MALAYSIAN JOURNAL OF INNOVATION IN ENGINEERING AND APPLIED SOCIAL SCIENCE (MYJIEAS)
e-ISSN: 2811-3780
VOLUME 04, ISSUE 01

Optimizing Environmental and Performance Characteristics of Candle From Waste Cooking Oil

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Article History: Received 04092024; Revised 02102024; Accepted 30102024;

ABSTRACT – Waste cooking oil (WCO) poses a significant environmental hazard due to its improper disposal practices. Disposal of WCO directly into kitchen sinks results in its congealing within pipes, leading to obstruction and accumulation in drainage systems. Utilizing WCO for candle production offers a feasible solution due to its simplicity and flexibility in the manufacturing process. This study aims to produce candles from WCO and soy wax. Candles were manufactured using different ratios of WCO to soy wax (9:1, 8:2, and 7:3). Melting point determination, light emission analysis, lifespan assessment, and measurement of volatile organic compounds (VOCs) and PM2.5 in their soot were performed. Based on the characterization tests done, candle with a 9:1 WCO to soy wax ratio achieved optimal characteristics, including higher melting points, brighter light emission and longer lifespans. Additionally, when compared to the other ratios, candle 9:1 shows the highest average VOC and the lowest PM2.5 emission. Despite the high VOC value found, it is still remaining below the permissible limit, indicating that the candle is safe to the environmental and health. Finally, this paper's findings highlight the significance of taking into account a variety of environmental factors when assessing the sustainability of candle produced from WCO

KEYWORDS: Waste Cooking Oil, Soy Wax, Candle Production

1.0 INTRODUCTION

In contemporary times, the improper disposal of waste cooking oil (WCO) has emerged as a pressing environmental concern, posing detrimental effects on water ecosystems, landfills, and human well-being. The repercussions of WCO mismanagement manifest in various forms, from sewer blockages to water pollution and even hazardous gas emissions upon incineration. Addressing this multifaceted challenge necessitates innovative approaches to repurpose WCO sustainably, not only mitigating its adverse impacts but also harnessing its latent potential as a valuable resource [1].

Over the past two decades, numerous recycling and utilization techniques have been developed, yielding diverse products such as biodiesel, bio lubricants, and cleaning agents. Among these methodologies, the conversion of WCO into biodiesel has emerged as a frontrunner due to its efficiency [2]. However, alternative ways for WCO utilization, such as wax production, offer promising avenues for sustainable innovation. Plant-based wax production, in particular, holds appeal due to its abundance, biodegradability, and versatility in applications, with candle manufacturing standing out as a notable example [3].

The production of aromatherapy candles from WCO represents a novel endeavor with far-reaching benefits for both environmental sustainability and human well-being. Aromatherapy products, renowned for their therapeutic properties in promoting relaxation, mental clarity, and mood enhancement, epitomize the synergy between nature and holistic health. Utilizing natural components in candle production, such as soy wax derived from soybean oil, aligns with the ethos of sustainability and wellness [4]. Soy wax, characterized by its renewable nature and biodegradability, presents a compelling alternative to conventional paraffin wax, thus advancing the paradigm of eco-conscious consumer choices.

Moreover, the environmental ramifications of WCO mismanagement extend beyond pollution to encompass infrastructure maintenance and community awareness [5]. In regions like Malaysia, where WCO disposal facilities are underutilized and community awareness is lacking, the repercussions are stark, with clogged piping systems and compromised aquatic ecosystems being common outcomes. Addressing this knowledge gap and fostering a culture of responsible

WCO disposal are imperative steps towards mitigating environmental degradation and promoting community well-being [6].

Furthermore, the health implications of prolonged WCO exposure underscore the urgency of sustainable management practices. Studies have linked extended WCO ingestion and heating to various health ailments, including cancer, liver dysfunction, and cardiovascular diseases. The deterioration of WCO quality through repeated heating cycles exacerbates its toxicity, posing risks not only to human health but also exacerbating air pollution through the release of harmful vapors. The research investigates the feasibility and potential benefits of utilizing waste cooking oil and soy wax as primary materials in candle production.

