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Formulation and Analysis of Handwritten Batik Wax Quality from Recycled Materials

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Abstract

Used cooking oil can be utilized as an alternative raw material for making batik wax. Recycling batik wax involves using recycled materials such as used wax, used cooking oil, and other substances like paraffin, microwax, colophonium resin, and damar resin. The recycling of used wax and the utilization of used cooking oil are crucial for the batik industry as they reduce production costs and environmental pollution. A combination of Taguchi and Grey Relational Analysis (GRA) method is employed to obtain optimal values for the response characteristics of line width continuity and permeability of wax. Recycled and new wax is applied to mori fabric and compared based on batik quality criteria. The research results indicate that the optimal composition for recycled wax consists of 510 grams of used wax (41.5%), 36 grams of used cooking oil (2.9%), 102 grams of paraffin (9.8%), 84 grams of microwax (6.8%), 300 grams of colophonium resin (24.4%), and 180 grams of damar resin (14.6%). According to batik experts' assessments, the quality of recycled batik wax is equivalent to that of new batik wax. Recycled batik wax has the melting point of 67.9 °C, the viscosity value of 90.15 cP, and the production cost of Rp 30.909,00.

Keywords: *Grey Relational Analysis, Recycled Wax, Taguchi Method, Used Cooking Oil Used Wax*

1. Introduction

Batik, one of Indonesia's cultural heritages, holds profound philosophical and artistic significance. The development of traditional handwrittenbatik craftsmanship as part of Indonesian culture has garneredinternational attention. This is evident in the 2020 batik export value reaching USD 17.5 million, further increasing to USD 25.34 million in 2022 (Balai Besar Kerajinan Batik Kementerian Perindustrian, 2023). The high export value reflects a significant global interest in batik, as illustrated in Figure 1, which depicts the export value of batik graph.

The batik-making process comprises three stages: batik pattern drawing, colouring, and removing wax (Simamarta, 2014). Handwrittenbatik patterns are created using hands and tools. The batik waxing process involves the application of wax using a *canting* tool (small dipper) or stamp (SNI Batik-Pengertian dan Istilah, 2014). Batik wax is a colour barrier during waxing (Haerudin & Atika, 2018). The primary raw materials for batik wax production include beeswax, colophonium resin, pine resin (resin from the Shorea Sp. tree), paraffin, microwax, and animal fat (Susanto, 2018).

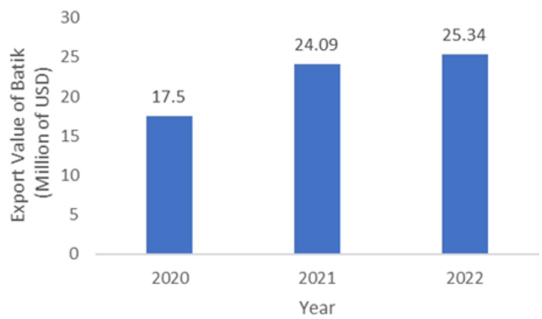

Figure 1. Export Value of Batik (Balai Besar Kerajinan Batik Kementerian Perindustrian, 2023)

The quality of batik wax is influenced by its raw materials. Renewable raw materials include beeswax, colophonium resin, pine resin, and animal fat. Beeswax, known as *kote*, has a dark yellow colour, adheres well to fabric, is durable, and remains unaffected by climate changes, quickly releasing hot water during the wax removal (Susanto, 2018). Beeswax has a textured, soft, and sticky consistency, turning brownish to almost yellow when heated. It forms a thick brownish liquid when heated but is challenging to melt due to its soft and

[1]* Penulis Korespondensi

sticky texture (Dulmalik et al., 2020). Beeswax is shown in Figure 2.

Figure 2. Beeswax (Susanto, 2018)

Colophonium resin shown in Figure 3 is derived from the Merkusii Pine tree. It appears as transparent, yellow glass and has a tough texture. When heated, colophonium resin transforms into a slightly thick yellow liquid (Dulmalik et al., 2020). Including colophonium resin in wax mixtures enhance hardness, prevents quick solidification, and contributes to the overall quality of batik wax.

Figure 3. Colophonium Resin

Pine resin shown in Figure 4 comes from the Shorea spec tree. It is broken into small pieces and cleaned after extraction from the damar tree. Pine resin resembles slightly brownish glass with a texture akin to hard sugar crystals. When heated, it quickly melts into a thick, brownish liquid (Dulmalik et al., 2020). Pine resin is a mixture that allows the wax to form lines and adhere well to the fabric. It has properties such as resistance to melting, quick solidification, and resistance to alkali solutions (Susanto, 2018).

Figure 4. Pine resin

Animal fat is white like butter. It is derived from beef or buffalo fat. Animal fat has a low melting point, around 45°-49°C, and quickly becomes liquid. Animal fat is used in small quantities to lower the melting point, allowing easy wax removal (Susanto, 2018). An alternative to animal fat is coconut or vegetable oil (Atika & Haerudin, 2013).

