1.0% to 3.6% [5,14,18,19]. It has even been observed that jackfruit seeds have a higher fiber content than jackfruit pulp [5]. Jackfruit seed powder is a useful functional food ingredient because of its high dietary fiber content, which is important for many areas of human health [1]. This fiber's capacity to avoid constipation and encourage regular bowel movements makes it an important dietary component [1,5,18,19]. In addition to lowering the risk of heart disease, controlling high blood pressure, and lowering high cholesterol, the high fiber content aids in weight management by encouraging fullness [1, 5]. Furthermore, consuming enough fiber from jackfruit seeds is linked to improved blood glucose regulation, which suggests that products containing it may be appropriate for those with diabetes mellitus [1]. Additionally, the fiber supports digestive health. A lower incidence of cardiovascular disease and other cardiometabolic risk factors has been associated with increased dietary fiber intake [5]. When it comes to cocoa, the main attention has been on its scent profile and how jackfruit seed powder might be able to replace it based on aroma and other useful qualities [2,8].

*NCP-natural cocoa powder, NCL- Natural Cocoa Liquor, ACP- Alkalised Cocoa Powder

2.2. Bioactive Compounds and Health Benefits: Jackfruit seeds are known to contain a number of antioxidant components, such as flavonoids, tannins, and polyphenols [5,16,17]. The substantial total phenolic content (TPC) in jackfruit seeds—which is even said to be higher than in the edible flesh—has been the subject of numerous investigations [17,20]. The potent antioxidant qualities found in jackfruit seed extracts are closely linked to this high polyphenolic concentration [16]. Certain phenolic acids, such as tannic acid, gallic acid, ferulic acid, and caffeic acid, have been found in various jackfruit portions. According to certain research, jackfruit in its early phases, when the seeds and meat are inseparable, have a higher TPC [17,20]. Jackfruit seeds' antioxidant potential is also influenced by the flavonoids they contain [5,16-18]. The phytochemical profile of jackfruit is also influenced by tannins, another class of polyphenols [3,7,20]. Numerous tests, including as metal chelating, reducing power, and free radical scavenging, have been used to show the antioxidant activity of jackfruit seed extracts [16]. When it comes to reducing alcohol-induced cytotoxicity, the potent antioxidant properties of jackfruit axis extract are observed to be more effective than vitamin C [14]. Regarding cocoa, it is concentrated more on the production of aroma, especially through fermentation and roasting, and the potential of jackfruit seeds as a replacement due to their functional qualities and aroma [2,7,8,11]. Although it is stated that chocolate's high polyphenolic content has enormous health benefits [10], the studies does not specifically break down the polyphenols, flavonoids, or tannins that are found in cocoa seeds or cocoa seed powder. The impact of pulp preconditioning on the amount of polyphenols in cocoa beans during fermentation is mentioned in one study [2].

Jackfruit seeds have anti-diabetic and anti-inflammatory qualities. The anti-inflammatory and hypoglycaemic properties of the jackfruit plant, especially its seeds, have long been utilized in medicine [14,18]. Flavones, a noteworthy class of bioactive dietary components with anti-inflammatory qualities, are found in jackfruit seeds, which lends credence to this [3, 5]. Additionally, certain substances, such as artocarpin, which is extracted from jackfruit seeds, have the ability to block α-glucosidase and α-amylase [5]. Jackfruit seeds may be used as an ingredient in hypoglycaemic functional meals since these enzymes are involved in the metabolism of carbohydrates and their inhibition may result in hypoglycaemic effects [5]. Products containing jackfruit seeds may be appropriate for people with diabetes mellitus because of their high dietary fiber content, which also helps control blood glucose levels [1]. Additionally, a lower incidence of cardiovascular disease and other cardiometabolic risk factors is linked to higher intakes of dietary fiber, which is plentiful in jackfruit seeds [5]. Jackfruit seed powder's excellent nutritional profile contributes to cardiovascular health. It has a high dietary fiber content [1,5,14].

2.3. Functional properties and food application: Jackfruit seed flour (JSF) is a useful component in many culinary applications due to its many functional qualities [1]. Its water absorption capacity (WAC) is one of its noteworthy features. Research has indicated that JSF typically has a high WAC [1]. For example, (*Artocarpus heterophyllus)* JSF from different origins had WAC values that ranged from 72.00 ± 0.20% to 450 ± 70.71% [1]. The gelatinization of the starch in JSF is the cause of the high WAC [1]. Because it improves the texture and flavour of baked goods, this feature is preferred. JSF is also a good binding agent because it absorbs water more effectively than the majority of commercial flours. JSF also has a notable oil absorption capability (OAC). Nonetheless, some research suggests that extruded products containing JSF have low OAC, which may result in less fat and better product

performance. Nevertheless, JSF's capacity to absorb oil can help food products have a better texture and retain their flavour. Depending on where the jackfruit seed flour comes from, the fat absorption capacity (which is related to OAC) might vary from 86.00 ± 0.50% to 300 ± 0.00% [1].

