

Characterisation of Arabica Coffee Pulp - Hay from Kintamani - Bali as Prospective Biogas Feedstocks

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Abstract. The huge amount of coffee pulp waste is an environmental problem. Anaerobic fermentation is one of the alternative solutions. However, availability of coffee pulp does not appear for year-round, whereas biogas needs continuous feedstocks for digester stability. This research uses coffee pulp from Arabica Coffee Factory at Mengani, Kintamani, Bali–Indonesia. The coffee pulp was transformed into coffee pulp-hay product by sun drying for preservations to extend the raw materials through the year. Characterization of coffee pulp-hay was conducted after to keep for 15 mo for review the prospect as biogas feedstocks. Several parameters were analyzed such as C/N ratio, volatile solids, carbohydrate, protein, fat, lignocellulose content, macro-micro nutrients, and density. The review results indicated that coffee pulp-hay is prospective raw material for biogas feedstock. This well-proven preservation technology was able to fulfill the continuous supply. Furthermore, some problems were found in the recent preliminary experiment related to the density and fungi growth in the conventional laboratory digester. Further investigation was needed to implement the coffee pulp – hay as biogas feedstocks.

Key words: Environmental problems, floating feed, hay technology, low density feed, preservation feedstocks, waste to energy

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1 Introduction

Coffee pulp (CP) is one of the huge wastes which is produced by Coffee Factories (CF). Weight volume of CP is 41 % to 50 % in wet basis [1, 2], or 20 % to 29 % in dry basis [2, 3]. CP is commonly disposed to the river or environment around the CF [4, 5] which produces negative impact since CP contains toxic compound namely caffeine, alkaloids, tannins and polyphenolics [6, 7].

Baier and Hofmann in Bombardiere [8] and reference [9] showed that CP is a prospective organic compound as biogas raw material. Biogas is the renewable energy resource which is needed by CF [10], particularly for reducing fossil energy cost and increasing efficiency. Mulato [11] and Mulato & Suharyanto [12] said that the biogas of CF waste production is able to utilize as energy resources of coffee drying, lighting and circulating pump generator.

However, CP does not available for year-round as biogas feedstock. Coffee harvesting is conducted between June and September every year in Indonesia, so CP is available for 3 mo to 5 mo [13]. Whereas, Steiner [14] stated that the anaerobic digester does not economical when operated less than 8 mo. Some references [12, 13] suggested utilization of cow-dung as replacement feedstocks while there is no availability of CP, but not every CF have stabled cattle ranch. Furthermore, CP replacement by cow-dung and vice versa provide negative impact possibility to anaerobic stability process [15] and disrupt the steady-state/start-up process which conducted for 2 mo to 3 mo [16–18].

Other references [14, 19] suggested to apply silage technology on CP, so biogas feedstock is available for a year. However, it has several drawbacks such as anaerobic storage requirement, component addition (molasses), etc. Therefore, this study was conducted to review effective preservation of CP by sun drying or hay technology.

2 Materials and methods

CP was collected from peeling machine by the wet base system for coffee time processing in July 2016 to August 2016 from Arabica CF at Mengani, Kintamani, Bali, Indonesia. Coffee of Kintamani-Bali is a pioneer plantation product in Indonesia as the first obtained of certifications geographical indications (GI) at 2008 from 10 Indonesian Arabica coffee products [20]. CP was dried under the sunshine for about 5 d on the drying floor until water content about 12 %. Then, the dried pulp or hay pulp (HP) was stored in burlap sacks placed in the warehouse. After 15 mo, HP was characterized in the laboratory of Indonesian Research Institute for Animal Production in Ciawi, Bogor, Indonesia to determine the suitability of HP as biogas feedstock. Analysis methods were shown in Table 1.

Table 1. Laboratory analysis methods of hay pulp as biogas feedstock.

