Jackfruit Waste Utilizd in Sustainable Energy and Biochemicals

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Jackfruit (*Artocarpus heterophyllus* L.) trees are known to produce huge fruits from their stems and are unique in terms of food utilization as vegetables and fruits. Jackfruit trees are cultivated throughout the lowlands in south and southeast Asian countries. In addition, it is found in east Africa, as well as throughout Brazil and Caribbean nations such as Jamaica.

jackfruit waste zero waste bioconversion bioenergy

1. Introduction

Jackfruit (*Artocarpus heterophyllus* L.) trees are known to produce huge fruits from their stems and are unique in terms of food utilization as vegetables and fruits. Jackfruit trees are cultivated throughout the lowlands in south and southeast Asian countries. In addition, it is found in east Africa, as well as throughout Brazil and Caribbean nations such as Jamaica. Many countries such as Malayasia, the Philippines, Cambodia, and Sri Lanka, including Bangladesh (where jackfruit is the national fruit), are taking aggressive efforts to bring about greater areas for jackfruit plantation; therefore, the production and productivity of jackfruit are likely to increase over the years, as will jackfruit waste. Jackfruit is one of the most demanded fruit crops in India too. In India, it is grown/cultivated in low-elevation regions throughout all the states [1]. Several wastes are generated from its ripe fruits and this fruit waste is more palatable than waste from raw fruit [1][2]. Jackfruit has shown various nutrients such as crude protein (CP ~7.9%), crude fibre (CF ~14.1%), calcium (0.8%), and phosphorus (0.1%). Except for these nutrients, ripe and raw jackfruit wastes are also utilized as potential substrates for energy production and nitrogen-free extracts (NFE ~65%). The rind of the ripe fruit is a good source for cattle foods and this waste of jackfruit is a non-edible portion (~59.2%), such as perianth meal, rind, and core meal. This waste matter is utilized for total dry meal recovery (11.6%) [2]. Some analyses have been performed on jackfruits waste compositions (for perianth meal, rind, and core meal), which contain ash (6 to 7.5%), carbohydrates (20–29%), crude protein (8–10.6%), crude fate (1.7 to 7.3%), and crude fibres (12–17.3%). Some studies have been conducted on the utilization of jackfruit wastes and these are used for food, feed, and other industry applications. Some non-edible portions of jackfruit (such as peels and axis) are reported with edible products (seed), and still, these waste matters are underutilized worldwide such as in Bangladesh, India, and other countries [3]. Different waste portions of jackfruits are generated during juicy edible bulbs. The thick peels of jackfruits can be utilized for different valuable product generations such as biofuel, non-porous adsorbents, and nutrient-enriched cattle feeds. Normally, non-porous adsorbent is used in the removal of dye. The peel and central axis of the jackfruit are also utilized for pectin extraction [4]. Its seed power is reported to be used in various bakery products. From this fruit, seed powder, starch, and protein fraction are isolated and then utilized in their purified form for food formulations at the industry level [1][3][4].

While jackfruit has massive potential with unlimited benefits, its waste products are much more than those of any other tropical fruits. According to Sundarraj and Ranganathan [5], 75% of the jackfruit products in India get wasted due to inadequate marketing, negligence, and a lack of processing facilities, and it is estimated that almost 20,000 million Indian rupees worth of jackfruit waste are reported only in the two Indian states of Karnataka and Kerala, which are major jackfruit-producing states. The non-edible parts of jackfruit that form the waste, however, can be made effective to use by bioconversion using various technologies.

2. The Utilization of Jackfruit (*Artocarpus heterophyllus* L.) Waste towards Sustainable Energy and Biochemicals

Jackfruits have been analysed during different seasons by various workers [4][5][6][7][8] for their nutritional and antioxidant properties. The findings of these studies have indicated that jackfruits serve as a valuable source in the development of nutraceuticals, which are currently in high demand worldwide [6]. Jackfruits in different seasons are reported to differ in phytochemicals such as phenolics, terpenoids, steroids, glycosides, saponins, alkaloids, and tannins and these compounds are known to possess antioxidant properties. Diversity in the secondary metabolites in jackfruit has been reported and attributed to variations in functionally, nutritionally, and medically important jackfruit wastes [4][6]. From jackfruit waste, antibacterial and antioxidant activity agents/compounds can be evaluated from the extracts that are obtained from methanol extract from jackfruit leaves and stem barks, and then they are applied as a peel-off mask. From the extraction of these properties from jackfruit waste, the first raw material was macerated using the methanol agent and then filtrates were evaporated for some time to obtain a concentrated crude extract [6]. This extract was evaluated using different tests such as phytochemistry screening and also antibacterial tests on *Propionibakerium acnes* and *Staphylococcus aureus* at different concentrations of extracts using the DPPH (a,a-diphenyl-β-picrylhydrazyl) method [8].

