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RESEARCH ARTICLE

A COMPARATIVE ASSESSMENT OF FRUIT COMPONENTS OF RECOMMENDED COCONUT (*Cocos nucifera* L.) CULTIVARS IN SRI LANKA

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Abstract

The coconut (*Cocos nucifera* L.) is one of the major plantation crops in Sri Lanka, which contributes to both local consumption and export income generation. The recommended coconut cultivars (RCC) play a major role in that, providing higher nut production. The absence of information on dry matter (DM), crude fat (CF) of the kernels, coconut milk yield (CMY), and total solids of coconut milk (TS) in the RCC has created a knowledge gap in identifying specific cultivars for better end use. Therefore, the objectives of the current study were to conduct a comparative fruit component analysis that measures all of the above parameters. The studied materials were CRIC60, CRIC65, CRISL98, CRISL2004, CRISL2012, CRISL2013, and CRISL2020. Six fully matured nuts were collected from six palms of each variety at the Raddegoda Estate, Kurunegala, Intermediate zone. Measurement included weights of the fresh nuts (FNW), de-husked nuts (DNW), husk (HW), shell (SW), kernel (KW), nut water (WW), DM, and CF content of the kernel. After that, CMY content per nut and unit fresh weight of kernel were assessed and followed by the measurement of TS. Experiments were arranged in a CRD with one-way ANOVA. Means were compared using Tukey's test at $\alpha = 0.05$. The highest FNW, DNW, SW, and KW were observed in CRISL98. There was no significant difference for the DM%, CF%, CMY per unit fresh kernel weight, and TS% in CM. CRISL98 stands out with the highest CMY per nut. Overall, the results indicate that CRISL98 is the best option in terms of per-nut value. However, as there are no significant differences in unit weight or percentage values of DM, CF, CMY per unit fresh kernel weight and TS, each cultivar has equal potential to use in any end use. This is the first study to report all these components in RCC in Sri Lanka.

Keywords: Cultivar evaluation, Crude fat, Coconut milk yield, Kernel attributes

INTRODUCTION

The coconut (*Cocos nucifera* L.) is one of the major plantation crops in Sri Lanka and ranked among the top six producers globally (Nuwarapakasha *et al*, 2022). Due to the diverse uses of all parts of the plant, it is also called the "tree of life" (Perera *et al*., 2010a). Nearly 65-70% of Sri Lanka's nut production is used for local consumption, while the rest supports the export industry (Samarajeewa, 2002; Ranasinghe, 2017). In 2024, industries engaged in coconut export generated USD 854.93 million (Coconut Development Authority, 2024). Among the many important parts of the coconut, the coconut fruit holds the highest economic value. Each part of the husk, shell, and both solid and liquid endosperm is used for diverse product development, fueling a multi-million-dollar export industry in Sri Lanka. For instance, in 2024, husk (fiber and finished product), shell, and kernel products generated approximately Rs 70.5 billion, Rs 47.7 billion, and Rs 138.6

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billion, respectively (Coconut Development Authority, 2024).

Apart from its export value, the coconut also plays a vital role in Sri Lanka's local culinary and food culture. It is the second most important food in Sri Lanka, second only to rice (Mufeeth *et al*., 2021). Traditionally, coconuts have been a staple in the Sri Lankan diet, providing essential nutrients and serving as a major source of dietary fats. As a result, Sri Lanka reports the highest per capita coconut consumption in the world (Samarajeewa, 2002). The per capita coconut consumption, including coconut oil, is 122 nuts per year in Sri Lanka (Periyapperuma *et al*, 2023). For the security of both the export market and local consumption, the improved coconut cultivars play a major role. Although breeding of coconut is a long-term and strenuous process, the Coconut Research Institute of Sri Lanka (CRISL) has recommended seven improved cultivars: CRIC60, CRIC65, CRISL98, CRISL2004, CRISL2012, CRISL2013, and CRISL2020 (Coconut Research Institute, 2018). These cultivars were well reported for the higher nut yield and kernel production in numerous studies (Perera *et al*., 2010b; Dissanayaka *et al*., 2012; Perera *et al*., 2014a; Meegahakumbura *et al*., 2019). However, in the above evaluation studies, the nuts were primarily assessed for basic fruit component (BFC). That includes the weights of fresh nuts, de-husked nuts, husk, kernel, and coconut water of the nuts. Parameters measured in BFC analyses do not provide information on kernel attributes such as dry matter content (DM), crude fat content (CF), coconut milk yield (CMY), and total solids in coconut milk (TS), which have remained unresearched. Measurements of DM and CF of the kernel indicate valuation in dry kernel and oil content, respectively (Alyaqoubi *et al*., 2015; Oh *et al*., 2018). The absence of the above information has created a knowledge gap in identifying specific cultivars for better end use. Therefore, the objectives of the current study were to conduct a comparative fruit component analysis that examines the DM, CF, and CMY of coconut kernels along with the BFC of recommended coconut cultivars in Sri Lanka.