No	Variable	Methods
1	Mg, K, Na, Fe, Ca	Atomic Absorption Spectroscopy (AAS)
2	S, C/N ratio, phenol total	spectrophotometry
3	water, fat, ash, lignin content	gravimetry
4	Protein	destructive auto analysis
5	Neutral Detergent Fiber (NDF)	neutral detergent solvent extraction
6	Acid Detergent Fiber (ADF)	acid detergent solvent extraction
7	Cellulose	acid extraction
8	Carbohydrate, Volatile Solid (VS), N content, hemicellulose	calculation
9	Density	true density

3 Result and Discussions

3.1 C/N ratio

C/N ratio analysis results of arabica coffee HP-GI Kintamani is shown in Table 2. Table 2 shows HP is commonly appropriate as biogas feedstock [21–26], except standard 4 [27, 28]. The previous studies showed that C/N ratio of CP is 40.0 to 71.2 [29, 30]. Furthermore, C/N ratio of cow-dung is 16.67 [31] or 21.00 [32]. It indicates that pulp storage as hay for 15 mo reduce C/N ratio to the ideal value.

Table 2. C/N ratio comparison of coffee pulp-hay

	coffee pulp-hay	standard			
		1	2	3	4
C/N ratio	20.06	10 to 30	15 to 25	20 to 30	23 to 32
Reference	This study	[21, 22]	[23, 24]	[25, 26]	[27, 28]

3.2 C/N ratio

Volatile Solid (VS) of arabica coffee HP-GI Kintamani is shown in Table 3. Table 3 shows that VS of HP is appropriate to some references [33–35]. VS is a necessary factor to predict methane amount production [24, 35, 39, 40], wherein the higher ratio of VS produced greater methane [41, 42].

The previous study said that cow-dung is an ideal substrate for anaerobic digestion [43], but other studies stated about vice versa indication that cow-dung produced low yield biogas [44, 45]. The biogas volume of CF waste is 18 times higher than cow-dung [13] which supports also by VS data in Table 3. However, the higher VS was inducted into the digester, also produce the larger amount of volatile acid [39] which influencing digester alkalinity and pH. Therefore, the high VS content had to insert slowly into an anaerobic digester.

Table 3. Volatile solid comparison of coffee pulp-hay

	coffee pulp-hay	fresh coffee pulp		cow-dung	
Volatile Solid	91.02	91.10	92.80	94.00	27.80 to 39.60
Reference	This study	[33]	[34]	[35]	[32, 36–38]

3.3 Carbohydrate, Protein and Fat Contents

Carbohydrate, protein and fat contents of arabica coffee HP-GI Kintamani is shown in Table 4. Table 4 shows that carbohydrate, protein and fat contents of HP after 15 mo storage are appropriate to the references range [5, 48, 49], even particularly for carbohydrate content is higher than references [46, 47]. Moreover, it also shows that HP contents are higher than cow-dung. However, carbohydrate dominant of HP provided negative impact possibility in the anaerobic process. Some references [24, 50, 51] stated that the possibility of buffer capacity is weak, with the impact of problems in the alkalinity of the substrate. It supported by other references [23, 24, 28] which said that carbohydrate dominant produced the low quality of biogas related to the high number of C-atoms in the substrate.

Table 4. Carbohydrate, protein, and fat contents comparison of coffee pulp-hay

	coffee pulp-hay	previous studies	cow-dung
Carbohydrate (%)	65.99	35.00 to 63.20 ¹⁾	41.15
Protein (%)	11.00	0.80 to 15.00 ²⁾	9.55
Fat (%)	1.54	0.83 to 7.00 ³⁾	0.40
Reference	This study	¹⁾ [46, 47], ²⁾ [5, 48], ³⁾ [49, 48]	[32]

3.4 Lignocellulose content

Carbohydrate was divided into simple carbohydrate (monosaccharide dan disaccharide) and complex carbohydrate (polysaccharide). Some references [29, 47, 52] stated that CP was categorized rich lignocelluloses as the common characteristic of agricultural wastes [53]. Table 5 shows lignocellulose content consist of cellulose, lignin, and hemicellulose. Table 5 indicates that lignocelluloses of HP are appropriate to some references range [5, 33, 54–57], but lignin content of HP is lower than references [56, 57]. Moreover, cellulose and hemicellulose (a+b) of cow-dung is higher than HP, but it has similar lignin content.

