

Coconut Husk and Processing Effects on Chemical and Physical Properties of Coconut Coir Dust

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Abstract. Chemical properties of unprocessed coconut (*Cocos nucifera* L.) husks varied significantly among 11 sources tested. The pH and electrical conductivities were significantly different among husk sources and ranged from 5.9 to 6.9 and 1.2 to 2.8 mS·cm⁻¹, respectively. The NH₄⁺, NO₃⁻, Ca, and Mg levels did not differ significantly among husk sources and ranged from 0.2 to 1.8, 0.2 to 0.9, 2.9 to 7.3, and nondetectable to 4.6 mg·kg⁻¹, respectively. Levels of P, B, Cu, Fe, Ni, S, Zn, Mn, and Mo were all significantly different among husk sources and ranged from nondetectable levels to 33 ppm. The levels of Na, K, and Cl were significantly different among husk sources and ranged from 23 to 88, 126 to 236, and 304 to 704 ppm, respectively. Coir dust (CD) produced by screening of waste-grade coir through 3-, 6-, or 13-mm mesh screens had significantly different fiber content, bulk densities, total solids, total pore space, air-filled pore space, water-filled pore space, and water-holding capacities as compared with nonscreened waste-grade coir. However, screen size did not significantly affect the physical properties of CD. Neither compression pressure nor moisture level during compression of CD blocks significantly affected rehydration of compressed CD or physical properties of rehydrated CD.

Artificial substrates are used extensively in the production of containerized greenhouse and nursery crops. Economics, availability of new materials, and environmental concerns relating to peat mining have stimulated interest in new substrate components. Most research into the development of new substrate components has focused on the use of municipal or agricultural wastes. Materials such as paper sludge (Chong and Cline, 1993; Tripepi et al., 1996), coal bottom ash (Butler and Bearce, 1995), shredded rubber (Evans and Harkess, 1997), kenaf (Wang, 1994), cotton waste (Wang, 1991), and composted yard waste (Beeson, 1996) have been proposed as sub-

strate components. However, some of these materials are not produced in large enough volumes to impact the market, and others are highly variable and may contain undesirable materials, such as glass, metal fragments, lead, and mercury.

Coconut coir dust (CD) has been proposed as an alternative substrate component. Evans et al. (1996) examined the chemical and physical properties of CD from numerous sources and reported that properties were generally within acceptable ranges except for electrical conductivity and chloride, which often exceeded recommended levels. Coir dust has also been demonstrated to be suitable for use in substrates through numerous production trials (Evans and Stamps, 1996; Loksha et al., 1988; Meerow, 1995; Seeni and Latha, 1990; Stamps and Evans, 1997).

Coir dust is primarily produced in Sri Lanka, India, the Philippines, Indonesia, Mexico, Costa Rica, and Guyana. The Philippines reportedly is one of the largest producers of coconuts with >427 million trees (Barile and Sangalang, 1990). Sri Lanka produces ≈350,000 to 500,000 tons of new CD annually (Hearth, 1993). With this level of production, large volumes of CD are potentially available to horticultural markets.

The raw material for the production of CD is the mesocarp tissue, or husk, of the coconut fruit. Husks may be soaked in water to soften them and facilitate grinding. After grinding of the husk, the long fibers are removed and used for various industrial purposes, such as rope and mat making. The remaining material, com-

posed of pith tissue and short- and medium-length fibers, is commonly referred to as waste-grade coir (WC). The WC may be screened to remove part or most of the fiber, and the remaining product is referred to as CD. After screening, CD is allowed to dry to a specific moisture level and is then compressed into bales, wrapped, and shipped. The moisture level and compression pressures vary between producers.

In an earlier work (Evans et al., 1996), we reported significant differences in the physical and chemical properties of CD collected from different sources. However, we did not determine the factors contributing to this variability. The degree of variability observed in CD might have been due to the husk itself, or to the processing methods, namely, the screening and compressing of the CD. In this research, our objectives were to determine the effects of the husk and processing methods on the physical and chemical properties of CD.

Materials and Methods

Coconut husk effect on chemical properties. Coconut husks were collected at 11 locations in the Philippines and Indonesia. Husks were collected directly from coconut plantations and had not been soaked in water or processed. The husks were ground in a hammer mill and screened to remove the long- and medium-length fibers. Mineral element concentration of the resulting CD samples was determined using the saturated media extract method as outlined by the North Central Regional Committee for Soil and Plant Analysis (Warncke, 1988). Electrical conductivity (EC; measured as mS·cm⁻¹) was determined using a Beckman (Cedar Grove, N.J.) solubridge, and the pH was determined using an Orion (Cambridge, Mass.) pH meter. Nitrate nitrogen (NO₃⁻) concentration was determined using the copperized cadmium reduction procedure (Keeney and Nelson, 1982) and ammonium (NH₄⁺) was determined by the nitroprusside-salicylate procedure (Wall et al., 1975). The Cl concentration was estimated by the mercury thiocyanate procedure (Fixen et al., 1988). For P, K, Ca, Mg, B, Fe, Mn, Zn, Cu, and Na, the filtered extract was used for simultaneous inductively coupled argon plasma emission spectrometry (Jones, 1977; Munter and Grande, 1981). Five replications were tested for each husk source. An analysis of variance (ANOVA) was conducted to determine if husk source significantly affected chemical properties. Where significance differences existed, a least significant difference (LSD) mean separation test (alpha = 0.05) was conducted to establish significant differences between means.

