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GRATED COCONUT WASTE AS HEATING JACKET AND TEMPERATURE STABILISER IN THE PRODUCTION OF VIRGIN COCONUT OIL BY NATURAL FERMENTATION

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ABSTRACT

One of the challenges in the production of virgin coconut oil (VCO) by natural fermentation is to keep the process temperature at the optimum condition for the growth of the bacteria. Grated coconut waste (GCW) is the waste from VCO productions that could undergo a solid state fermentation in which the reaction is exothermic so that the heat is generated during the fermentation. In this research, the use of GCW as a heating jacket and temperature stabilizer during the VCO production and particularly the effects of the mass ratio of GCW to coconut cream and the length of GCW fermentation times to the process temperatures, VCO yields and VCO quality were studied. It was found that the solid state GCW fermentation was an exothermic reaction and could reach a temperature of 40 ^{0}C in the 7 (seven) days of fermentation. GCW with fermentation times of 24, 48 and 72 hrs, respectively, could be used as a heating jacket and temperature stabiliser. The optimum mass ratio of GCW to coconut cream which led to the maximum VCO yield of 22% was 2:1. The VCO contained lauric acid of 50% and moisture of < 0.5%, it was colourless and had a specific coconut oil aroma which met an Indonesian National Standard (INS) and Asian and Pacific Coconut Community (APCC) standard. The use of GCW as a heating jacket was not only avoiding the failure of the VCO production by natural fermentation due to a low process temperature but also enhancing the VCO yield as well as keeping the VCO quality.

Keywords: grated coconut waste, heating jacket, lauric acid, temperature stabiliser, VCO.

1. INTRODUCTION

Virgin coconut oil (VCO) is produced from fresh and mature coconuts by mechanical or natural techniques with or without heating in which there is no chemical refining, bleaching or deodorising (RBD) so that the nature of the oil is unchanged [1]. The essential compounds, especially saturated fatty acids, are preserved during the production of VCO and those compounds are beneficial to the human wellbeing [2-3]. Saturated fatty acids in VCO consist approximately 64% of medium chain fatty acid (MCFA) with carbon chains between C_6 and C_{12} [3]. Lauric acid (C_{12}) is the main MCFA in VCO, its content can reach approximately 52% [4]. In the human body, lauric acid is easily digested and metabolised to form monolaurin, a monoglyceride compound, which has roles as antibiotic, antivirus and antifungal. With its high content of lauric acid, VCO has a better quality than other edible oil [5-9].

There are two-step processes in the production of VCO through natural fermentation. Firstly, a mixture of water and grated coconut are pressed to form an emulsion of coconut milk, then the emulsion is left for 30-45 mins to form layers of coconut cream (top layer) and water (bottom layer). The cream is then separated from the layers. Secondly, the coconut cream is fermented for at least 24 hrs to form layers of VCO, residue and water. The VCO produced is then separated from the layers [10-11]. There are no chemicals, enzyme, yeast or bacteria added during the natural fermentation process; rather the fermentation occurs naturally with the help of bacteria inclusively available in the process [10].

It is important to keep the operation condition, such as temperature, favourable for the growth of bacteria in the natural fermentation of coconut milk to produce VCO. Man *et al* [12] investigated the use of *L. plantarum* in the fermentation of coconut milk to extract VCO and reported that the best condition for bacterial growth was under a microaerophilic condition (between 40–50^{o}C). In tropical countries such as Indonesia, the temperature could drop to 20^{o}C, therefore to keep the temperature favourable for bacterial growths the fermentor was equipped with electrical heater [10].

During natural fermentation process, coconut kernels which consist of water, oil, protein and polysaccarides [13] are grated and pressed to obtain coconut milk which mostly contains oil and water, whereas the polysaccharides are left in the grated coconut waste (GCW). Polysaccharides in GCW can be fermented to form more simple compounds by solid state fermentation [14]. Fermentation of polysaccharides is an exothermic process [15], thus the GCW fermentation generates heat. The heat could be utilised to stabilise the temperature in the second phase of natural fermentation of coconut milk to produce VCO. The utilisation of GCW as a heating jacket in the fermentation process is a smart and green way to reuse the waste and to reduce the electricity cost.