Non-renewable raw materials for wax include paraffin, microwax, and used wax. Paraffin shown in Figure 5, a byproduct of crude oil processing, is white or light yellow. It is used in wax mixtures to enhance water resistance and ease of wax removal. Paraffin is relatively cheaper than other wax materials and has quick solidification, easy liquefaction, and resistance to alkali solutions (Susanto, 2018).

Figure 5. Paraffin

Figure 6. Microwax

Microwax shown in Figure 6, a finer type of paraffin, is derived from petroleum refining. It has a light yellow colour and can be used as a substitute or to reduce the use of beeswax, making the wax more pliable and more accessible to remove. Microwax serves the same purpose as beeswax, reducing the need for beeswax in the mixture (Dulmalik et al., 2020). The more microwax used in the composition, the lower the melting point during the raw material melting process (Malik et al., 2018).

Other alternatives for wax composition include used wax and recycled cooking oil (waste oil). Used wax shown in Figure 7 can replace beeswax, and coconut oil/vegetable oil can substitute animal fat (Atika & Haerudin, 2013). *Lerob* wax is collected during the wax removal process, and when cleaned from impurities, it is referred to as used wax. Continuous heating of used wax can cause damage and stickiness due to reduced oil content. Used wax is used as a filler, especially for the wax blocking and colour-covering processes (Sri Soedewi, 2011). Used wax that has undergone the wax removal process is reused with the addition of other raw materials.

Figure 7. Used Wax

Reusing used cooking oil has adverse health effects, as oil with high free fatty acid content increases the risk of cancer (Kuo & Ann, 2018). Improper disposal of used cooking oil poses environmental risks. Used cooking oil also contributes to water pollution in rivers, reservoirs, and water channels, damaging aquatic ecosystems (Wan Azahar et al., 2016). Each household generates approximately four litress of used cooking oil per month, based on data from households in the Jabodetabek region (Vanessa & Bouta, 2017). This data suggests a considerable volume of used cooking oil produced by households. If a city consists of 200,000 households, households' estimated volume of used cooking oil is around 800,000 litress per month (Astuti et al., 2021). Previous research has explored the processing and utilization of used cooking oil in candles, such as aromatherapy candles from used cooking oil (Wardani et al., 2021) and environmentally friendly candle production in Batu City (Aini et al., 2020). The functions of raw materials wax can be seen in Table 1.

Using used wax and used cooking oil affects the quality and physical characteristics of the wax. The composition of wax using recycled materials is expected to produce similar quality and physical characteristics as new wax. Quality wax must meet specific criteria, namely: excellent adhesion to the fabric, easy removal and reattachment, protection of the fabric from dyes, easy freezing, quick melting when heated, solubility in organic solvents such as gasoline, kerosene, and thinner at room temperature, no colour residue on the fabric, and resistance to cracking (Balai Besar Kerajinan Batik, 2006). The characteristics of wax can be identified from various aspects, including the melting point (Lutfinor, 2014). The melting points of each raw material used in wax can be found in Table 2.

Used wax serves as a filling material in the batik wax mixture. The used wax must be processed beforehand to eliminate impurities (Atika & Haerudin, 2013). Previous research utilized used wax and cooking oil as raw materials for batik wax (Setyo Wibowo, 2022). Another study also employed used wax as one of the raw materials for batik wax due to the relatively high market price of beeswax compared to other batik wax materials (Fauziyah et al., 2021).

This study utilizes previously used materials such as colophonium resin, pine resin, paraffin, microwax, and recycled materials. The recycled materials in this study include used wax and used cooking oil. The used wax and used cooking oil undergo pre-treatment before being used as raw materials for batik wax. This research aims to identify the optimal composition of recycled wax, compare the physical properties (melting point and viscosity) of new and recycled wax, assess the quality comparison between recycled and new wax, and determine the production cost of recycled wax. Additionally, using used cooking oil and wax can reduce production costs and environmental pollution.

2. Methods

The methods employed in this research are the Taguchi method and the Grey Relational Analysis (GRA) method. The Taguchi method aims to make products or processes robust to various factors (Soejanto, 2009). The Grey Relational Analysis Method (GRA) is a multi-objective optimization or multi-attribute decision-making (MADM) method applied to processes or experiments with more than one type of response that may have different units and scales (Davim, 2012).

