

Application of Palm Solid Waste Ash as A Ceramic Glazing Material

Penerapan Abu Limbah Padat Sawit sebagai Bahan Glatsir Keramik

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ABSTRACT

The aim of this research is to develop a glaze from palm oil solid waste ash. Oil palm plants were chosen because the ash of palm fronds, stems and trees have not been utilized optimally, only used as organic fertilizer and material for making furniture. This research is applied research involving expertise in the field of fine arts, especially ceramic art and chemical engineering, with an inquiry-based research approach. Laboratory tests (EDX Report) were carried out so that the process of modifying the ash glaze formula could be carried out more accurately. The output of this research is the palm oil solid waste ash glaze formula/recipe and ash analysis table along with test pieces of ash glaze trial results and ceramic work prototypes. In practice, organic ash cannot be used alone but must be mixed with other ingredients so that it can potentially be processed into glaze. The glaze formula used in this research contains different mixtures of ingredients. In this research, organic ash was mixed with soil (Sukabumi and Kebumen) and ready-to-use frit glaze (F.107 and F.3T). Next, the ash glaze is burned at cone temperatures 5 and 6 (1150 °C–1200 °C). The test piece material used is Sukabumi clay which has been proven to be compatible with the oil palm plant ash glaze formula, resulting in a more varied, attractive, artistic and unique visual appearance of the work.

Keywords: Ceramics, Glaze Ash, Waste, Palm Oil, natural materials

ABSTRAK

Penelitian ini bertujuan untuk mengembangkan glasir dari abu limbah padat kelapa sawit. Tanaman kelapa sawit dipilih karena abu pelepah, batang dan pohon kelapa sawit belum dimanfaatkan secara optimal, hanya digunakan sebagai pupuk organik dan bahan pembuatan furnitur. Penelitian ini merupakan penelitian terapan yang melibatkan keahlian di bidang seni rupa khususnya seni keramik dan teknik kimia, dengan pendekatan penelitian berbasis inkuiri. Uji laboratorium (EDX Report) dilakukan agar proses modifikasi formula ash glasir dapat dilakukan dengan lebih akurat. Luaran penelitian ini berupa formula/resep glasir abu limbah padat kelapa sawit dan tabel analisis abu beserta potongan uji hasil uji coba abu glasir dan prototipe karya keramik. Dalam praktiknya, abu organik tidak dapat digunakan sendiri, melainkan harus dicampur dengan bahan lain sehingga berpotensi diolah menjadi glasir. Formula glasir yang digunakan dalam penelitian ini mengandung campuran bahan yang berbeda-beda. Pada penelitian ini abu organik dicampur dengan tanah (Sukabumi dan Kebumen) dan frit glasir siap pakai (F.107 dan F.3T). Selanjutnya abu glasir dibakar pada suhu kerucut 5 dan 6 (1150 °C–1200 °C). Bahan uji benda uji yang digunakan adalah tanah liat Sukabumi yang telah terbukti kompatibel dengan formula glasir abu tanaman kelapa sawit sehingga menghasilkan tampilan visual karya yang lebih bervariasi, menarik, artistik dan unik.

Kata Kunci : Keramik, Abu Glatsir, Limbah, Kelapa Sawit, bahan alam.

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1. INTRODUCTION

Ceramic technology experimentation activities have resulted in the formulation of new ceramic base materials and glazes as well as new ceramic firing formation techniques. Ceramics are objects whose manufacturing process uses soil or silicate rock and through a high temperature firing process (Ferrer et al, 2015; Rahaman, 2017; Yustana, 2020; Dadkhah et al, 2023). In making ceramics, glazing is a common method for producing a layer of color on the body of the ceramic (Pradell, and Molera, 2020). The beauty of a glaze is influenced by several factors, including the suitability of the type and technique of the glaze to the shape of the ceramic, surface quality, texture and color of the glaze and maturity of the glaze.

Aesthetic value comes from the concept of art personally and the most important thing is the artist's way of thinking (Jamuni, 2016; Murphy, 2023). The function of using glaze is to close the pores of the ceramic body so that the ceramic is watertight and makes the ceramic stronger and more resistant to weather disturbances, chemicals and general physical disturbances such as scratches (Anufrik et al, 2016). Apart from that, the glaze layer also provides beauty and uniqueness through the unique color and texture of the glaze (Said et al, 2014; Muhdy et al, 2017; Kalilu and MICHAEL, 2021).