The present study examines the possibility in using GCW as a heating jacket and temperature stabilization in the natural fermentation process of coconut milk to optimize the production of virgin coconut oil. The mass ratio of GCW to coconut cream and the effect of the use of grated coconut waste to the quality of the VCO are also studied. Understanding the optimum condition of the use of GCW in the natural fermentation to produce VCO is beneficial in the application of this technology by small VCO industries.

2. METHODOLOGY

a) Materials, equipment and instruments

Approximately 10-12 month-old tall variety coconuts were used as fresh coconuts to provide coconut milk, GCW and coconut water. Coconut milk was the main raw material for VCO production, GCW was used as the heating jacket and temperature stabiliser, while coconut water was used as a pressing media.

A set of peeling, grating, pressing and separating equipment was used to separate coconut cream in the first step of the process. Furthermore, a set of fermentor equipped with GCW heating jacket was used in the second step of the fermentation process. The VCO was filtered using whatman paper no 10. Density of VCO was determined using a picnometer, while the chemical compositions of VCO was determined using a gas chromatography (GC).

b) Procedures

Fresh coconuts were peeled and cut to obtain coconut kernels; coconut water was drained from the coconut and put in the container to be used as pressing media. The coconut kernels then grated and mixed with coconut water with the mass ratio of coconut water to grated coconut of 3:2. The mixture was manually pressed for 15 minutes to produce coconut milk and grated coconut waste. The coconut milk then transferred into a big funnel separator and left for 45 mins to form two (2) layers, i.e. water layer (top) and cream layer (bottom). The water then was separated from the cream layer. The produced cream was measured for its volume (Vc_0). Afterwards, the first separation process was then continued to the second step. The cream was transferred into five (5) fermentors; each of them had a capacity of 1000 ml (Vc_1). Four (4) of the fermentors were equipped with GCW jacket with the mass ratio of GCW to coconut cream (GCW-cream ratio) of 3:1, 2:1, 3:2 and 1:1, respectively, while one of them was not equipped with GCW jacket (ratio 0:1). To study the effect of GCW as a heating jacket, an empty fermentor equipped with GCW jacket was also run (GCW-cream ratio of 1:0).

All the fermentors were left for 24 hrs so that three layers, namely, water layer (bottom), VCO layer (middle) and residue layer (top), were formed. The temperatures of the GCW jacket and cream mixture fermentation systems were measured at 0, 6, 12, and 24 hours, respectively. There were 3 (three) types of GCW used in this research, namely the GCW fermented for 24 hrs, 48 hrs and 72 hrs, which from now onwards is referred as 24-hrs fermented GCW, 48-hrs fermented GCW and 72-hrs fermented GCW, respectively. Figure-2 shows the main steps of the production of VCO using GCW as heating jacket and temperature stabiliser.

The VCO was filtered through a what man no. 10 filter paper. The volume and density as well as chemical, biological and organoleptic analysis were determined based on previous methods [16]. The yield of VCO was determined in Equation.(1).

$$yield(\%) = \frac{V.\rho}{m.\alpha}100 \qquad (1)$$

where V was volume of VCO (mL), ρ was density of VCO (g/ mL), m was mass of fresh grated coconut (g) and α was the fraction of processed coconut cream to form VCO ($\alpha = Vc_1/Vc_0$).