Table 5. Cellulose, lignin, and hemicellulose contents comparison of coffee pulp-hay.

	coffee pulp-hay	previous research	cow-dung
Selulosa (a) (%)	25.84	17.70 to 49.87 ¹⁾	22.28 to 26.59
Hemiselulosa (b) (%)	4.37	2.30 to 21.80 ²⁾	11.27 to 23.55
Lignin (%)	12.46	17.50 to 31.58 ³⁾	11.24 to 12.67
(a) + (b) (%)	30.21	20.00 to 87.00	33.55 to 50.14
Reference		¹⁾ [54, 55], ²⁾ [5, 33], ³⁾ [56, 57]	[31, 32]

3.5 Nutrient

Steiner [14] dan Tadesse & Mebratu [30] stated that CP nutrient is appropriate as biogas feedstocks and met the requirement of C:N:P = 250:10:1, but it did not show nutrient content value. Table 6 shows macronutrient content of HP. Nutrient contents of C, N, P, and S of HP lower than the references requirement [23, 25]. C nutrient was needed by microbes as energy resources [59]. Madigan and Martinko [60] said that 50 % of dry weight cell was carbon. N nutrient was needed to construct cell structure which required 14 % of dry weight of microbes [59, 60].

Table 6 supports references [50, 61] which said that agricultural wastes and or agro-industry were categorized as poor nutrients. However, HP nutrient shows appropriate to previous research range [30, 33, 59], even C nutrient is higher than reference [58]. Based on this data, HP nutrient did not decrease after 15 mo storage and was higher than cow-dung nutrients [32]. It was supported by Higashikawa [62] which found that CP nutrient was higher at N, K, and B variables, but lower at P, Mg, and Mn variables.

Table 6. Macronutrients contents comparison of coffee pulp-hay.

	coffee pulp-hay	standard		previous research	cow-dung
		1	2		
Carbon (%)	35.31	100	500 to 1 000	30.37 ¹⁾	19
Nitrogen (%)	1.76	10	15 to 20	0.80 to 1.90 ²⁾	0.90
Phosphat (%)	0.20	1	5	0.13 to 0.20 ³⁾	0.20
Sulphur (%)	0.18	1	3	--	--
Reference	This study	[25]	[23]	¹⁾ [58], ²⁾ [33, 56], ³⁾ [30, 56]	[32]

Table 7 shows that HP contains inhibitors, particularly as micronutrients namely Ca, Mg, and Na. CP was a substance rich in hydroxyl groups, so it had the ability to absorb heavy metal [2, 33, 66–70]. This property caused HP micronutrients were categorized as inhibitors, but microbes had the ability to degrade toxic material [71, 72]. Furthermore, Table 7 also indicates HP contains phenol as an inhibitor. It also supported by some references about CP phenol content [33, 73, 74], but microbes also degraded phenol in anaerobic digestion [75, 76].

Table 7. Micronutrients of P, K, Ca, Mg, Na and total phenol comparison of coffee pulp-hay.

	coffee pulp-hay	Standard Stimulatory	Standard Moderately Inhibitors
C/P	177	150 to 300 ¹⁾	
C/K	11	40 to 100 ¹⁾	
K (mg L ⁻¹)	329	200 to 400 ²⁾	2 500 to 4 500 ²⁾
Ca (mg L ⁻¹)	4 600	200 to 400 ²⁾	2 500 to 4 500 ²⁾
Mg (mg L ⁻¹)	1 100	75 to 150 ²⁾	1 000 to 1 500 ²⁾
Na (mg L ⁻¹)	500	100 to 200 ²⁾	3 500 to 5 500 ²⁾
Phenol (mg L ⁻¹)	5 500		2 400 ³⁾
Reference		¹⁾ [63], ²⁾ [64]	²⁾ [64], ³⁾ [65]

Fe micronutrient content of HP-GI Kintamani is low which is shown in Table 8. It was lower than stimulatory requirement [77, 78], but it still in previous research range [63, 80], and lower than others previous research [81, 82]. The low Fe content of HP-GI Kintamani was needed further study, it was possibly caused by Kintamani land was categorized Inceptisol [83]. Inceptisol Kintamani was the young land of Batur Volcano eruption. Some references [84, 85] stated about Inceptisol characteristics such as pH was acidic to slightly acidic; soil electrical conductivity (EC) was very low; whereas organic matter, total nitrogen, cation exchange capacity (CEC), saturation bases, potassium potency and Iron Hydrous Oxide were low. Nandini and Narendra [85] found that Fe content of Bangli, Kintamani soil was in the range of 15.0 mg/kg to 18.4 mg/kg which categorized very low

Table 8. Iron nutrient content comparison of coffee pulp-hay.

