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Crystal Exergy Value (Wax) Crude Palm Oil (CPO) Influence Based On The Mixed Type

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ABSTRACT

Liquid wax (wet wax) is a source of heat energy and lighting produced from palm oil to provide illumination where needed. The need for candles is used for lighting the environment, the place, and the heating of the objects for need. The manufacture of liquid candles is to provide the base oil of crude palm oil mixed evenly in the melting point of solid paraffin. Paraffin and CPO are melted together and placed, then cooled. The wax ignition process produces heat and light. Results that can be shown with a comparison between palm oil and solid paraffin will produce hardness, texture, and flame ignition. With 50 grams of paraffin, 50 gr CPO and 1 kg of oxygen (1: 5) of the fuel of 250 gr O_2, will produce 1300 gr CO_2, 1175gr H_2O, -1487,5 gr O_2 and 940 gr N_2. Different paraffin granules, will produce the same product in energy balance, while the value of N_2 remains. Experimental value from mixing CPO and paraffin by 50 gr: 50 gr yielding entropy generation (S gen) and CPO wax exudo of 257.16 kJ / kmol.K and 77,918.67 kJ/kmol and its value decreases based on paraffin administration.

INTRODUCTION

Existence value is the value/amount of work potential of the energy available in the system/object. Experiments can be described from potential energy and kinetic energy [1-3]. Exergy in candles made from Crude Palm Oil base material can be obtained by knowing the potential energy and kinetics it has, such as the temperature, as well as the entropy of the object [4-5].

Liquid wax (wet wax) is a solid fuel that has the heat energy stored in itself and gives rise to light. Candles are usually used for paraffin materials as raw materials, have n-octadecane/ C_8H_{18} content, which are used as heat storage and still have n-actan organic hydrocarbon compounds as main components and have thermo physic behavior [6-7].

Characteristics and thermo physical properties of paraffin can be seen in the Table 1.

Table 1. Characteristics and thermo physical properties of paraffin [8]

Melting Temperature	46.7 ºC
Thermal Conductivity (Solid)	0.1383 W/m ºC
ThermalConductivity (Liquid)	0.1383 W/m ºC
Specific Heat (Solid)	2890 J/kg.K
Specific Heat (Liquid)	2890 J/kg.K
Density (Solid)	947 kg/m^3
Density (Liquid)	750 kg/m^3
Latent Heat	209000 J/kg

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Paraffin is one of the materials that can be used as a phase transformer material, since the beneficial properties of paraffin material can absorb heat and can be continued by heat conveyance for solar water heater, which is attached to copper material as an absorber heat absorption [9].

According to Napitupulu (2014), paraffin can change phase from solid to liquid at melting temperature of 59.1ºC This indicates that the phase change from solid to liquid does not require high temperatures. Low temperature changes can be obtained at a cheap and affordable price [10-11].

In liquid wax test process can be used method of test of material concentration by using X-Ray fluorescence spectrophotometer with CH2 equal to 99.92%, Si 283 ppm, Mg 236 ppm, Al 138 ppm, Ca 69 ppm, Sb 18 ppm, P 16 ppm [12].

Liquid candles that have the characteristics of chemically and physically provide stored energy and can be analyzed to determine the energy balance that occurs in it. According to Rahardja, (2015), Energy balance is the result of change in form in other forms. Energy balance can be obtained by knowing the reactants and products produced [13]. In the process of energy owned by liquid candles is by providing heating and combustion, so it can be known the potential energy it has. Liquid candles to be scrutinized are a combination of paraffin and Crude Palm Oil (CPO). CPO is the result of processing of Fresh Fruit Bunches from Palm Oil processing, where processing is usually done at Palm Oil Processing Plant (PMKS).

EXPERIMENTAL METHOD

Research methods are performed as in Fig. 1.