Glazes on ceramic works are generally made from mineral and oxide materials that are insoluble in water with the main element being silica, which is alkaline, neutral and acidic with the molecular formula $RO_2-R_2O_3-RO_2$ and sodium soda. The glaze component is a combination of one or more

basic oxides (flux), acid oxides (silica) and neutral oxides (alumina) (Sianita et al, 2017). Colorants for chemical glazes are obtained from mineral rocks which produce coloring oxides such as: iron oxide (FeO), copper oxide (CuO₂), cobalt oxide (CoO) and other rock minerals. Apart from oxide glaze, there is an ash (organic) glaze which can be used as a glaze after mixing it with other ingredients such as lime, feldspar, ball clay and silica. Some of the ash derived from plants can be used as a material for making decorative ceramics [Muhamad Nor and Hazwani, 2016; Muangkaew, 2022; Schettino and Holand, 2015). Using ash from plants produces a unique texture in ceramic work and a different character than in general (Putra and Deni, 2019). The results of burning ash glaze are no less interesting than glaze in general. The unique, natural feel of the texture and color of the ash glaze is its own attraction. Adding ash to ceramic glaze is rarely done by craftsmen and ceramicists in Indonesia. They seem more interested in using factory-made glaze formulas that are ready to use and practical to process, but the price is relatively expensive because the glaze coloring ingredients must be exported from abroad.

One sector that is Indonesia's mainstay or advantage is plantations, especially the commodity palm oil. Researchers are interested in choosing palm oil waste which is the remains from the process of cultivating oil palm plants and from the palm oil processing industry. Palm oil waste is the remains of oil palm plants which are not included in the materials used in the production process, so they are wasted and have not been utilized (Haryanti et al, 2014; Harahap, 2017). Every

year palm oil production increases, so there will be an increase in waste from the Palm Oil Processing industry. Even though organic waste can decompose, the accumulation of organic waste also needs to be reduced so that it can be controlled and not pollute the environment (Oetopo et al, 2021; wang et al, 2023). Efforts to process palm oil solid waste by the government and entrepreneurs have been carried out but are not yet optimal, especially for solid waste. So far, palm oil solid waste has only been used as organic fertilizer for plants. The type of waste chosen to be used in this research is solid palm oil waste in the form of empty bunches, shells and palm fiber which are burned and turned into ash. According to several studies, natural biomaterials are commonly non-toxic, non-polluting and harmless to health, and have antioxidants and antimicrobials which add to the positive effects of these natural material (Aishwarya and Anchana, 2014; Sun et al, 2023). From the point of view of ceramic art, the use of waste can be an impetus for the development of creative media and innovation (Marwanto et al, 2022).

It is hoped that mixing the basic glaze ingredients and ash extract from palm oil solid waste will produce an attractive natural color effect because the color and texture of the resulting glaze are never the same. This difference in visual characteristics is caused by the fact that the mineral content in the clay where oil palm grows is not the same. All these natural transformation processes occur in a burning furnace which involves the three main natural elements, namely: air, earth and water. Apart from that, the ash glaze processing technique and the glazing technique also have a big influence on the texture and surface properties of the glaze.

2. MATERIALS AND METHODS

2.1. Materials

The material in this research is palm oil waste ash from combustion taken from two places. The first waste is taken from PT. Pugung Raya is in Banyu Irang Village, Bati Bati, South Kalimantan and the second waste is taken from PT. Austindo Nusantara Jaya Agri, Binanga, North Sumatra. Then, the ceramic material is clay taken from Sukabumi and Kebumen as well as glazing material.

2.2. Methods

This research is interdisciplinary research involving expertise in the field of fine arts, especially ceramic art and chemical engineering. The research method uses an experimental method with a one-shot case study type pre-experimental approach. The experimental research method is a method used to find the effect of certain treatments on others under controlled conditions (Sugiyono, 2015). The analysis process for the application uses descriptive qualitative by looking at the results of the application of palm ash waste to ceramic products. The stages in this research are as follows:

- a. Element content of Palm Oil Solid Waste Ash using EDX. This step is carried out so that the process of modifying the ash glaze formula can be carried out more accurately.
- b. Element content in soil used as raw material for making ceramics using EDX. Soil content tests are carried out to determine soil content that can affect results.
- c. Making Test Pieces and Prototypes of Ceramic Works which are carried out to apply the results of the formulas made into ceramic works and analyzing the prototype results.