Fe nutrient of coffee pulp-hay	Stimulatory	Inhibitor	Previous Research
136 mg kg ⁻¹ or 0.014 %	0.02 % [77] 0.40 % [78]	0.18 % [79]	0.015 % (Bressani in [80]) 0.01 % to 0.50 % [63] 0.025 % [81] 0.287 % [82]

3.6 Density

The true density value of HP-GI Kintamani showed 0.40 g mL^{-1} , which was lower than the bulk density of previous research of 0.53 g mL^{-1} [82]. The low density has a negative impact which was also reported by the previous research of dry husk *Jatropha curcas* Linn. (DH-JcL) with true density of 0.59 g mL^{-1} [32].

Moreover, other problems were obstruction of DH-JcL inclusion since the inlet digester blocked; then DH-JcL floated on the digester substrate, so methanogenic bioconversion process was not optimized. Praptiningsih et al. [86] overcame the floating DH-JcL by utilizing ballast weight. The floating HP problem was confirmed in preliminary studies of biogas using HP-GI Kintamani was conducted in November 2017 to February 2018 at Waste Laboratory of Nutrition and Animal Husbandry Laboratory of Muhammadiyah University of Malang, Indonesia. Another negative impact was the easiness growth of fungi on CP which found when it was drying under the sun as hay on the CF. The fungi were suspected dormant for 15 mo of HP storage process. However, it was grown rapidly when HP was mixed to water diluents in the conventional laboratory digester which is shown in Figure 1.a-d

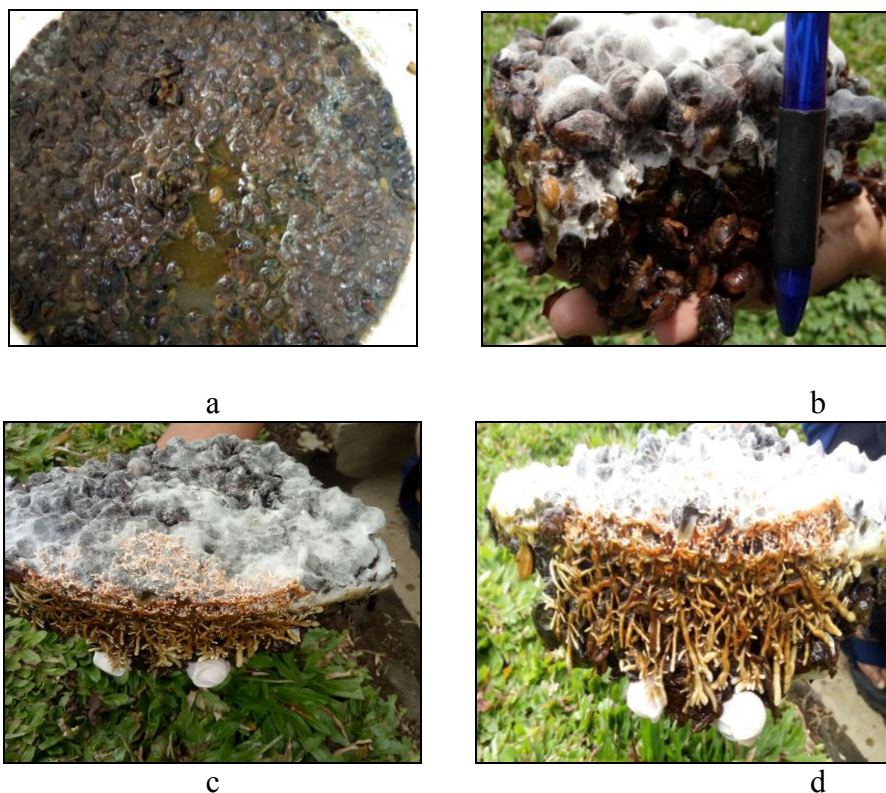


Figure 1. (a) the floating HP digestate on the substrate; (b) The thickness of HP digestate which blocking biogas goes to gas holder; (c, d) two types of fungi on digestate.

4 Conclusion

Based on the data was concluded that coffee pulp-hay after 15 mo storage was appropriate as biogas feedstock. The further investigation was needed to overcome the dormant fungi problems on the HP storage but grown rapidly when HP was utilized as biogas substrate.

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