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Production and added value of waste cooking oil product derivatives in the Bali Province

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KEYWORDS

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ABSTRACT

Waste cooking oil or waste cooking oil (WCO) is the remaining oil (or by-products) produced during food frying. In 2019, the cooking oil consumption in Bali Province was 4,735,057 L/month and the WCO produced was estimated about 3,314,540 L/month. The Government of Bali plans to manage WCO in an integrated manner WCO in an integrated manner by processing it as derivative products with economic value. The study aimed to transform WCO into high-value added products (i.e. aromatherapy candles, liquid soap, and biodiesel), and to analyze their economy valued added. The Hayami method was used to determine the economyvalue added of each product. The results showed that WCO was most widely used in producing biodiesel (84%), candle (17%), and liquid soap (10%). Based on the Hayami method, the added value from candle products was IDR. 4,838 / kg (or added value ratio of 9.68%), was classified as a low added product. The added value of liquid soap was IDR 8,495/kg (or added value ratio of 47.38%), classified as a high added value product. While, biodiesel products generating the added value of IDR 2,363/kg (or added value ratio of 25.57%), classified as a medium added value product.

Introduction

Cooking oil is one of the most essential components in food preparation, as it is used in substantial quantity for food frying in home, restaurants or in food industry. Remaining oil generated during frying is called waste cooking oil (WCO) (Man et al., 2010). WCO are basically a mixture of triglycerides and fatty acids, contaminated by some derivatives during the frying process, such as free fatty acids (FFA), heterocycles, Maillard reaction products, and metal traces originated from pads and food leaching. WCO can produced from various types of cooking oil such as palm oil, coconut oil, corn oil, and vegetable oil (European Waste Catalog, 2020).

Total consumption of cooking oil in Bali Province was 4,735,057 L/month (Bali Statistics Agency, 2019). Consumption is grouped based on several sources such as households, catering services and hotel, restaurant, and café (horeca). Our preliminary research study showed that the WCO production in Bali Province was estimated of 3,314,540 L/month, with the assumption of 30% cooking oil depreciation after use.

Many studies reported that WCO is potential to be valorised as derivative products such as biofuel (Chrysikou et al., 2019; Hazrat et al., 2019; Ray and Prakash, 2019); bio-lubricant (Abdulbari et al., 2011; Karmakar et al., 2017); and animal feed ingredients (Magrinyà et al., 2012). WCO can also be processed into paraffin, transesterification products, and other value added products (Panadare and Rathod, 2015); hydrogen gas (French and Czernik, 2003); soap (Sanaguano-Salguero et al., 2018); and candle (Nane et al., 2016).

The valorisation of WCO into those derivative products can give value added to WCO, as well as can reduce the environmental pollution and health problems. The added value method is one of the most important indicators resulting from a company's activities and reflects its economic strength (Căruntu and Lăpăduşi, 2012). Hayami method, one of the value added methods, can be used to analyse the added value of a product, and also to identify the value of output, production productivity, contribution of other inputs, company profits, and labor (Aji et al., 2018).

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Until year 2020, there is only one organization that manages WCO in Bali known as the Yayasan Lengis Hijau (YLH). YLH processes WCO into biodiesel with a production capacity of 1000 L/day or 30,000 L/month. Therefore, about 2.9 million L/month of WCO are still potential to be further valorised. YLH purchased WCO at the price ranged from IDR 2,000/L to IDR 3,000/L, which then processed into biodiesel sold at a price in the range of IDR 10,000-11,000/L.

YLH has supplied biodiesel to Green School at Sibang, Badung Regencies, as well as to several hotels in Bali. Besides biodiesel, other potential products that can be developed from WCO are liquid soap and aromatherapy candles. These products can be used as tourism support products with natural product branding. In 2018, tourists visit to Bali were approximately 6,070,473 people (Bali Provincial Statistic, 2019). This may open opportunities for the processing and development of WCO, which can contribute to provide benefits economically, environmentally and socially in the Province of Bali. Therefore, the research on production and added value of WCO derivative products (i.e. biodiesel, soap and aromatherapy candle) were carried out. This study aimed to transform WCO into high-value added products (i.e. aroma therapy candles, liquid soap, and biodiesel), and to analyse their value added.

