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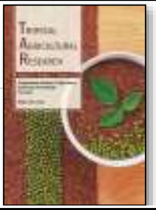

RESEARCH

Impact of Soil Suitability Class, Variety, Milling Method, and Ageing Status on Some Chemical Properties of Coco Pith

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ABSTRACT

Given that coco pith is a versatile growing medium, understanding the factors that influence its physico-chemical properties is crucial for optimizing its use. This study examines how soil suitability class, coconut variety, milling method, and ageing status affect electrical conductivity, pH, and the concentrations of Na^+ and K^+ in coco pith. Husks from *Tall×Tall* (TT) and *Dwarf×Tall* (DT) varieties were processed using dry and wet milling methods, with and without ageing, across 43 blocks representing different soil suitability classes. Results showed that milling method significantly (P<0.0002) influences electrical conductivity, with dry milling producing higher conductivity (1887.07 µS cm^{-1}) than wet milling (1337.25 µS cm^{-1}). Ageing markedly reduced electrical conductivity (P<0.0001), and no significant differences between milling methods were observed for aged coco pith. A three-way interaction between variety, milling method, and ageing status influenced pH (P=0.0007). DT variety processed via dry milling exhibited higher pH values (6.6±0.1), while wet milling consistently yielded lower pH (6.3±0.1). Aged coco pith had an average pH of 6.4, slightly lower than the 6.7 of non-aged pith. Soil suitability class also impacted pH, with S_2 showing the lowest (6.4) and S_4 the highest (6.7) (P<0.05). Na^+ levels were significantly reduced in aged coco pith across all combinations due to enhanced particle breakdown (P=0.0488). Both milling method and ageing status affected K^+ levels (P<0.0001), with ageing leading to reduced concentrations. These findings underscore the importance of ageing and milling methods in improving coco pith quality by optimizing its chemical properties.

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INTRODUCTION

Growing horticultural crops on soilless substrates has long been practiced globally (Xiong et al., 2017; Blok et al., 2021). A variety of vegetable crops including tomatoes, peppers, and cucumbers, as well as fruit crops such as blueberries and strawberries, and a broad range of floricultural crops, are grown using this system. In controlled environment agriculture (CEA) systems, solid substrates are used to produce about 95% of greenhouse vegetables globally (Asaduzzaman, 2015). According to Xiong et al., (2017), the two primary substrates (Blok et al., 2021) employed in substrate mixtures are peat and coco pith (CP).

However, due to emerging ecological and environmental concerns, the present status of agriculture is in search of sustainable sources of alternative substrates mainly for peat. The CP as a byproduct of coconut coir fiber processing has gained widespread recognition as a versatile and sustainable alternative growing medium (Adhikari, 2016; Surve et al., 2023). Its unique physical structure, water retention capabilities, compressibility for transportation, and easy absorption capability, when rehydrated, make it an attractive choice for soilless cultivation systems. Therefore, it has become one of the best plant growth substitutes for soilless culture among commercial growers (Evans et al., 1996).

A number of research studies (Ahmed et al., 2004; Ameri et al., 2012; Konduru et al., 1999) have emphasized the significance of controlling soluble salts and ions for the best possible plant growth. Further studies (Holman et al., 2005; McLachlan et al., 2013) highlighted the relationship between soluble salt levels and plant health and stressed the necessity of close observation and management to avoid negative impacts on growth. Moreover, Hitti et al., (2023) provided insightful information about how pH, EC, and Na^+ levels affect plant performance, highlighting the relationship between ion composition, EC, and general plant health. Variations in pH have a direct impact on nutrient solubility, absorption by plants, and microbial activity in substrates (Altland et al., 2008). Therefore, the influence of soluble salts and ions on pH is equally significant (Noguera et al., 2003; Ameri et al., 2012).

Although CP is an extremely effective substrate with many favourable growth features, it is not without limits when used in its unprocessed form. These limitations distinguish CP from many other known substrate types by making it difficult to employ directly as a substrate in advance cropping systems without adequate preparation. Physical, chemical (Evans et al., 1996) and biological (Thendaramani et al., 2018) components are among these constraints, and their best use requires careful study. Only when chemical parameters such as EC, pH, Na^+, and K^+ of a substrate fall within ranges that support ideal plant growth, it meets the requirements for soilless cultivation (Handreck, 1993). Thus, EC, pH (Paramanandham et al., 2013; Ross et al., 2010), and Na^+ and K^+ contents in CP are the most significant chemical characteristics that have been found to have the potential to impact plant development performance (Gbollie et al., 2021). As nuts develop on coconut palms, soluble mineral salts such as sulphates, carbonates, and chlorides of Na^+ and K^+ accumulate and cause increased concentrations (Xiong et.al., 2017). As a perennial semi-halophyte (Flowers and Colmer, 2008), coconuts take up these chemical components from the soil and store them throughout their whole structure (Evans et al., 1996).