3. RESULTS AND DISCUSSION

3.1. Laboratory Test of Element Content in Palm Oil Solid Waste Ash and Clay

The first stage carried out was carrying out an EDX test on two types of palm ash. This was done to determine and analyze the mineral element content in palm oil solid waste ash originating from Sumatra and Kalimantan Islands. The results showed that there were a difference in chemical elements for each type of ash (Figure 1, Figure 2, Figure 3, and Figure 4). The lab test process was also carried out on the Frit Glaze and the type of clay that will be used in this ash glaze research. The results of the elemental analysis of the 2 variants of Palm Oil solid waste ash showed that the elemental composition of each sample was as shown in the following data.

Figure 1 showed that the results of chemical lab tests on Palm Oil Solid Waste Ash contained 9 mineral elements which had a percentage of more than 1 %, namely: K 11.455 %, Ca 26.324 %, Si 36.235 %, S 1.113 %, Fe.17.973 %. Al 2.586 %, P. 1.174 %, Ti 1.145%, Mn. 1,127 %. The table shows that Kalimantan palm oil ash is rich in iron oxide (Fe_2O_3) content of 17,973 %. If a glaze is made, the presence of iron oxide is used as a dye and melter, strengthener and thickener for the resulting glaze (Hartono, 1983). The color of the glaze produced with iron oxide ranges from brown, ocher yellow and greenish. Apart from that, there is also a manganese oxide (MnO) content of 1.127 % which has the potential to be used as a coloring in glazes even though the content is relatively small. The glaze color produced by the element Manganese (Mn), which has metal characteristics similar to iron oxide (Fe), will produce brown and purplish colors. Meanwhile, the Ti content of 1.145 % gives the glaze a pale gray color effect.

As shown in Figure 2, the chemical lab test results (EDX Report) on Palm Oil Solid Waste Ash, there are 5 mineral elements that have a

percentage of more than 1 %, namely: K 71.493 %, Ca 17.050 %, Si 6.720 %, S 1.233 % and P 1.227 %. These five minerals will affect the quality of the palm oil solid waste ash glaze produced. There is a very large potassium element of 71.49 % which has the potential to be used as a coloring in glaze. The color produced by the mineral Potassium Carbonate (K_2CO_3) is a shiny opaque white that resembles pearl white. The mineral element Si or Silicon 6,720 % in Sumatran palm oil solid waste has the potential to form a strong framework and tend to have a slightly glossy effect when used as a glaze mixture. After the lab test process on palm oil waste, the next process is to carry out lab tests on the clay used.

As shown in Figure 3, the chemical lab test results (EDX Report) on Sukabumi Clay, there are 6 mineral elements that have a percentage of more than 1 %, namely: K 15.502 %, Ca 1.012 %, Si 55.718 %, Fe 5.485 %, Al 16.703%, Ti 3.829 %. The mineral element Potassium 15.502 % in Sukabumi clay has the potential to form a thick white glaze or opa and tends to be dull if used as a glaze mixture. This type of glaze is known as Clay Glaze which is a development from Engobe to Glaze on the surface of the ceramic body. Engobe is a ceramic coloring technique with a composition containing more natural ingredients and is commonly used in traditional ceramic making (Yana et al, 2013). The relatively large Si content of 55.718 % will strengthen the ceramic body frame and give a slightly thick effect to the glaze. Furthermore, the mineral Fe 5.485 % has the potential to produce yellow ocher and yellowish-brown colors if used as a coloring in glaze. The percentage of coloring oxide determines the quality of the color produced.

EDX Report							Report No.
Sample Information							
Sample Name Limbah sawit kalimantan							
Meas. Date 2022/11/15 11:36:59							
Comment Comment							
Group Elemental Analysis							
Operator Wisnu S							
Measurement Condition							
Channel	kV	uA	Filter	Acq.	Collimator	10mm	Atmos. Air
Al-U	50	45-Auto	----	0 - 40	0.00-40.00	Live- 100	DT% 30
C-Sc	15	510-Auto	----	0 - 20	0.00- 4.40	Live- 100	30
Quantitative Result							
Analyte	Result		Std.Dev.	Calc.Proc	Line	Intensity	
Si	35.235	%	[0.355]	Quan-FP	SiKa	1.7159	
Ca	26.324	%	[0.096]	Quan-FP	CaKa	12.6316	
Fe	17.973	%	[0.065]	Quan-FP	FeKa	149.5154	
K	11.455	%	[0.067]	Quan-FP	K Ka	4.4997	
Al	2.586	%	[0.348]	Quan-FP	AlKa	0.0363	
P	1.174	%	[0.135]	Quan-FP	P Ka	0.0838	
Ti	1.145	%	[0.046]	Quan-FP	TiKa	2.6158	
Mn	1.127	%	[0.015]	Quan-FP	MnKa	6.9058	
S	1.113	%	[0.058]	Quan-FP	S Ka	0.2076	
Cu	0.580	%	[0.018]	Quan-FP	CuKa	6.4576	
Sr	0.325	%	[0.009]	Quan-FP	SrKa	9.7245	
Rb	0.323	%	[0.010]	Quan-FP	RbKa	8.9028	
Zn	0.259	%	[0.014]	Quan-FP	ZnKa	3.4132	
Ag	0.181	%	[0.027]	Quan-FP	AgKa	1.4865	
Cr	0.092	%	[0.019]	Quan-FP	CrKa	0.4400	
V	0.071	%	[0.024]	Quan-FP	V Ka	0.2397	
Os	0.038	%	[0.035]	Quan-FP	OsLa	0.1925	