Materials and Methods

Population and Sample

Population determination and sampling in this study was carried out using purposive sampling. The population in this study was determined as all WCO producers in Bali. Based on the purposive sampling approach, 3 districts were selected, include Badung, Denpasar, and Gianyar as the research location. This selection was based on several criteria, as follows having the highest population density, the most tourism industry activities, and the most trading activities. Therefore, it was assumed that there are a high WCO production in the selected districts.

Aromatherapy Candle-making Procedure

The materials used for making aromatherapy candles were WCO, activated charcoal, alcohol, stearic acid, aroma therapy perfume, and candle wicks. The process of making candles was based on Arnata et al. (2017), with several modifications. The process consists of three stages, include bleaching, mixing and cooling. Bleaching was carried out by mixing WCO with activated charcoal as much as 5% of the WCO volume. The mixture was then heated to 75^0 C, and stirred for 10 minutes, following cooling and filtering using filter paper. Bleaching process aimed to remove certain minor compounds or compounds such as colors, free fatty acids, peroxides, odors and non-fat substances from oil (Palanisamy et al., 2011; Guzialowska-Tic, 2013).

Weighed as much as 12.5 g of 50% alcohol, 12.5 g stearate and 5 g WCO. In the mixing stage, the stearic was firstly heated until it melts, then added with WCO, stirred until homogeneous, then added with the alcohol and deodorizer. In the cooling stage, the formed mixture was then given with a candle wick, and cooled down for a week to get a solid waxy texture.

Parameters analysed include hardness (N/m^2) using Texture Analyzer (TAXT Plus Microstable USA); density (g/cm^3) using the Mitchual et al. (2014) approach; ash content (%) using AOAC (1990); time of lights up or duration of light (minutes) using the Onuegbu et al. (2011); and the calorific value (cal/g) using a calorimeter bomb.

Liquid Soap-making Procedure

Liquid soap production followed Widyaningsih et al. (2018) with several modifications. First, WCO was purified with activated charcoal and then filtered. Then, prepared a mixture solution (i.e. solution 1) consists of KOH and WCO, which a basic solution for making liquid soap. Weighed 20% KOH solution mixed with MGB at ratio 6:5. Then heated in a water bath shaker at a temperature of 70-80^{o}C for 4-5 hours. The reaction that occurs between KOH and WCO is called as a saponification reaction, which is the hydrolysis of fats to fatty acids and glycerol in alkaline conditions (Naomi, 2013). Solution 1 was then added with glycerin and distilled water (at ratio of 1:10), this is called as solution 2. Solution 3 was prepared by dissolving Tween 80 into 70% sucrose (at ratio of 1:2) and heated at 70-80 ^{o}C until homogeneous. Liquid soap was made by mixing solution 2 and solution 3 at ratio of 1:1, heated at 60-70 ^{o}C for 30 minutes, following cooled down step to a temperature of 25-40 ^{o}C.

Parameters analysed include foam height (cm) according to Sari and Ferdinan (2017); pH and specific gravity (g/mL) (based on SNI 06-4085-1996); water holding capacity (%) according to Alamsyah et al. (2009); foam stability (%) according to Piyali et al. (1999); and viscosity (cP) according to ASTM D2196 method.