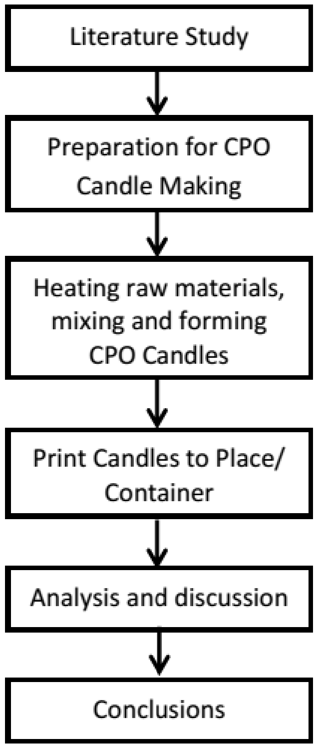

Fig. 1. Flow chart this research

The study phase of this research is carried out as follows:
1. Preparation for CPO candle making
2. Heating raw materials, mixing and forming CPO Candles.
3. Print Candles to place/container.
4. Testing for samples and analysis data.

RESULTS AND DISCUSSION

Density values

Density is the density of an object possessed from its constituent particles which is expressed between mass and volume. Candles with CPO base material have a density that can be obtained by knowing the mass of the object (kg), as well as the volume of space it has. Candles with CPO base ingredients are mixed with paraffin 25%, 50%, 75% and 100% to produce the density Table 2 as follows.

Table 2. Mass Data and Volume Test

No	Mass of samples		Mass (kg)	Dimension (m)			Volume (m^3)
	Paraffin (gr)	CPO (gr)		Length	Width	High	
1	50.0	50	0.009	0.035	0.017	0.015	0.000008662
2	37.5	50	0.016	0.031	0.030	0.017	0.000015810
3	25.0	50	0.011	0.030	0.021	0.018	0.000011025
4	12.5	50	0.010	0.030	0.021	0.016	0.000010080

By knowing the table data above, it can be seen the results of the density of the CPO-based wax in Fig. 2.

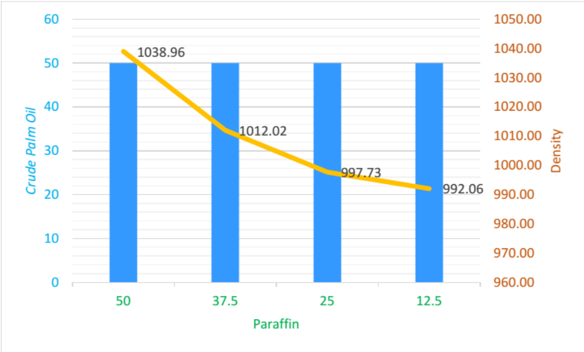

Fig. 2. Type of Wax Mass.

By looking at the graphic image above, there are several differences, namely by giving a mixture of the same CPO and Paraffin (1: 1), then obtaining the density type: 1038.96 kg/m^3. By giving wax mixture between CPO and paraffin, which is 1: ¾, the wax density is 1012.02 kg/m^3. This means that showing by mixing different CPO and paraffin will reduce the value of the mass of the object / candle. Likewise, mixing between CPO and paraffin in comparison (1: ½ and 1: ¼) will reduce the density value that occurs in the mixed candle. The density values are 997.73 kg/m^3 and 992.06 kg/m^3.

Heat value of wax

The combustion process carried out on CPO-based candles will produce carbon dioxide, water, oxygen, nitrogen, ash and others. In the balance of combustion energy the wax can be obtained by the element and it is known the temperature value of the combustion results. By knowing the combustion value that occurs at 1400°C, the mass of 100 gr (0.1 kg), the heat / heat value of the candle will be obtained base equation (1).

$$Q = Xa \, . \, m. \, Hc$$
$$Q = 100\% \ x \ 0.1 \ kg \ x \ 1400^oC = 140 \ Watts \quad (1)$$

For effective combustion heat can be calculated using equation (2).

$$\Delta hc \ eff = Xa \, . \, Hc$$
$$\Delta hc \ eff = 100\% \ x \ 1400^oC = 1400^oC \quad (2)$$

Whereas to find out the emission of combustion radiation can be calculated using equation (3).

$$Xr = Qr/m.Hc$$
$$Xr = 140 \ Watts/(0.1 \ kg \ x \ 1400^oC)$$
$$Xr = 1 \quad (3)$$

Energy balance

Energy balance is the balance (stability) of a substance/object in the process of changing a form into another form, by not reducing or exceeding the substance that has changed the form. Changes in substances in solid form will be able to change in the form of liquid and gas, and the mass of the initial shape is the same as the shape that has changed. This process is said to be the balance of form and energy in other forms.

