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Crystal Palm Sugar Yield Optimization and Its Chemical and Sensory Characteristics

Marwati[1], Irma Febriandini[1], Krishna Purnawan Candra[1], Yuliani[1], Hamka[2]

[1]Department of Agricultural Product Technology, Faculty of Agriculture, Mulawarman University, Jl. Tanah Grogot, Kampus Gunung Kelua, Samarinda 75119,
[2]Study Program of Plantation Product Technology, Politeknik Pertanian Negeri Samarinda, Jl. Sam Ratulangi, Kampus Politani Samarinda, Samarinda 75131
Corres Author Email: candra@faperta.unmul.ac.id

ABSTRACT

Crystal palm sugar (CPS) is crystal brown sugar produced from palm tree sap. The quality of CPS depends on the quality/freshness of the sap, while the sap quality depends on the tapping method and its freshness. This study aimed to determine the appropriate sap tapping time of Arenga palm (Arenga pinnata) for raw material in CPS processing. The sap tapping time was carried out at 3, 6, 9, and 12 hours, each with four replications. Sap tapping was done by adding five grams of sodium bicarbonate into the sap container. Parameters observed were sap pH, yield, chemical properties (moisture content, ash content, and reducing sugar content), and sensory properties (color, aroma, texture, and taste) of the CPS. The data were processed by ANOVA and polynomial regression. The results showed that sap tapping time significantly affected (p<0.05) the sap pH and reducing-sugar content of CPS, but not (p>0.05) the yield, water content, ash content, and sensory response of CPS. However, using quadratic polynomial regression shows that CPS yield is optimum by processing the palm sap at about seven hours of tapping time, i.e., 14.56% and 12.47% for coarse and fine CPS, respectively. Sap tapping time of 6.8-7.1 h is recommended to be practiced for producing the CPS to get the highest yield. The CPS produced from the sap with tapping time of 6.8-7.1 h has a reducing sugar content of 26.94% and overall hedonic characteristics of moderately like. The hedonic quality characteristics of the CPS are typical palm sugar for aroma, slightly brown for color, slightly hard for texture, and sweet for taste.

***Keywords**: Palm; Sugar; Sap; Tapping; Arenga Pinnata*

INTRODUCTION

Crystal palm sugar (CPS) is a derivative product of sap from various palm tree types like Arenga palm (*Arenga pinnata*), coconut tree (*Cocos nucifera*), palmyra palm (*Borassus flabellifer*), nipa palm (*Nypa fruticans*), and palm oil (*Elais guineensis* Jack) (Kurniawan, Jayanudin, Kustiningsih, & Adha Firdaus, 2018; Le, Lu, & Li, 2020). The CPS form is a coarse or fine crystal (Mirza, Alindra, & Yunior, 2022) instead of regular palm sugar, which is in the solid form of a cube, cylinder, cone, or sphere with a mass of about 250-1.000 g, namely jaggery (Kurniawan et al., 2018). The CPS produce from fresh palm sap (Baharuddin, Muin, & Bandaso, 2007; Zuliana, Widyastuti, & Susanto, 2016) or jaggery as the raw material for CPS (Hikmah, Fadillah, & Putra, 2022; Siska, Nugroho, Handayani, & Syahruddin, 2022).

The CPS has advantages compared to the solid form of palm sugar because of the lower water content (Natawijaya, Suhartono, & Undang, 2018), so it has a long shelf life, easy to be packed and used. On the other hand, the shelf life of jaggery becomes a problem in the rainy season (Hikmah et al., 2022; Siska et al., 2022). The jaggery usually has a moisture content of 3.5-26.78% (Klau, Ngginak, & Nge, 2019; Natawijaya et al., 2018), while the CPS has a 1.37-2.43% (Zuliana et al., 2016). Therefore, this makes the CPS more valuable than the jaggery (Al-Manan et al., 2021; Hanum, Sari, Fitrianti, & Hendriani, 2021; Yelfiarita, Filiani, & Veronice, 2022).

Palm sugar in jaggery or CPS is usually produced by small-scale/home industries (Amirah, Is, Nurinaya, & Bawa, 2022). However, their produce has met the Indonesian

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national standard of palm sugar (SNI 01-3743-1995) (Badan Standardisasi Nasional, 1995), which means that the product is of good quality (Mita, Asyik, & Sadimantara, 2022). Equipment, machines (Al-Manan et al., 2021), and method (Candra, Suprapto, & Ishaq, 2012; Zuliana et al., 2016) for palm sugar or CPS production has been developed. However, the quality of CPS, including its yield, depends not only on the equipment, machine, and processing method. It is known among palm sugar artisans that the yield and quality of palm sugar also depend on sap freshness (Ishaq, Candra, & Suprapto, 2010). However, until now, it isn't easy to find scientific evidence to prove the knowledge.

