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Enhancing Sustainable Agriculture through King Coconut Husk Ash: Investigating Optimal Processing Parameters for High Potassium Content and Efficient Waste Management

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Abstract: The global demand for bottled king coconut water has led to a significant accumulation of empty king coconut husks in nut water export industries, posing challenges in managing and disposing of this agricultural waste. To address this issue, the production of king coconut husk ash (KCHA) has emerged as an eco-friendly solution. This product can be applied as a fertilizer, soil amendment, or after mixing with compost to enhance its nutrient value. This study aimed to determine the optimal cut size and moisture level for obtaining a high yield of KCHA with the maximum potassium content. The experiment involved drying full, half, quarter, and chip-sized husks in a dehydrator at 60°C for 0, 2, 4, 8, 12, 24, and 48 h. The findings revealed that reducing the particle size of the husks accelerated the drying process. Ash produced with chips exhibited the most favorable characteristics, reaching the desired dryness in a relatively shorter time while yielding the highest KCHA content. Moreover, the results indicated that the optimal duration for dehydrating the husks to produce ash was 24 h at 60 °C, resulting in highest moisture loss. This processing condition facilitated the efficient conversion of king coconut husks into potassium-rich ash. Implementing these findings into the production of KCHA as a nutrient-rich fertilizer or soil amendment offers a sustainable approach to improve agricultural practices while reducing the dependence on synthetic fertilizers and mitigating the environmental challenges associated with their accumulation.

Keywords: Ash; Cut size; King coconut; Potassium; Soil amendment

1. Introduction

Sustainable agriculture has emerged as a crucial paradigm in the face of global challenges such as climate change, diminishing natural resources, and food security concerns. In pursuit of eco-friendly solutions, researchers have turned their attention to agricultural waste valorization, aiming to harness the potential of various byproducts to enhance soil fertility and reduce the dependence on chemical fertilizers [1].

The king coconut (*Cocos nucifera* var. *aurantiaca*), indigenous to Sri Lanka, has long been cherished for its sweet and refreshing water [2]. The global demand for bottled king coconut water has led to a significant accumulation of empty king coconut husks in nut water export industries, posing challenges in managing and disposing of this agricultural waste [3]. But it has drawn interest as a valuable resource with multifaceted applications in present the world. Particularly, the conversion of king coconut husk into ash has shown promise as an effective and sustainable soil amendment.

Researchers have reported that coconut husk is a rich reservoir of potassium (K) and other essential nutrients, making it a promising alternative to synthetic fertilizers [4]. Since the king coconut is in the immature stage of this, same qualities should be expected. Utilizing king coconut husk ash (KCHA) as a soil amendment not only reduces the dependency on chemical fertilizers but also presents an eco-friendly solution to the environmental burden posed by agricultural waste. In addition to its agronomic potential, the proper management of agricultural waste is equally significant for sustainable agricultural practices. To fully harness the potential of king coconut husk ash as a sustainable soil amendment, it is essential to investigate the optimal processing parameters that yield high K content. The processing conditions, including temperature, duration, and pre-treatments, significantly influence the final nutrient composition of the ash. An in-depth exploration of these parameters will provide valuable insights into maximizing the K content of KCHA and ensuring its efficacy as a soil enhancer. This study aimed to investigate the optimal cut size and moisture level for obtaining a high yield of KCHA with the maximum K content while simultaneously addressing efficient waste management strategies.

2. Material and Methods

The research was carried out at the Agronomy Division of the Coconut Research Institute in Lunuwila, Sri Lanka. Fresh king coconut husks (KCH) were collected from the "Silvermill" Group of the company located at Loluwagoda, Mirigama. The study investigated two factors: the cut size (whole husk, half husk, quarter husk, and chips) and the dehydration time (0, 2, 4, 8, 12, 24, and 48 hours) (Figure 1).