Table 1. Raw Materials of Wax and Their Functions (Sri Soedewi, 2011) (Subarno, 2000)

No	Raw Material of Wax	Function
1	Beeswax	Enhancing adhesion, providing flexibility to prevent the wax from breaking easily, and facilitating the easy removal of wax during the waxing process
2	Microwax	Aiding in adhesion and imparting flexibility (elasticity) to the wax
3	Used Wax	The adhesive strength of the wax

No	Raw Material of Wax	Function
4	Animal fat	Accelerating the melting point and facilitating the easy removal of wax during the waxing process
5	Used Cooking Oil	Speeding up the melting point and easing the removal of wax during the waxing process
6	Paraffin	Facilitating the easy removal of wax during the waxing process
7	Colophonium resin	The permeability of the wax, accelerating the freezing point of the wax, facilitating easy removal during the waxing process, and enhancing adhesion
8	Pine resin	Accelerating the freezing point of the wax and increasing adhesion

Table 2. The Melting Point of Wax Materials (Atika & Haerudin, 2013)

No	Raw Materials	Melting Point (°C)
1	Pine resin	85 - 94
2	Colophonium resin	85 – 88
3	Beeswax	66 – 78
4	Used wax	66 – 76
5	Microwax	70
6	Paraffin	54 – 58
7	Animal fat	56 – 62

The Taguchi method is used to determine the optimal values of factors for characteristics of wide line continuity represented by standard deviation and wax permeability represented by root mean square deviation. The Taguchi method provides analysis for only one response characteristic. GRA can combine multiple response values into a single response. The input values in GRA are Signal-to-Noise Ratios (SNR) obtained from Taguchi data for each response characteristic. The final result of GRA is the GR-Grade used to generate a response table and main effect plot, similar to Taguchi analysis, as shown in Figure 8.

2.1 Pre-treatment of Used Wax and Used Cooking Oil

Pre-treatment aims to enhance the quality of the raw materials used. The detailed steps for pre-treating used wax are as follows:

1. Select used *lerob* wax from a single batik waxing.
2. Weigh 6.5 kg of *lerob* wax and place it in a pot.
3. Add 13 kg of water to the pot, maintaining a *lerob* wax-to-water ratio of 1:2.
4. Boil the *lerob* wax for 60 minutes, stirring continuously.
5. Stir the *lerob* wax evenly for 15 minutes at 80°C.
6. Allow the treated *lerob* wax to settle for 24 hours. The resulting sedimented wax is referred to as Used Wax.
7. Remove impurities from the bottom surface of the *lerob* wax (Figure 9). The cleaned wax is referred to as used wax.

The pre-treatment steps for used cooking oil are:

1. Choose used cooking oil from household consumption.
2. Pour the used cooking oil into a bottle.
3. Weigh 450 grams of used cooking oil.
4. Add 45 grams of calcium powder, maintaining a used cooking oil to calcium powder ratio of 10:1.
5. Stir until evenly mixed.
6. Allow the mixture to stand for 48 hours.
7. Filter the used cooking oil using filter paper.

The comparison of used cooking oil filtration results, as shown in Figure 10.

2.2 Experimental Design Determination

1. Factor and Level Determination

Factors and levels are determined based on litresature and expert interviews. The study involves the main ingredients for wax composition: used wax, pine resin, colophonium resin, microwax, paraffin, and used cooking oil. The independent variables are the use of used wax, used cooking oil, paraffin, and microwax. The constants are colophonium resin and pine resin. Factor and level of experiment is shown in Table 3.