The freshness of the palm sap corresponds to the method (Gunawan et al., 2020) and time of sap tapping. Therefore, this study examined the effect of palm sap tapping time on the yield and the chemical and sensory properties of CPS from Arenga palm sap.

MATERIALS AND METHODS

Materials

Palm sugar artisans in Lempake Village in Samarinda City provide Arenga palm sap. Chemicals (sodium thiosulfate, potassium iodide, hydrochloric sulfate, and amylum) for sugar analysis were p.a. (pro analysis) grade and provided by Riedel-Haen.

Experimental Design

This research was a single-factor experiment (sap tapping time) arranged completely randomized design. The sap tapping time consists of 4 levels of treatment, i.e., 3, 6, 9, and 12 h. Parameters observed were palm sap pH, crystal palm sugar (CPS) yield, and CPS's chemical- and sensory characteristics. Data were analyzed by ANOVA followed by the LSD test, except for sensory data, which was analyzed by the Friedman test followed by Dunn's test.

Yield, Chemical- and Sensory-Characteristics

The yield of CPS was calculated based on the weight of Arenga palm sap used at each process batch (replication). Chemical characteristics, such as pH, were tested according to the method suggested by Apriyantono (1989), while moisture content, ash content, and reducing sugar were analyzed according to the method described by Sudarmadji et al. (2010). Hedonic sensory and hedonic quality characteristics for aroma, color, texture, and taste were tested based on the method recommended by Lawless and Heymann (2010) and Setyaningsih et al. (2010) with the scale of 1-7 (Table 1.). Sensory data obtained for each treatment was 60 derived from four replications, each tested by 15 panelists.

Tabel 1. Score and description of sensory hedonic and quality hedonic test*

a. Sensory hedonic characteristics	
Score	Aroma, Color, Texture, Taste
1	*dislike very much*
2	*dislike moderately*
3	*dislike slightly*
4	*neither like nor dislike*
5	*like slightly*
6	*like moderately*
7	*like very much*

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b. Sensory hedonic quality characteristics

Score	Aroma	Color	Texture	Taste (sweetness)
1	*Not typical palm sugar at all*	*Very light yellowish brown*	*Very soft*	*Not at all sweet*
2	*Slightly typical palm sugar*	*Light yellowish brown*	*Soft*	*Slightly sweet*
3	*Moderately typical palm sugar*	*Yellowish brown*	*Slightly soft*	*Moderately sweet*
4	*Typical palm sugar*	*Light brown*	*Slightly hard*	*Sweet*
5	*Strongly typical palm sugar*	*Brown*	*Hard*	*Strongly sweet*
6	*Very strongly typical palm sugar*	*Dark brown*	*Very hard*	*Very strongly sweet*
7	*Extremely typical palm sugar*	*Very dark brown*	*Extremely hard*	*Extremely sweet*

CPS Processing

Palm sap provided by tapping times of 3, 6, 9, and 12 h was carried out in the artisan's Arenga palm trees. Five mL of saturated $CaCO_3$ solution was poured into the palm sap plastic container before collecting the sap.

The CPS processing was conducted by the method described by Fahri et al. (2010). First, the Arenga palm sap was filtered by fine cloth, added 0.5 g $Na_2S_2O_5$ per L, mixed until homogenous, and cooked at 110-120^oC. Next, the temperature was decreased to 70^oC following the sap becoming viscous and stirring quickly by a wood fork until crystals were formed. The crystal was then mashed by blender three times 10 seconds, sieved by 20 mesh (0.841 mm), and packed. The CPS that passes the sieve belongs to fine CPS and the rest to coarse CPS.

RESULTS AND DISCUSSION

Sap pH and CPS Yield

Arenga palm could produce 10-15 L sap per flower stem per day (Hidayah, Hermawan, Suseno, Suryadarma, & Nugroho, 2019). The sap tapping time (3-9 h) has significantly affected the pH of the palm sap (Table 2.). The longer the tapping time, the lower the pH value of the palm sap. The lower sap pH may occur due to the spontaneous fermentation by Saccharomyces and lactobacillus from the environment (air or the sap container) (Law, Abu Bakar, Mat Hashim, & Abdul Hamid, 2011). However, the sap tapping time (3-9 h) does not significantly affect the CPS yield.

Table 2. Effect of sap tapping time on sap pH and crystal palm sugar (CPS) yield

Tapping time of sap (h)	Sap pH	Yield (%)	
		Coarse CPS	Fine CPS
3	7.75±0.50 a	13.12±2.34	11.21±2.99
6	7.50±0.58 ab	14.80±1.04	12.89±1.02
9	7.00±0.00 b	13.83±0.54	12.18±0.71
12	6.00±0.00 c	12.17±1.19	10.79±1.32

Note: Data within the same column followed by different letters show significantly different (LSD, $p<0.05$).