According to Landis (1990), the pH of a grow medium or substrate in soilless culture has a major impact on the availability of plant nutrients, especially micronutrients, which in turn has an impact on plant development and yield (Rippy et al., 2004). Evans et al., (1996) noted that various sources of CP differ significantly in terms of pH, EC, and other chemical components. Electrical conductivity and pH of solutions are often associated with the presence of soluble salts such as Chlorides of Na^+ and K^+ (Hem,1985), Sulphates (SO_4^{-2}) (Stumm and Morgan, 1996; Drever,1997), Carbonate (CO_3^{-2}) and bicarbonates (HCO_3^{-1}) (Langmuir, 1997; Drever, 1997) of Ca^{+2} and Mg^{+2}.

These soluble ion amounts in CP can vary depending on several factors, including the growing environment of coconut, CP extraction techniques, and pH and EC levels of the CP. Elevated pH and EC levels have a direct and significant detrimental effect on plant growth, especially when they reach severe levels in CP. While pH indicates acidity or alkalinity, the level of EC indicates the capacity to conduct electrical currents in CP, because of dissolved salts (Altland et al., 2008). These conditions are important in nutrient dynamics between substrate and plant root system. The availability of plant nutrients decreases as EC reaches higher extremes and pH reaches higher or lower extremes, impacting nutrient absorption and consequently disrupting enzyme activity and other metabolic activities essential for the healthy development of plants. Extreme Na^+ and K^+ concentrations in substrates affect pH and EC, which in turn affects element mobilizations in plants (Camberato et al., 2009) and even cause plant toxicity. Electrical conductivity and pH in CP must be carefully managed and adjusted to maximize its viability as a growing medium in horticulture. Nevertheless, despite the importance of these elements, little is known about the factors of these ions found in CP substrates utilized in soilless farming techniques.

This study aimed to assess the impacts of various factors on the levels of pH, EC, Na^+ and K^+ in processed CP intended for value added plant propagation products used in CEA systems. Given their recognized influence on key chemical properties, the study examined factors such as soil suitability class, variety, milling method, and aging status.

METHODOLOGY

Selection of sample plots and collection of husk samples

Coconut estates with over 100 coconut palms were selected from the Kurunegala, Gampaha, and Puttalam Districts, representing the Coconut Triangle, which is the most prominent coconut growing area in Sri Lanka. This area spans three distinct agro-climatic regions: the Low Country Intermediate Zone (LCIMZ), the Low Country Wet Zone (LCWZ), and the Low Country Dry Zone (LCDZ), classified based on mean annual rainfall and elevation (0–300 m above sea level).