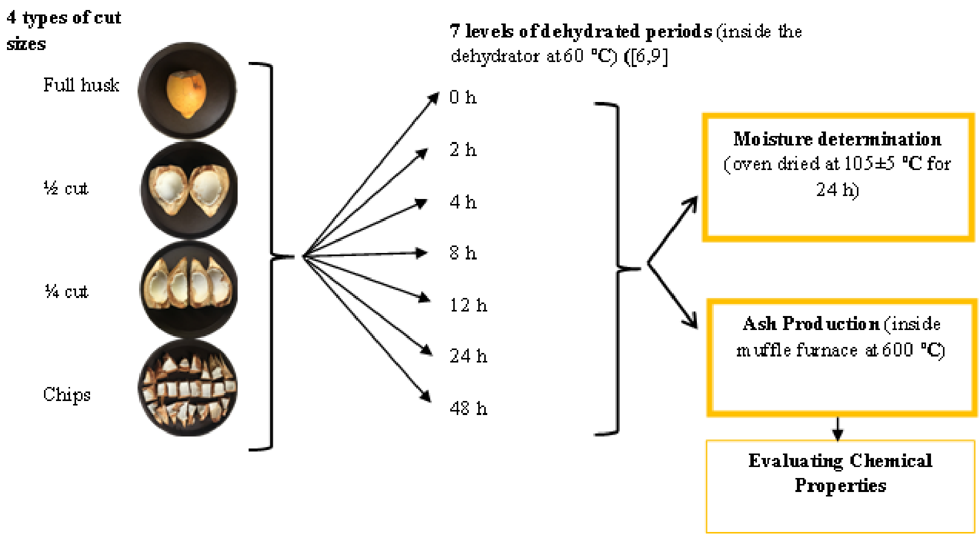

Figure 1. Methodology adapted for KCHA production and evaluation.

All the data collected were analyzed using IBM SPSS statistical software (Version 26.0). The effect of cut size and the dehydrated time was analyzed using one-way ANOVA. Mean separation was done using Duncan's Multiple Range Test.

3. Results and Discussion

3.1. Moisture content of husks varies with dehydration time

Reducing the moisture content of KCH is essential for producing ash because moisture in the husk interferes with the combustion process. During combustion, the husk is subjected to high temperatures, causing the organic matter to break down and release volatile gases. If the husk contains a high moisture content, a significant portion of the heat energy produced during combustion is used to evaporate this water, leaving less energy available for the combustion of the organic material. The presence of excess moisture can also lead to incomplete combustion, resulting in the production of more smoke, less ash, and lower quality of the produced ash. In addition to affecting the combustion process, high moisture content can lead to issues with storing and handling the husk, as it can promote the growth of mold and bacteria. Reducing the moisture content of the husk before combustion ensures better combustion efficiency, higher ash yield, and improved ash quality, making it a more suitable soil amendment and value-added product [5].

Fresh husks collected from processing factories after the extraction of nut water had 86-87% of moisture content. As shown by Table 1, by extending the dehydration period as well as reducing the cut size of the KCH, the moisture content can be minimized. There were significant differences in the dehydration time durations of moisture content of king coconut husk ($p < 0.001$). In each dehydration time period, chips showed more moisture losses compared to full husk drying. The highest moisture is removed when the smaller the cut size. Numerically 2, 4, 8, 12, 24, and 48 h dehydration caused 7.1, 28.5, 30.4, 40.5, 71.2, and 47.2 % moisture loss compared to full husk respectively. Except for the whole husk, all husk cut sizes reached < 10 % dryness in 48 hours of drying. Within 24 h of drying at 60 °C, nearly all of the moisture in the chips evaporated. As a result, while drying king coconut husk, chips may be the most effective drying particle size, reaching dryness in 24 hours at 60 °C in continuous drying. If the particle size is larger, it must dry for 48 hours before being utilized in the production process.

Table 1. Retained moisture (%) and ash yield (%) of different cut sizes of husk at different dehydration time period.