Table 1. The Hayami's calculation formula

	Output, Input, and Price	Formula
1	Output (kg/day)	(1)
2	Raw material Input (kg)	(2)
3	Labor (working day)	(3)
4	Conversion factor	(4)=(1)/(2)
5	Labor coeficient (working day/kg)	(5)=(3)/(2)
6	Output price (IDR)	(6)
7	salary (IDR/working day)	(7)
	Revenue and Profit	
8	Raw material Price (IDR/kg)	(8)
9	Other input Price (IDR/kg)	(9)
10	Product Price (IDR/kg)	(10)=(4) x(6)
11	a. Added Value (IDR/kg)	(11a)=(10)-(8)-(9)
	b. Added Value Ratio (%)	(11b)=(11a)/(10) x 100
12	a. Labor Income (IDR/kg)	(12a)=(5) x (7)
	b. Share of Labor (%)	(12b)=(12a)/(11a)x 100
13	a. Profit (IDR/kg)	(13a)=(11a)-(12a)
	b. Profit Rate (%)	(13b)=(13a)/(10)x 100
	Production owner compensation factor	
14	Margin (IDR/kg)	(14) =(10)-(8)
	a. Rate of Labor Income (%)	(14a)=(12a)/(14) x 100
	b. Other input donations (%)	(14b)=(9) /(14) x 100
	c. Company profit rate (%)	(14c) = (13a)/(14) x 100

Biodiesel-making Procedures

The biodiesel production was following the method described by Wahyuni et al. (2015). First, methoxide solution was prepared by adding methanol and KOH at ratio of 4:1 v/v and heated at 75 ^oC for 10 min. The biodiesel processing from bleached WCO was a transesterification reaction by adding a solution of methoxide at ratio of 1:1. The transesterification process began with heating the WCO at 75 ^oC, stirring for 20 minutes, following an addition of methoxide solution. The methoxide solution acts as a catalyst to speed up of the chemical reaction of biodiesel by reducing the energy needed when starting the reaction. Methoxide has almost water-free properties, thus the biodiesel yield is higher, with more consistent quality and lower cost of purification (Jackson, 2006). Transesterification reaction is more preferred than esterification due to its faster reaction time and less alcohol required (Gerpen, 2005).

WCO and methoxide were stirred at 1000-1050 rpm with a mixer for 5 minutes, then deposited until 2 layers were formed, where the top layer was biodiesel and the bottom layer was glycerol. Biodiesel was separated from the glycerol using a suction pump. Then, biodiesel was washed three times using water in a ratio of 1: 1. Biodiesel was separated from water by heating at 100 ^oC until most of the water was evaporated.

Biodiesel's parameters analysed include density at 40 ^oC (kg/m^3) using the ASTM (American Society for Testing Material) D 1298 method, kinematic viscosity at 40 ^oC (cSt) using the ASTM D 445 test method, water content (%) using the ASTM D 2709 method, and the cetane number using the ASTM D 613, Standard Test Method for Cetane Number of Diesel Fuel Oil.

Added Value Analysis

According to Hayami et al. (1987), there are two ways to calculate added value, such as for processing and marketing. The procedure for calculating the added value according to the Hayami Method can be seen in Table 1. The materials used for making aromatherapy candles were WCO, alcohol, stearic acid, and aromatherapy perfume. Activated charcoal, deodorizers, molds, candle wicks and packaging were then grouped as other inputs. The materials used for making liquid soap were KOH, WCO, glycerin, sugar, aquades, tween 80, and the other input was packer. The materials used to make biodiesel were WCO, methanol, and KOH. Water and packaging were then grouped as other inputs. Hubeis (1997) classified the ratio of added value into three categories of low (if the percentage is <15%), medium (if the percentage between 15% - 40%), and high (if the percentage is >40%).

Table 2. Characteristics of Aromatherapy Candle

Characteristics	Specification
1. Hardness (N/cm^2)	31.679
2. Density (g/cm^3)	1.623
3. Heat value (cal/g)	9,489.802
4. Duration of burning (minutes)	27.04
5. Ash content (%)	0.109

Results and Discussion

Characteristics and Added value of Aromatherapy Candle

Characteristics of aromatherapy candle are presented in Table 2. Aroma therapy candle had 1.623 g/cm^3 density and 31.679 N/cm^2 of hardness. The density of candle made from WCO was higher than that of the paraffin candle (0.88-0.94 g/cm^3) and bees wax candle (0.95 g/cm^3) (Hossain et al., 2010). The density of WCO candle structure was possibly due to the large content of free fatty acids (FFA). The high FFA content was directly proportional to the level of wax hardness, and the level of hardness was influenced by the level of wax density (Rezaei, 2002). Density and hardness are directly proportional to the long burning of the candle. A previous study by Rezeai (2002) found that candle with high FFA content had a low burn rate. The solid texture of the candle causes the candle to be more difficult to burn, thus affecting the duration of light. The duration of light of WCO candle was 27.04 minutes.