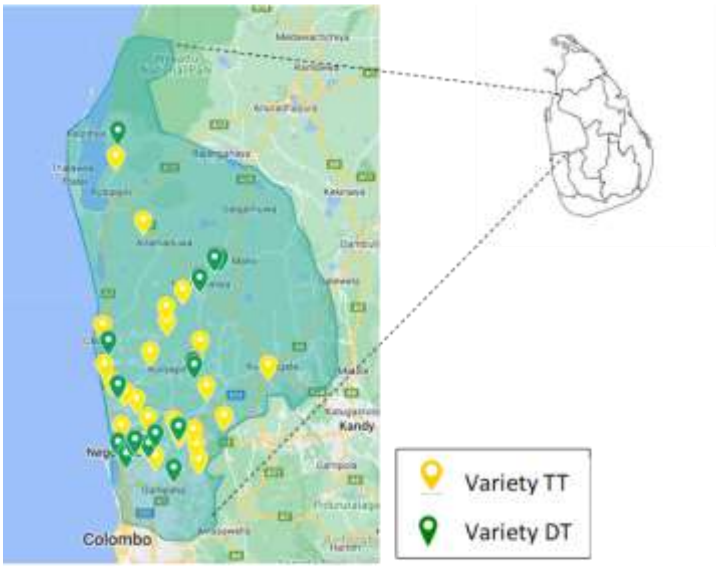

Figure 1. Sampling locations of the study

The selected estates included some with the Tall×Tall (TT) variety and others with the Dwarf×Tall (DT) variety of coconut. Out of the selected 48 estates, 30 estates consisted of the TT variety, and the other 18 were the DT variety. Nut samples, each consisting of 150–200 mature nuts, were collected from the harvests obtained in August 2020 and December 2021 from each estate. The nut samples were labeled with their respective estate numbers (A1–A48), securely packed in polypropylene bags, and transported in canopy-covered trucks under ambient temperature conditions to the factory premises of Jiffy (Pvt.) Ltd. in Kobeigane, Kurunegala District. Out of the 48 samples, only 43 samples found to be within soil suitability guidelines and the final sample count was However, 25 estates for the TT variety and 18 for the DT variety. Nevertheless, these 25 estates belonged to four soil suitability classes. The breakdown of the number of estates belonging to each soil suitability class and variety combination is given in Table 1.

Milling and ageing

Each nut sample brought was randomly divided into four equal portions. Two portions were dehusked soon after transporting them to the factory, and the husks were subjected to coir fiber extraction using the "Dry" milling method separately. The other two portions of the nuts were left to wither separately under natural conditions for approximately three weeks before dehusking. These partially dried, brown nuts were then dehusked and the husks were separately identified for fiber extraction using the "Wet" milling method. Note that withering is a component of the wet milling process.

Two husk portions intended for dry milling were processed using a decorticator (Niro et al., 2012), and CP was collected separately. The CP of one portion underwent aging for 16 weeks, maintaining a moisture content of around 70% with periodic turning for aeration. After that the CP was subjected to the routine follow– up process and sun drying respectively before it was used for chemical analysis. The other dry milled portion was sun dried and used for chemical parameters after the follow-up process without undergoing ageing. The aged CP portion from dry milling was also sun-dried and stored for subsequent chemical analysis after the follow-up process. Similarly, the two husk portions designated for wet milling were placed separately in nylon bags appropriately labelled and soaked in a retting pit for 16 weeks. After soaking, the husk portions were removed from the retting pit, drained, and milled to collect CP separately. Out of these two portions, one portion underwent the follow-up process and sun drying respectively and was stored for subsequent chemical parameter testing. The other wet-milled portion was aged for 16 weeks, sun dried after the follow-up process, and then stored for testing.

The follow-up process for all four portions involved soaking the CP in a calcium nitrate solution for buffering at a rate of 4 kg per cubic meter of CP (industry standard). This was followed by washing twice with fresh water, with an electrical conductivity ranging from 0.2 to 0.5 mS cm^{-1} and a pH ranging from 5.8 to 7.2.

Table 1. Number of selected estates belonging to different soil suitability class classes and varieties

Soil suitability class	Variety	Number of Estates
S_1	TT	4
S_1	DT	9
S_2	TT	10
S_2	DT	5
S_3	TT	7
S_3	DT	2
S_4	TT	4
S_4	DT	2
	Total	43

Experimental design

The study involved four factors: (i) soil suitability class with four levels (S_1, S_2, S_3, S_4) (Somasiri et al., 2006), (ii) variety with two levels (TT and DT) (Liyanage et al., 1988), (iii) milling method with two levels (dry and wet), and (iv) aging status with two levels (with aging and without aging). The structure of the study is that there are several estates for each combination of soil suitability class and variety, and the husk sample from each estate was divided into four portions and allocated into four combinations of milling method and aging status. Thus, each estate satisfies an experimental block. Since estates vary depending on the combination of soil suitability class and variety, estates are nested within each soil suitability class and variety combination. Moreover, the number of blocks (estates) per combination varied from 2 to 10. Thus, the study setup can be identified as the experimental design of the form unbalanced nested block design.

Sampling for testing chemical parameter

A sampling of CP was carried out to analyse the chemical properties, EC, pH, and Na^+ and K^+ concentrations in both demineralized water and $CaCl_2$ extracts. Electrical conductivity was measured in micro siemens per centimetre ($\mu S\ cm^{-1}$), while Na^+ and K^+ concentrations in both extracts were measured in millimoles per Liter ($mmol\ l^{-1}$). The sampling was conducted at four distinct stages, each consisting of three replicates. Initially, samples were collected after each milling process of husk samples from each block (estate), and these samples were then tested for chemical parameters. Following this, CP samples were gathered after an additional 16-week ageing period, followed by the standard follow up process, either from the dry milling or the wet milling process and subjected to chemical parameter testing. This comprehensive sampling approach allowed for the assessment of chemical properties at different stages of processing and ageing.