Jackfruit seed protein isolates have demonstrated powerful foaming and emulsifying properties, indicating potential for use as food additives in these fields [5]. The flavour characteristics and texture of baked goods are positively impacted by the inclusion of jackfruit seed flour in composite flours, which may be indirectly related to some degree of emulsification enhancing these attributes [1]. The addition of jackfruit seed flour has a major impact on the rheological and textural properties of food products. The addition of JSF to extruded items can alter their crispness and hardness. Research has indicated that extrudates containing JSF may have a reduced and more tolerable hardness than control samples. JSF's high starch content (60–80%) improves the textural qualities and hardness of extruded goods. However, because gluten is absent, a higher concentration of JSF in baked goods may result in decreased volume and worse textural qualities [1]. Because composite flours with a high water absorption capacity have a positive effect on the texture of baked goods, JSF's water absorption capacity also affects texture. Because JSF can produce polymer networks, it can reduce the spread ratio for cookie-like items, which can alter the final texture. The strength and consistency of pastes made during food processing are influenced by the pasting qualities of jackfruit seed flour, which might change depending on the processing techniques used [1,12]. JSF has low viscosity and high solubility [2].

Functional qualities of cocoa powder are essential in the food and confectionery industries [21]. Relatively free-flowing, stable, and possessing good reconstitution qualities such as wettability, solubility, and dispersibility are all characteristics of high-quality cocoa powder. These characteristics affect the finished product, as do pH, fineness, and fat content [21]. Although not as specifically described as for JSF, the texture and mouthfeel contributions of cocoa in chocolate and beverages suggest some interaction with both the water and fat phases with regard to water and oil absorption ability. Cocoa powder's wettability and solubility indicate that it has the ability to interact and absorb water, which is crucial for uses like chocolate drinks and baked items [21]. Cocoa powder has low foaming and emulsification capabilities. Its function in producing stable chocolate emulsions, however, indicates a certain amount of emulsifying potential, most likely as a result of its complex makeup, which includes proteins and lipids [21]. The texture, viscosity, and mouthfeel of chocolate and other products are greatly influenced by the rheological and textural properties of cocoa powder [21]. The rheological characteristics of chocolate masses are influenced by elements such as the fat content and particle size of the cocoa powder [2]. Compared to jackfruit seed flour, which likewise has low viscosity and great solubility, cocoa powder's viscosity is seen as a good quality [2]. For their use, food powders' rehydration characteristics including those of cocoa are crucial [2].

After comparing the two, we can conclude that cocoa powder and jackfruit seed flour both have useful qualities for culinary uses. High water and oil absorption capabilities of JSF help preserve texture and flavour in baked goods and extruded goods [1]. Although there is little direct data on JSF's emulsification and foaming in these applications, its protein concentration points to promise [5]. Depending on the food matrix, JSF has different textural and rheological effects. It can make extruded items firmer, but at greater concentrations, it may cause problems with density and texture in gluten-based bread products [1]. The wettability, solubility, and contribution to the textural and rheological characteristics of chocolate and beverages are characteristics that define the functioning of cocoa powder [21]. Its application in emulsions and formulations suggests these interactions, even though precise water and oil absorption values are not specified. Potential as a cocoa substitute has been demonstrated by fermented jackfruit seed flour, which even has comparable or superior technological qualities and chocolate scent, including a suitable low viscosity and high solubility [2,8]. Dry jackfruit seed flour could be used in place of 50% and 75% of cocoa powder in specific cappuccino recipes without appreciably changing the product's technological or sensory qualities. Another low-cost cocoa alternative that has been investigated is roasted jackfruit seed flour, which adds chocolate flavour and aroma [2,7,9].