For the best evaluation of these phytochemicals, some additional tests have been performed that can prove the characteristics of peel-off masks, such as homogeneity, pH, organoleptic, and irritation tests. Some phytochemical screenings have proved the domination of tannin and saponin in these extracts [7][8]. In the context of jackfruit waste, these are rich sources of carbohydrates, protein, fats, and phytochemicals. This organic extraction or utilization serves as a promising feedstock for valuable bioproducts, including fuels/chemicals synthesis. Several pre-treatments (such as biological, physical, and chemical, including green solvents) have been applied as effective valorisation strategies for jackfruit waste matters [9]. The implementation of these strategies has facilitated the transformation of waste into products that possess added value, including, but not limited, to bioethanol, biogas, bioplastic, feeds, and functional compounds/food additives. The utilization of jackfruit waste for bioenergy production and recovery represents a promising avenue for sustainable and eco-friendly food waste-based renewable resources. This approach offers an economically feasible alternative to non-renewable fossil fuels [10]. Further efforts have been performed on efficient bioconversion tasks/techniques, applied for jackfruits that can generate/produce valuable biomaterials/chemicals, and this is only to be achieved via a microbial fermentation process. This conversion can help to obtain sustainable products with the mitigation of jackfruit generation/accumulation and support for a green environment. Some reports have claimed the utility of jackfruit peel for the remediation of dye colour from contaminated aquatic environments [8][9]. The implementation of said technology has the potential to facilitate the creation of an environmentally sustainable economic framework cantered on the repurposing of waste materials. Many studies have been carried out on the utilization of jackfruit waste for the production of value-added products, with the ultimate goal of mitigating waste generation and promoting environmental sustainability. In an attempt to utilize jackfruit waste, the production of plastic from jackfruit seed starch has also been carried out. The resulting plastic was strengthened through the incorporation of microcrystalline cellulose (MCC) derived from cocoa pod husks, with glycerol serving as the plasticizer [11]. This study aimed to identify the optimal mass and volume of microcrystalline cellulose (MCC) and glycerol concentration for the production of bioplastics in a high yield. Before the bioplastic production, MCC bio-production was achieved with cocoa pod husks, and these husks were subjected to a pre-treatment task with the help of alkali agents, bleaching, and an HCl acid solution to obtain effective hydrolysis [12]. In this, the degree of crystallinity of the MCC determination was carried out with the help of analytical techniques such as XRD (X-ray diffraction), with a functional groups determination using FTIR (Fourier-transform infrared) and also a morphological properties analysis using scanning electron microscopy (SEM). Some researchers have relied on results for isolated MCC from pod husks and discussed it as a rod-like form with a respective length (5–10 µm) and diameter (11.63 nm) with a high crystallinity [11][13]. From the isolated MCC utility in bioplastic synthesis, the tensile property of bioplastic was determined at a starch to MCC mass ratio (8:2). Further tasks were performed in addition to 20% glycerol with a measured tensile strength (0.637) and good elongation (at break of 7.04%) [14]. From analytical measurements using FTIR spectroscopy for bioplastic functional groups studies, greater numbers of -OH groups were found in bioplastics, and these were reinforced with filler MCC, with the representation of a hydrogen bond [11][14].

Biofuels such as biodiesel, an eco-friendly and renewable biofuel, have emerged as a cutting-edge substitute for petroleum-based diesel. This fuel possesses comparable traits to conventional fossil fuels and exhibits a remarkably low emission profile. The adoption of biodiesel not only seeks to diminish the reliance on non-renewable resources, but also fosters economic growth while boosting energy security, as detailed previously [15]. Nevertheless, through an exhaustive exploration of the existing scientific literature, it becomes evident that the untapped potential of jackfruit waste in promoting sustainable energy and achieving zero waste remains largely unexplored [16]. The scarcity of research has left unanswered questions about the true potential of jackfruit waste as a feedstock for combustion and bioenergy generation [16]. To bridge this knowledge gap, it becomes imperative to delve into the scientific exploration of jackfruit waste combustion. For instance, several research endeavours have investigated the untapped possibilities of jackfruit and its byproducts, encompassing edible fruit, seeds, peels, and latex-like filaments (rags or perianth) [17][18]. These comprehensive investigations have been centred on evaluating the nutritional content, mineral composition, and physicochemical properties of these diverse components. However, previous studies have convincingly established that jackfruit and its waste harbour essential elements such as potassium, magnesium, and calcium, which play pivotal roles in facilitating the catalytic process of biodiesel synthesis [15][17]. In the realm of scientific research, an intriguing area yet to be fully explored lies in the use of jackfruit waste, such as jackfruit peel waste (JPW), as a catalyst in biodiesel production. Presently, the open literature is conspicuously void of significant investigations into the production and application of JPW biomass catalysts, creating a stimulating challenge for researchers [16][17]. The scarcity of information concerning JPW biomass catalysts serves as the impetus behind investigations on the same, as it endeavours to bridge the existing knowledge gap in the realm of catalyst development for biodiesel production. By focusing on JPW, an abundantly available agricultural waste material, the research attempts to transform it into a valuable resource, i.e., catalysts that proficiently convert waste cooking oil (WCO) into biodiesel [16][17][18]. This is supported by the fact that using the K_2O from JPW ash as a cost-effective solid catalyst for biodiesel generation is feasible. By leveraging JPW biomass as a distinct solid catalyst, this approach bears several merits. Foremost, it upholds environmental friendliness by repurposing an agricultural waste product that would otherwise be discarded, thus contributing to waste reduction and fostering sustainability in biodiesel production [18]. The catalyst proves renewable, reusable, recyclable, non-hazardous, and environmentally benign, with vast applications across diverse fields. Aligned with these principles, Mulkan et al. [15] diligently conducted their investigation, culminating in compelling evidence showcasing the successful application of JPW as a solid catalyst for biodiesel synthesis. Further, the United Nations has taken significant steps toward ensuring a sustainable future for the entire world by 2030 [15][19]. One of its key initiatives involves the establishment of the Sustainable Development Goals (SDGs), with SDG 7 specifically focusing on promoting the sustainable utilization of bioresources to increase the proportion of renewable energy in the global energy mix. Additionally, SDG 7 aims to provide sustainable energy services to all nations [15][18]. Over the past few decades, considerable efforts have been made to adopt cleaner and greener technologies that harness various bioresources. These endeavours have led to the continuous implementation of innovative technologies [18][19].

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