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RESEARCH ARTICLE

Effects of retting and drying on quality of coir pith and coco discs

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Abstract: Volume expansion ratio (VE) and water retention capacity (WRC) are the most important quality parameters for compressed coir pith products and specifically for coco discs used as potting medium. The effects of time duration of retting, method of retting and drying techniques on the quality of coir pith and coco discs were examined. Quality variations in coir fibre with the time duration of retting were also analysed. VE and WRC of coco discs were found to increase significantly, while the pH changed marginally and electrical conductivity (EC) dropped significantly with the increase of retting time. VE, WRC, pH and EC after 12 weeks of retting were found to be 5.77 ± 0.19, 5.87 ± 0.35, 5.99 ± 0.04 and 63 ± 8 µs/cm, respectively. Length, tensile strength and breaking load of coir fibre were found to improve from 133 ± 1 to 182 ± 9 mm, 81 ± 7 to 104 ± 12 N/mm^2 and 3.58 ± 0.42 to 4.32 ± 0.38 N, respectively within 4 to 12 weeks of retting. Time duration for retting could be reduced to less than 4 weeks to achieve similar properties in coir fibre and coir pith by crushing the husks before retting. Oven drying resulted in rupturing of the cells and case hardening of coir pith. Hot air drying was found to be the most effective method for drying coir pith as compared to sun drying and oven drying.

Keywords: Coco discs, coir fibre, coir pith, drying of porous materials, retting.

INTRODUCTION

Compressed or compacted coir pith products are an innovative growth media vastly used in agricultural and horticultural industries. Coir pith is a light, spongy and ligno-cellulose material, generated as a byproduct when extracting coir fibre from the husks of coconuts (Kadalli & Nair, 2000). It is becoming popular due to its high quality characteristics such as high water retention ability due to the porosity of the cell structure, and fertility as it contains macro and micro nutrients (Abad *et al*., 2002; Prabhu & Thomas, 2002; Krisnamurthy *et al*., 2009). It has been identified as an alternative to peat for growing ornamental crops such as ixora, majesty palm, anthurium and ericaceous plants (Meerow, 1994; Scagel, 2003; Reghuvaran & Ravindranath, 2014).

Method of extraction, area of cultivation and ageing were found to influence the composition, particle size distribution and the physicochemical properties of coir pith (Moorthy & Rao, 1998; Tharanga *et al*., 2005). The increase in particle size leads to decrease in porosity, density, absorptivity and electrical conductivity whilst increasing the pH of raw coir pith (Ross *et al*., 2012). Particle size distribution of coir pith may also be influenced by the method of preprocessing of coconut husks, namely, crushing, soaking, water spraying and retting. The physicochemical properties such as pH, electrical conductivity, C/N ratio and cation exchange capacity of coir pith samples were found to significantly differ between and within those of the samples obtained from different countries and significantly differed from those of sphagnum peat (Evens *et al*., 1996; Konduru *et al*., 1999; Abad *et al*., 2002).

Sun drying is a cost effective heating method and widely used for drying of various vegetables, fruits and agricultural products including oil palm trunk waste (Nadhari *et al*., 2014), finger millets (Radhika *et al*., 2011), mint, parsley, basil (Akpinar, 2006) and sweet cherry (Domaz & Ismail, 2011). Sun drying can be identified as the main technique for drying coir pith due to the reason of cost effectiveness. However, the coir industry is now looking for alternative options to overcome the disadvantages of sun drying due to its longer time period of drying, uncertainty in weather

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conditions, excessive labour requirement, large area requirement, insect infestation and addition of other foreign materials.

The methods of preprocessing of coconut husks before extracting fibre and the methods of extracting fibre have been modified over the past years (Tharanga *et al*., 2005). Different drying techniques such as flash drying have also been introduced recently (Zotarelli *et al*., 2012). Consequently, the quality of coir pith and hence the quality of compressed coir pith products such as coco discs is greatly affected. The objective of the present study is to examine the effect of time duration and the method of retting the coconut husks, and the method of drying the coir pith on the quality of coir pith and coco discs.

METHODOLOGY

The quality parameters of coir pith were examined by performing three types of experiments; time duration of retting, method of retting, and drying technique. Currently coir mills in Sri Lanka follow different retting and extraction methods. Therefore, quality variations with respect to the method of retting and extraction were analysed for coir pith samples obtained from 6 different mills. A separate study under controlled conditions was carried out to examine the effect of retting time. Experiments for evaluating drying techniques were also carried out under controlled conditions.