Data analysis

According to preliminary data analysis, it was found that all test results exhibited a normal distribution, enabling the investigation of the effect of factors and their interactions through unbalanced analysis of variance (ANOVA). Data analysis was performed using the SAS (SAS On Demand for Academics, 2013) software package. Given the unbalanced design, the ANOVA model was fitted using PROC GLM of SAS, and post hoc mean separation was conducted using the least square means (LSMEANS).

Measuring EC and pH: 1:1.5 (Dutch) saturated media extract (SME) method.

A representative sample of dried CP was placed onto a plastic tray and thoroughly mixed with deionized water until very mild wetness was noticeable to fingers upon gentle squeezing. The moist CP was then filled into a 60 ml calibrated measuring cylinder, lightly pressed, and levelled. The sample within the cylinder was transferred to a 250 ml beaker. A 90 ml of deionized water was then added, and the mixture was stirred well with a glass rod and left for 30-45 minutes with two intermittent stirring. Following this period, the pH of the solution was measured using a pH meter (model: Orion three star, made in UK). Subsequently, the solution was filtered through a strainer into a measuring cylinder. Electrical conductivity was determined using an EC meter (model: Orion three star, made in UK), and the readings were recorded. The sample test was replicated three times.

Measuring Na^+ and K^+ concentration in water extract (Na_h and K_h) and $CaCl_2$ extracts (Na_Cl and K_Cl)

The sample preparation step was similar to the solution preparation described under measuring EC and pH measurements. The Na^+ and K^+ ion extraction for demi water was performed using deionized water and $CaCl_2$ solution. the $CaCl_2$ extraction was done by using $CaCl_2$ solution at 4000 ppm concentration. The solutions were then filtered through filter papers, and one filtrate was tested for K^+ and the other for Na^+ using a calibrated "Labtron-LFP A30" flame photometer (Brand: Labtron, Model LFP A30, made in UK), with readings recorded for analysis. All samples were tested in triplicates.

RESULTS AND DISCUSSION

Effect of milling method and ageing on EC

The analysis of results revealed a significant ($P<0.0002$) influence of the milling method on the EC of CP (Figure 1). The CP made from dry milling was higher in EC (1887.07 µS cm^{-1}), compared to that of wet milling (1337.25 µS cm^{-1}) before ageing. The interaction is of the form that regardless of the milling method, ageing status effects on reducing the level of EC. However, without ageing, the CP resulted from dry milling showed higher EC than wet milling.

The findings indicate a reduction in EC from non-aged to aged CP, regardless of the milling method. For horticultural substrates, an EC range of 0.5 to 1.5 mS cm^{-1} is generally considered ideal (Awang et al., 2009). EC in CP is mainly influenced by the presence of soluble salts, particularly sodium (Na^+) and potassium (K^+) chlorides (Hem, 1985; Evens et al., 1996). Dry milling tends to produce CP with higher EC levels, requiring additional treatments, such as washing with fresh water, to lower the salt content. In contrast, CP from wet milling typically has a lower EC, making it more suitable for immediate use with minimal further processing. The difference in EC levels between the milling methods arises from the fact that husks used for wet milling are soaked for 16 weeks prior to processing, which allows some soluble salts to leach out (Abad et al., 2005; Awang et al., 2009). In contrast, dry milling utilizes unsoaked husks, retaining more of the salts.

The results suggest that if aging can be implemented in industrial practices, prioritizing the sourcing of dry milled CP would be more advantageous, given the production constraints associated with wet milled CP.

Effect of variety, milling method and ageing status on pH

The interaction effects of variety, milling method and ageing status on pH are summarized in Table 1. A significant three-way interaction effect (P=0.0007) is evident between the three factors. In the presence of this three-way interaction, overall, two-way interaction effects were also detected between the milling method and ageing status (P<0.0001), as well as between variety and ageing (P=0.0220). The soil suitability class had a significant main effect on pH.

Table 2. Summary of significant P<0.5 values for main effects and interactions for different chemical properties

	EC	pH	Na_h	Na_Cl	K_h	K_Cl
VAR×MM×Ag		0.0042**	0.0488*			
SS×MM×Ag				0.0405		
MM×Ag	0.0002**	0.0002**			<0.0001**	<0.0001**
VAR×Ag		0.0129**				
SS×MM			0.0214*	0.0084**		
SS×Ag			0.0211*	0.0219*		
VAR		<0.0001**				
MM	<0.0001**	0.0011**			<0.0001**	<0.0001**
Ag	<0.0001**	<0.0001**	<0.0001**	<0.0001**	<0.0001**	<0.0001**
SS		0.0204*	0.0488*	0.022*		