METHODOLOGY

Study location

All the recommended coconut cultivars (RCC) by CRISL, namely, CRIC60, CRIC65, CRISL98, CRISL2004, CRISL2012, CRISL2013, and CRISL2020, were studied. Selection and hybridization were the primary breeding methods involved in the development of these cultivars (Table 1). The nuts, belonging to seven coconut cultivars, were collected from the Raddegoda Estate (7.5126208416580935°N, 0.53751004229929 °E) in Kurunegala, located in the Intermediate Zone of Sri Lanka. Six same-aged coconut palms were randomly chosen for each cultivar, resulting in a total of 42 palms. From each palm, six fully matured nuts were harvested. The analyses were conducted in the product processing laboratory of the Coconut Product Processing Research Division and the cultivar evaluation laboratory of the Genetics and Plant Breeding Division of CRISL.

Table 1: Recommended coconut cultivars of Sri Lanka, parentage, and type of cross

Cultivar	Parentage (Maternal × Paternal)	Type of cross
CRIC 60	Sri Lankan Tall × Sri Lankan Tall	Mass selected population
CRIC 65	Sri Lankan Green Dwarf ×Sri Lankan Tall	Inter-varietal hybrid
CRISL98	Sri Lankan Tall × San Ramon Tall	Intra-varietal hybrid
CRISL2004	Sri Lankan Green Dwarf × San Ramon Tall	Inter-varietal hybrid
CRIL2012	Sri Lankan Brown Dwarf × Sri Lankan Tall	Inter-varietal hybrid
CRISL2013	Sri Lankan Brown Dwarf × San Ramon Tall	Inter-varietal hybrid
CRISL2020	Sri Lankan Tall × Malayan Red Dwarf	Inter-varietal hybrid

Data collection

Basic fruit component study

The weights of the fresh nuts (FNW), de-husked nuts (DNW), husk (HW), shell (SW), kernel (KW), and nut water (WW) were measured. The kernels from each palm were kept separately for further analyses. The Brix value of the nut water was measured using a refractometer (KRUSS, HBT-10T Refractometer). The share of husk, shell, kernel, and water weights was calculated as a ratio to FNW.

Determination of dry matter and crude fat content of coconut kernel

A 5g sample of fresh kernel was oven-dried at 105°C using a laboratory oven (Memmert, UN30, Germany) until a constant weight was achieved to determine the DM content. Then, the same dried sample was used to determine the CF content using the Soxhlet method, as described in the AOAC (1995) procedures (AOAC International, 1995).

Determination of the coconut milk yield per nut, the coconut milk yield per unit fresh weight of kernel, and the total solid content in coconut milk

The remaining fresh kernel was used to expel the coconut milk (CM) using a hydraulic press machine (SKY004, Sakaya, Thailand). The finely grated kernel was weighed and placed into clean muslin cloth bags. The bags were then subjected to a hydraulic press (1HP) until the completion of milk extraction. The extraction of the coconut milk was done without the addition of water, solely on the moisture within the kernel.

The total CMY that can be expelled from a nut, the CM weight per unit weight of fresh kernel, and the CM volume per unit weight of fresh kernel were calculated. The total solid content of the extracted CM was determined according to the procedure described by Lakshanasomya *et al.* (2011), with slight modifications. Ten grams of homogenized coconut milk were measured into a clean, flat-bottomed petri dish. The dish was then placed in an oven and dried for 24 hours at 105°C. Following the drying process, the dish was cooled in a desiccator and weighed immediately. The proportion of residue obtained was reported as the total solids content of coconut milk.

Data analysis

The experiments were arranged as per the Completely Randomized Design. Data analyses were conducted following the General Linear Model through one-way ANOVA. Means were compared using Tukey's test at $\alpha = 0.05$. Data analyses were performed using Minitab 19 version (Minitab LLC, 2019).