Figure 1. Elemental Composition of Kalimantan Palm Oil Solid Waste Ash

EDX Report							Report No.
Sample Information							
Sample Name Limbah sawit sumatera							
Meas. Date 2022/11/15 11:42:33							
Comment Comment							
Group Elemental Analysis							
Operator Wisnu S							
Measurement Condition							
Channel	kV	uA	Filter	Acq.	Collimator	10mm	Atmos. Air
Al-U	50	58-Auto	----	0 - 40	0.00-40.00	Live- 100	DT% 30
C-Sc	15	381-Auto	----	0 - 20	0.00- 4.40	Live- 100	29
Quantitative Result							
Analyte	Result		Std.Dev.	Calc.Proc	Line	Intensity	
K	71.493	%	[0.124]	Quan-FP	K Ka	78.8220	
Ca	17.050	%	[0.063]	Quan-FP	CaKa	10.5452	
Si	6.720	%	[0.091]	Quan-FP	SiKa	1.0595	
S	1.233	%	[0.015]	Quan-FP	S Ka	1.0600	
P	1.227	%	[0.039]	Quan-FP	P Ka	0.4157	
Fe	0.776	%	[0.008]	Quan-FP	FeKa	11.8557	
Rb	0.491	%	[0.003]	Quan-FP	RbKa	34.8422	
Mn	0.270	%	[0.005]	Quan-FP	MnKa	2.9358	
Zn	0.244	%	[0.004]	Quan-FP	ZnKa	8.1919	
Sr	0.191	%	[0.003]	Quan-FP	SrKa	14.6437	
Cu	0.149	%	[0.004]	Quan-FP	CuKa	4.2199	
Br	0.086	%	[0.003]	Quan-FP	BrKa	5.1877	
Ti	0.054	%	[0.012]	Quan-FP	TiKa	0.1948	
Zr	0.018	%	[0.002]	Quan-FP	ZrKa	1.4960	

Figure 2. Elemental Composition of Sumatran Palm Oil Solid Waste Ash

EDX Report							Report No.	
Sample Information								
Sample Name	Tanah Sukabumi- dtk							
Meas. Date	2018/11/14 10:20:15							
Comment	Comment							
Group	Elemental Analysis							
Operator	w isnu							
Measurement Condition								
Channel	kV	uA	Filter	Acq.	Collimator	10mm	Atmos.	Air
Al-U	50	30-Auto	----	0 - 40	Analysis 0.00-40.00	Time Live- 100	DT%	29
C-Sc	15	433-Auto	----	0 - 20	0.00- 4.40	Live- 100		30
Quantitative Result								
Analyte	Result			Std.Dev.	Calc.Proc	Line		Intensity
Si	55.718	%		[0.378]	Quan-FP	SiKa		4.4611
Al	16.703	%		[0.303]	Quan-FP	AlKa		0.5734
K	15.502	%		[0.073]	Quan-FP	K Ka		8.9627
Fe	5.845	%		[0.030]	Quan-FP	FeKa		110.1389
Ti	3.829	%		[0.046]	Quan-FP	TiKa		19.2185
Ca	1.012	%		[0.029]	Quan-FP	CaKa		0.7573
S	0.481	%		[0.036]	Quan-FP	S Ka		0.1246
Zr	0.223	%		[0.004]	Quan-FP	ZrKa		21.0297
Cu	0.139	%		[0.008]	Quan-FP	CuKa		4.3168
V	0.138	%		[0.020]	Quan-FP	V Ka		1.0246
Rb	0.116	%		[0.005]	Quan-FP	RbKa		9.4309
Mn	0.088	%		[0.012]	Quan-FP	MnKa		1.1932
Sr	0.076	%		[0.004]	Quan-FP	SrKa		6.6635
Cr	0.043	%		[0.012]	Quan-FP	CrKa		0.4290
Y	0.037	%		[0.004]	Quan-FP	Y Ka		3.3559
Zn	0.031	%		[0.007]	Quan-FP	ZnKa		1.1489
Nb	0.019	%		[0.003]	Quan-FP	NbKa		1.8742