Experiments on retting time

Dry coconut husks were obtained from Lunuwila, Sri Lanka for analysing the effect of retting time. About 150 dry husks were retted in a tank and the Ceylon drum method was used for fibre extraction. Thirty husks were used at a time to extract coir pith and 5 replicate samples of 700 ± 2 g were randomly selected. Each sample was separately sun dried to achieve a moisture content of 16 – 17 % (w/w, dry basis). Coco discs were made by compressing the dried coir pith using a hydraulic press machine (0 – 3000 psi, 30 hp) under 1600 ± 100 psi. Coco discs with 5 replicates were used to determine the quality parameters such as pH, electrical conductivity, volume expansion and water retention capacity according to the Sri Lanka Standards (SLSI 1219, 2001). The effect of retting time on the quality variations in coir fibre was examined with triplicate experiments. For the determination of length and breaking load, 2 g coir fibre samples with 3 replicates were grouped into standard length fractions of 0 – 100 mm, 101 – 200 mm and more than 200 mm. The number of fibres in each length category and the weight were recorded. The diameter of 30 fibres in each category was measured. Using the tensile strength tester (Admet, Expert 5601 SM 100, USA) breaking load and the elongation of 10 fibres in each length category were measured (SLSI 115, 2009).

Experiments on method of retting

Coir pith samples obtained from 6 different mills practicing different methods of retting were examined in this study (Table 1). Five coir pith samples were randomly selected from each mill and the properties were analysed. Two of the mills (mill 1 and mill 2) use raw coconut husks (green husks) and the others use dry coconut husks (brown husks) for their operations. Retting was performed by steeping the husks in water for long periods (1 to 4 months) and soaking was performed by steeping the husks for a short period of 1 week. Water spraying was done using a rubber hose at a rate of 6 – 8 L/min, 3 times a day while sprinkling was done using a sprinkler system at a rate of 1 – 2 L/min operating continuously for 1 d.

Table 1: Treatment of coconut husks before extracting fibre

Mill no.	Method of extraction	Type of husks	Pre-processing methods	Average moisture content of coir pith (% w/w dry basis)
1	D1 Method	Green - raw	Intermittent water spraying three times a day for 1 day	328 ± 1^a
2		Green - raw	Continuous water sprinkling for 1 day	350 ± 3^b
3		Brown - dry	Soaking up to 7 days	194 ± 2^c
4	Ceylon drum method	Brown - dry	Retting (1 month) after crushing the husk	463 ± 2^d
5		Brown - dry	Retting (3 months)	416 ± 2^e
6		Brown - dry	Retting (4 months)	502 ± 1^f

Means with different superscripts within the same column are significantly different from each other at $p < 0.05$ level

The six mills (Table 1) were categorised into two types according to the method of extraction, namely, D1 method and Ceylon drum method (Tharanga *et al.*, 2005). In the D1 method husks are half broken by spikes fitted to a rotating drum. The half broken husks are then transferred to a turbo cleaner in order to defibre by means of beaters fitted to the main shaft of the turbo cleaner. In the Ceylon drum method breaking and cleaning of husks are done by means of spikes fitted to two rotating drums called the breaker drum and the cleaner drum, respectively.

Experiments on drying techniques

Fresh coir pith samples were collected from a coir mill located at Lunuwila, Sri Lanka. These samples were used to examine the drying characteristics and the quality of coir pith for 3 different types of techniques; sun drying, oven drying and hot air drying. All the experiments on drying techniques were replicated 5 times.

Coir pith samples of 300 ± 2 g were dried as a thin layer for both sun drying and oven drying. The sun drying experiments were conducted at the Coconut Research Institute, Lunuwila. Aluminium trays were used for sun drying under atmospheric conditions; temperature 29 ± 2 °C, relative humidity 60 ± 5 % and solar intensity 13 – 15 MJ/m^2. Temperature and relative humidity were recorded just above the coir pith using a thermometer with hygrometer (Easy view 25, USA). Solar intensity was measured using a pyranometer (Hukseflux, Watchdog 1450, USA). Oven drying was carried out at 140 °C in an oven (SANYO Gallenkamp PLC, OPL25.DTI-C, UK) with an accuracy of ± 1°C.

