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Sivaramakrishnan K
PG Scholar, Department of
Agronomy, College of Agriculture
Vellayani, Kerala Agricultural
University, Thiruvananthapuram,
Kerala, India

Sudha B
Associate Professor, Department of
Agronomy, College of Agriculture,
Vellayani, Kerala Agricultural
University, Thiruvananthapuram,
Kerala, India

Shalini Pillai P
Professor and Head, Department
of Agronomy, College of
Agriculture, Vellayani, Kerala
Agricultural University,
Thiruvananthapuram, Kerala,
India

Abhishek C
Director and Senior Scientist
(Engineering) National Coir
Research and Management
Institute Kudappanakkunnu,
Thiruvananthapuram, Kerala,
India

Sarada S
Assistant Professor and Head
Department of Vegetable Science
College of Agriculture, Vellayani,
Kerala Agricultural University,
Thiruvananthapuram, Kerala,
India

N Sravya
PhD Scholar, Department of
Agronomy, College of Agriculture
Vellayani, Kerala Agricultural
University, Thiruvananthapuram,
Kerala, India.

Corresponding Author:
Sivaramakrishnan K
PG Scholar, Department of
Agronomy, College of Agriculture
Vellayani, Kerala Agricultural
University, Thiruvananthapuram,
Kerala, India

From urban waste to organic wealth: recycling tender coconut husk for sustainable agriculture

Sivaramakrishnan K, Sudha B, Shalini Pillai P, Abhishek C, Sarada S and N Sravya

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Abstract

The rapid growth in tender coconut consumption has generated massive quantities of husk waste, particularly in urban areas where improper disposal creates significant environmental and public health risks. Characterized by a high lignocellulosic content, these husks decompose slowly in nature, often taking up to a decade to break down. This review explores the transformation of this biomass into high-value green resources for sustainable agriculture.

Key strategies for resource recovery include co-composting and vermicomposting, which convert husks into nutrient-dense organic manure. Specifically, vermicomposting with species like *Eudrilus eugeniae* can reduce decomposition time to just 70 days, significantly boosting nitrogen and phosphorus levels. Furthermore, thermochemical conversion into biochar offers a stable means of carbon sequestration while improving soil porosity and nutrient retention. The efficacy of processed husk as a lightweight, high-moisture retention potting medium for nurseries and its utility as a long-lasting mulch to prevent soil erosion. Beyond soil health, the husk serves as a feedstock for bioenergy and biodegradable industrial products. By adopting these circular economy principles, tender coconut waste can be transformed from an urban pollutant into a versatile asset for enhancing agricultural productivity and environmental sustainability.

Keywords: Tender coconut husk, co-composting, vermicomposting, biochar, potting media sustainable agriculture.

Introduction

Tender coconut water is a refreshing natural beverage with considerable nutritional and therapeutic values. The growing demand for tender coconut water has led to a substantial increase in the generation of a biowaste i.e., tender coconut husk, particularly around tender coconut parlours, urban marketplaces, and temple premises ^[1]. This issue becomes more significant as the husk accounts for nearly 60-65 per cent of the total weight of a tender coconut ^[2]. The discarded husks retain moisture and provide favourable breeding conditions for mosquitoes, thereby increasing the risk of vector-borne diseases, especially during the monsoon season ^[3]. Uncontrolled burning of husk contributes to environmental pollution and greenhouse gas emission ^[4]. As such, the environmental and health concerns posed by this biowaste especially in thickly populated urban sites is quite enormous. Due to their hardy texture and lignin rich nature, these residues remain undecomposed for long ^[5], which is yet another problem. As a disposal mechanism, the husks are periodically transported from urban regions to rural sites and land-filling tracts. However, prospects are much high for recycling this biowaste to valuable bioresource in support of sustainable agriculture.

Despite these disposal challenges, tender coconut husk (TCH) possesses considerable potential for value addition because of its fibrous and biodegradable composition. Tender coconut husk has the potential for conversion into several useful products including compost, biochar, activated carbon, biodegradable containers, biofuel briquettes and many such products ^[6]. In this context, exploring sustainable and economically viable approaches for the utilization of tender coconut husk has become increasingly important. The fibre extracted from the coconut mesocarp are inexpensive, renewable, recyclable, and non-poisonous, making them highly suitable for

agricultural and environmental applications [7].

Recycling of tender coconut husk to TCH compost

Tender coconut husks are primarily composed of lignin (30-42%), cellulose (54-65%), and hemicellulose (7-13%) [8]. As the biomass is predominantly lignocellulosic in nature, husks exhibit high resistance to microbial degradation under natural conditions. As a result, complete decomposition of tender coconut waste may require more than two years if left unmanaged [9].