Figure 3. Elemental Composition of Sukabumi Clay

Sample Information

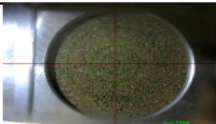
Sample Name Tanah Kebumen

Meas. Date 2019/07/17 09:16:10

Comment Comment

Group Elemental Analysis

Operator wisnu



Measurement Condition

Channel	kV	uA	Filter	Acq.	Analysis	10mm	Atmos.	Air
Al-U	50	33-Auto	----	0 - 40	0.00-40.00	Live- 100	DT%	31
C-Sc	15	260-Auto	----	0 - 20	0.00- 4.40	Live- 100		29

Quantitative Result

Analyte	Result	Std.Dev.	Calc.Proc	Line	Intensity
Si	38.955 %	[0.371]	Quan-FP	SiKa	3.7018
Fe	31.342 %	[0.058]	Quan-FP	FeKa	813.1933
Al	12.124 %	[0.329]	Quan-FP	AlKa	0.3919
Ca	7.034 %	[0.041]	Quan-FP	CaKa	9.5922
K	5.065 %	[0.041]	Quan-FP	K Ka	4.6906
Ti	2.371 %	[0.026]	Quan-FP	TiKa	20.2753
Tm	1.384 %	[0.006]	Quan-FP	TmLa	8.3261
Mn	0.814 %	[0.009]	Quan-FP	MnKa	16.1858
Sr	0.331 %	[0.005]	Quan-FP	SrKa	22.9777
Zr	0.125 %	[0.004]	Quan-FP	ZrKa	9.3708
Ag	0.121 %	[0.013]	Quan-FP	AgKa	2.3157
V	0.120 %	[0.011]	Quan-FP	V Ka	1.5082
Zn	0.090 %	[0.005]	Quan-FP	ZnKa	2.7936
Cr	0.049 %	[0.007]	Quan-FP	CrKa	0.8496
Ni	0.039 %	[0.006]	Quan-FP	NiKa	0.8471
Y	0.037 %	[0.003]	Quan-FP	Y Ka	2.6921

Figure 4. Elemental Composition of Kebumen Clay

The results of chemical lab tests (EDX Report) on Kebumen Clay (Figure 4) contained 7 mineral elements which had a percentage of more than 1 %, namely: K 6.065 %, Ca 7.034 %, Si 38.955 %, Fe 31.342 %, Al 12.124 %, Ti 2.371 % and Tm 1.384 %. The mineral element Si or Silicon 38.955 % in Kebumen clay has the potential to form a framework that is quite strong and tends to be somewhat glossy when used as a glaze mixture. This type of glaze is known as Earth Glaze which is a development from Engobe to Glaze on the surface of the ceramic body. The iron oxide mineral content (Fe_2O_3) which is quite large, 31.342 % in the glaze, has the potential to be a coloring agent in the glaze and as a thickener for the glaze. The resulting color can be ocher brown, dark brown or brownish green depending on the combustion temperature and the percentage of oxide content in it. The Titan oxide element (TiO_2) produces a dull and opaque effect.

3.2. *Process for Making Test Pieces and Prototypes of Ceramic Works*

After the Laboratory Test stage, the process of making 16 test pieces is carried out in the form of small bowls with a diameter of 8 cm and a height of 6 cm. Apart from that, prototypes for ceramic works were also made in the form of 1 medium sized vase and 2 small sized vases. Making test pieces and prototypes of ceramic works is done using rotary techniques by workers at the Elina Keramik studio, Bandung. The biscuit burning process is carried out using an LPG stove at a temperature of 900 °C. Next, the glaze will be fired using cone 5 and cone 6 stakes at a temperature of 1190 °C – 1220 °C.

Furthermore, palm oil solid waste (shells) will be given the code AG.014 to indicate that Palm Oil is the 14th Organic Ash whose mineral content has been lab tested. Then the next job is to refine the leaf ash by pounding it

and then filtering it twice with sizes of 60 and 80 mesh. Apart from palm oil solid waste ash, the processing process is also carried out on Sukabumi and Kebumen clay so that it is smooth enough when processed into ash glaze.