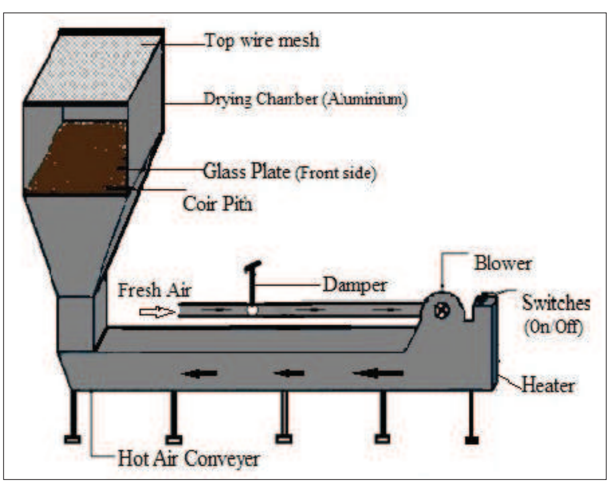

Figure 1: A sketch of the hot air dryer

A laboratory scale dryer was used for hot air drying (Figure 1). The drying chamber (1 × 1 × 1 ft^3) was fabricated using stainless steel plates with a wire mesh of 0.5 mm placed at the bottom to facilitate air flow and to retain the coir pith. The top of the chamber was fitted with a hinged wire mesh of 0.5 mm to avoid entrainment of coir pith. A glass plate was fixed to the front to observe the fluidising effect of coir pith. A blower with the specifications of air flow 1500 L/min, static pressure 32.0 mbar and motor rating 0.08 kW was used to blow the air. The air was heated using a 9 kW electrical heater. A damper was used to regulate the air flow to the blower and thereby to control the air flow in the drying chamber.

Hot air temperature was maintained at 140 °C with an accuracy of ± 1 °C. Four different velocities of 1.4, 1.7, 2.0 and 2.5 ms^{-1} were used with an accuracy of ± 0.1 ms^{-1}. The maximum velocity was corresponding to the full load capacity of the selected blower and the damper in fully open position. The other velocities were achieved by partially closing the damper. Velocity was measured using an anemometer (Lutron, LM 8100, Thaiwan). With continuous drying, most of the coir pith particles carted off with the air flow and then dropped down after hitting the top mesh. Some of the large particles (about 10 % of the total amount) carted off to the middle part of the vessel and then dropped down by gravity. This procedure was repeated until the coir pith was dried completely.

Data analysis

Moisture content

Moisture content of the coir pith samples was analysed using the standard oven method according to the Sri Lanka standards (SLSI 1219, 2001).

Particle size distribution

Dry coir pith having a moisture content of 16 – 17 % (w/w, dry basis) was first sieved using a net of mesh size ¼ inch to remove the large particles. Three samples of 500 ± 2 g were randomly selected to analyse the particle size distribution using sieves of mesh size 0.5, 1.0, 2.0, 2.8 and 4.0 mm. The average weight of coir pith for each mesh size was then obtained using an electronic balance (Shimadzu, Bx–K/BW-K, Japan). Sieved coir pith was categorised into three main types as coarse, medium and fine based on the particle size of greater than 2.8 mm, between 1.0 - 2.8 mm and less than 1.0 mm, respectively (Tharanga *et al.*, 2005).

Microbial content

The coir pith samples were analysed for common bacterial species (pour plate method) *E.coli* and *Salmonella* according to the Sri Lanka Standards (SLSI 516, 1991).

Physicochemical properties

Coco discs were prepared using dried coir pith samples having a moisture content of 16 – 17 % (w/w, dry basis) by compressing under 1600 ± 100 psi. The specifications of coco discs were: height 24 ± 1 mm, diameter 78 ± 1 mm and weight 60 ± 2 g. Electrical conductivity (EC), pH, volume expansion ratio (VE), water retention capacity (WRC), and compaction ratio (CR) of coco discs were analysed. The bulk density (BD) of coir pith before compaction was measured for each sample. All the tests were carried out according to the Sri Lanka Standards (SLSI 1219, 2001).

Compressed coco discs were allowed to expand by adding water and the VE was calculated as the ratio of final volume to the initial volume. WRC was determined as the maximum amount of water that could be absorbed per unit weight of compressed coco disc. For the determination of pH and EC, coco discs were wetted to the saturation limit using distilled water. Thereafter 300 mL of distilled water was added to each 50 mL of wetted coco disc sample and the mixture was stirred for 1 hr on a mechanical shaker. The filtrates of these samples were used to measure the pH and EC using a pH meter (Hach, HQ 40 D, USA) and EC meter (Hach, MM150, USA).

Coir pith samples having a moisture content of 16 – 17 % (w/w, dry basis) were used to measure the bulk density. The samples were filled into a 1000 mL cylinder and a 650 g weight was applied on the top (SLSI 1219, 2001). The BD was calculated as the ratio of the weight and the volume of coir pith in the cylinder. CR was measured as the ratio of bulk density of coco disc to the bulk density of coir pith.

Microstructure

Microstructure of the coir pith samples was observed using a scanning electron microscope (LEO, 1420vp, England).