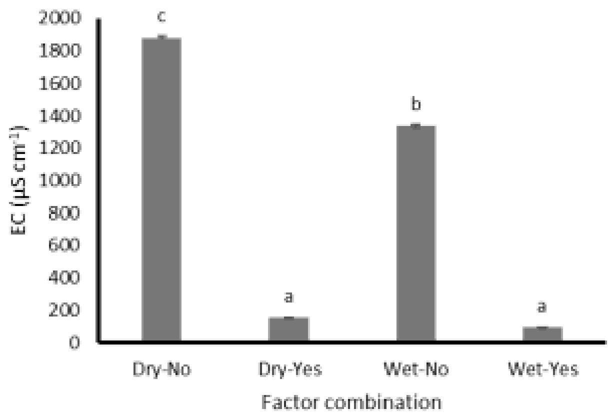

Figure 2. Electrical conductivity of coco pith (CP) processed using wet and dry milling methods, with and without ageing (Yes/No). [Error bars indicate SE means. Means with different letters are significantly different at $\alpha = 0.05$.].

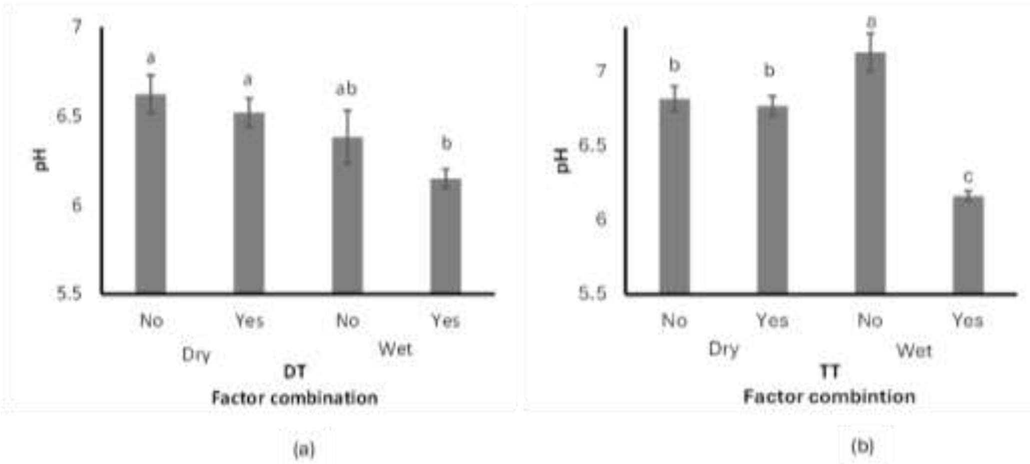

Figure 3. Adjusted means (least square means) of pH of coco pith processed under three factor factorial combinations of variety, milling method, and ageing status. (a) Interaction effect of milling method and ageing status on variety DT. (b) Interaction effect of milling method and ageing status on variety TT. (Dry – dry milling method, Wet – wet milling method, Yes – with aging, No – without aging [Error bars indicate SE of means]. Least square means with the same letter are not significantly different at $\alpha = 0.05$)

According to Figure 02, the three–way interaction on pH may be interpreted as the interaction between the milling method and ageing status varies depending on the variety. With TT, ageing status did not have any effect if the milling method was dry milling, but the pH was higher without aging than with aging when the milling method was wet milling. The Aging of wet milled CP resulted in a lower pH value of 6.16 in both DT and TT varieties. With DT, overall, the CP made by the dry milling method was higher (6.57±0.05) in pH than that made by wet milling method (6.24±0.09), and CP made without aging was higher than that made with aging. Irrespective of ageing status and milling method, the DT variety consistently displayed a lower pH value (6.42), compared to the TT variety (6.72). Overall, aging status exhibited a substantial effect (P<0.0001) in pH values that, on average, aged CP resulted in a lower pH of 6.4, while on average, non–aged CP showed a higher pH of 6.74. It is clear that aging has a huge effect regardless of variety and milling method where aging substantially reduces pH (Figure 2). The overall milling method effect (P=0.0011) was that the CP of dry milling resulted in a pH of 6.68, while wet milling yielded 6.56. Soil suitability class also effected on pH of CP but there was not any interaction between this factor with any other factor ($P>0.05$). Out of the soil suitability classes, S_2 class resulted in the lowest ($P<0.0001$) pH of 6.42 while S_4 class resulted in the highest ($P<0.0001$) pH of 6.71.