The process of combustion of liquid wax which is a fuel and included in organic n-actan hydrocarbon compounds that have a considerable chemical value. In the process of burning liquid wax, the chemical equation (4).

$$50 \ gr \ C_{20}H_{42} + 50 \ gr \ (C_3H_5(C00R)_3 + 250 \ gr \ (O_2 + 3.76 \ N_2) \rightarrow CO_2 + H_2O + O_2 + N_2 \quad (4)$$

Liquid wax will experience burning with oxygen (1: 5) as its support, mixing CPO and paraffin (liquid wax) will require oxygen, and can produce reactions of carbon dioxide (CO_2), water (H_2O), oxygen (O_2), and nitrogen (N_2) in combustion. So that it can be calculated as follows:

Element of C	$50 \ C_{20} + 50 \ C_3 + 50 \ C_3 = x \ C$	(5)
	$1000 \ C + 150 \ C + 150 \ C = x \ C$	
	$1300 = x$	
Element of H	$50 \ H_{42} + 50 \ H_5 = y \ H_2$	
	$2100 \ H + 250 \ H = y \ H_2$	
	$2350 \ H = y \ H_2$	
	$y = 2350/2 = 1175$	
Elemnt of O	$50 \ O_3 + 50 \ O_3 + 250 \ O_2 = x \ O_2 + y \ O + z \ O_2$	
	$150 + 150 + 500 = x \ 2 + y + z \ 2$	
	$800 = 1300 \ X \ 2 + 1175 + z \ 2$	
	$800 = 2600 + 1175 + z \ 2$	
	$800 = 3775 + z \ 2$	
	$800 - 3775 = z \ 2$	
	$z = -2975 / 2 = -1487,5$	
Element of N	$250 \ X \ 3.76 \ N_2 = w \ N_2$	
	$1880 \ N_2 = w \ N_2$	
	$N = 1880/2 = 940$	

The balance of the chemical reaction that occurs in combustion of methane gas fuel can be expressed as follows use equation (6).

$$50C_{20}H_{42} + 50(C_3H_5(C00)_3 + 250(O_2 + 3.76 \ N_2) \rightarrow 1300CO_2 + 1175H_2O + -1487.5O_2 + 940N_2 \quad (6)$$

The schematic image to show the burning of liquid wax is illustrated in Fig. 3.

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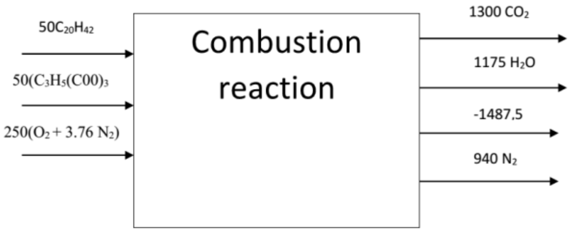

Fig. 3. Schematic Reaction of Chemical Liquid Candles

From the results of the calculation above, we can obtain the value of the chemical element of each comparison between Paraffin and CPO with the provision of a fixed oxygen. The results of the calculation can be seen in Table 3.