Statistical analysis

One way analysis of variance (ANOVA) was used to determine the statistical significance ($p < 0.05$ level) of the parameters using SAS 9.1.3 software.

RESULTS AND DISCUSSION

Effect of time duration of retting

Table 1 shows that the retting time differs significantly among the coir pith mills practicing different methods of retting. Consequently the average moisture content of the coir pith samples collected from these mills was significantly different. Figure 2 indicates that the most important properties of coco discs, namely, VE and WRC, notably increase with retting time. Statistical analysis (ANOVA) confirmed that there is a significant

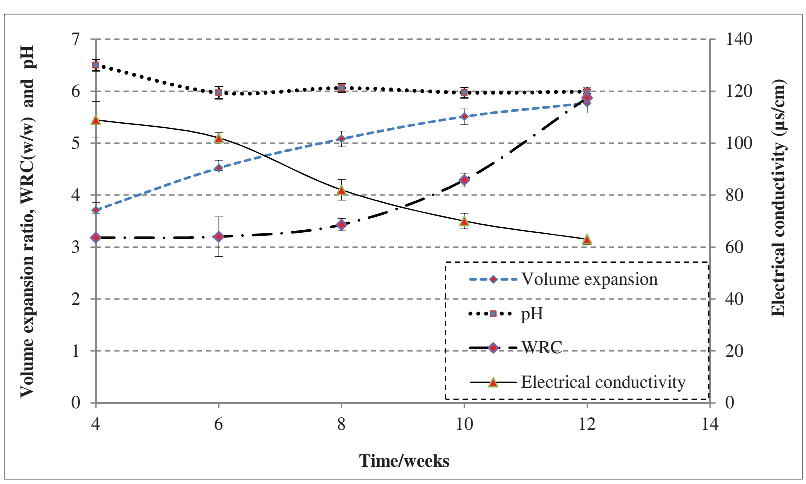

Figure 2: Variation of quality of coir pith with duration for retting

difference ($p < 0.05$) in VE between the study periods from 4 wks (3.71 ± 0.07) to 12 wks (5.77 ± 0.19) of retting time. Although the change in WRC from 4 wks to 8 wks was not significant ($p < 0.05$), the WRC was found to increase significantly ($p < 0.05$) from 8 wks (3.43 ± 0.12) to 12 wks (5.87 ± 0.35). The retting process leads to the degradation of coarse coir pith particles into small and medium size particles having numerous number of pores. Consequently the particle size distribution becomes narrow and the specific surface area of coir pith particles increases. According to Jayaseeli and Raj (2010), a high specific surface area contributes to a high WRC. A similar explanation holds for the volume expansion.

Figure 2 depicts that the pH of the coir pith has significantly reduced from 6.50 ± 0.11 in 4 wks to 5.97 ± 0.12 in 6 wks. The change in pH with further retting was not significant ($p > 0.05$) and the pH after 12 wks was found to be 5.99 ± 0.04. These values were found to be within the standard pH of 4.5 to 6.8 required in coir pith (SLSI 1219, 2001). The availability of potassium ions in coir pith increases the pH, while polyphenolic compounds decrease the pH. The slight reduction of pH may be attributed to the leaching out of both potassium ions and polyphenolic compounds from husks during retting. The electrical conductivity (EC) significantly reduced with the period of retting. The reduction of potassium ions in coconut husk might have mainly contributed to the change in EC. The EC changed from 109 ± 7 µs/cm in 4 wks to 63 ± 8 µs/cm in 12 wks and these values were within the standard of less than 500 µs/cm (SLSI 1219, 2001).

Retting is an essential processing step for manufacturing good quality coir fibre. It is a microbial process leading to the degradation of pectin and polyphenolic compounds in coir fibre and hence this natural process facilitates the extraction of coir fibre (Ravindranath, 2001). Table 2 summarises the effect of retting time on the length, tensile strength and breaking load of coir fibre. The results indicate that all the important properties relevant to coir fibre notably improve with retting time. However, comparable properties could be obtained with a lesser retting time of 4 wks as compared to 3 months of conventional retting, by crushing the husks before retting. In Sri Lanka most of the coir fibre mills practice conventional retting of husks for 3 months and some of the mills now operate with lesser retting time by crushing the husks before retting. Crushing must be done without damaging the fibre, and it facilitates water absorption. A locally fabricated crusher is used for this purpose and it has two sets of rotating spiked drums with 364 spikes per drum. Crushing is usually done for about 15 – 30 s per husk.