Time (h)	Retained moisture % at each cut size				Ash yield (%) at each cut size			
	Full husk	½ th husk	¼ th husk	Chips	Full husk	½ th husk	¼ th husk	Chips
0	86.44^{c*}	85.91^{d}	86.92^{e}	86.58^{d}	0.88^{b}	1.23^{b}	1.28^{c}	1.25^{b}
2	85.96^{bc}	84.40^{c}	79.47^{de}	78.84^{d}	1.06^{b}	1.25^{b}	1.53^{c}	2.09^{b}
4	82.04^{bc}	73.05^{c}	70.37^{cd}	53.55^{c}	1.29^{b}	1.53^{b}	1.67^{c}	1.78^{b}
8	80.43^{bc}	69.98^{c}	69.42^{cd}	50.06^{b}	1.29^{b}	1.39^{b}	2.15^{bc}	3.98^{b}
12	78.49^{bc}	68.71^{c}	61.67^{c}	38.02^{b}	1.10^{b}	1.67^{b}	1.97^{bc}	3.98^{b}
24	75.20^{b}	34.05^{b}	23.18^{b}	3.99^{a}	2.04^{ab}	3.96^{a}	3.20^{a}	7.34^{a}
48	49.46^{a}	7.19^{a}	5.52^{a}	2.27^{a}	2.74^{a}	4.84^{a}	5.40^{a}	7.48^{a}
CV	15.508	44.835	50.74	69.66	48.91	48.91	64.23	63.69
p value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.01	< 0.01	< 0.001	< 0.001

Moisture remained at each cut size were shown as a percentage of the weight of dry husks after dehydration in different drying periods at 60°C. *Mean with each superscripted by different letters in the same row are significantly different.

3.2. Ash yield with different KCH cut sizes and dehydration periods

The acquired ash yield from the dehydrated period showed a significant increasing trend as the dehydrated duration increased gradually (Table 1). The husks chips with the lowest moisture (2 %) yielded the most significant ($p < 0.001$) ash yield (7.5 %) when dried for 48 hours at 60°C, which was not substantially different from the ash obtained from the chips dried for 24 hours. This clearly shown that the lower the moisture content of the husk, the higher the ash output.

The significant increasing trend in ash yield as the dehydrated duration increases can be attributed to the removal of moisture from the KCH during the dehydration process. As the dehydration time prolongs, more water is eliminated from the husk, resulting in a higher concentration of solid matter. This, in turn, leads to a higher yield of ash when the dehydrated husks are combusted. [6] also observed a similar relationship between moisture loss and solid gain in various plant materials.

3.3. Total Potassium content (K) of different KCH cut sizes and dehydration periods

K is one of the essential macronutrients required for the growth and development of plants. It plays a crucial role in various physiological processes, including enzyme activation, osmoregulation, and nutrient transport within the plant [7]. Studies have shown that the ash obtained from coconut husk after combustion is rich in K content (6.50 % at 300 °C of combustion temperature) [8]. Coconut husk ash has been recognized as a valuable source of K, and it can be used as a natural alternative to synthetic potassium fertilizers in agriculture.

As shown in Table 2, there was no significant difference in the K content of KCHA among full husk and ½ th cut size with dehydration period ($p > 0.1$). But there is a significant difference between ¼ th cut size and chips particle size with dehydration period ($p < 0.01$). The K content of KCHA in this study ranged from 18 % to 36 % on a dry basis.

Table 2. Total potassium (K) content (%) of different cut sizes of husk at different dehydration time periods.

Time (h)	Total K content (%) at each cut size			
	Full husk	**½ th husk**	**¼ th husk**	**Chips**
0	27.22	28.90	16.50^{c*}	19.55^{b}
2	26.53	14.81	18.90^{bc}	17.81^{b}
4	32.88	40.38	44.61^{a}	43.74^{a}
8	31.25	30.63	31.30^{abc}	35.57^{ab}
12	31.38	28.16^{ab}	27.88^{abc}	25.06^{b}
24	31.47	31.72^{ab}	37.05^{ab}	25.88^{ab}
48	28.69	29.99^{ab}	25.55^{abc}	24.41^{b}
CV	18.70	33.76	37.86	36.77
p value	> 0.1	> 0.1	< 0.01	< 0.01

*Mean with each superscripted by different letters in the same row are significantly different.