2.0 MATERIALS AND METHODS

The methodology involved in this study comprises of three stages which are collection, handling and preparation of raw material, production of candles from waste cooking oil and characterization tests of candles.

2.1 Collection, handling and preparation of raw material

The main raw materials used in candle production are waste cooking oil and soy wax. Waste cooking oil was collected from households and restaurants in Taman Pagoh Jaya. After collection, the waste cooking oil was filtered with filter paper to eliminate any precipitate and unwanted contaminants. The waste cooking oil was ensured contaminant-free and not rancid. To mitigate the issue of strong odor from waste cooking oil, the oil was heated with a lime zest solution. Besides removing the bad odor of waste cooking oil, this solution could also aid in producing candles with aromatherapy benefits

As for soy wax, it was produced through the extraction of soybean powder. Soxhlet extractor was used with ethanol as the solvent (see Figure 1). Firstly, the soybean powder was inserted into a thimble. Next, 250 ml of ethanol was added and heated in a beaker at the bottom of the apparatus, causing it to vaporize and rise through a reflux condenser. The solvent vapor was then condensed and dripped onto the soybean powder, where it gradually dissolved to produce soybean oil. The mixture of solvent and oil then flows back into the flask continuously until the soybean oil is fully extracted.

Figure 2. Extraction of soy wax

2.2 Production of candle from waste cooking oil and soy wax

In this study, three different ratios of soy wax and waste cooking oil were utilized to produce candles. The ratio of soy wax to waste cooking oil are 9:1, 8:2, and 7:3. First of all, the soy wax was melted in a beaker using a Bunsen burner. Once the wax had completely melted, waste cooking oil was added into the beaker and stirred continuously using a glass rod to ensure homogeneous mixing. Candle dye was also added to the mixture to enhance the color during heating. The mixture was then poured into the candle mold and the wick was immediately placed in the mold. 3 drops of essential oil were also added to provide an additional aromatic scent to the candle. The candle was then left to cool and solidified at room temperature for 24 hours until it hardened.

2.3 Characterization tests of candle

The characterization tests that were carried out in this study are melting point, light ability and lifespan. Apart from that, the soot characteristics, Volatile Organic Compound (VOC) and Particulate Matter (PM2.5) produced by the candles while burning were also analyzed. These tests are important to ensure that the candles have the potential to be utilized in daily life applications whilst producing less impact on human health and environment.

For the melting point determination, the candles with three different ratios were placed in three separate beakers with a thermometer. The beaker was then heated with a low heat source and stirred to avoid rapid heating. Once the candle was melted, the melting point was immediately recorded. As for lifespan, the candles were burnt and the time before the candles completely melted was measured and recorded. The light abilities tested were also carried out from the burning of candles in the dark condition. The brightness, color and size of the flame were compared and recorded.

Next, the health and environmental impact of candle burning was analyzed by determining the amount of VOC and PM2.5 emissions. The candles were burnt in an empty room at room temperature and pressure to ensure there was no other source of gas emission and mimic real application of candle in daily life. The soot characteristics were observed by placing paper on top of the flame while the VOC and PM2.5 were measured using Aeroqual Series 500.

3.0 RESULTS AND DISCUSSION

3.1 Melting point

Candles' environmental impact can be affected by their melting point. Lower-melting temperature candles may burn warmer consuming more resources and producing more waste. Higher melting point candles, on the other hand, could last longer and need to be replaced less frequently, resulting in a reduction in the overall amount of resources used and waste produced

For the melting point of a candle was very much affected by the raw materials that are being used in the production of it. Soy wax melting point was recorded between 46 ˚C to 52˚C [7], while WCO has a lower melting point between 30-35 ˚C [8]. Adding WCO will occasionally decrease the melting point of the candle. Melting points for the 9:1, 8:2, and 7:3 ratios were 56°C, 54°C, and 52°C, respectively. Figure 2 below shows the average melting point of the candle based on the ratio.