Screen size effect on physical properties. Waste-grade coir (WC) from the Philippines was screened through 3-, 6-, and 13-mm-diameter mesh rolling screens for 10 min. Because of the different size openings in the screens, different amounts and sizes of fibers passed through. Fiber remaining in the screen was discarded and the CD passing through the screens was collected for testing. The amount of pith and fiber in the resulting coir was

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determined by separating particles of 100-g samples with a CSC Scientific (Fairfax, Va.) rotary shaker for 10 min using screen sizes of 8.0 and 6.3 mm. Short fibers remaining in the coir were collected in these screens while pith tissue passed through. Bulk density (Bd), total solids (TS), total pore space (TPS), air-filled pore space (AFP), water-filled pore space (WFP), and water-holding capacity (WHC) of each of the screened CD products and the unscreened WC were determined using methods as described by Evans et al. (1996). Five replications were tested for each screened and unscreened material. An ANOVA and LSD mean separation test were conducted as previously described.

Compression effects on physical properties. Waste-grade coir from the Philippines was screened through a 13-mm-diameter mesh rolling screen for 10 min to remove the medium- and most of the short-length fibers. The resulting CD was compressed to form blocks using a steel cylinder ($30.5 \times 21.5 \times 11.5$ cm) and a Universal Testing Machine (SATEC Systems Inc., Grove City, Pa.). For each compression, 300 g (3060 cm^3) of the CD at moisture levels of 20%, 25%, 30%, and 35% (w/w) were placed into the cylinder and subjected to compression pressures of 70, 88, 106, 141, and $176 \text{ kg}\cdot\text{cm}^{-1}$. Pressures were maintained for ≈ 10 s and the blocks were removed. The CD blocks were rehydrated and air-dried to the original moisture level and the percentage of returned volume was measured. The physical properties of each of the resulting screened products and the unscreened WC were determined using methods previously described. Three replications were tested for each treatment. Multiple regression analysis was used to determine whether moisture and compression pressure had a significant effect on the returned volume and physical properties of CD.

Results and Discussion

Coconut husk effect on chemical properties. Extract pH and electrical conductivity differed significantly among husk sources (Table 1). However, the NH_4^+ , NO_3^- , Ca, and Mg levels, which ranged from 0.2 to 1.8, 0.2 to 0.9, 2.9 to 7.3, and nondetectable to $4.6 \text{ mg}\cdot\text{L}^{-1}$, respectively, did not differ significantly among husk sources (data not shown). Husks had significantly different levels of P, B, Cu, Fe, Ni, S, Zn, Mn, and Mo and ranged from nondetectable levels to $33 \text{ mg}\cdot\text{L}^{-1}$ (data not shown). Some of the most significant differences in chemical composition between husk sources were for Na, K, and Cl (Table 1).

Previously, Evans et al. (1996) reported that CD from 12 sources contained significantly different levels of mineral elements. Some of the highest values and most significant variation were for K, Na, and Cl. We speculated that the high levels and variability in the levels of these elements could be due to either the husks or the processing methods. In this study, we observed high levels and wide variation in these elements in unprocessed coconut husks.

Coconuts are thought to require salt appli-

cation for optimal growth, and many growers apply salts, such as NaCl and KCl, around coconut trees (Copeland, 1921; Menon and Pandalai, 1958). Coconuts are semi-halophytes and application of NaCl was shown to increase the Na and Cl content of the leaves (Remison et al., 1988). Baseden and Southern (1959) reported that the primary anion in coconut nut water was Cl^- and that levels ranged from 1790 to $2146 \text{ mg}\cdot\text{L}^{-1}$. Baseden and Southern (1959) were not able to correlate Na or K levels with proximity to the ocean. Thus, it is reasonable that the coconut fruit ion concentration, including the husk, may contain high levels of Na, K, and Cl and that these levels may vary depending upon factors such as fertilization practices.

Many CD producers and marketers have speculated that when high Cl, K, and Na levels occurred in CD, it was due to the soaking of husks in saline water (personal communication). Although this practice could certainly contribute to high levels of these elements, it is clear from this study that the husk has a significant impact on chemical properties of CD and that management of soaking water will not necessarily eliminate these elements from CD.