At the beginning of the glaze processing process, the solution is made slightly thicker by adding approximately 40 % water. This ash glaze is used to glaze the inside of the test piece bowl using the pouring technique. Next, to glaze the surface of the object, dip and brush techniques are used. Using these two glaze application techniques is the most suitable technique for ash glaze because it will give a unique and interesting texture effect.

The process of glazing the inside of the test piece is carried out using a pouring technique with a rather thick and thick solution mass so that the color layer and glaze surface results in better results. Then the application of ash glaze on the outside is done using a dip and brush technique. Both techniques are more suitable for ash glazes. The spray technique is not suitable because the solution mass must be finely filtered and made slightly liquid otherwise it will potentially clog the sprayer when used. Furthermore, for the decoration process of ceramic work prototypes, dip and brush techniques were used because the supply of palm ash was limited. Meanwhile, the inside is glazed using a pouring technique with frit glaze without palm ash.

The burning of all ash glaze test pieces and ceramic work prototypes was carried out using a gas furnace with a firing temperature of 1180 °C – 1220 °C for 8 hours. The ceramic objects to be fired are arranged in 3 levels. Test pieces are arranged at the bottom and middle. Meanwhile, the prototype is placed at the top. Burning is carried out in the morning from 08.00 to 16.00 in the afternoon. The new furnace opened the next day.

This ash glaze research provided results in the form of ash glaze test pieces using 4

formulas. Formulas A and B use a mixture of Frit Glaze, while formulas C and D use a mixture of Sukabumi and Kebumen clay. 4 test pieces were made for each formula so that in total there were 16 test pieces with 3 ceramic work prototypes in two sizes. Next, observations were made on 6 visual

parameters which gave an overall picture of the appearance of the 014 ash glaze which was fired at a temperature of 1180 °C – 1220 °C (cone 5 and cone 6 stakes). Based on manual visual observations, the following data was obtained.

Table 1. Glaze Composition with AG.014 as Main Component

No.	Material (% b/b)	Ash Glaze Code			
		Formula A	Formula B	Formula C	Formula D
1.	Palm Oil Solid Waste Ash (Sumatra/Kalimantan)	50	50	50	50
2.	Glaze F,107	40	-	-	-
3.	F.3T glaze	-	40	-	-
4.	Sukabumi Clay	-	-	40	-
5.	Kebumen Clay	-	-	-	40
6.	Quartz	10	10	10	10

Table 2. Observation Results of Formula A Palm Oil Solid Waste Ash Glaze

No	Visual Parameters	Test Piece Code AG.014 with Formula A			
		Formula A AG.A 014 S	Formula A AG.A1 014	Formula A AG.A2 014	Formula A AG.A3 014
1.	Color	pure white, plain	plain cream	ocher yellow	gray green
2.	Fluidity	Good	Good	Good	Good
3.	Shine	Semi	Matt	Matt	Semi
4.	Closing Nature	Good	Good	Good	Good
5.	Color Evenness	Good	Good	Good	Good
6.	Texture	good, soft and smooth	good, soft and smooth	good, soft and smooth	Good, a bit harsh

Overall the test piece with Formula A matured well, giving even melting and color density with matt and semi-matt glaze characteristics. The composition of ingredients in Formula A produces varied colors such as white, cream, ocher yellow and grayish green. The surface of the glaze is

smooth, slippery, especially palm ash mixed with F.107 frit glaze. The fine nature of Frit glaze powder dissolves easily when mixed with palm ash. Meanwhile, the Kebumen clay mixture produces a slightly rough surface effect. To produce a smooth surface, the Kebumen clay must be ground again and

filtered finely and the glaze solution must be filtered to a size of 120 mesh. Sumatran palm ash produces a purer white with smooth and semi-matt glaze properties, while Kalimantan palm ash produces a white, slightly yellow

cream effect with the same glaze properties. The cream color appears because the Fe content in Kalimantan palm ash is greater.

Table 3. Observation Results of Formula B Palm Oil Solid Waste Ash Glaze

No	Visual Parameters	Test Piece Code AG.014 with Formula B			
		Formula B AG.B 014 S	Formula B AG.B1 014	Formula B AG.B2 014	Formula B AG.B3 014
1.	Color	milky white, plain	white, slightly pale blue	gray on the inside, ocher yellow on the outside	milo chocolate, plain
2.	Fluidity	Good	Good	Good	Good
3.	Shine	semi	semi	semi-	Matt
4.	Closing Nature	Good	Good	Good	Good
5.	Color Evenness	Good	Good	Good	Good
6.	Texture	Good, it's a bit thick at the bottom so it's a bit lumpy	good, smooth and smooth with fine black spots	good, smooth and smooth with color gradations	Good, a bit harsh