Among the various sustainable utilization strategies, composting has emerged as one of the most practical and environmentally beneficial approaches for managing tender coconut husk waste. Composting refers to the biological transformation of organic residues into stable humus-like materials, which helps in improving soil fertility and soil structure [10]. Composting increases the nutrient value of coir pith, reduce the wider C:N ratio, and also to reduce the lignin and cellulose content. Application of coir pith compost increase the soil native micro flora, water holding capacity and organic carbon status of the soil [11].

A study conducted at Faculty of Agriculture, Annamalai University, [12] revealed that coir pith compost, a material similar to THC compost applied @ 10 t ha⁻¹ increase grain yield of barnyard millet by 21 per cent and straw yield by 23 per cent compared to application bone meal powder @ 1 t ha⁻¹.

Co-composting as a promising composting strategy for TCH

Co-composting refers to the aerobic decomposition of more than one organic residues simultaneously to produce a stable, humus-rich material with enhanced nutrient value. Compared with composting of a single substrate, co-composting helps overcome limitations such as nutrient imbalance, slow degradation, and poor microbial activity [13].

Organic residues possessing high nitrogen content and a narrow C:N ratio, such as animal manures, are often combined with carbon-rich bulking materials to maintain favourable conditions for microbial growth and aeration during decomposition [14]. In this context, tender coconut husk serves as an excellent carbonaceous substrate because of its fibrous and lignocellulosic composition. Co-composting of tender coconut husk with other organic materials helps balance nutrient availability, regulate moisture content, and enhance microbial degradation. Several additives and co-substrates including fly ash, phosphate rock, jaggery, biochar, pig manure, and wood chips have been reported to improve composting efficiency and nutrient enrichment [15]. Similarly, supplementation with nitrogen-rich organic sources such as poultry manure, leguminous biomass, farmyard manure, and oil cakes can effectively lower the C:N ratio of the composting mixture, thereby accelerating decomposition [16].

The biodegradation coconut waste can be further enhanced through the inoculation of lignocellulose-degrading microorganisms. Fungal species such as *Aspergillus*, *Trichoderma*, and *Pleurotus* are effective because of their extensive hyphal growth and ability to secrete extracellular enzymes capable of degrading complex lignin and cellulose fractions [17]. Since tender coconut husk contains nearly 80 per cent moisture [18], maintaining proper aeration and microbial balance becomes essential for efficient compost maturation. Moreover, amendments such as rock phosphate and lime enrich the nutrient content and also weaken the lignocellulosic complexes, thereby facilitating faster decomposition of the husks [19].

A recent study at Kerala Agricultural University, [20] revealed that addition of poultry manure (10 kg), FYM (5 kg), lime (0.5 kg), rock phosphate (0.5 kg) and 250 g of *Trichoderma asperellum* (talc based) to 90 kg of shredded tender coconut husk resulted in good quality and nutrient rich compost. The microbial load of the compost was higher and the composting process was fast enough in generating mature compost within 60 days time. The study also confirmed that TCH compost applied @ 20 t ha⁻¹ could increase the yield of leafy vegetable amaranthus by 21 per cent compared to application of FYM @ 25 t ha⁻¹. There are several other reports regarding the effective use of coir pith compost, a material similar to THC compost, as good organic manure. The use of coir pith compost as manure @ 5 t ha⁻¹ for maize and reported 17 per cent yield enhancement compared to the use of FYM at a higher quantity. The same study also noted that yield attributes of maize viz., number of grains per cob also increased upto 15 per cent with the supply of coir pith compost compared to FYM addition. They attributed the improvement in yield attributes to the better retention of soil moisture in field which occurred due to the addition of water retaining compost [21].

Vermicomposting

In addition to the conventional composting and co-composting techniques, vermicomposting has emerged as an efficient and eco-friendly approach for the bioconversion of tender coconut waste into nutrient-rich organic manure. Vermicomposting is widely recognized as a sustainable waste management technology that transforms organic residues into high value organic manure through the activity of earthworms [22]. Vermicomposting process involves bio-oxidation and stabilization of organic matter mediated by earthworms along with diverse microbial populations present in the substrate [23].