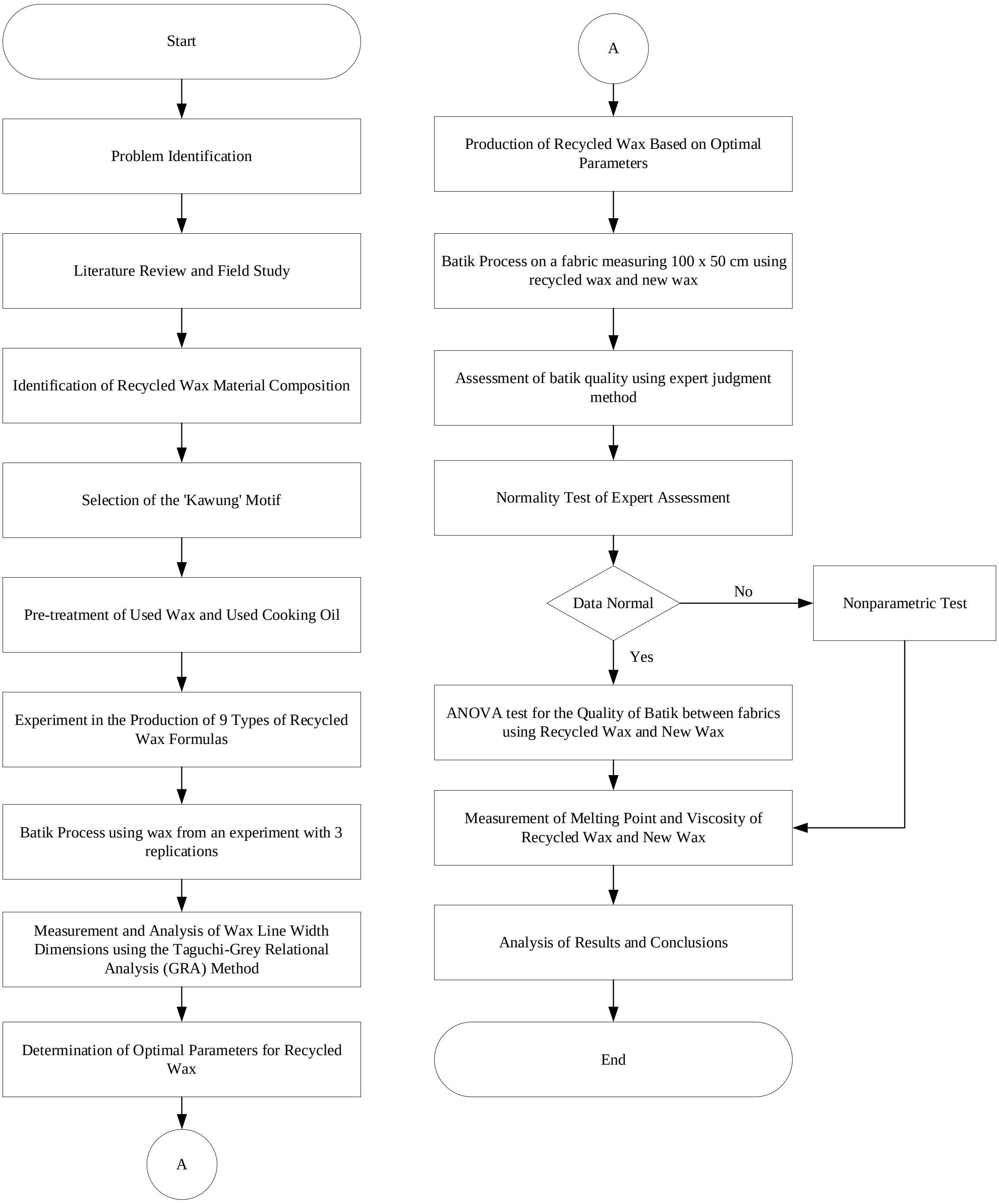

Figure 8. Research Flowchart

Figure 9. Results of *Lerob* Wax Treatment

Figure 10. Comparison of Used Cooking Oil Filtration Results

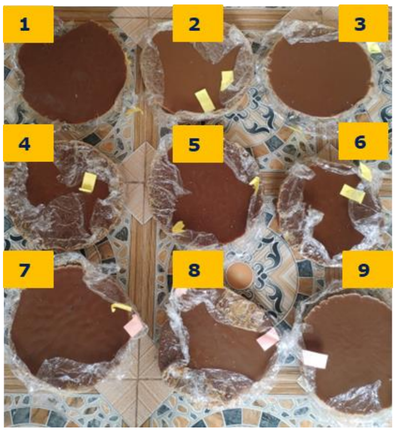

Figure 11. Results of Recycled Wax Production Experiment

2. Taguchi Design Determination

The orthogonal array is created by determining the number of factors and levels for the experiment. Four factors with three levels each are used in nine experiments with three replications, resulting in the chosen L9 (3^4) orthogonal array (OA). The systematic structure of an OA can provide an organized arrangement of experimental parameters capable of influencing a process (Krishnaian & Shahabudeen, 2012). Researchers can determine the number of experimental units, the arrangement of parameters, and the levels that can represent the entire experimental space through the use of an OA table. The Taguchi experimental design can be observed in Table 4.

2.3 Experiment of Recycling Wax Production

The steps for recycling wax production are as follows:

1. Weigh each raw material for recycled wax.
2. Ignite the gas stove.
3. Put pine resin in the pot and melt it for 10 minutes until the solution reaches 71°C.
4. Add colophonium resin to the solution, stir for 10 minutes until homogeneous and the solution reaches 81°C.
5. Add used wax to the solution and stir for 6 minutes until homogeneous and the solution reaches 76°C.
6. Add microwax to the solution and stir for 7 minutes until homogeneous and the solution reaches 73°C.
7. Add paraffin to the solution and stir for 7 minutes until homogeneous.
8. Turn off the gas stove and let the solution stand for 1 minute.
9. Add used cooking oil and stir until homogeneous.
10. Filter the recycled wax solution using a filtration table. Results of recycled wax production experiment is shown in Figure 11.

2.4 Optimal Parameter Determination

The analysis of determining the optimal factor values involves two stages: Taguchi analysis and Grey Relational Analysis (GRA). This analysis is performed using Minitab Software for interpreting experimental data.

1. Taguchi Method

Taguchi analysis is used to determine the optimal values of factors for the characteristics of wide line continuity represented by standard deviation and wax permeability represented by root mean square deviation. The input values in Minitab are SNR values obtained from measurements on batik fabric.

2. Grey Relational Analysis (GRA)

While Taguchi's analysis provides analysis for only one response characteristic, GRA can combine multiple response values into a single response. The stages of GRA analysis are as follows (Sood et al., 2009):

1. Grey-Relational Generation (GR-Generation):

The first stage involves the normalization of data. Data with different units and scales are transformed into a standardized range from 0 to 1.