The heating value of WCO candle was 9,489.802 cal/g. This value was lower than paraffin candle (1,051.2 cal/g) (Hammins and Bundy, 2005). The heating value was influenced by the moisture content, ash content and texture of the candle. A material with denser texture has higher tendency to produce a lower heating value. This is in accordance to Arnata et al. (2017), who studied about bioethanol gel, reported that materials with high hardness and density would be more difficult to burn and take longer to transfer heat.

Analysis of the added value of candles can be seen in Table 3. The total raw material required was 90 kg consisting of 15.3 kg WCO or 17% WCO and 74.7 kg of other material such as stearic acid, alcohol and perfume. The daily output was 60 kg or as many as 3,000 pieces of candles designed with a weight of 20 g per pieces. The candle was then packaged using cardboard packaging, contained 25 pcs of candles/box and sold at IDR 37,500/box or IDR 1,500/piece. The price was obtained from the cost of production multiplied by the expected profit of 21%.

In this study, the workers used were 2 people. Salary was assumed IDR 85,000/working day (8 hours) for each worker, based on the Denpasar City minimum working salary. The coefficient of labor is 0.022 working day/kg, indicating that the labor needed to process 1 kg of raw material (a mixture of WCO, stearic acid and alcohol) was 0.022. The conversion factor was obtained at 0.67, showing that every 90 kg of raw material made up of 15.3 kg WCO (17%) and 74.7 kg of other materials (83%) processed could produce 60 kg of candle. From Table 3, it can be seen that the processing of WCO into a candle produces an added value of IDR 4,838/kg (or an added value ratio of 9.68%). This added value was obtained from the added value per day of IDR 290,250 divided by daily production of 60 kg. Based on Hubeis's value added criteria, the added value of the candle from WCO was classified as a low (Hubeis. 1997)

Characteristics and Added value of Liquid Soap

Characteristics of liquid soap are presented in Table 4. The specific gravity (1.02 kg/L) and pH (7.49) of liquid soap are in accordance with SNI 06-4085-1996, approved by the Indonesian National Standardization Agency. Water holding capacity (WHC) of 93.408% indicates that soap had high humidity. Oktari et al. (2017) in their research on liquid soap stated that high humidity content in soap demonstrating its ability to maintain the amount of water inside.

The stability of foam was 82.634%, possibly due to stearic acid and palmitic acid contained in WCO, thus it was able to maintain the stability of the foam (Cavitch, 2001).

Analysis of the added value of liqud soap can be seen in Table 3. The daily output was 25 kg and the amount of raw material for day production was 25.8 kg (composed of 2.5 kg WCO or 10 % WCO, 3.3 kg KOH, 17.5 kg aquadest, 1 kg glycerin, 1 kg sucrose, and 0.5 kg tween 80 as a stabilizer). The conversion factor was obtained at 0.97, which means that every 25.8 kg of raw material processed will produce 25 kg of liquid soap.