The initial value of pH at three hours of tapping time was 7.75. The initial high pH of palm sap was reached by adding lime to the sap container, which aimed to neutralize the acid caused by the fermentation of Saccharomyces cerevisiae and LAB microorganisms that spontaneously grew. The neutral Arenga palm sap pH was reached at a sap tapping time of 9 hours.

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The tapping time 3-12 h affected insignificantly on the CPS yield (Table 2), however the trend of the CPS yield show a positive parabole (red and blue line on Figure 1) with the optimum point is at palm sap tapping time of 6.7969-6.8320 h for coarse CPS showing yield of 14.5647% (red line) and at 7.1133 h for fine CPS showing yield of 12.7437% (blue line).

In this research, the total yield of CPS is between 22.96-27.69%, which contains coarse and fine CPS of 12.17-14.80% and 10.79-12.89%, respectively. This yield is two times higher than the CPS yield in Pekalongan (10%), as reported by Hidayah et al. (2019). Some other reports show that the CPS yields vary depending on the place; e.g., Tasikmalaya is 13.07% (Natawijaya et al., 2018), 4.28-5.99% in Simalungun (Purba, Harmain, Simarmata, & Triastuti, 2022).

Chemical Characteristics

The sap tapping time (3-12 h) has significantly affected ($p<0.05$) the reducing sugar of CPS but not the moisture and ash content (Table 3.). The moisture, ash, and reducing sugar content are 3.15-3.32%, 0.11-0.14%, and 23.76-28.57%, respectively. The moisture content value slightly exceeds the water content required by SNI 01-3743-1995 with a maximum limit of 3,0% (Badan Standardisasi Nasional, 1995); however, the ash and reducing sugar content meet the standard, i.e., 2% and 10%, respectively.

The longer the tapping time, the lower the content of reducing sugars (Figure 1), which is in line with the lowering of palm sap pH. It means that the reducing sugar become lower following the declining of the palm sap pH. The declining of reducing sugar content, which could be followed by the declining of the palm sap pH is critical in producing the CPS. Both are affected by the tapping time, the content of reducing sugar or the palm sap pH will decline following the length of sap tapping time.

The CPS production method is relatively same among places. It starts by cooking the sap at high temperature (110-120^{o}C) and at the end of the process (when a viscous sap is reached) the temperature decrease to about 70^{o}C and follows by stirring quickly. In this research, the reducing sugars content of CPS from Samarinda is higher than many other CPS produced elsewhere. For example, reducing sugar content in several CPS produced in Songkhla Province, Thailand, varied from 3.54 to 23.94% because of different heating times and temperatures (Phaichamnan, Posri, & Meenune, 2010). It means that the processing method of CPS (sap cooking and crystalization) is essential. In contrast, Zuliana et al. (2016) showed the opposite evidence that reducing sugars content of CPS prepared using regular palm sugar (cylinder form) increased from 1.25% to 3.75% as the regular palm sugar pH reduced 7.50 to 6.50.

Table 3. Effect of sap tapping time on chemical characteristics of crystal palm sugar (CPS)

Sap tapping time (h)	Moisture (%)	Ash (%)	Reducing sugars (%)
3	3.32±0.40	0.14±0.02	28.56±0.48 a
6	3.28±0.32	0.14±0.01	28.57±1.22 a
9	3.16±0.38	0.12±0.02	24.72±2.13 b
12	3.15±0.50	0.11±0.02	23.76±1.64 b

Note: Data (mean±SD) were calculated from four replications. Data within the same column followed by different letters show significantly different (LSD test, $p < 0.05$).

Figure 1 shows that the freshness of sap is also critical in preparing the CPS. An optimum CPS yield is reached at a palm sap tapping time of about seven hours (6.8-7.1 h), which resulted in a yield of 14.56% and 12.46% for coarse and fine CPS, respectively. The reducing sugars of the CPS produced is about 26.94%.