The pH level of growing media is an essential parameter influencing substrate quality. The recommended RHP standards for pH range for CP for value added products is between 3.5 and 7.5 (RHP module 490, 2023). pH acts as a key role in modulating the availability of nutrients to plants (Paramanandham et al.,2013). For optimal crop growth, maintaining substrate pH within the range of 5.4 to 6.8 is recommended (Penisi, 2023), and these CP samples meet ideal conditions for nutrient availability and plant health, with the exception of the TT variety × wet milled × non-aged sample. The outcome can be associated with the growing soil environment as Paramandham et al., 2013 witnessed a pH range from 5.98 to 8.4. The study revealed a pH range between 6.15 and 7.1, which aligns with the allowable pH range of RHP specifications.

Effect of variety, milling method and ageing on Na^+ in demi water extract

Figure 3 shows that there was a significant three-way interaction ($P=0.0488$) between the factors, variety, ageing status, and milling method, for Na_h. The demi water extract of the variety and milling method combinations after ageing had a significantly low level of less than <1.7 mmol l^{-1} (1±0.12) Na^+ concentration while the Na^+ without ageing was greater than 7.11 mmol l^{-1} (7.6±0.76). Variety DT with dry milling resulted in the maximum concentration of 8.9 mmol l^{-1}. After the ageing process, variety and milling method combinations resulted in little variation in Na^+.

Ageing has facilitated the release and removal of Na^+ from CP, as it extends the retting process through microbial activity. The microorganisms involved in retting continue to break down constituents such as cellulose and hemicellulose (Meenachchandram, 1979), causing CP particles to detach and reduce in size while releasing attached soluble salts into the water. This process facilitates the reduction of Na^+ levels in the CP.

There were two types of two-way interactions found for Na_h. The significant interaction ($P=0.0211$) between soil suitability class and ageing demonstrated that, following ageing, the Na^+ level in CP drastically decreased from 7.59±0.79 mmol l^{-1} to 1.02±0.04 mmol l^{-1}. Another significant two-way interaction ($P=0.0214$) was found between soil suitability class and milling method. Here the difference in Na^+ content between the two milling methods was minimal, with dry milling showing 4.56±0.8 mmol l^{-1} and wet milling showing 4.05±0.2 mmol l^{-1}.

Effect of soil suitability class, milling method and ageing status on Na^+ content in $CaCl_2$ extract

Figure 4 illustrates a significant ($P=0.0405$) three-way interaction between soil suitability class, milling method, and ageing status on Na^+ content in $CaCl_2$ extract. In the absence of ageing, the milling method and soil suitability class resulted in a higher concentration (9.52±1.21 mmol l^{-1}) of Na^+ in the CaCl2 extract. Sodium content in dry milled CP, without ageing, exhibited higher variability (9.77±1.77 mmol l^{-1}) across different soil suitability classes. In contrast, wet milled CP, without ageing, maintained a more consistent Na^+ content (9.22±0.3 mmol l^{-1}) (Figure 4). However, with ageing, the Na^+ content in both dry milled and wet milled CP became more consistent, with dry milled CP showing 1.44±0.1 mmol l^{-1} and wet milled CP showing 1.63 ± 0.18 mmol l^{-1}.

Moreover, Na^+ content in $CaCl_2$ extract exhibited two types of significant two-way interactions. One interaction was between soil suitability class and ageing status ($P=0.0219$), and the other one was between soil suitability class and milling method ($P=0.0084$).

The interaction between soil suitability class and ageing status showed that the $CaCl_2$ extracted Na^+ content across all soil suitability classes was high (9.52± 0.90 mmol l^{-1}) and variable without ageing. With ageing, the detected Na^+ concentrations were low (1.54±0.07 mmol l^{-1}) and more consistent. In the two-way interaction between soil suitability class and milling method, dry milled CP exhibited a Na^+ content of 5.61 ± 0.93 mmol

l^{-1}, while wet-milled CP had a Na+ content of 5.45±0.09 mmol l^{-1}. There were significant main effects of soil suitability class (*P*=0.0220) and ageing status (*P*< 0.0001) present on the Na^+ content of CP.

Effect of milling method and ageing status on K^+ content in water extract (K_h) and $CaCl_2$ extract (K_Cl) of CP.

An analysis of CP for K_h showed that milling method and ageing status have a significant (*P*<0.0001) two-way interaction. Figure 5 illustrates that when CP was produced using either wet or dry milling and without ageing, the K^+ content was higher (with dry milling 8.42 mmol l^{-1} and with wet milling 5.45 mmol l^{-1}). However, with ageing, the K^+ concentration fell to 0.43±0.11 mmol l^{-1} for both milling techniques.