Table 2: Quality parameters of coir fibre with respect to the retting time

Quality parameter	Time duration of retting					
	4 weeks	6 weeks	8 weeks	10 weeks	12 weeks	4 weeks after crushing husk
Length/mm	133 ± 1	136 ± 2	142 ± 12	168 ± 6	182 ± 9	186 ± 21
TS*/N/mm^2	81 ± 7	84 ± 7	88 ± 8	92 ± 1	104 ± 12	109 ± 27
BL**/ N	3.58 ± 0.42	3.61 ± 0.11	3.62 ± 0.53	3.65 ± 0.07	4.32 ± 0.38	4.23 ± 0.78

*TS = tensile strength; **BL = breaking load

Effect of method of retting

Particle size distribution of coir pith

Figure 3 shows the particle size distribution of coir pith obtained from the 2 different types of fibre extraction methods, namely, D1 method (mills 1, 2 and 3) and Ceylon drum method (mills 4, 5 and 6). The results indicate that for a given method of extraction, the amount of fine particles has increased with the increase of retting time. A longer period of retting is necessary for the Ceylon drum method but water spraying or sprinkling is sufficient for the D1 method. Although mill 4 used Ceylon drum method for fibre extraction, retting time was limited to one month. Mill 4 used an additional processing step of crushing before retting. As a result it had coir pith with the highest amount of medium size particles (about 85 %).

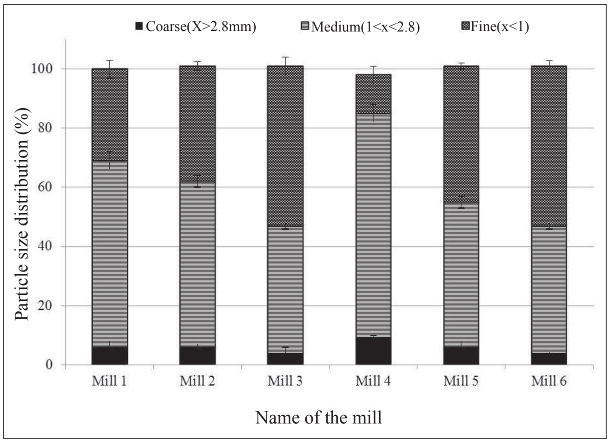

Figure 3: Particle size distribution of coir pith from different mills

Physicochemical properties of coco discs

The results clearly indicate that retting time has a significant effect on the properties of coir pith. The method of extraction is a physical process and influences the particle size distribution as can be seen in Figure 3. However, the results for the analysis of properties of coco discs given in Table 3 indicate that even if different methods of retting and extraction were used, coir pith obtained from different mills had similar properties. ANOVA test confirmed that the results are not statistically significant ($p > 0.05$). The only exception was the EC of coir pith from mill 1, which had a high EC due to the salinity of spraying water as it was close to the sea. Therefore, the observation of similar properties in coco discs from different mills might have attributed mainly to the randomness of raw coconut husks, which were transported to these mills from different areas belonging to different agro-ecological zones or coconut varieties. Further, they might be having different environmental conditions during storage and different times of storage.

Table 3: Physicochemical properties of coco discs

Mill no.	Method	VE	WRC(w/w)	pH	EC(µs/cm)
1	D1 method	6.1 ± 0.44 [a]	6.2 ± 0.43 [a]	5.8 ± 0.53 [a]	787 ± 57 [b]
2		5.2 ± 0.63 [a]	4.5 ± 0.73 [a]	5.6 ± 0.61 [a]	402 ± 137 [a]
3		5.3 ± 0.53 [a]	5.6 ± 0.62 [a]	6.0 ± 0.41 [a]	612 ± 103 [a]
4	Ceylon drum method	6.3 ± 0.62 [a]	5.9 ± 0.23 [a]	5.8 ± 0.21 [a]	577 ± 101 [a]
5		5.4 ± 0.57 [a]	5.9 ± 0.46 [a]	6.1 ± 0.23 [a]	490 ± 99 [a]
6		5.9 ± 0.51 [a]	6.4 ± 0.51 [a]	5.7 ± 0.55 [a]	386 ± 123 [a]

Means with different superscripts within the same column are significantly different from each other at $p < 0.05$ level

Microbial content

Microbial analysis revealed that the initial microbial content of coir pith obtained from the Ceylon drum method was about 10 times greater than that of the D1 method. Significantly high initial microbial content of the Ceylon drum method is mainly attributed to the higher number of microbes involved in the retting pit. Figure 4 shows the variation of plate count over drying time for sun drying of two samples, each representing the D1 method (mill 2) and the Ceylon drum method (mill 6).