RESULTS AND DISCUSSION

Analysis of the basic fruit component of the recommended coconut cultivars

A comprehensive fruit component analysis among the coconut cultivars is essential for understanding the best use of RCC. This information can be used by the breeders, food processors, and policy makers to guide effective strategies on local consumption and export commercialization. Among all the cultivars, the highest FNW, DNW, SW, and KW were observed in CRISL98 (Table 2).

Table 2: FNW, DNW, HW, SW, KW, WW, and Brix values of recommended coconut cultivars

Cultivar	FNW (g)	DNW (g)	HW (g)	SW (g)	KW (g)	WW (g)	Brix
CRIC 60	1477.88^{b}	738.88^{bc}	739.00^{a}	197.88^{b}	327.82^{bcd}	213.18^{bc}	4.41^{ab}
CRIC 65	1152.06^{c}	630.17^{c}	530.33^{c}	168.78^{b}	270.82^{d}	178.78^{c}	4.43^{ab}
CRISL 98	1900.13^{a}	1097.40^{a}	802.73^{a}	249.80^{a}	498.33^{a}	349.28^{a}	4.30^{ab}
CRISL 2004	1363.11^{bc}	794.06^{bc}	569.06^{bc}	189.94^{b}	353.61^{bc}	250.50^{bc}	4.27^{ab}
CRISL 2012	1157.39^{c}	693.94^{bc}	463.44^{c}	182.11^{b}	299.00^{cd}	212.83^{bc}	4.76^{a}
CRISL 2013	1302.76^{bc}	829.35^{b}	473.41^{c}	202.29^{b}	362.29^{bc}	264.77^{abc}	4.25^{ab}
CRISL 2020	1469.28^{b}	872.72^{b}	596.05^{bc}	201.22^{b}	387.33^{b}	284.18^{ab}	4.02^{b}

FNW: Fresh Nut Weight, DNW: Dehusked nut weight, HW: Husk weight, SW: Shell weight, KW: Kernel weight, WW: Water weight; Means with the same letter in each column are not significantly different, $P \leq 0.05$

This can be attributed to the genetic influence of its parentage: Sri Lankan Tall × San Ramon Tall. Both Sri Lankan Tall and San Ramon Tall have the advantage of producing high copra and high oil (Liyanage, 1958; Fernando, 1998; Bandaranayake *et al.,* 2005). Higher values observed for the above parameters suggest the suitability of CRISL98 for industries that engage in the value addition of kernels, husks, and shells. Superiority of the CRISL98 for fruit components was recorded previously, and the results of the current study reconfirm the previous results (Perera et.al., 2010b; Dissanayaka *et al*., 2012; Meegahakumbura *et al*., 2019). For most of the above parameters, other inter-varietal hybrids and CRIC60 showed results without any discernible trends (Table 2). For the HW, all inter-varietal hybrids showed lower weight compared to CRIC60 and CRISL98. Results also revealed that crosses such as CRIC65 and CRISL2012 have lower FNW and HW compared to CRIC60. However, results indicate that all inter-varietal hybrids also show DNW and KW comparable to CRIC60 (Table 2). Sri Lankan green and brown dwarfs were earlier reported for the lower husk and kernel weights (Liyanage, 1958; Perera *et al*., 1997). Therefore, these variations in results suggest that, in inter-varietal hybrids, the effect of the tall parent has masked that of the dwarf parent for DNW and KW, while for FNW and HW, that is not prominent.

A previous study in Malaysia has reported that coconut water obtained from the tall variety was significantly higher than that of the dwarf and hybrid varieties (Asaad *et al*., 2022). However, a similar trend was not observed in the present study. This discrepancy could be due to variations in genetics and geographical locations. CRISL2020 recorded the highest brix value and was significantly different from CRISL2012, which showed the lowest. The remaining five cultivars did not differ significantly from each other or either of CRISL2012 and CRISL2020 (Table 2). This suggests a relatively similar potential among cultivars for value addition through coconut water-based products. According to Jayasinghe *et al*. (2023), Brix values for king coconut water, a premium beverage coconut of Sri Lanka, are 5.0. Therefore, compared to that, the coconut water from these cultivars might not be appropriate for beverage purposes in its natural form.

Identification of nuts with a higher HW/FNW, SW/FNW, and both KW/FNW and WW/FNW ratios is important in coir fibre production industries, shell processing industries, and food processing industries, respectively. The above ratios did not reveal any consistent pattern or significant trend indicating a preferential change in any component among the cultivars (Table 3).