2.4. Comparative analysis of jackfruit and cocoa seeds powder in food applications: -

2.4.1. Bakery Products (bread, cookies, cakes): In order to improve the nutritional profile of a variety of baked goods, jackfruit seed flour (JSF) has been investigated as a supplement or replacement [1]. According to research, adding up to 25% of JSF to bread can double its crude fiber content and enhance its overall nutritional value without noticeably affecting its acceptability or taste [1, 3, 14]. Higher substitution rates (over 25–30%), however, have a tendency to adversely affect flavour, taste, colour,

and texture; the lack of gluten frequently results in a brownish colour and poor texture. Similar to this, JSF may replace up to 30% of refined wheat flour in cakes without having a negative sensory impact. In certain instances, this has resulted in a larger cake volume because of its capacity to absorb fiber, oil, and air [1]. JSF has been added to cookies and biscuits at several percentages; acceptance generally declines at higher quantities (over 30–50%) since the texture is affected by the absence of gluten [1,14]. According to certain research, using JSF can result in biscuits with an acceptable texture with a gluten concentration of up to 8%. On the other hand, because of its unique flavour and colour, cocoa powder is mostly utilized in baked goods including cakes, cookies, and brownies [1,2]. When combined with wheat flour, cocoa powder does not have the same gluten-related restrictions as JSF, even though its fat and fine particle concentration add to the texture. Because of its functional qualities, such as its ability to absorb water, JSF is being researched for gluten-free baking choices [1,14,22].

2.4.2. Beverages (cocoa drinks, plant-based milk, smoothies): FJS (fermented jackfruit seed) flour, has demonstrated great promise as a cocoa powder alternative in drinks, especially because of its chocolate aroma [2,8]. According to studies, beverages created with FJS may include odour-active ingredients and volatile chemicals that are comparable to those made with non-alkaline cocoa powder [8]. Dry jackfruit seed flour (DJS) could be used in place of 50% and 75% of cocoa powder in cappuccino recipes without noticeably altering the physicochemical characteristics or sensory acceptability [2,9]. JSF's excellent solubility and low viscosity make it an ideal alternative to cocoa powder in beverages [2]. A common ingredient in chocolate drinks, cocoa powder adds flavour, colour, and a little thickness to the texture. For beverage applications, its reconstitution qualities, such as wettability and solubility, are crucial [23].

2.4.3. Confectionery (chocolates, energy bars, desserts): Studies show that jackfruit seed powder, especially fermented jackfruit seed powder, can partially substitute cocoa powder in chocolates [10]. According to one study, adding fermented jackfruit seed powder to diet chocolates in place of 10% cocoa powder did not significantly change the proximate composition and reduced the glycaemic index [10]. The ability of roasted jackfruit seeds to produce a chocolate scent has also been investigated, indicating that they may find use in chocolate or chocolate-flavoured confections [2,7]. Jackfruit seed flour has been added to energy bars to enhance their nutritional, phytochemical, and sensory qualities [1]. The bar would be held together by its binding qualities, which are probably connected to its ability to absorb water. In addition to its fat content (cocoa butter) and tiny particle size, cocoa powder is a key ingredient in chocolate confections, contributing to their distinctive flavour, colour, and texture [23]. It is frequently used in sweets to add flavour and aesthetic appeal.

2.4.4. Dairy Alternatives (vegan yogurt, ice creams, cheese): In one study, it was investigated whether jackfruit seed powder might be used in place of some of the skim milk powder for making yogurt [6]. A 3% substitution produced the maximum percentage of ash, total solids, and carbohydrates, but it also had the lowest microbiological quality and organoleptic acceptance [6]. Better physical acceptability was demonstrated at a lower substitution level. This implies that while JSF may have a part in changing the makeup of dairy substitutes, the best formulations are essential to preserving quality. Similar to its use in conventional dairy products, cocoa powder is largely utilized for flavour in dairy substitutes such vegan chocolate yogurt and ice cream [6].

2.4.5. Meat Substitutes & Protein Enrichment (jackfruit as meat analog, cocoa protein use): Remarkably, the use of jackfruit by-products (such as seeds, rind, and rags) in creating vegetarians' healthy meat substitutes [13,14]. In comparison to conventional meat substitutes, formulations containing up to 58% jackfruit by-products and 20% essential wheat gluten were favoured for texture and general appeal and demonstrated higher levels of protein and dietary fiber [13]. The protein composition of these analogues is influenced by the jackfruit seeds themselves [13]. Although cocoa powder has some protein, it is not primarily used for protein enrichment or as a foundation for meat alternatives.