Table 3. Balance of Chemical Elements

No	Comparison of reactants		Oxygen	Nitrogen	Value of Chemical Element Products			
	Paraffin (gr)	CPO (gr)	O_2 (gr)	N_2 (gr)	C (gr)	H (gr)	O (gr)	N (gr)
1	50.0	50	250	940	1300	1175.0	-1487.50	940
2	37.5	50	250	940	1050	912.5	-1106.25	940
3	25.0	50	250	940	800	650.0	-725.00	940
4	12.5	50	250	940	550	387.5	-343.75	940

The reactant given the same ratio between paraffin and CPO will decrease the values C, H, O decreases, while the value of N remains the same. The decrease in paraffin given will also decrease the value of the product. The results of calculation of liquid wax Enthalpy can be seen in Table 4.

Table 4. Liquid Wax Enthalpy Calculation

Elements of reactants	ĥ°f	ĥ30°C	ĥ1400°C	N	Reactants of H
		ĥ303K	ĥ1673K		
	(kJ/kmol)	(kJ/kmol)	(kJ/kmol)	(kg)	
$C_{20}H_{42}$	(249950)	77184.74	426171.87	0.05	4951.86
$C_3H_5(C_3O_3O_3)$	(382456)	115140.00	635740.00	0.05	6907.20
O_2	-	8739.00	55542.00	0.25	11700.75
N_2	-	8725.00	53039.00	0.94	41655.16
Total					**65214.97**
Elements of products	ĥ°f	ĥ30°C	ĥ1400°C	N	Products of H
		ĥ303K	ĥ1673K		
	(kJ/kmol)	(kJ/kmol)	(kJ/kmol)	(kg)	
CO_2	(393520)	9434.00	80078.00	1.30	(419738.80)
H_2O(g)	(241820)	9968.00	66129.00	1.18	(218149.33)
O_2	-	8739.00	55542.00	(1.49)	(69619.46)
N_2	-	8725.00	53039.00	0.94	41655.16
Total					**(665852.43)**

In Table 4, the enthalpy values of each chemical element that occur in the burning of CPO candles are shown. By knowing the enthalpy calculation of each chemical element, enthalpy of reactants and products can be obtained. In the mixing ratio of CPO and paraffin given, enthalpy results from several mixtures can be obtained. Enthalpy from mixing CPO and paraffin can be seen in Fig. 4.

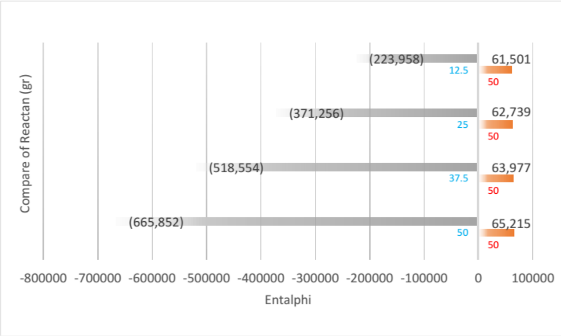

Fig. 4. Enthalpy of reactants and wax products

Comparison of reactants between CPO and paraffin (50 gr: 50 gr) obtained product enthalpy of -665,852 kJ/kmol (product H value was minus which stated that there was energy out), while for reactant enthalpy was 65215 kJ / kmol. By mixing different/declining CPO with paraffin, a decrease in product enthalpy and reactant enthalpy will also occur. The product enthalpy values and reactants in mixing 50 gr CPO with paraffin 12.5 gr (1: ¼) yielded H products of -223958 kJ/kmol and H reactants of 61.501 kJ/kmol.

By knowing the products and reactants produced from burning CPO candles, heat can be calculated (Q_{out}) that can be generated from the combustion use equation (7), (8), (9) and (10).

$$Q = H \text{ product} - H \text{ reactant} \quad (7)$$

$$q_{out} = H \text{ product} - H \text{ reactant} \quad (8)$$

$$Q = \Sigma N \text{ product } (\bar{h}^\circ f + \bar{h} - \bar{h}_0) \text{ product} - \Sigma N \text{ reactant } (\bar{h}^\circ f + \bar{h} - \bar{h}_0) \text{ reactant} \quad (9)$$

q_{out} = (-665852.4)-(65.215,0)
= -731,067.39 kJ.kg/kmol.
q_{out} = -731067.39 kJ.kg/kmol. / 114.231 kg/s kmol
= -6399.90 kJ/s = 6399.90 kW

Tproduct = H product × mass CPO (10)
T product = (-6658524) × 0.05 kg
= -66585.24 kJ.kg/kmol

Below is a graph of the heat value that comes out and the T product from mixing CPO and paraffin wax illustrated in Fig. 5.