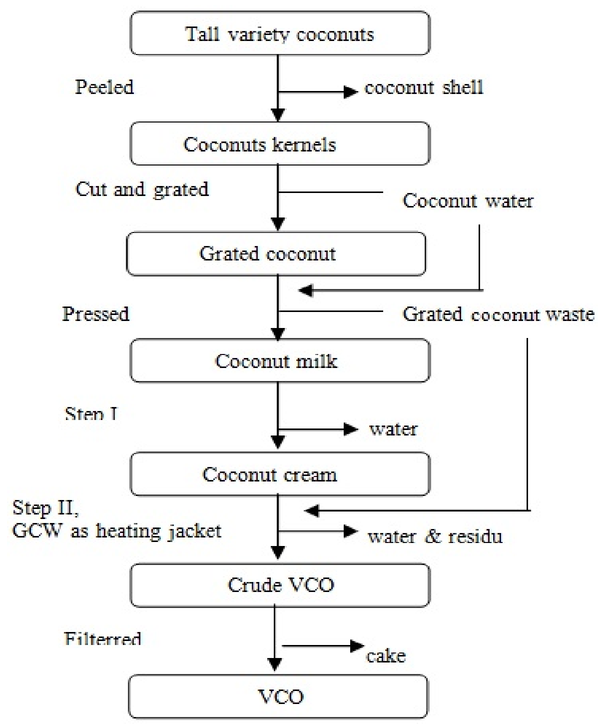

Figure-1. Block diagram of VCO production procedures using GCW as a heating jacket.

3. RESULTS AND DISCUSSION

a) Performances of GCW as a heating jacket

Table-1 shows temperatures of GCW used as a heating jacket at various GCW− cream ratios in the second step of VCO production using 24-hrs fermented GCW, 48-hrs fermented GCW, and 72-hrs fermented GCW, respectively. It can be seen from the table that the temperature ranges of GCW jackets vary at 32–39 ^{0}C. It is observed when the GCW left in a closed system (ratio 1:0), its temperature increased. It is also shown for the fermented GCW from 24 to 72 hrs, that the longer the fermentation time the higher the temperature of the GCW jacket.

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The polysaccharides (carbohydrates) in GCW could undergo a fermentation reaction with the help of inherent bacteria. The bacteria helped the hydrolysis of carbohydrates to form glucose. The glucose was then further fermented to produce alcohol and carbon dioxide and release energy [17], as can be described in (R.1) as follows:

$$(C_6H_{12}O_n)_n + n\ H_2O \rightarrow n(C_6H_{12}O_n) \rightarrow 2n\ C_2H_5OH + 2n\ CO_2 + Energy \quad (R.1)$$

To further study the effect of GCW as a heating jacket, two (2) sets of systems, namely GCW−cream ratio of 2:1 (as a heating jacket) and 1:0 (not as a heating jacket) were observed their temperature profiles from 0 to 96 hrs. The temperature profiles are shown at Figure-2.

Table-1. Temperatures (^{0}C) of GCW jacket at various GCW-cream ratios at various observation times.

GCW cream ratio	Temperatures, °C											
	24-hrs fermented GCW				48-hrs fermented GCW				72-hrs fermented GCW			
	Observation times, hrs				Observation times, hrs				Observation times, hrs			
	0	6	12	24	0	6	12	24	0	6	12	24
1:0	32,5	35	35,5	35	35	36	37	37,5	37,5	38	39	39
3:1	32,5	34	34,5	35	35	35,5	35	36	36	36,5	36,5	37
2:1	32,5	33,5	34	34,5	34,5	35,5	35,5	36	36	36	36,5	36
3:2	32,5	33	34	34,5	34,5	35	35,5	35,5	35,5	36	36	35,5
1:1	32,5	33	33,5	34	34	34,5	33,5	34	34	34,5	34	34
1:0	-	-	-	-	-	-	-	-	-	-	-	-

Temperature is a physical indication that the metabolisms of microorganisms in the fermentation occurred [18]. The temperature of non-heating GCW jacket could reach 40 ^{0}C, while the heating GCW jacket reached 36 ^{0}C. In the solid state fermentation due to a poor conductivity of the wet solid, the heat is kept in the medium [14]. Figure-2 shows that there is a significant temperature difference between heating GCW jacket and non heating GCW jacket. This suggests that the heat from GCW jacket was transferred via convection into the cream mixtures of the VCO fermentation process.