2. Grey-Relational Coefficient (GR-Coefficient):

Data values are converted into coefficients that indicate the correlation between a specific experimental outcome and the best experimental result.

3. Grey-Relational Grade (GR-Grade):

The GR-Grade value is a combination of the GR-Coefficient values for each response.

Table 3. Factor and Level of Experiment

No	Factor	Level	Percentage
1	Used Wax	1	42.5%
		2	40%
		3	37.5%
2	Used Cooking Oil	1	2.5%
		2	3%
		3	3.5%
3	Paraffin	1	8.5%
		2	10%
		3	11.5%
4	Microwax	1	6%
		2	7%
		3	8%
5	Colophonium resin	1	25%
		2	25%
		3	25%
6	Pine resin	1	15%
		2	15%
		3	15%

Table 4. Wax Recycled Experiment Design

Experiment	Used Wax (grams)	Used Cooking Oil (grams)	Paraffin (grams)	Microwax (grams)	Colophonium Resin (grams)	Pine resin (grams)
1	510	30	102	72	300	180
2	510	36	120	84	300	180
3	510	42	138	96	300	180
4	480	30	120	96	300	180
5	480	36	138	72	300	180
6	480	42	102	84	300	180
7	450	30	138	84	300	180
8	450	36	102	96	300	180
9	450	42	120	72	300	180

2.
5 Batik Pattern Drawing Using Experimental Wax

The experiment was conducted by one batik craftsman. The experimental wax is applied to primisima mori fabric using a *canting* with an inner diameter of 1.1 mm, creating a kawung motif shown in Figure 12. Each experimental wax is replicated three times, resulting in 27 trials. Before waxing, the experimental wax is melted and heated to 90°C.

2.6 Measurement of Physical Properties of Recycled Wax

The measured physical properties of recycled wax are melting point and viscosity. The melting point is measured independently, while viscosity is measured in the Food Technology and Agricultural Product Testing Laboratory. The steps for measuring the melting point are as follows:

1. Weigh 100 grams of wax.
2. Put the wax in a small pan and melt it using an electric stove.
3. Measure the wax's melting point temperature as it melts completely.
4. Repeat the test for recycled wax and new wax three times.

2.7 Quality Data Collection for Batik Results

The batik process involves three fabrics using new and recycled wax. Evaluation is conducted by three experts with over ten years of experience. The evaluation criteria following previous research include wax permeability, line continuity, line neatness, pattern angle quality, wide line continuity, line accuracy, batik pattern drawing (*klowong*) result quality, overall assessment, artistic value, and colour seepage (Setyo Wibowo, 2022).

Figure 12. Batik Pattern Drawing Using Wax Experimental Results

Table 5. Taguchi Experiment Results After Colouring

Experiment	Compositions	Replication 1	Replication 2	Replication 3
1	Used wax: 510 grams Used cooking oil: 30 grams Paraffin: 102 grams Microwax: 72 grams			
2	Used wax: 510 grams Used cooking oil: 36 grams Paraffin: 120 grams Microwax: 84 grams			
3	Used wax: 510 grams Used cooking oil: 42 grams Paraffin: 138 grams Microwax: 96 grams			
4	Used wax: 480 grams Used cooking oil: 30 grams Paraffin: 120 grams Microwax: 96 grams			

Table 5. Taguchi Experiment Results After Colouring (Continued)

Experiment	Compositions	Replication 1	Replication 2	Replication 3
5	Used wax: 480 grams Used cooking oil: 36 grams Paraffin: 138 grams Microwax: 72 grams			
6	Used wax: 480 grams Used cooking oil: 42 grams Paraffin: 102 grams Microwax: 84 grams			
7	Used wax: 450 grams Used cooking oil: 30 grams Paraffin: 138 grams Microwax: 84 grams			
8	Used wax: 450 grams Used cooking oil: 36 grams Paraffin: 102 grams Microwax: 96 grams			
9	Used wax: 450 grams Used cooking oil: 42 grams Paraffin: 120 grams Microwax: 72 grams			

Table 6. Standard Deviation of Batik Pattern Drawing After Colouring

Experiment	Replication 1	Replication 2	Replication 3	Average
1	0,335	0,512	0,777	0,541
2	0,584	0,580	0,495	0,553
3	0,652	0,792	0,404	0,616
4	0,767	0,631	0,647	0,681

Experiment	Replication 1	Replication 2	Replication 3	Average
5	0,581	0,741	0,556	0,626
6	0,484	0,728	0,537	0,583
7	0,725	0,699	0,602	0,675
8	0,553	0,661	0,554	0,590
9	0,846	0,580	0,564	0,663

Table 7. Root Mean Square Deviation (RMSD) of Batik Pattern Drawing After Colouring

Experiment	Replication 1	Replication 2	Replication 3	Average
1	0,326	0,355	0,369	0,350
2	0,282	0,332	0,368	0,327
3	0,331	0,660	0,225	0,405
4	0,279	0,343	0,272	0,298
5	0,249	0,325	0,279	0,284
6	0,411	0,252	0,545	0,403
7	0,566	0,302	0,472	0,446
8	0,525	0,271	0,304	0,367
9	0,553	0,385	0,696	0,545