Overall the test piece with Formula B matured well, giving even melting and color density with matt and semi-matt glaze characteristics. The composition of the ingredients in Formula B produces varied and unique colors such as pearl white, salted egg white, graded gray, ocher brown, and milo chocolate. The surface of the glaze is smooth, slippery, especially palm ash mixed with F.3T frit glaze. Meanwhile, the Kebumen clay mixture produces a slightly rough surface effect. To produce a smooth surface, the Kebumen clay must be ground again and filtered finely and the glaze solution must be filtered to a size of 120 mesh. Sumatran and Kalimantan palm ash when mixed with F.3T glaze in formula B gives a different color. Kalimantan palm ash glaze is more attractive because it has a texture of black spots.

Overall the test piece with Formula C is less mature, with visual effects like engobe.

Then re-firing was carried out by adding F.107 glaze to give the glaze a glossy effect. It turned out that it was quite successful in turning engobe into a glaze, even though the surface was not smooth, it gave sufficient melting results and even color density with matt and semi-matt glaze characteristics. It is necessary to modify the composition of Formula C by adding quartz and feldspar as in the composition of the 2019 ash glaze formula with a higher firing temperature. The composition of the ingredients in Formula C produces less varied colors such as dark grey, grayish brown and blackish brown. The surface of the ash glaze mixed with Sukabumi clay produces a slightly rough surface effect. To produce a smooth surface, the Sukabumi clay must be ground again and filtered finely and the glaze solution must be filtered to a size of 120 mesh.

Table 4. Observation Results of Formula C Palm Oil Solid Waste Ash Glaze

No.	Visual Parameters	Test Piece Code AG.014 with Formula C			
		Formula C AG.C 014 S	Formula C AG.C1 014	Formula C AG.C2 014	Formula C AG.C3 014
1.	Color	pearl white, concentrated	chocolate cream, plain	brownish grey	gray on the inside, dark brown on the outside
2.	Fluidity	not evenly distributed	Good	Good	Good
3.	Shine	Matt	semi-	semi-	Glossy
4.	Closing Nature	Enough	Good	Good	Good
5.	Color Evenness	Good	Good	Good	Good
6.	Texture	slight crawling, fine cracks	good, plain, a bit slippery	Good, a bit smooth with dark brown to gray gradations	Good, a bit slippery and crawling like orange peel on the inside

Table 5. Observation Results of Formula D Palm Oil Solid Waste Ash Glaze

No.	Visual Parameters	Test Piece Code AG.014 with Formula D			
		Formula D AG.D 014 S	Formula D AG.D1 014	Formula D AG.D2 014	Formula D AG.D3 014
1.	Color	rather dark grey	dark brown grey	blackish brown	blackish brown
2.	Fluidity	Good	Good	Good	Good
3.	Shine	semi-	semi-	semi-	Glossy
4.	Closing Nature	Good	Good	Good	Good
5.	Color Evenness	Good	Good	Good	Good
6.	Texture	a bit rough like sand	rough like sand	rough like sand	a bit rough like sand

Overall the test piece with Formula D is not as mature as the Formula C results, with visual effects like engobe. Then re-firing was carried out by adding F.107 glaze to give the glaze a glossy effect. It turned out that it was quite successful in turning engobe into a glaze, even though the surface was not smooth, it gave sufficient melting results and even color density with matt and semi-matt glaze characteristics. It is necessary to modify the composition of Formula D by adding quartz

and feldspar as in the composition of the 2019 ash glaze formula with a higher firing temperature. The composition of the ingredients in Formula D produces less varied and unique colors such as medium gray, dark gray, grayish brown, and blackish brown. Tends to be somewhat similar. The surface of ash glaze mixed with Kebumen clay produces a slightly rough surface effect. To produce a smooth surface, the Sukabumi clay must be

ground again and filtered finely and the glaze solution must be filtered to a size of 120 mesh.

The appearance of the glaze seen on the test piece is greatly influenced by the composition of the formula as seen in formulas A, B, C and D which have special characteristics. This is where the attraction of ash glaze lies, especially since the main ingredient in palm oil solid waste ash in each location has a different mineral composition in the clay.



Figure 5. AG Test Piece Results AG.014 with Formula A, B, C, D

Figure 5 shows Test Piece AG.014 with Formulas A and B are more varied, unique and interesting than Formulas C and D. The character of the palm oil solid waste ash glaze turns out to be more successful with the composition of formulas A and B. Meanwhile, the composition of formulas C and D It must be modified again so that the nature of the Engobe changes to a more semi-glossy or glossy ash glaze with the addition of feldspar and lime and quartz elements.