Studies have reported substantial increases in nitrogen and phosphorus levels of tender coconut waste degraded with *Eudrilus eugeniae* by 158 per cent and 130 per cent, respectively, compared to raw tender coconut waste. In addition to macronutrients, micronutrients such as copper iron, zinc, and manganese were also found to increase, thereby enhancing its agronomic value [24]. The application of vermicomposting technology to tender coconut waste has shown promising results in reducing decomposition time and improving compost quality. Biodegradation of tender coconut residues using the earthworm species *Eudrilus eugeniae* significantly shortened the composting period, with mature vermicompost being obtained within 65-70 days and a compost recovery rate of nearly 63 per cent of the substrate. The resulting vermicompost exhibited a near-neutral pH ranging from 6.9-7.3, indicating its suitability for agricultural applications [25].

Incorporating suitable organic amendments during vermicomposting enhance nutrient recovery and improve the overall nutrient value of resulting compost. In this context, vermicomposting of coconut husk supplemented with pig slurry in 80:20 ratio by weight demonstrated superior performance, resulting in higher concentrations of nitrogen (2.1%), phosphorus (1.4%), and potassium (1.1%). This combination also achieved a fertilizer index of 4.7, which was considerably greater than that obtained from vermicomposting coconut husk alone (2.7) [26].

Biochar from Tender coconut husk

Apart from compost-based recycling approaches, thermochemical conversion of tender coconut waste into biochar has emerged as another promising strategy for sustainable

management of the residue. Biochar is a stable, carbon-rich, and highly porous material produced through the pyrolysis of biomass under oxygen-limited [27]. The production of biochar from coconut biomass involves a series of controlled processing steps. Initially, Coconut biomass residues are sun-dried and layered within kilns, where they undergo carbonization at 350-450 °C for 2-6 hours. Combustion is halted by sprinkling water, after which the cooled biochar is crushed into coarse particles. The material is then sieved to obtain a particle size of 1.5-3.0 mm and stored for future agricultural applications [28].

The conversion of tender coconut waste into biochar offers multiple agronomic and environmental benefits. The application of biochar to soil can improve its physical, chemical, and biological properties, thereby enhancing crop growth, productivity, and economic returns. Owing to its highly porous structure and large surface area, biochar possesses a remarkable capacity to adsorb and gradually release water and nutrients, while simultaneously stabilizing carbon within the soil system and reducing carbon emissions into the atmosphere [29]. These characteristics make tender coconut husk biochar an effective soil amendment for improving nutrient retention.

Characterization studies reported that biochar produced from tender coconut husk possesses favourable chemical properties, including alkaline pH (8.53), high total organic carbon content (70.10%), and appreciable cation exchange capacity (15.26 cmol kg⁻¹). The biochar also contains essential plant nutrients such as nitrogen (1.52%), phosphorus (0.40%), potassium (2.26%) and considerable quantities of calcium, magnesium, sulphur, iron, manganese, boron. The abundance of exchangeable cations such as potassium, calcium, and magnesium further highlights the ability of biochar to function as a temporary nutrient reservoir, thereby reducing nutrient losses through leaching [30].

Furthermore, the concentrations of heavy metals including Pb, Cd, Ni, Cr, Zn, and Cu in TCH biochar were well below permissible threshold limits, indicating its safety for agricultural application [31]. Biochar-induced improvements in soil aggregation, porosity, and water retention can also reduce soil erosion and phosphorus loss from agricultural lands [32]. Such modifications are particularly beneficial in degraded and compacted soils where restricted aeration and low oxygen diffusion adversely affect root growth and microbial activity.

In a study conducted at college of agriculture, vellayani, experimented with the application of TCH biochar as organic manure for yard long bean, biochar applied @ 20 t ha⁻¹ along with PGPR (2%) and NPK fertilizers (20:30:10 kg ha⁻¹) significantly increased the yield characters of yard long bean such as pod length by 20.31 per cent (54.50 cm), pod girth by 36.84 per cent (3.90 cm), mean pod weight by 18.04 per cent (26.63 g) and number of pods per plant by 30.77 per cent (51), compared to the control treatment that had not received biochar [33].

Similarly, the pot culture study found that amending soil with tender coconut husk biochar and coconut leaf vermicompost enhanced dry matter accumulation, arbuscular mycorrhizal colonization, root nodulation, and microbial activity in cowpea compared to soil amended with coconut leaf vermicompost alone. The study also demonstrated that the combined application of tender coconut husk biochar and coconut leaf vermicompost increased chilli yield by 50 per cent compared to non-amended soils [28].

THC biochar has also shown considerable potential as soil amendment in alleviating the adverse effects of soil compaction. Reduced soil pore space, poor aeration, and restricted root proliferation commonly observed in compacted soils could be

mitigated through the incorporation of tender coconut husk biochar. Improvements in root growth and fresh root biomass following coconut-derived biochar application have been reported in chilli and ginger cultivation systems [34] [35]. TCH biochar applied @ 10 t ha⁻¹, FYM @ 5 t ha⁻¹ and recommended fertilizer dose 55:35:70 kg ha⁻¹ of NPK increased fruit yield of okra upto 69 per cent compared to the conventional nutrient management practices alone without biochar addition [36].