Table 8. Calculation of SNR

Experiment	S/R Ratio of Continuity of Line Width	S/R Ratio of Wax Permeability
1	4,870	9,108
2	5,123	9,650
3	3,922	7,025
4	3,299	10,467
5	3,993	10,875
6	4,550	7,530
7	3,388	6,752

3. Result and Discussion

The experiment was conducted by applying recycled wax on a mori fabric with a kawung motif. The kawung motif is composed of small oval shapes resembling (Kusrianto, 2013). After completing all the experiments, measurements were taken on the width of the wax lines on the fabric, both on the upper and lower surfaces. The Taguchi experiment results after colouring are presented in Table 5.

The response characteristics of the batik process were evaluated by measuring the continuity of the wax and the permeability of wax. The continuity of the wax is represented by the Standard Deviation (SD) value, and the permeability of wax is represented by the Root Mean Square Deviation (RMSD) value. The calculated response of SD value represents the variation between the values of specific points scattered across the entire pattern concerning the overall average width of the pattern lines. The calculated response of RMSD value reflects the variation between the values of surface points on the upper and lower parts of the fabric.

The goal of this research is to minimize both response values. The smaller the values of these responses, the better the quality of the batik process. Therefore, Taguchi analysis was conducted using the "Smaller is Better" criterion for the Signal Noise to Ratio (SNR). The experimental results for SD and RMSD values are presented in Table 6 to Table 7.

The SD and RMSD values were further processed using the Taguchi method to obtain SNR values based on the "Smaller is Better" criterion. The SNR results for batik pattern drawing are presented in Table 8.

3.1 Taguchi Analysis of Wax Line Width Continuity

Taguchi analysis was performed using Minitab Statistical software to generate response values for Signal to Noise Ratios and Main Effects Plots of the wax line width continuity characteristics. The results of the analysis are presented in Table 9 and Figure 13.

Based on the SNR values, it was determined that the continuity of the wax line width in the batik pattern drawing is influenced in the following order: recycled wax, paraffin, used cooking oil, and microwax. The main effect plot graph indicates the optimal values for each factor. The optimal values are level 1 for recycled wax, level 2 for paraffin, level 2 for used cooking oil, and level 2 for microwax.

Table 9. Response Table SNR for SD

Level	Used Wax	Used Cooking Oil	Paraffin	Microwax
1	3.857	4.027	4.870	4.323
2	4.029	4.601	4.016	4.416
3	4.896	4.154	3.896	4.043
Delta	1.038	0.574	0.974	0.373
Rank	1	3	2	4

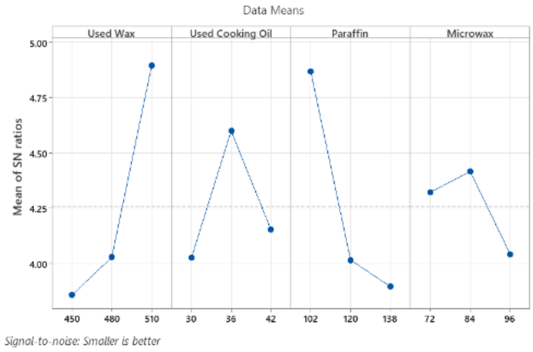

Figure 13. Main Effect Plot for SD

Table 10. Response Table SNR for RMSD

Level	Used Wax	Used Cooking Oil	Paraffin	Microwax
1	7.000	8.880	8.579	8.442
2	9.782	9.781	8.498	8.201
3	8.889	7.009	8.593	9.027
Delta	2.782	2.773	0.096	0.826
Rank	1	2	4	3

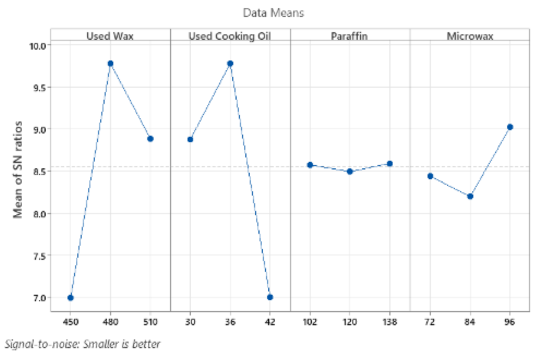

Figure 14. Main Effect Plot for RMSD

3.2 Taguchi Analysis of Wax Permeability

The results of the Signal Noise Ratios and Main Effects Plots analysis for the wax permeability characteristics are presented below. Based on the SNR values, it was determined that the wax permeability is influenced in the following order: recycled wax, used cooking oil, microwax, and finally, paraffin. The main effect plot graph indicates the optimal values for each factor. The optimal values are level 1 for recycled wax, level 2 for used cooking oil, level 3 for paraffin, and level 3 for microwax. The results of the analysis are presented in Table 10 and Figure 14.