Table 3. The Hayami's Calculation Results for Aromatherapy Candle, Liquid Soap and Biodiesel

	Output, Input and Price	Aromatherapy Candle	Liquid Soap	Biodiesel
1	Output (kg/day)	60	25	100
2	Raw material Input (kg)	90	25.8	119
3	Labor (working day)	2	2	4
4	Conversion factor	0.67	0.97	0.84
5	Labor coeficient (working day/kg)	0.022	0.078	0.034
6	Output price (IDR)	4,500,000	462,500	1,100,000
7	Salary (IDR/working day)	85,000	85,000	85,000
	Revenue and Profit			
8	Raw material Price (IDR/kg)	2,313,750	210,800	587,500
9	Other input Price (IDR/kg)	396,000	25,000	100,534
10	Product Price (IDR/kg)	3,000,000	448,159	924,370
11	a. Added Value (IDR/day)	290,250	212,359	236,336
	b. Added Value Ratio (%)	9.68	47.38	25.57
12	a. Labor Income (IDR/kg)	1,889	6,589	2,857
	b. Share of Labor (%)	0.65	3.10	1.21
13	a. Profit (IDR/kg)	288,361	205,770	233,479
	b. Profit Rate (%)	99.35	96.90	98.79
	Production owner compensation factor			
14	Margin (IDR/kg)	686,250	237.359	336,870
	a. Rate of Labor Income (%)	0.28	2.78	0.85
	b. Other input donations (%)	57.70	10.53	29.84
	c. Company profit rate (%)	42.02	86.69	69.31

Table 4. Characteristics of Liquid Soap

Characteristics	Specification	SNI 06-4085-1996
1. pH	7.486	6-8
2. Density (kg/mL)	1.02	1.01-1.10
3. WHC(%)	93.408	-
4. Foam height (cm)	2.876	0.5-2
5. Foam stability (%)	82.634	-
6. Viscosity (cP)	549.2	400-4,000

Table 5. Characteristics of Biodiesel

Characteristics	Specification	SNI 7182-2015
1. Kinematic Viscosity (40˚C}	4.832 cSt	2.3-6.0 cSt
2. Density (40˚C)	859.36 kg/m^3	850-890 kg/m^3
3. Water content	0.041%	Max 0.05%
4. Cetane number	56.18	Min 51

From Table 3, it was known that the processing of WCO into a liquid soap produces an added value of IDR 8,495/kg (or an added value ratio of 47.38 %). This added value was obtained from the added value per day of IDR 212,359 divided by daily production of 25 kg. The added value of the liquid soap was classified as a high added value ratio (Hubeis, 1997).

Characteristics and Added value of Biodiesel

Characteristics of biodiesel were presented in Table 5. Biodiesel from WCO was in accordance with the characteristics set by the Indonesian National Standards (SNI 7182:2015). According to Farouk et al. (2016), biodiesel from WCO content kinematic viscosity value 3.658 cSt and cetane number 55.45-56.10. Research conducted by Tsoutsos et al. (2019) stated that the biodiesel from WCO had cetane number was 55.26 and kinematic viscosity value was 4.832 cSt. All of these studies met the SNI 7182:2015 criteria.

Analysis of the added value of biodiesel can be seen in Table 3. The daily output was 100 kg and the amount of raw material for day production was 119 kg (100 kg WCO or 84 % WCO and 19 kg methanol and KOH). This biodiesel production follows the biodiesel procedure carried out by Rahadianti et al. (2018).

The conversion factor was obtained at 0.84, which means that every 119 kg of raw material processed could produce 100 kg of biodiesel. From Table 5, it shows that the processing of WCO into biodiesel produces an added value of IDR 2,363/kg (or an added value ratio of 25.57 %). This added value was obtained from the added value per day of IDR 236,336 divided by daily production of 100 kg. The added value of the biodiesel was classified as a medium added value ratio (Hubeis, 1997).

Conclusion

Waste cooking oil can be processed into aroma therapy candle, liquid soap and biodiesel. The composition of WCO in aroma therapy candle products was 17%, in liquid soap was 10% and in biodiesel was 84%. Based on the Hayami method, the added value from candle products was IDR 4,838/kg or an added value ratio of 9.68%, classified as a product with a low added value ratio. Liquid soap products produced added value of IDR 8,495/kg or an added value ratio of 47.38 %, classified as a product with a high added value ratio, and biodiesel products generated added value of IDR 2,363/kg or an added value ratio of 25.57%, classified as a product with a medium added value ratio.

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