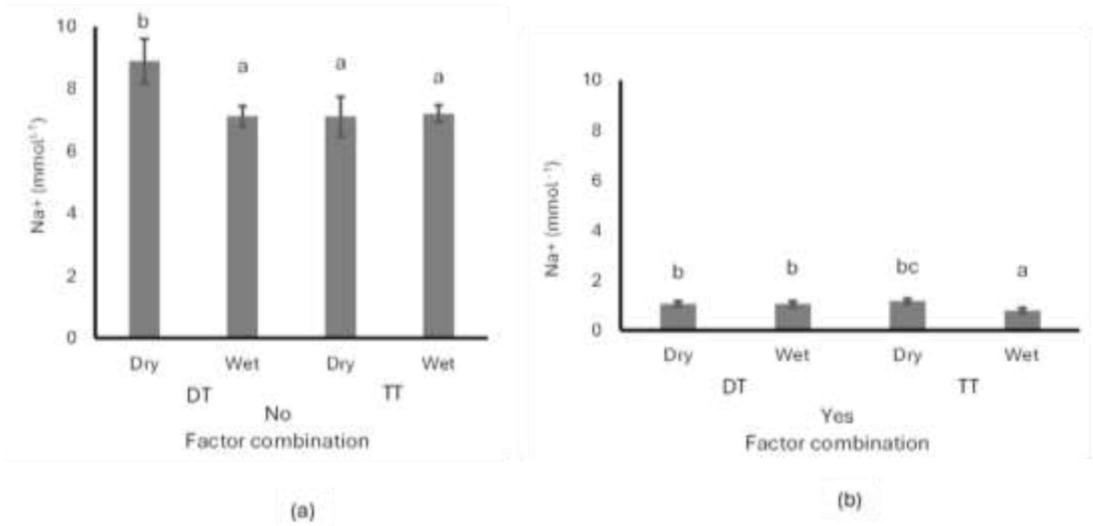

Figure 4. Na^+ content of CP processed from variety TT and DT, with dry milling (Dry) and wet milling (a) before ageing (No) and (b) after ageing (Yes) in demi water extract. [Error bars indicate SE of means. Least square means with the same letter are not significantly different at $\alpha = 0.05$

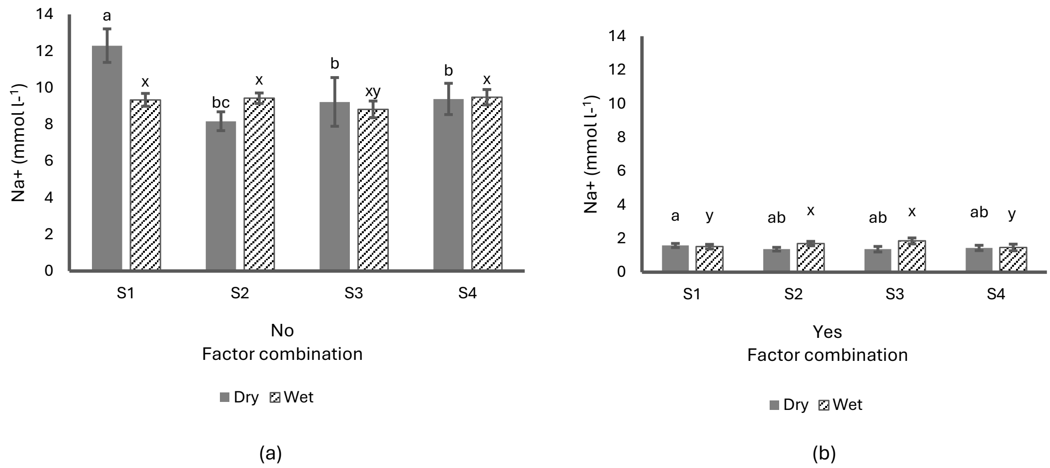

Figure 5. Na^+ content of processed CP of different combinations of factors, soil suitability class, milling method, and ageing in $CaCl_2$ extract. (a) before ageing (No) and (b) after ageing (Yes) Dry = dry milling, Wet = wet milling). [Error bars indicate SE of means. The Least square means with the same letter are not significantly different at $\alpha = 0.05$]