3.3 Grey Relational Analysis (GRA)

Taguchi analysis was used to obtain optimal values for the characteristics of wax line width continuity and wax permeability. Grey Relational Analysis (GRA) was then employed to obtain an overall response value by combining the values from the characteristics of wax line width continuity and wax permeability. The SNR values obtained from the Taguchi method were used in the GRA analysis. The purpose of GRA analysis is to minimize the sensitivity of the response to variations, resulting in a robust analysis. The final step involves calculating the GR Grade. The GR Grade calculation assigns weights to each response. In this study, each response has equal weight. The GR Grade values serve as inputs for the overall response analysis using Taguchi. Since the values in this calculation are transformed SNR values, the analysis is based on the "Larger is Better" characteristic. The results of the GRA analysis are presented in Table 11 and Figure 15.

Table 11. Response Table GR Grade

Level	Used Wax	Used Cooking Oil	Paraffin	Microwax
1	-7.531	-5.283	-4.409	-5.083
2	-4.177	-3.002	-5.040	-5.056
3	-3.922	-7.344	-6.181	-5.490
Delta	3.608	4.342	1.772	0.434
Rank	2	1	3	4

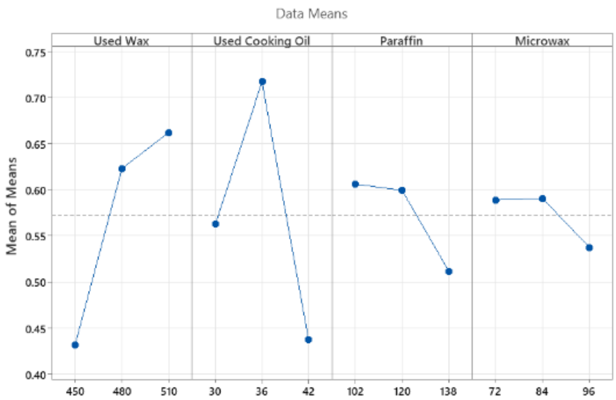

Figure 15. Main Effect Plot GR Grade

Table 12. Optimal Value Factors

Factor	Level	Value
Used wax	1	510 grams
Used Cooking Oil	2	36 grams
Paraffin	1	102 grams
Microwax	2	84 grams

Table 13. Summary of Quality Assessment by Experts After Colouring

Criteria	Recycled Wax			New Wax		
	Mori Fabric 2	Mori Fabric 3	Mori Fabric 5	Mori Fabric 1	Mori Fabric 4	Mori Fabric 6
Wax Permeability	4,67	4,00	4,67	4,00	4,67	4,00
Line Neatness	4,33	4,33	4,00	4,67	4,33	3,67
Line Continuity	3,67	4,33	3,67	4,00	4,33	4,00
Line Width Continuity	3,33	4,00	4,00	4,00	3,67	4,33
Pattern Angle Quality	4,33	4,33	4,33	4,33	3,67	3,67
Quality of Batik Pattern Drawing Result	4,00	4,00	4,33	4,00	4,33	4,00
Overall Assessment	4,00	4,00	4,33	4,33	4,33	4,33
Artistic Value	4,00	4,00	4,33	4,00	4,00	4,33
Colour Seepage in Wax	4,67	3,00	2,00	2,67	4,00	3,00
Average	4,02			4,02		

Based on Figure 15, the delta values indicate the magnitude of the influence of a factor on the overall response characteristics of batik pattern drawing. An enormous delta value indicates a more significant influence of the factor on the response and vice versa. According to the SNR data, it can be determined that the overall batik pattern drawing is influenced by factors in the following order: used cooking oil, recycled wax, paraffin, and microwax. The main effect plot graph indicates the optimal values for each factor. The optimal values are level 2 for used cooking oil, level 1 for recycled wax, level 1 for paraffin, and level 2 for microwax.

3.4 Analysis of Optimal Level Selection for Factors

The selection of optimal response levels is determined based on the GRA results. According to these results, the optimal levels for each factor that yield the most favourable outcomes are presented in Table 12.

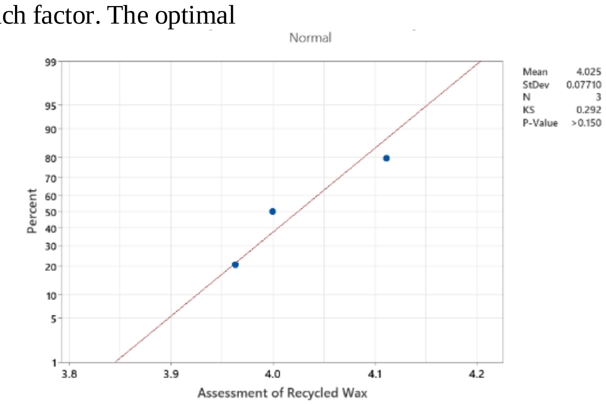

Figure 16. Normality Test Results for the Evaluation of Recycled Wax Quality After Colouring