Table 3: Proportion of different fruit components to the fresh nut weight

Cultivar	HW/FNW	KW/FNW	SW/FNW	WW/FNW
CRIC 60	0.49[a]	0.23[b]	0.14[ab]	0.15[b]
CRIC 65	0.46[a]	0.24[ab]	0.15[ab]	0.15[b]
CRISL 98	0.42[abc]	0.26[ab]	0.13[b]	0.18[ab]
CRISL 2004	0.40[bc]	0.27[ab]	0.14[ab]	0.19[ab]
CRISL 2012	0.42[abc]	0.26[ab]	0.16[a]	0.17[ab]
CRISL 2013	0.36[c]	0.28[a]	0.16[a]	0.20[a]
CRISL 2020	0.41[bc]	0.26[ab]	0.14[ab]	0.19[a]

HW/FNW: husk weight to fresh weight nut ratio, KW/FNW: kernel weight to fresh nut weight, SW/FNW: shell weight to fresh nut weight ratio, WW/FNW: water weight to fresh nut weight ratio; Means with the same letter in each column are not significantly different, $P \leq 0.05$

Instead, a scattered response was observed, with component proportions varying slightly but not systematically. The data supported the conclusion that overall nut growth and increased nut size do not result in a diminution or increase of any fruit component. For instance, CRISL98 reported the largest nut size among the tested cultivars, but for the fractions of husk, kernel, and water, which were observed as no significant difference from any other cultivar (Table 2). The proportions of each fruit component of the traditional coconuts of Sri Lanka were evaluated in a previous study, and reported that the highest proportion of husk was in *Nawasi* and the highest proportion of kernel and water in *Thembili* (Perera *et al*., 2014b). However, in evaluations of RCC, the determination of the above ratios was not common. Instead, the weights of individual components are reported separately. For the discussion purpose of the current study, these ratios were estimated for the CRISL98 cultivar using mean values reported by Meegahakumbura *et al*, (2019). As per the study, HW/FNW, KW/FNW, and WW/ FNW ratios for CRISL 98 were 0.52, 0.21, and 0.13, respectively, and appear close to values observed in the current study.

Dry matter content and crude fat content of coconut kernel

As ANOVA revealed no significant differences among cultivars, post-hoc comparisons were not performed for DM and CF contents of the kernels (Table 4).

Table 4: **The dry matter and crude fat of the kernel of recommended coconut cultivars**

Cultivar	DM (%)	CF (%)
CRIC 60	54.96	74.18
CRIC 65	55.11	71.32
CRISL 98	52.84	68.35
CRISL 2004	56.04	65.75
CRISL 2012	55.62	70.00
CRISL 2013	52.34	65.71
CRISL 2020	56.38	70.64

DM: Dry Matter, CF: Crude Fat % on a DM basis

The moisture content in the coconut kernel of Sri Lankan Tall is reported as 61-70% by a previous study, which implies DM% is 30-39% and that is different from the present study (Weerakoon *et al*., 2024). This could be due to the differences in the stage of maturity of the nut sampled, sample size, or the environmental conditions of the crops grown. Liyanage (1958) reported that the fat content of tall and dwarf coconuts in Sri Lanka changes within a narrow range of values, which could explain the limited diversity in CF% observed in the present study. Non-significant differences observed in DM content could be another reason for the results of CF content. The DM and CF content of RCC in Sri Lanka is also not reported in previous literature.

The coconut milk yield per nut, the coconut milk yield per unit fresh weight of kernel, and the total solid content in coconut milk

In the current study, CM was extracted from the nuts solely based on the moisture retained within the kernels. CRISL 98 stands out with a significantly higher CMY per nut compared to other cultivars, corresponding to its higher kernel content (Table 5).

Table 5: Coconut milk yield per nut of recommended coconut cultivars

Cultivar	Weight of total milk yield per nut (g)	Volume of total milk yield per nut (mL)
CRIC 60	201.68^{bc}	202.86^{bc}
CRIC 65	183.91^{c}	195.00^{c}
CRISL 98	334.06^{a}	348.54^{a}
CRISL 2004	227.91^{bc}	238.28^{bc}
CRISL 2012	186.04^{c}	194.34^{c}
CRISL 2013	240.40^{b}	248.72^{b}
CRISL 2020	252.83^{b}	257.60^{b}

Means with the same letter in each column are not significantly different, $P \leq 0.05$