3.3. Analysis of Prototype Ceramic Works

In this research, trials were also carried out on the application of ash glaze to ceramic work prototypes in the form of vases with varying sizes. The following is a visual display of the prototype:

3.3.1 Vase Work 1: Natural Antique Vase

Vase 1 has a base diameter of 9 cm and a height of 16 cm (Figure 6). The material used

is Sukabumi soil which is classified as a fine earthenware type with a burning temperature of up to 1250 °C. The surface of ceramic objects is partly flat and partly textured with repeated concave lines circling the ceramic body. The glaze used is ash glaze with code AG.D 014 for the body of the vase and code AG.B1 014 for the neck of the vase. Then the entire surface is covered with F.107 glaze.



Figure 6. Natural Antique Vase Red, prototype 1 with AG 014

The brush technique was used to glaze this vase because of the limitations of the main ingredient in palm ash glaze. The glaze coating process is carried out 3 to 4 times until sufficient thickness is achieved. Next, the ceramic object is baked for 8 hours. The glaze results obtained are not all evenly colored, visible traces of circular and irregular brush strokes on the neck. Vase looks more expressive and artistic. The greenish and brownish gray color appears due to the mixture of Chrom and Fe oxides with palm ash and F.3T glaze. Meanwhile, the glaze on the body looks dull or somewhat dull with a reddish brown color. The red iron oxide mineral element in Kebumen soil contained in the composition of formula D influences the appearance of a reddish brown color. The appearance of the glaze is not too glossy so the overall appearance of Vase 1 resembles Japanese ceramic work which looks classic and unique.

3.3.2 Vase Work 2: Red Brown Engobe Vase



Figure 7. Red Brown Engobe Vase, prototype 2 with AG 014

Vase 2 has a base diameter of 14 cm and a height of 18 cm. The material used is Sukabumi soil which is classified as a fine earthenware type with a burning temperature of up to 1250 °C. The surface of ceramic objects is partly flat and partly textured with repeated concave lines circling the ceramic body. The glaze used is ash glaze with code AG.D 014 for the body of the vase and code AG.B1 014. This ash glaze uses a mixture of Sukabumi clay and Kebumen soil so that the visual appearance of the vase is stronger, characteristic of Clay Glaze which is a development of Engobe .

The brush technique was used to glaze this vase because of the limitations of the main ingredient in palm ash glaze. The glaze coating process is carried out 3 to 4 times until sufficient thickness is achieved. Next, the ceramic object is baked for 8 hours. The glaze results obtained are not shiny and tend to be dull like the character of Engobe. Circular brush marks are visible on the top of the vase. The vase appears with a brownish red engobe with a simple pattern. The brownish red color appears due to a mixture of red iron oxide and black iron oxide found in palm ash (formula C

and D) and Kebumen clay and Sukabumi clay. The appearance of the glaze is not too glossy, it is quite thick with a rough surface so that the overall appearance of the Vase 2 work is quite successful in representing a unique Clay Glaze.

4. CONCLUSIONS

Based on research results, it has been confirmed that palm oil solid waste ash from Sumatra and Kalimantan can be used as raw material for ash glaze with the code AG.014. The four types of ash glaze which are formulated as Formulas A, B, C and D begin to mature at a temperature of 1150 °C – 1200 °C and the four ash glazes are coded AG.A.014, AG.B.014, AG. C. 014, AG.D. 014 produces different colors depending on the formula. The color of the 014 ash glaze is very varied, such as white, cream, blue, white and salted egg blue, ocher yellow, ocher green, milo brown, slightly dark brown, gray brown, shades of gray, indicating that the dominant coloring is iron oxide or Fe, Manganese and Chromium oxides.

The amount of fusing content in the ash glaze affects the appearance (gloss) of the ash glaze. The greater the amount of palm oil solid waste ash in the glaze, the better and more even the covering or opac properties. Ash glaze with a mixture of frit glaze formula (F.107 and F.3T) produces a clear, smooth, evenly opaque ash glaze that is beautiful and unique. Ash Glaze with a mixture of Sukabumi and Kebumen clay produces an ash glaze called Clay Glaze which looks like Engobe. Different oil palm farming locations (Sumatra and Kalimantan) affect the ash glaze produced because the mineral composition of agricultural clay in different locations has a different composition. This is the natural attraction and charm of Ash Glaze. To produce

a unique texture effect, palm oil solid waste ash is not washed first but is directly mixed with other glaze ingredients after being filtered using an 80 mesh sieve.

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