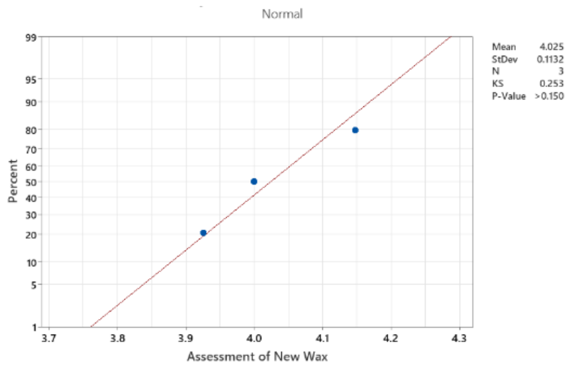

Figure 17. Normality Test Results for the Evaluation of New Wax Quality After Colouring

Table 14. ANOVA Test Results for Expert Evaluation of Batik Quality After Colouring

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Assessment of Recycled Wax	6	0.82579	0.13763	8.36	0.111
Error	2	0.03292	0.01646		
Total	8	0.85871			

Table 15. Comparison of Physical Properties between Recycled Wax and New Wax

Type of Wax	Melting Point (°C)	Viscosity (cP)
Recycled Wax	67,9	90,15
New Wax	61,17	52,50

3.5 Validation Testing with Expert Judgment

The selected optimal factor values were used to create batik on a fabric measuring 100x50 cm. Expert judgment testing was conducted at The Center for Standardization and Services for Craft and Batik Industry by three batik experts. The summarized expert assessments after dyeing are presented in Table 13.

Based on Table 13, it is evident that the results of batik quality using recycled wax are comparable to those using new wax. However, further analysis is needed to conclude. Normality tests were performed to assess the distribution of data in each group. ANOVA tests were conducted to determine if there were significant differences between batik results using recycled and new wax.

Based on the normality test data in Figure 16 and Figure 17, both batik results using recycled and new wax have p-values above 0.05, indicating that the data is normally distributed and ANOVA tests can be conducted. According to the ANOVA test results shown in Table 14, the p-value is greater than 0.05, indicating that there is no significant difference in the quality of batik after dyeing using recycled and new wax.

3.6 Analysis of Physical Characteristics of Wax

The physical properties measured in this study are melting point and viscosity. Wax viscosity was measured at 70 °C. A comparison of the physical properties of recycled and new wax is presented in Table 15.

According to Table 15, the melting point of recycled wax is higher than that of new wax. The melting point of recycled wax approaches the melting point of beeswax, ranging from 62-64 °C. The raw materials of the wax influence this melting point mainly used cooking oil. Used cooking oil functions to lower the melting point of the wax. The higher viscosity of recycled wax indicates that it is denser than new wax.

Table 16. Total of Cost Production

Material Cost					
No	**Component**	**Amount**	**Unit**	**Price (Rp)**	**Total of Price (Rp)**
1	Used Cooking Oil	0,03	kg	10000	300
2	Paraffin	0,084	kg	34000	2856
3	Microwax	0,069	kg	55000	3795
4	Colophonium Resin	0,25	kg	26000	6500
5	Pine resin	0,15	kg	48000	7200
6	Calcium Powder	0,003	kg	2000	6
Pre-treatment Material Cost					
1	Gas Consumption Cost	33	minutes	45	1485
2	Labour Cost	33	minutes	188	6204
Cost Production					
1	Gas Consumption Cost	11	minutes	45	495
2	Labour Cost	11	minutes	188	2068
Total Cost Production					30909

3.7 Analysis of the Cost of Production for Recycled Wax

The production of recycled wax incurs various costs, including material costs, pre-treatment material costs, and production costs. Material costs refer to the expenses for raw materials used to produce recycled wax. In contrast, pre-treatment material costs involve processing or improving the quality of used wax and used cooking oil. A detailed explanation can be found in Table 16.

The selling price of new wax is approximately Rp 35,000.00. When comparing the selling price of new wax with the production cost of recycled wax, it is recommended for batik entrepreneurs to produce recycled wax themselves rather than buying new wax, as the expenses incurred are lower than the cost of purchasing new wax.

4. Conclusion

Based on the discussion conducted in this research, the optimal composition of recycled wax is as follows: 510 grams of used wax (41.5%), 36 grams of used cooking oil (2.9%), 102 grams of paraffin (9.8%), 84 grams of microwax (6.8%), 300 grams of colophonium resin (24.4%), and 180 grams of pine resin (14.6%). Recycled wax has a melting point of 67.9 °C and a viscosity of 90.15 cP, while new wax has a melting point of 61.7 °C and a viscosity of 52.5 cP. Expert assessments of wax quality revealed no significant difference between the quality of recycled wax and new wax. The production cost of recycled wax is approximately Rp 30,909.00, which is cheaper than the selling price of new wax, which is around Rp 35,000.00.

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