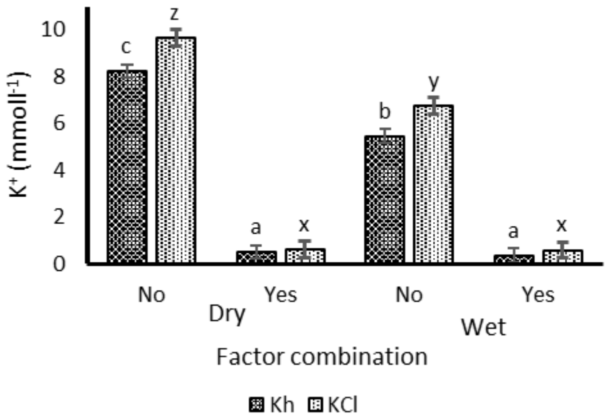

Figure 6. Interaction effect of milling method and ageing on K^+ in CP for K_h and K_Cl. (K_h=K^+ content in water extraction and K_Cl=K^+ content in $CaCl_2$ extract). [Error bars indicate SE of means. LS means that do not share the same letters are significantly different at α =0.05]

Furthermore, both milling method and ageing status found to have significant main effects on K_h of CP. Dry milling resulted in a K^+ content of 4.37 mmol l^{-1}, while wet milling yielded 2.90 mmol l^{-1}. Regarding ageing status, the K^+ content without ageing was 6.84 mmol l^{-1}, whereas after ageing it decreased to 0.42 mmol l^{-1}. Both milling and ageing status demonstrated significant main effects at P<0.0001.

In parallel to the measures of K_h of CP, K_Cl was also present in the same pattern only with the exception, that all the levels were greater than that was present in the water extract. According to Figure 5, the K_Cl was found to be having a two-way interaction between milling and ageing status (P<0.0001). In that, both dry milling and wet milling had a high level of K^+ in CP, without ageing (with dry milling 9.66 mmol $l^{-1}$with wet milling 6.76 mmol l^{-1}) which became a lower value of 0.6 mmol $l^{-1}$with aging for both dry milling and wet milling.

The Milling method and ageing status had significant main effects on the K_Cl of CP (P<0.0001). The CP from dry milling had a K^+ content of 5.13 mmol l^{-1} and it was 3.67 mmol l^{-1} from wet milling. The main effect of ageing status was of the form, that the K^+ content, without aging and with aging were 8.2 mmol l^{-1} and 0.6 mmol l^{-1} respectively, demonstrating the effectiveness of ageing on K_Cl.

As per the specifications provided in the RHP (https://www.rhp.nl) guidelines for CP (Module 490, 2023), strict adherence to predefined levels of chemical criteria, particularly EC, pH, Na^+ and (K^+) contents, is imperative. Deviations from the optimal allowable threshold levels of these chemical conditions (EC, pH) and elements (Na^+, K^+) can negatively impact crop growth and development.

Significant interaction effects between the milling method and aging status, along with their independent effects, were observed for K_h and K_Cl contents in CP (Table 1). These interactions highlight notable variations in the accumulation of soluble salts, which directly influence EC. This suggests that during milling and aging, these salts may leach out from CP. Consequently, clear differences emerge, particularly when comparing non-aged to aged CP and dry milling to wet milling. Also, wet milled CP has the potential to reduce EC levels to minimal values by the end of the aging process.

Coco pith from the dry milling process, before aging, is similar to its natural form and retains its original salt content. Sodium, a common element in soils (Maathuis, 2014), is especially abundant. Since the coconut tree is a semi-halophyte, it stores high levels of Na+ in the CP. The higher levels of K^+ content in CP would have followed the same phenomenon that absorb and assimilate K^+ from soil.
Overall, ageing status and milling method had the most impact on the important chemical parameters that are being studied of the four

main factors that were looked at. Ageing status shows up as a critical component for every element examined, with milling method having a particular effect on K^+, pH, and EC. Significant effects on K^+, pH, and EC were also observed in the two-way interaction between milling method and ageing state. The significance of collecting wet milled raw CP as the source raw material in value addition requirements is highlighted by this study. The use of aged raw CP is essential for manufacturing value-added CP products. As per the specifications provided in the RHP (https://www.rhp.nl) guidelines for CP (Module 490, 2023), strict adherence to predefined levels of chemical criteria, particularly EC, pH, Na^+ and (K^+) contents, is imperative. Deviations from the optimal allowable threshold levels of these chemical conditions (EC, pH) and elements (Na^+, K^+) can negatively impact crop growth and development.

CONCLUSION

This study emphasizes that wet milling combined with ageing significantly enhances the chemical properties of CP, reducing electrical conductivity, Na^+, and K^+ levels while achieving optimal pH, ideal for value-added growing media. Practitioners can choose between wet milled CP without ageing or dry milled CP with ageing to balance cost and process efficiency.

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