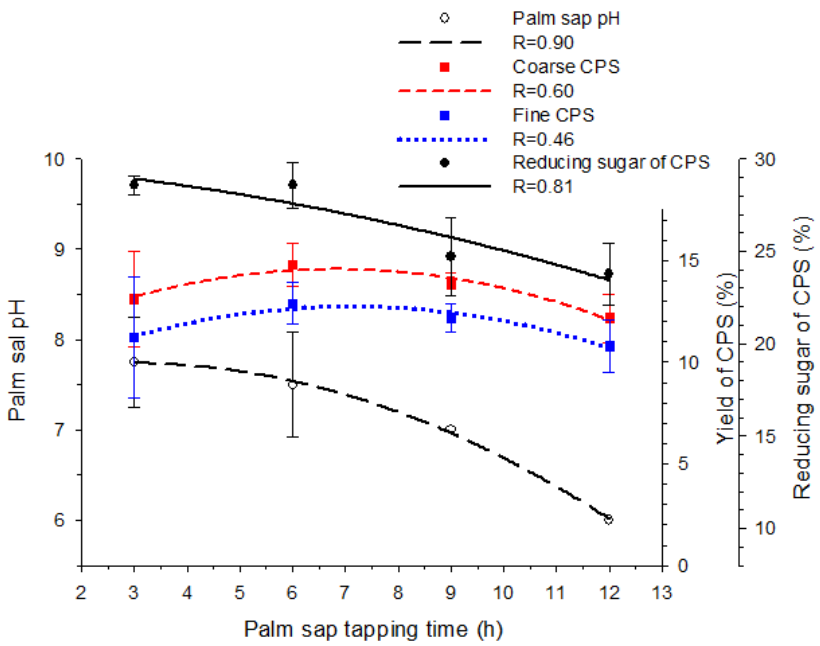

Figure 1. Effect of Arenga palm sap freshness on the yield and reducing sugar content of crystal palm sugar (CPS). Data were analyzed by quadratic polynomial regression. The sap provided by tapping time of 6.8 and 7.1 h shows the optimum yield of coarse (14,56%) and fine CPS (12,47%), respectively. The CPS has reducing sugar content by 26,94%.
The regression equation are:
Reducing sugar content of CPS (%) = $7.5625 + 0.1208\ A - 0.0208\ A^2$
Yield of coarse CPS (%) = $10.2650 + 1.2623\ A - 0.0926\ A^2$
Yield of fine CPS (%) = $8.4144 + 1.2167\ A - 0.0855\ A^2$
Palm sap pH = $29.7525 - 0.2042\ A - 0.0269\ A^2$
A = Palm sap tapping time (h)

Sensory Characteristics of CPS

The palm sap tapping time (3-12 h) has not significantly (p>0.05) affected the hedonic and quality hedonic sensory response of all attributes except the sweetness (Table 3.). The panelists voted *neither like nor dislike* for aroma, color, texture, and overall performance attributes, while voted *slightly like* for the sweetness of CPS produced from palm sap of 6 h tapping time. For the hedonic quality, the panelists assessed sweetness, slightly brown color, and hard texture with a distinctive aroma of brown sugar. The sensory score on the CPS test is presented in Table 4.

Table 4. Effect of sap tapping time on sensory characteristics of crystal palm sugar (CPS)

Sap tapping time (h)	Typical palm sugar aroma	Color	Texture	Sweetness	Overall
	*Sensory hedonic score**				
3	4.0	4.0	4.0	4.0 a	4.0
6	4.0	4.0	4.5	5.0 b	4.0
9	4.0	4.0	4.0	4.0 ab	4.0
12	4.0	4.0	4.0	4.5 ab	4.0
	*Sensory hedonic quality score**				
3	4.0	4.0	4.0	4.0 a	
6	4.0	4.0	4.0	5.0 ab	
9	4.0	5.0	4.0	5.0 ab	
12	4.0	4.0	4.0	5.0 b	

Note: Data ($\tilde{x}$) calculated from 60 data from 15 semi-trained panelists using four replications for each treatment. Data analyzed by Friedman test. Data of sensory hedonic or hedonic quality characteristics within the same column followed by different letters showed significant differences (Dunn's test, p<0.05). Sensory scores are referred to Table 1.

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The CPS produced from palm sap tapped by 3-12 h show relatively the same or slightly higher quality than palm sugar or CPS produced from another place reported. For example, Mita et al. (2022) reported that Arenga palm sugar produced by artisans in Tanjung Batu Village and Kabangka Village, Muna District, Sulawesi Tengara Province, has a sensory hedonic response of *like moderately* for color, aroma, taste, and texture. Meanwhile, Natawijaya et al. (2018) reported that CPS and solid-form palm sugar quality, i.e., pH, texture aroma, and taste, are relatively the same, namely 6-7, hard, typically palm sugar aroma, and sweet, respectively. The exception is for color, which shows *brown* and *light brown* for solid-form palm sugar and CPS, respectively. Therefore, the recommended palm sap tapping time due to this research is 6-7 h.

CONCLUSION

The sap tapping time has affected the sap pH significantly ($p<0.05$). The optimal sap tapping time for crystal palm sugar powder (CPS) processing is 6.8-7.1 h, which collects sap with a pH of 7.4. The coarse and fine CPS yields were 14.56% and 12.47%, respectively, with a reducing sugar content of 26.94%. The CPS has the sensory response for overall hedonic characteristics of *moderately ike* and the hedonic quality characteristics of *typical palm sugar* for aroma, *slightly brown* for color, *slightly hard* for texture, and *sweet* for taste.

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