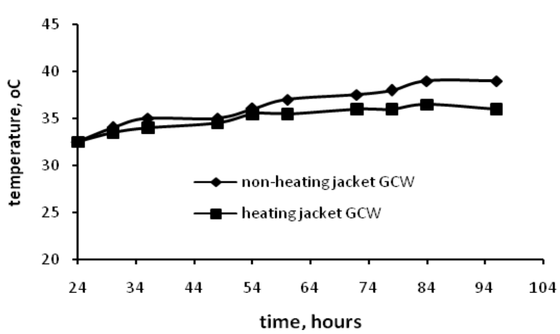

Figure-2. Temperature profiles of heating jacket GCW and non-heating jacket GCW.

b) Effects of GCW as a heating jacket

Figure-3 shows the effect of GCW on stabilising temperatures of coconut cream mixtures in the second phase of the natural fermentation process at various GCW ratios of 1 day-fermented GCW, while the VCO yields of the process are shown at Figure-4. It can be seen that at GCW ratio of 0:1 (the process without GCW jacket), the temperature of the process dropped to 27 ^{0}C at the end of the process. In the eastern part of Indonesia, during a cold-rainy season the temperature could be as low as 20 ^{0}C, thus without a proper heating the natural fermentation of coconut milk to produce VCO could fail as at that temperature the fermentative bacteria could not actively metabolise.

It can be seen from Figure-3 and Figure-4 that the temperatures of the cream at GCW ratio of 1:1 ranged from 30-31 ^{0}C, the VCO yield was c.a. 18%. Increasing the GCW ratio at 3:2 increased the cream temperature to 32 ^{0}C and the yield to 19.5%. At GCW ratio of 2:1 the cream temperature stabilised at approximately 32-33 ^{o}C and gained yield of 21%. Further increase the GCW ratio to 3:1 increased the cream temperature to 34 ^{0}C, however the VCO yield is almost unchanged. At GCW ratio of 2:1, the heat evolved from the fermentation of GCW could stabilise the temperature of the VCO fermentation process to produce an optimum yield of VCO.

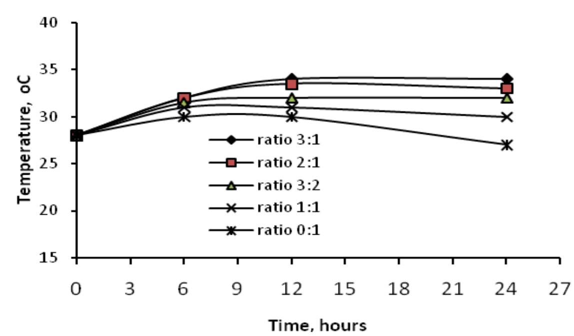

Figure-3. Effects of 48-hrs fermented GCW jacket on the cream mixture temperatures of VCO fermentation process at various GCW-cream ratios

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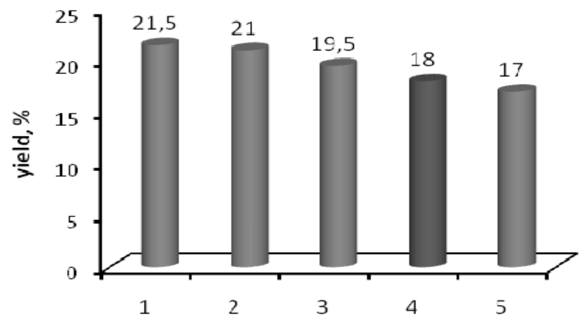

Figure-4. Yields of VCO at various GCW-cream ratios for 48-hrs fermented GCW jacket. GCW-cream ratio 3:1 (1), ratio 2:1 (2), ratio 3:2 (3), ratio 1:1 (4) and ratio 0:1 (5).