Screen size effect on physical properties. While screening significantly reduced the amount of fiber, the amount remaining did not differ significantly among screen sizes (Table 2). Bulk density, TS, WFP, and WHC of WC were significantly lower and TPS and AFP were significantly higher than the same properties of screened CD (Table 2).

Thus, screening of WC significantly im-

pacted the physical properties of the resulting CD. However, physical properties among screen sizes were not significantly different. It was visually apparent that fiber had little impact on properties until there was enough fiber to begin coalescing and forming mats or balls within the coir dust. Otherwise, the fiber simply packed down within the pith tissue and had little impact on physical properties.

Compression effects on physical properties. The percentage volume recovered after rehydration ranged from 78% to 91% (v/v) of the original volume and the Bd ranged from 0.06 to $0.07 \text{ g}\cdot\text{cm}^{-3}$ (data not shown). Neither of these properties were significantly affected by compression pressures or moisture level. Total pore space, AFP, WFP, TS, and WHC (data not shown) ranged from 78% to 91%, 6% to 10%, 71% to 76%, 18% to 22%, and 850% to 1071%, respectively, and these properties were not significantly affected by compression pressures or moisture level (data not shown).

Anecdotal reports and our own experience has shown that if coir is placed under too much pressure, it may fail to rehydrate and expand. We failed to observe any negative effects of compression in our study. The moisture levels and pressures used in the industry vary widely. However, based upon anecdotal reports, the highest pressures used in this study should have resulted in poor rehydration and expansion. This contradiction may have occurred for several reasons. The first is that anecdotal reports concerning pressures and moistures used may not be accurate. Many coir produc-

Table 1. Chemical properties and concentrations of unprocessed coconut husks from different locations.

| Source | | pH | EC ^z | K ^y | Na ^y | Cl ^y |
|---------------------|-----------------|-----|-----------------|----------------|-----------------|-----------------|
| Country | City | | | | | |
| Philippines | Davao City | 6.9 | 1.2 | 127 | 84 | 305 |
| | Katitipan | 6.8 | 1.5 | 171 | 53 | 421 |
| | Panakan | 6.3 | 2.2 | 220 | 75 | 647 |
| | Panakan | 6.3 | 2.0 | 216 | 81 | 528 |
| | Lajang | 5.9 | 1.6 | 195 | 23 | 420 |
| | Kasilac | 6.7 | 1.7 | 218 | 35 | 423 |
| | San Pablo City | 6.3 | 2.2 | 209 | 37 | 608 |
| | Gis Gis | 5.9 | 2.8 | 204 | 89 | 744 |
| | Tiaong | 6.2 | 2.0 | 236 | 27 | 514 |
| Indonesia | Raiugkas Bitung | 6.0 | 1.6 | 213 | 58 | 423 |
| | Lampung | 6.4 | 2.4 | 202 | 39 | 731 |
| Significance of F | | *** | * | *** | *** | *** |
| LSD _{0.05} | | 0.5 | 0.7 | 33 | 29 | 206 |

^zElectrical conductivity (EC) reported as $\text{mS}\cdot\text{cm}^{-1}$.

^yValue reported as $\text{mg}\cdot\text{L}^{-1}$ in saturated media extract.

*,***Significant at $P \leq 0.05$ and 0.001 , respectively.

Table 2. Effect of screen size on physical properties of coir dust.

| Screen size (mm) ^z | Fiber (% w/w) | Bulk density ($\text{g}\cdot\text{cm}^{-3}$) | Total solids (% v/v) | Total pore space (% v/v) | Air-filled pore space (% v/v) | Water-filled pore space (% v/v) | Water-holding capacity (% w/w) |
|-------------------------------|---------------|--|----------------------|--------------------------|-------------------------------|---------------------------------|--------------------------------|
| Unscreened | 18 | 0.4 | 12 | 88 | 20 | 67 | 1241 |
| 13 | 5 | 0.6 | 15 | 85 | 7 | 77 | 1382 |
| 6 | 5 | 0.6 | 16 | 84 | 5 | 78 | 1396 |
| 3 | 4 | 0.6 | 16 | 84 | 7 | 78 | 1357 |
| Significance of F | | *** | *** | *** | *** | *** | *** |
| LSD _{0.05} | | 6 | 0.01 | 2.9 | 2.9 | 4.0 | 43 |

^zUnscreened indicates waste grade coir and numbers indicate the diameter openings of the respective screen sizes.

***Significant at $P \leq 0.001$.

ers compress coir into bales based upon the ratio of initial to final volume. For example, many producers compress the CD so that the initial to the compressed volume is 6:1. In many cases, the exact compression pressures may not be known. Secondly, pressures were maintained for only 10 s in our study. Maintaining pressures for a longer time might have changed the results. Within the moisture, pressure, and time ranges used in this study, CD blocks were produced that rehydrated, expanded, and had acceptable physical properties for use as a substrate component.

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