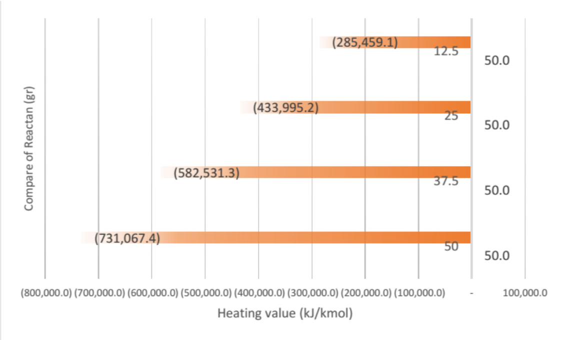

Fig. 5. Comparison of reactants and heat values

In the picture above, there is a calorific value from the mixing ratio of CPO and paraffin, where by giving 50 gr CPO and 50 gr paraffin, the calorific value (*Q*) obtained is -731067.4 kJ/kmol. This calorific value decreases with paraffin which is mixed together with CPO. The large calorific value between 50 gr CPO and paraffin 12.5 gr, obtained a heating value of -285459.1 kJ/kmol. Fig. 6 demonstrate the relationship between the ratio of reactants, heat out and product T.

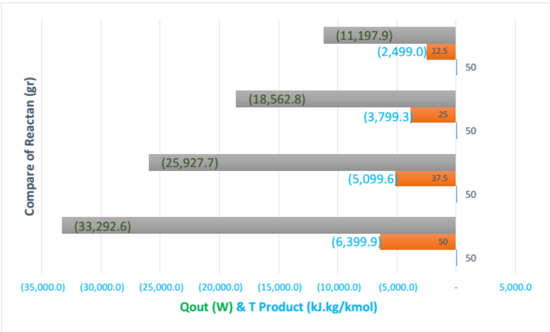

Fig. 6. The relationship between the ratio of reactants, heat out and product T

In the graph above, shows the value of heat generated by mixing 50 gr CPO wax and 50 gr paraffin, resulting in heat out (q_{out}) of -33292.6 kW and a product T of -6399.9 kJ.kg/kmol. The comparison value of CPO wax reactants will give a decreasing value to the value of the outgoing heat (q_{out}) and the product T. In the graph above, the decline is seen. In Table 4 below, CPO candles with the same mixing (1: 1) will produce an entropy value.

Table 4. Entropy of CPO Candles

Elements of reactants	Ni (kg)	Yi	$\bar{S}_i$(T, 1 atm) (kJ/kmol.K)	= -Ru ln Yi Pm (kJ/kmol.K)	Ni Si (kJ/kmol.K)
$C_{20}H_{42}$	0.05	1.19	360.79	-1.44	18.11
$C_3H_5(C_30_30_3)$	0.05	1.19	-2412.76	-1.44	-120.57
O_2	0.25	5.94	205.04	-14.82	54.97
N_2	0.94	22.35	191.61	-25.83	204.40
Total				**S Reactan**	**156.91**
Elements of products	Ni (kg)	Yi	$\bar{S}_i$(T, 1 atm) (kJ/kmol.K)	= -Ru ln Yi Pm (kJ/kmol.K)	Ni Si (kJ/kmol.K)
CO_2	1.3	15.89	213.80	-22.99	307.83
H_2O(g)	1.175	14.36	188.83	-22.15	247.90
O_2	-1.4875	-18.18	205.04	-24.11	-340.87
N_2	0.94	11.49	191.61	-20.30	199.19
Total				**S Product**	**414.06**

So that for the calculation of S_{gen} can be written according to equation (11) and (12).

$$Si = Ni\ \bar{S}I\ (T,Pi) = Ni\ [\bar{S}I\ (T,Po) - Ru \ln Yi\ Pm] \quad (11)$$

$$S\ gen = S\ product - S\ reactan = \Sigma\ Np\ \bar{S}p - \Sigma\ Np\ \bar{S}r \quad (12)$$

$$S\ gen = 414.06\ kJ/kmol.K – 156.91\ kJ/kmol.K = 257.16\ kJ/kmol.K$$

In CPO wax with different paraffin administration, it can be seen the entropy value of the product and reactants in Fig. 7.