Tender coconut husk based potting media

Tender coconut husk has also gained considerable attention as a sustainable component in potting media for nursery and greenhouse crop production. Artificial substrates widely used in containerized cultivation systems and are generally composed of materials such as peat, silt, farmyard manure, vermiculite, and compost. These components largely determine the bulk density, porosity, aeration, and water-holding capacity of the growing medium. Recycling coconut waste into potting media helps tackle waste management issues in coconut producing areas [37].

The incorporation of coconut husk-based materials into potting mixtures can significantly reduce the overall weight of the media, thereby facilitating easier handling, transportation, and management of nursery containers [38]. Coconut-derived substrates have shown promising performance in soilless cultivation systems, particularly for high-value vegetable crops such as tomato [39]. Due to the shorter fibre length and spongy structure of tender coconut husk, the material can be effectively composted and processed into a lightweight growing medium with favourable physical characteristics.

Compared to peat, coconut husk is generally less acidic and exhibits relatively higher electrical conductivity, making it a suitable substitute for peat-based media in crops such as lettuce [40]. Adequate water retention in potting media is essential for minimizing water loss, nutrient leaching, and surface runoff. Media possessing water-holding capacities greater than 35 per cent are considered ideal for container crop production [41]. In this context, potting media containing coconut husk had recorded higher water-holding capacity (41.34%) compared to conventional mixtures containing only silt and farmyard manure (31.35%), resulting in improved plant growth and development [42].

Coconut husk possess comparatively low bulk density (0.18 g cm⁻³), low particle density (0.8 g cm⁻³), high porosity and appreciable cation exchange capacity, enabling efficient retention of essential nutrients such as potassium, sodium, calcium, and magnesium [43]. Similar findings confirmed that coconut husk dust contributes to improved porosity and lightweight characteristics of growing media [44].

Other Uses of tender coconut husk in agriculture

In addition to its applications in composting, biochar production, potting media preparation, and energy generation, tender coconut husk has several other important uses that enhance its value as a versatile biomass resource in sustainable systems. The inherent fibrous structure, high lignocellulosic content, and durability of coconut residues make them suitable for a wide range of environmental, agricultural, and industrial applications. Due to slow decomposition rate and high moisture retention capacity, coconut husk provides long-lasting soil cover and minimizes evaporative water loss [45]. Field studies have shown that mulching with coconut husk can significantly improve crop performance. Nutmeg cultivated under coconut husk mulch recorded 11.9 per cent higher yield compared to paddy straw mulch [46]. In addition, coconut husk cover has been reported to

reduce soil erosion and runoff substantially, with nearly two times lower soil loss compared to bare soil conditions ^[47].

Coconut husk burial in staggered trenches is another effective technique for conserving soil moisture in coconut and arecanut plantations. The husks are placed with the concave side facing upward in trenches about 45-75 cm depth and convenient length and width helping to maintain moisture during dry periods and enrich the soil with nutrients, particularly potassium ^[48]. Adoption of coconut husk burial techniques in trenches of 3.5 m length, 1 m width and 0.5 m depth across the slope between two rows of cashew plants improve the water retention in the soil for longer periods ^[49].

Incorporation of coconut husk fibre has led to improvement in tensile strength, elongation at break, and surface hardness of bio composite materials making them suitable for packaging applications ^[50]. The pulp extract from tender coconut husk can be utilised in making paper plates, cups, glass covers, and garden articles such as paper pots for seedling and packaging by moulding into the desired shape and size ^[2].

Conclusion

The increasing consumption of tender coconuts in urban and peri-urban areas has led to the accumulation of large quantities of husk waste, which is often poorly managed and becomes an environmental burden due to its slow natural decomposition. However, this lignocellulosic, carbon-rich biomass can be effectively converted into valuable resources through sustainable approaches such as co-composting, vermicomposting, and biochar production, which enhance soil fertility, carbon sequestration, and nutrient retention. Husk can also be utilized as potting media component and as good quality mulch. Beyond agriculture, tender coconut husk finds applications in renewable energy, wastewater treatment, erosion control, and coir-based industries. Overall, its utilization supports circular economy principles by transforming waste into useful products, while promoting environmental sustainability and resource efficiency. Essentially this urban waste can be recycled as organic wealth in promotion of sustainable agriculture.

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