The best cut size and the dehydration time, which give the highest ash yield and K content was determined using a weighted average index. The results of the 28 different treatment combinations (cut size (4) x dehydration time periods (7)) were ranked as shown in Figure 2.

Time (h)

Cut size	**0**	**2**	**4**	**8**	**12**	**24**	**48**
Full	23	22	15	16	19	14	12
½ th cut	21	28	10	17	20	9	5
¼ th cut	27	25	4	6	18	7	8
Chips	26	24	13	3	11	1	2

Figure 2. Ranking of 28 treatment combinations.

3.4. Potential of pH and Electrical conductivity (EC) ranges of KCHA as a nutrient supplement

The pH and EC of ash are important factors to consider when using it as a fertilizer source because they directly impact soil health, nutrient availability, and plant growth. The pH of ash determines its acidity or alkalinity playing a critical role in nutrient availability and microbial activity. Ash with a high pH (alkaline) can raise the soil pH, making it less acidic. This can be beneficial for acidic soils, as it helps to neutralize the acidity, making nutrients more accessible to plants. When ash is used as a fertilizer source, its EC can influence soil salinity levels. Excessive salts can negatively affect plant growth by creating osmotic stress, reducing water uptake by plants, and disrupting nutrient uptake. According to the results shown in Table 3, pH values of KCHA ranged between 9.92–11.05. The pH values of KCHA were not observed a significant difference or a trend with treatments ($p > 0.05$). Electrical conductivity was ranged from 10 µS/cm to 40 µS/cm. There were no significant differences with dehydration time and EC of produced KCHA except chips ($p > 0.1$). There was a significant difference with EC of ash which produced chips in different dehydration periods ($p < 0.1$). By considering the 'partial eta squared' values no significant effect on ash pH or ash EC were identified in relation to the cut size of KCH. However, the pH and EC of the KCHA were significantly altered due to dehydration time. The interaction effect of cut size and dehydrated time has little or no effect on the pH and EC levels of KCHA.

Table 3. pH and EC values of KCHA produced from different cut sizes of husks at different dehydration time periods.

Considered factor	pH		EC (µS/cm)	
	Significance	Partial Eta Squared	Significance	Partial Eta Squared
Cut size	0.438	0.047	0.386	0.052
Dehydrated time	0.000	0.410	0.028	0.216
Interaction effect of cut size and dehydrated time	0.352	0.266	0.387	0.259

4. Conclusion

Sustainable agriculture has become increasingly important in addressing global challenges such as climate change, depleting natural resources, and food security concerns. The valorization of agricultural waste, particularly king coconut husk, has emerged as a promising eco-friendly solution to enhance soil fertility and reduce reliance on chemical fertilizers. This study focused on the production of KCHA as a sustainable soil amendment. The findings demonstrated that the moisture content of the husks significantly influenced the ash yield, with lower moisture content leading to higher ash output. Additionally, the K content of KCHA was observed to increase with longer dehydration times. The research also revealed that the cut size of king coconut husks had a limited effect on the pH and EC of the ash. However, the dehydration time had a significant impact on the pH and EC levels of KCHA. In light of these findings, the use of king coconut husk ash as a nutrient supplement and soil enhancer can contribute to sustainable agriculture practices, mitigate environmental burdens posed by agricultural waste, and promote eco-friendly solutions in the global pursuit of a more sustainable and resilient agricultural system. Further research and field trials are warranted to fully explore the practical applications of KCHA in different soil types and crop systems.

Supplementary Materials: Not applicable

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