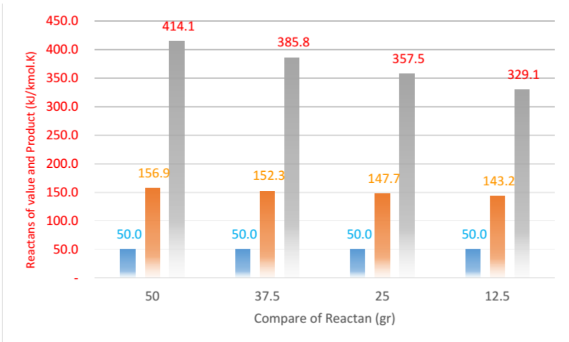

Fig. 7. Entropy value of products and reactants

In the graph above, by giving a mixture of CPO and paraffin (50 gr: 50 gr), it produces product entropy and reactants of 414.1 kJ/kmol.K and 156.9 kJ/kmol.K, the smaller the mixture of paraffin, the more the product entropy decreases and the reactivity entropy. To obtain the results of Exergy destroyed can be calculated by equation (13).

$$X\ destroyed = T0 \times S\ gen \quad (13)$$
$$= (30°C + 273°C) \times 257.16\ kJ/kmol.K\ C_3H_5(C_30_30_3)$$
$$= 77918.67\ kJ/kmol\ C_3H_5(C_30_30_3)$$

The reversible work that occurs in the system can be obtained using equation (14).

W rev = X destroyed = $T0$ x S gen (14)

W rev = 77918.67 kJ/kmol $C_3H_5(C_30_30_3)$

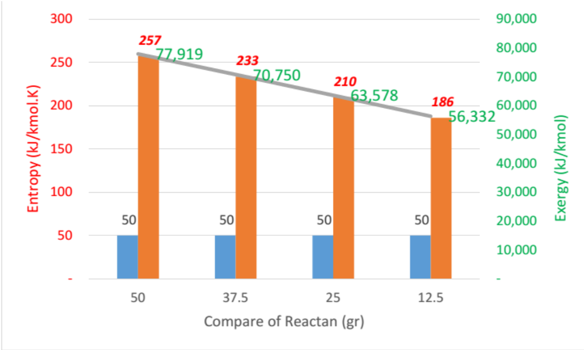

Fig. 8. Exergy and Entropy of CPO Candles (Sgen)

Fig. 8 above shows various Exergy values from mixing CPO wax. By mixing 50 gr CPO and 50 gr paraffin, it produces an exergy value of 77919.67 kJ/kmol while the gene entropy (Sgen) is 257.16 kJ/kmol.K. Mixing different CPO and paraffin will result in decreasing Exergy and gen entropy (Sgen).

CONCLUSION

The results of this study provide conclusions, namely: (1) By giving 50 gr paraffin, 50 gr CPO and giving oxygen (1: 5) from the fuel amounting to 250 gr O_2, will produce a reaction of 1300 gr CO_2, 1175 gr H_2O, -1487.5 gr O_2 and 940 gr N_2. Giving paraffin that is different, will produce a product which is based on energy balance, while the value of N_2 is fixed. (2) The Exergy value of mixing CPO and paraffin by 50 gr: 50 gr produces entropy generation (S gen) and exergy from CPO wax of 257.16 kJ/kmol. K and 77918.67 kJ/kmol and its value decreases based on paraffin administration.

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