Data showed that, CMY of hybrid cultivars is capable of producing milk yield the same or better than CRIC60, masking the effect of the dwarf parent (Table 5). Among the inter-varietal hybrid cultivars, CMY per nut of CRISL2013 was higher than CRISL2012, where in both Sri Lankan Brown Dwarf is the maternal parent (Table 1). This could be due to the superiority of San Ramon Tall over Sri Lankan Tall (Fernando *et al*., 1998). The fruit attributes of CRISL 2020, whose maternal parent was a Tall coconut (Table 1), did not show better values over other inter-varietal hybrids, indicating that there are no maternal effects on the fruit component. A previous study conducted by Perera *et al*. (2014a) reported that, absence of maternal effect for precocity, yield, and weight of fruit components in CRIC65. For all the cultivars, both coconut milk weight and volume changed in a similar trend, indicating that the density of the coconut milk does not vary among the cultivars (Table 5).

The mean comparison was not performed as ANOVA revealed no significant differences among cultivars for the CMY per unit fresh weight of kernel and TS% of CM (Table 6). Liyanage (1958) reported that kernels of dwarf coconut are poor in quality. However, results showed that all inter-varietal hybrids have the same potential to produce coconut milk per unit fresh weight of kernels as CRIC60 and CRISL98 (Table 6).

Table 6: Milk yield per unit fresh kernel weight and total solids in coconut milk from recommended coconut cultivars

Cultivar	CMW/FKW (g/g)	CMV/FKW (mL/g)	TS (%)
CRIC 60	0.66	0.68	43.81
CRIC 65	0.65	0.67	49.17
CRISL 98	0.68	0.70	51.42
CRISL 2004	0.64	0.67	45.72
CRISL 2012	0.61.	0.64	51.27
CRISL 2013	0.66	0.69	48.86
CRISL 2020	0.65	0.66	54.53

CMW/FKW: Coconut Milk Weight per Fresh Kernal Weight, CMV/FKW: Coconut Milk Volume per Fresh Kernal Weight, TS: Total Solids in coconut milk

This indicates that the hybrid vigor of all the inter-varietal hybrids can mask the dwarf parent effect for CM production. CM is produced domestically by squeezing grated meat by hand; however, on a bigger scale, the milk is extracted by the use of a screw press or hydraulic system. The first involved the addition of water, while the last two methods solely happen through the moisture within the kernel. The TS% of the CM depends on the method of CM extraction. For instance, a study conducted in Ghana, which CM had extracted by the addition of water, reported that the TS of the CM was 32.4% (Tulashie *et al*., 2022). In addition to that, the type of coconut and the extraction condition decided the composition of CM. The main component of the TS of CM is fat and followed by carbohydrates and proteins (Azlin-Hashim *et al*., 2019; Tulashie *et al*., 2022). Non-significant results for these parameters suggest a possibility of using kernels for reliable value addition irrespective of the cultivar (Table 6). No previous literature has reported a study on the CMY of RCC in Sri Lanka; hence, the present research is the first report on this aspect.

CONCLUSIONS

In Sri Lanka, coconut is a vital plantation crop that supports both domestic consumption and exports. The recommended coconut cultivars provide greater support for that. Even though individual fruit components have been reported in previous studies, information on DM, CF, and CMY of kernels of the recommended coconut cultivar is not available. Therefore, the current study was conducted to assess the aforementioned parameters along with the basic fruit components of recommended coconut cultivars. The studied materials were recommended coconut cultivars by the Coconut Research Institute of Sri Lanka, namely, CRIC60, CRIC65, CRISL98, CRISL2004, CRISL2012, CRISL2013, and CRISL2020. Significant differences were observed in the BFC study across different cultivars. The proportionate composition of fruit components relative to the fresh nut weight showed scattered results without any trend. No significant differences were found in DM% and CF% in kernel, milk yield per unit weight of fresh kernel, and TS% of coconut milk among cultivars. Overall, the results indicate that CRISL98 produced the highest fruit component values and CMY per nut. Nevertheless, as there are no significant differences in unit weight or percentage values of DM, CF, CMY per unit fresh kernel weight and TS, each cultivar has equal potential to use in any end use. This study presents the first comprehensive assessment of all the aforementioned fruit components in recommended coconut cultivars and provides a benchmark model for future studies on cultivar evaluation. We recommended studying the same parameters for different seasons and different locations to evaluate the effect of season and location on fruit components.

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AUTHOR CONTRIBUTION

DAC conceptualized the study. TOS and BRR wrote the manuscript. SWL and LAM conducted data collection. SRK and WPR performed data analyses. WSK revised the manuscript.

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