It was observed that sun drying is very effective in controlling the microbial levels in retted coir pith obtained from the Ceylon drum method, with a very sharp drop after 4 hours. The retaining microbial content in dried coir pith was less than 10^6 CFU/g and had no potential threat to human health (Bhila *et al*., 2010). The maximum level of *E.coli* in dried samples was found to be 20 CFU per g, which is within the limits of Sri Lanka Standards (SLS) (1991) (< 100 CFU per g). Dried coir pith samples were also found to be free from *Salmonella.* Therefore, the coir pith obtained from both methods were suitable for making coco discs after sun drying as microbial strains were within the allowable limits.

Effect of method of drying

Drying behaviour of coir pith

Hot air drying was the most effective method of drying with the highest drying rate, as compared to oven drying and sun drying (Figure 5). The longest time of 668 minutes to achieve a moisture content of 16 – 17 % (w/w, dry basis) was recorded with sun drying. Although the same temperature of 140 °C was used for oven drying and hot air drying, the required drying time was significantly different with 160 minutes and 97 minutes, respectively.

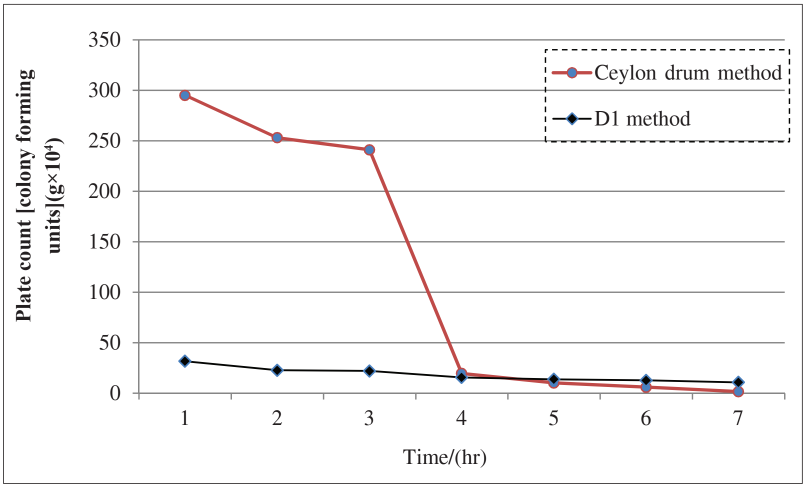

Figure 4: Effect of sun drying on the microbial content of coir pith obtained from the Ceylon drum method and D1 method

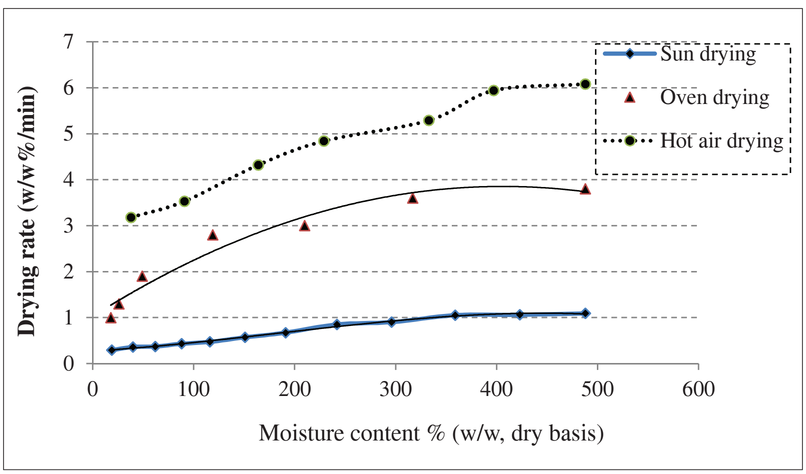

Figure 5: Drying behaviour of coir pith under different drying methods

As compared to oven drying, heat distribution is more uniform and also blowing air removes the moisture effectively in hot air drying. A drying time of 97 minutes was recorded for hot air drying at the highest air velocity of 2.5 ± 0.1 ms^{-1}, and a significant increase in drying time was observed with the reduction of air velocity. The time taken for drying of coir pith at air velocities 2 ± 0.1, 1.7 ± 0.1 and 1.4 ± 0.1 ms^{-1} were 101 ± 2, 106 ± 1 and 112 ± 3 minutes, respectively. Similar trends were observed by Niamnuy and Devahastin (2005) in their study of fluidised bed drying of coconut kernal.

Coir pith drying process had a short constant rate period at the initial stage followed by a long falling rate period. During the falling rate period, the drying rate was reduced almost linearly for sun drying and for hot air drying. This is in agreement with the observation of Mujaffar and Sankat (2005) on the air drying behaviour of shark fillets. Oven drying showed a rapid reduction of the drying rate at the final stage as compared to other methods. This may be attributed to the case hardening effect on some of the particles, due to uneven heating especially at the local heating zones such as the walls of the metal container. Consequently moisture diffusion might have been considerably affected resulting in the reduction of drying rate. Similar results were observed by Li *et al*. (2015) in their study on convective drying of mixture of sewage sludge and saw dust in a fixed bed.