The effects of 48-hrs fermented GCW on stabilising the temperatures of the cream mixtures are shown at Figure-5 and the VCO yields of this process are presented at Figure-6. It can be seen from Figure-5 that without a GCW heating jacket, the temperature of the process could drop to 29 ^{0}C at the end of the batch. Equipping the fermentation process with 48-hrs fermented GCW jacket, it generally can stabilise the temperature of VCO fermentation process. With an increase in GCW-cream ratio, the temperature of the fermentation process increased. The VCO yield firstly increased quite significantly with an increase in the GCW-cream ratio, however increasing GCW-cream ratio from 2:1 to 3:1 did not affect the VCO yield. The temperature of VCO fermentation process at GCW ratio of 2:1 was 22 ^{0}C and the VCO yield was 22%.

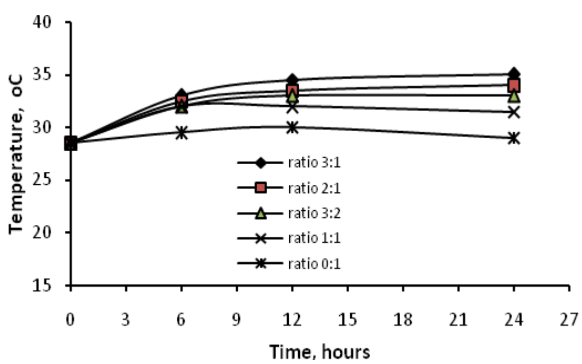

Figure-5. Effects of 48-hrs fermented GCW jacket on the cream mixture temperatures of VCO fermentation process at various GCW-cream ratios.

Figure-7 and Figure-8 present the effects of 72-hrs fermented GCW jacket on the temperatures of cream mixtures and VCO yields, respectively. As also observed from previous processes, without GCW jacket the temperatures of the process dropped to 29 ^{o}C at the end of the process. Using 72hrs-fermented GCW as a heating jacket could slightly increase the temperature of the process; however there was an insignificant increase in the VCO yield. Furthermore, it was observed that the72-hrs fermented GCW jacket had a nasty smell. When the product handling is not properly done, the smell of the GCW jacket could affect the aroma of the VCO products. Technically the GCW is not suitable to be used as a heating jacket anymore if the GCW is fermented for longer times (120–168 hrs). Although the GCW could stabilise the cream temperature around 30–32 ^{o}C, it has been rotten and smelly.

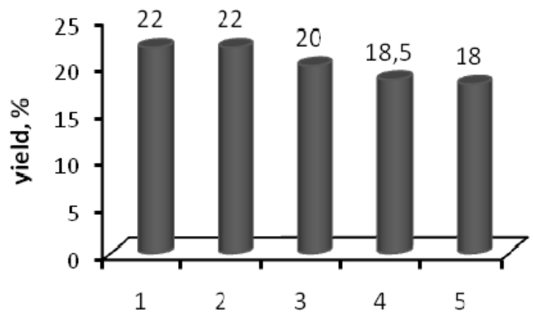

Figure-6. Yields of VCO at various GCW-cream ratios for 48-hrs fermented GCW jacket. GCW-cream ratio 3:1 (1), ratio 2:1 (2), ratio 3:2 (3), ratio 1:1 (4) and ratio 0:1 (5).

Organoleptic analysis of the VCO products resulted that the VCO products from the processes equipped with 24-hrs fermented GCW and 48-hrs fermented GCW jackets were described to have a specific aroma of coconut oil and colourless. The specific aroma of coconut oil was associated with a slight sweet cooked coagulated coconut milk smell [1]. On the other hand, VCO products from the process equipped with 72-hrs GCW jacket were described to have rancid aroma and taste. The unpleasant aroma and taste of 72-hrs fermented GCW VCO products was affected by a careless handling when separating the VCO products without closing the GCW jacket properly.