2.4.6. Gluten-Free & Functional Foods: Since jackfruit seed flour is naturally gluten-free, it may be used as an ingredient in baked goods and other items that are gluten-free [1,14]. It is positioned as a functional food component that can help prevent malnutrition and encourage healthy choices because of its high nutritional content, which includes protein, carbs, and phytonutrients [1]. When creating functional foods, its functional qualities such as bulk density and water-holding capacity—are also important [1]. Although the polyphenolic component of cocoa powder has health benefits [10], it is not commonly used as a gluten-free ingredient. Nonetheless, by offering nutritional content as well as possibly distinctive textures and flavours, JSF and cocoa powder can both support functional foods.

The potential of roasted jackfruit seed flour in functional meals looking for chocolate flavour profiles is further enhanced by its capacity to produce chocolate scent [2,7,8].

2.4.7. Sensory and Consumer Acceptance: Consumer and sensory acceptance are two major obstacles to using jackfruit seed flour (JSF) in food industry applications. Although JSF enhances nutritional qualities, larger concentrations tend to degrade textural and colour qualities, especially in bread products because of the lack of gluten, as mentioned in the review of JSF in extrusion and baking products [1]. For example, sensory panels determined that JSF additions above 30–50% in biscuits were objectionable [1]. Similarly, up to 30% JSF can be used in place of refined wheat flour in cakes without causing any harmful sensory effects, but going beyond this threshold could result in unfavourable impressions [1]. According to consumer research, extruded items containing JSF were more generally accepted than bread products with comparable substitutes, which may imply a preference based on the food matrix [1]. For JSF to be widely adopted, issues with taste, texture, and general acceptability are emphasized as obstacles that must be addressed [1]. On the other hand, people often accept cocoa powder because of its distinctive chocolate flavour and colour [10]. However, activities like fermentation and roasting can affect the sensory quality of cocoa [8]. Achieving a sensory scent that is equivalent to that of cocoa and commercial chocolate is essential for roasted jackfruit seed flours used as cocoa substitutes, and studies have assessed this using sensory panels [2].

2.4.8. Cost-Effectiveness and Availability: Particularly in areas where jackfruit is abundant, JSF is promoted as an affordable and accessible substitute that can address nutritional imbalance [1]. Valuation of jackfruit seeds, an underutilized by-product, can result in the creation of nutrient-dense food products and their sustainable use [1, 5]. On the other hand, according to the sources, the cost of cocoa has been increasing, which has prompted the food industry to look for alternatives [9]. Additionally, forecasts indicate that in the upcoming years, the demand for cocoa beans would surpass supply, which could have an impact on both price and availability [9]. Compared to cocoa, whose cultivation may be impacted by climate change, jackfruit seed flour, which is made from a waste product, may be a more cost-effective and sustainable ingredient [2]. However, the existing commercial production and processing of jackfruit, which is underutilized in underdeveloped regions, may limit the availability of JSF on a large industrial scale [5,14]. To guarantee a steady and economical supply of JSF, appropriate postharvest procedures and processing technologies are required [16,18].

3. Conclusion

The food business holds great promise for cocoa powder and jackfruit seed flour (JSF). Made from an underutilized jackfruit by-product, JSF offers a sustainable and affordable substitute for the rising price of chocolate. Due to their high starch, carbohydrate, protein, fiber, and mineral content, both components have advantages and can improve the nutritional value of a variety of dishes. The functional characteristics of JSF vary, though; it has qualities like bulk density, water absorption index, and water solubility index that are useful in some food processing methods like extrusion and as a binding agent in goods like yogurt.

Together with cocoa powder, the food sector may use JSF's potential to produce more inventive, wholesome, and sustainable food products. To reliably create JSF with desired sensory characteristics, research should be put into refining processing methods like as fermentation, roasting, and drying, with an emphasis on boosting chocolate fragrance and reducing off flavours. To guarantee a consistent supply of JSF for industrial uses, effective jackfruit seed processing infrastructure should be created and expanded. To determine whether JSF-containing products are acceptable to consumers and to create marketing campaigns that emphasize their sustainability and nutritional advantages, consumer research should be done.

Focusing on specific product uses where JSF's functional qualities are beneficial, for as a binder in yogurt, composite flours for baked goods, and extruded snacks. Examine hybrid applications that blend cocoa powder and JSF to cut costs without noticeably sacrificing flavour. To support its potential as a functional food ingredient, carry out more clinical research on the health advantages of jackfruit seed consumption. Maximizing the value of this resource can be achieved by investigating a variety of uses for jackfruit seeds outside of direct food consumption, such as bioplastics, food packaging, and other sustainable materials. By taking care of these issues, the food sector may successfully utilize the potential of jackfruit seed powder in addition to cocoa powder, creating more inventive, wholesome, and sustainable food products.

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