Table 4: Properties of sun dried, hot air dried and oven dried coir pith and coco discs

Sample	pH*	EC(µs/cm)*	VE**	WRC (w/w)**	BD (g//L)*	CR***
Sun drying	5.92 ± 0.1 ^{a}	542 ± 39 ^{a}	5.33 ± 0.37 ^{a}	6.52 ± 0.14 ^{a}	77.35 ± 2.52 ^{a}	5.7 ± 0.49 ^{b}
Hot air drying	6.06 ± 0.37 ^{a}	461 ± 77 ^{a}	6.42 ± 0.78 ^{b}	6.43 ± 0.43 ^{a}	76.35 ± 1.79 ^{a}	6.61 ± 1.04 ^{a}
Oven drying	6.44 ± 0.09 ^{b}	647 ± 105 ^{b}	5.80 ± 0.83 ^{a}	6.03 ± 0.84 ^{a}	83.46 ± 1.26 ^{b}	6.53 ± 0.35 ^{a}

Means with different superscripts within the same column are significantly different from each other at $p < 0.05$ level
* Coir pith; ** Coco discs; *** CR is the ratio of bulk density of coco disc to bulk density of coir pith

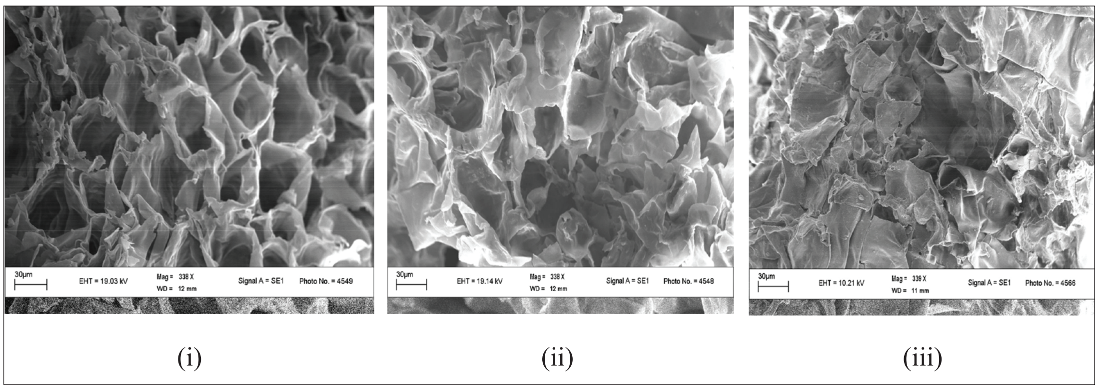

Figure 6: Scanning electron microstructure of (i) sun dried; (ii) hot air dried and (iii) oven dried coir pith

Physicochemical properties

The pH and EC of coir pith dried under sun and hot air were similar but significantly different to oven drying (Table 4). Scanning electron microstructure (SEM) analysis in Figure 6 indicates that the cells in oven dried coir pith are notably ruptured as compared to the other two methods. In oven drying, specially the particles close to the surface of the aluminium tray are subjected to uneven heat transfer as compared to the particles away from the surface. Uneven drying might have caused the rupturing of cells in coir pith and hence potassium ions can be easily released as coir pith contains high amount of potassium ions (0.7 – 0.8 %) (Radhakrishnan *et al.,* 2012). Consequently the pH and EC of oven dried coir pith are significantly higher than the coir pith dried under sun and hot air. Similar results were observed by Ozcan *et al*. (2005) for oven drying of basil.

Coir pith is a natural material and hence expands after compaction due to resilience. This could be observed with sun dried coir pith as the coco discs were expanded notably (about 1 – 2 mm) soon after compression. This behaviour can be called as instantaneous expansion. However, fast drying may significantly affect the resilience of coir pith. This could be observed with oven dried and hot air dried coco discs where instantaneous expansion was not noticeable. The bulk density of coir pith is mainly affected by particle size distribution. As explained earlier, uneven heat transfer in oven drying might have ruptured the cells in coir pith and hence the particle size distribution could be altered. This can be observed with the significantly high bulk density of oven dried coir pith as compared to the other two methods.