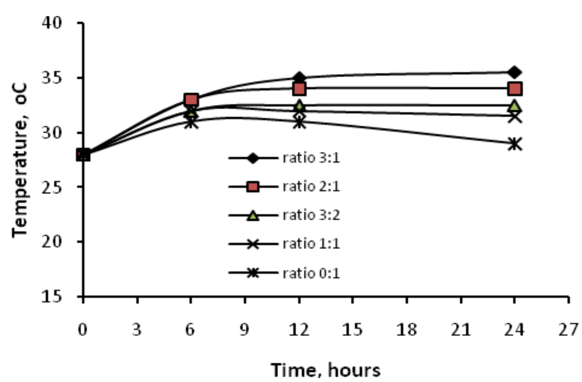

Figure-7. Effects of 48-hrs fermented GCW jacket on the cream mixture temperatures of VCO fermentation process at various GCW-cream ratios.

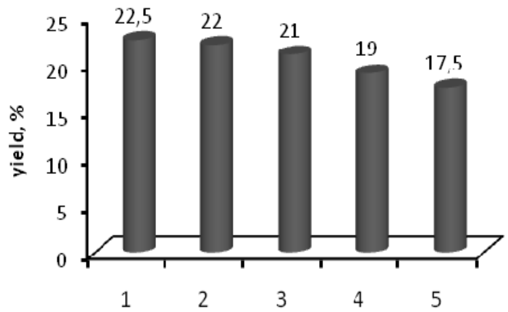

Figure-8. Yields of VCO at various GCW-cream ratios for 48-hrs fermented GCW jacket. GCW-cream ratio 3:1 (1), ratio 2:1 (2), ratio 3:2 (3), ratio 1:1 (4) and ratio 0:1 (5).

The physical and chemical characteristics of VCO obtained from the three processes are presented at table 2. It can be seen that there are no significant differences in the physical and chemical properties of all VCO products; the VCO obtained from the process without GCW jacket, 24-hrs GCW jacket, 48-hrs GCW jacket and 72-hrs have similar physical and chemical characterizations. It can be seen from Table 2 that the VCO produced from this research meets a standard of APCC [19]. It also meets the Indonesian National standard (INS) 7381 for VCO products [20].

4. CONCLUSIONS

Polysaccharides in GCW could undergo solid state fermentation to form more simple compounds and generate heat. The exothermic nature of fermentation of GCW could heat the GCW jacket to 40°C, the heat can be transferred convectively to heat the VCO fermentation process and stabilise the temperature of the process. The optimum GCW for VCO natural fermentation was achieved when using 48-hrs fermented GCW at GC–cream ratio of 2:1 which yielded 22% of VCO. All the VCO products met APCC and INS standards, however organoleptic analysis suggested that the process using 72-hrs fermented GCW had rancid aroma and taste.

Tabel-2. Characteristics of VCO.

Analyses	VCO without GCW heating jacket	VCO with GCW heating jacket	APCC Standard [19]	
Fatty acids:				
Caprilyc acid (C_8:0)	9	9.02	4-10	%
Capric acid (C_{10}:0)	7.3	7.3	4-8	%
Lauric acid (C_{12}:0)	49.98	50.03	45-56	%
Miristic acid (C_{14}:0)	17.05	16.44	16-21	%
Palmitic acid (C_{16}:0)	7.9	8.05	7.5-10.2	%
Stearic acid (C_{18}:0)	5.48	5.7	2-4	%
Oleic acid (C_{18}:1)	4.4	4.6	4.5-10	%
Linoleic acid (C_{18}:2)	1.8	1.69	0.7-2.5	%
Total solid	0.01	0.02	Max 0.05	%
Moisture content	0.21	0.22	Max 0.5	%
Density	0.92	0.93	0.915-0.92	g/ml
Calorific value	9353.54	9012.22	-	cal/g
Total Plate Count (total bacteria)	1.01E+01	1.07E+01	Max 10	cfu/ml
ß Caroten	2.56	2.13	-	ug/100g

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