Bulk densities of sun dried and hot air dried coir pith were similar as indicated in Table 4. However the compaction ratio (CR), which is the ratio of bulk density of coco disc to the bulk density of coir pith for sun drying was significantly lower than that for hot air drying. This may be mainly attributed to the significantly low bulk density of coco discs made from sun dried coir pith due to instantaneous expansion as explained above. On the other hand cells of oven dried coir pith are further ruptured during compression resulting in coco discs also having a higher bulk density. Therefore, even if the oven dried coir pith was having a high bulk density, the CR is very similar to hot air dried coir pith.

Volume expansion with the addition of water is mainly dependent on the water absorbing capacity of the cells. Therefore, oven dried coir pith has a significantly low volume expansion ratio (VE) as compared to hot air dried coir pith due to rupturing of cells. Sun dried coir pith is expected to have the highest VE but Table 4 indicates that VE of sun dried coir pith is comparable to oven dried coir pith. This may be mainly attributed to the high initial volume of coco discs of sun dried coir pith due to instantaneous expansion.

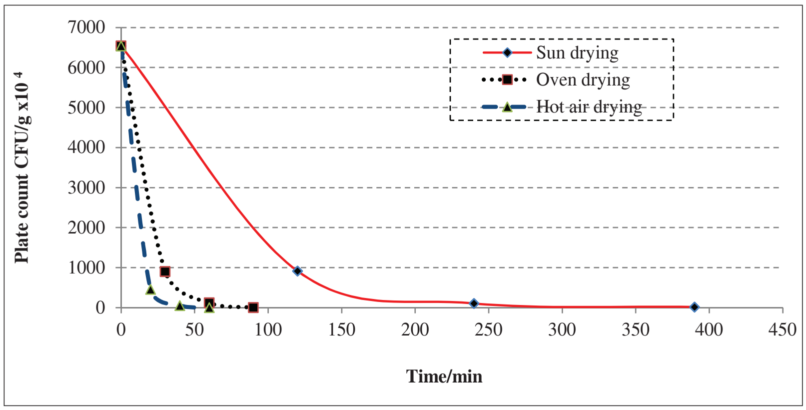

Figure 7: Effect of method of drying on the microbial content of coir pith

Microbial analysis of coir pith

Figure 7 depicts the reduction in microbial content in hot air dried, oven dried and sun dried coir pith. The reduction in microbial content with time is in accordance with the drying rate under different methods and it is mainly attributed to the effect of dehydration. The final microbial content of hot air dried, oven dried and sun dried coir pith were found to be 2.16×10^4, 3.56×10^3 and 1.43×10^5 CFU/g, respectively. In each drying method *E. coli* was found to be less than 3 per 1 g and *Salmonella* was not traceable.

CONCLUSION

Volume expansion ratio (VE) and water retention capacity (WRC) of coco discs significantly improved with the increase of duration of retting of the coconut husks. The changes in VE and WRC from 4 weeks to 12 weeks were found to be from 3.71 ± 0.07 to 5.77 ± 0.19 and from 3.43 ± 0.12 to 5.87 ± 0.35, respectively. A significant change in pH was found within the period of retting from 4 weeks (6.50 ± 0.11) to 6 weeks (5.97 ± 0.12) and there was no further change in the effect with further retting. Electrical conductivity (EC) significantly dropped from 109 ± 7 µs/cm in 4 weeks to 63 ± 8 µs/cm in 12 weeks. Retting facilitated the extraction of coir fibre and significantly improved the properties of fibre. The length, tensile strength and breaking load of coir fibre were found to improve from 133 ± 1 to 182 ± 9 mm, 81 ± 7 to 104 ± 12 N/mm^2 and 3.58 ± 0.42 to 4.32 ± 0.38 N, respectively within the time duration for retting from 4 weeks to 12 weeks. Similar improvement in the properties of coir fibre could be obtained by crushing the husks and retting for a short period of 4 weeks. Time duration had a strong influence on the particle size distribution of coir pith for a given method of fibre extraction. Methods with longer retting time gave a higher amount of fine particles (less than 1 mm), while crushing the husk before retting gave a higher amount of medium size (1 – 2.8 mm) particles. However no significant difference in the physicochemical properties of coir pith was found among the mills, as raw husks for the mill operations were random in nature. Oven drying caused rupturing of the cells and case hardening of coir pith particles especially when in contact with local heating zones. The most suitable method for drying coir pith was found to be hot air drying as compared to sun drying and oven drying when considering the shorter drying time, high VE and WRC. EC and pH in dried coir pith were found to be within the acceptable level for all the different mill operations and methods of drying. Microbial content significantly reduced at the very early stages for all the drying techniques and achieved acceptable levels in dried coir pith. There was no risk of *Salmonella*, *E. coli* and other microbial strains.

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