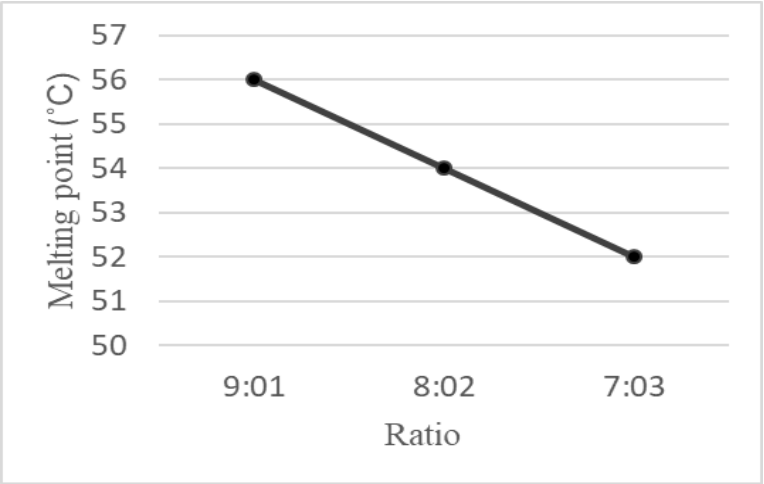

Figure 2. Average melting point of the candle

Crystalline structure and chemical structure of the materials can affect the melting point of the substance. Soy wax mainly consists of fatty acids and triglycerides [8]. It usually hardens at a higher temperature than cooking oil [9]. While on the other hand, WCO contains fatty acid and other contaminants, which contribute to lowering the melting point of candles. Changes in the proportion of these two components will therefore probably have an impact on the molecular configurations and intermolecular forces in the combination, which will ultimately have an impact on the melting behavior of the mixture.

3.2 Life span

The long lifespan of candles and energy efficiency are closely associated. Long-lasting, well-burning candles make the most of their energy content, which lowers the need for frequent replacements and energy-intensive manufacturing procedures. The study of the life span for candle 9:1, 8:2 and 7:3 resulted in varying average burn times of 99, 94, and 49 minutes, respectively. The result is as shown in Figure 3.

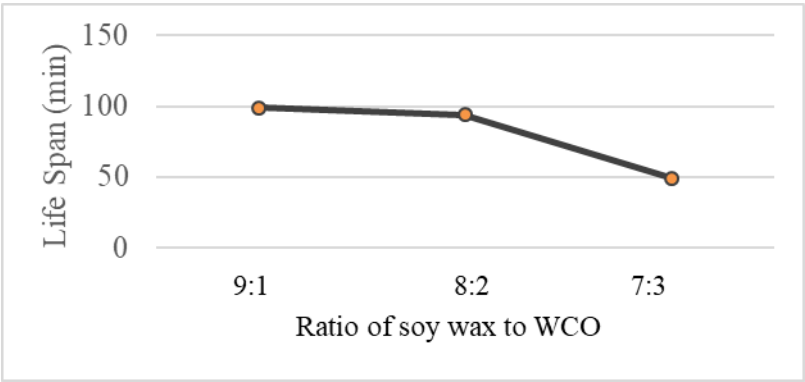

Figure 3: Average Life Span of Candle Sample (min)

The 9:1 ratio, featuring the highest content of soy wax, showed an extended average burn time of 99 minutes. The 7:3 ratios, with a higher concentration of waste cooking oil, demonstrated a relatively shorter average burn time of 49 minutes. The 8:2 ratios, positioned between the two extremes, yielded an average burn time of 94 minutes. This result demonstrated that increased soy wax concentrations lead to longer burn times owing to its lower melting point and slower combustion rate.

3.3 Light ability

A candle's ability to produce light dictates how well it can illuminate its surroundings. Candles have the power to optimize light, which can improve both the ambiance and usability of indoor areas. Furthermore, candles' visual characteristics—such as their color, brightness, and intensity of light—adjust to its decorative value and aesthetic appeal. The provided data reveals variations in light emission based on different ratios of soy wax to waste cooking oil in candle formulations. As shown on Table 1, across the three ratios (9:1, 8:2, and 7:3), distinct qualitative descriptions of brightness are observed for each sample.

Table 1: Light ability of candle with different ratio

Ratio	Light ability
9:1	Bright
8:2	Less dim
7:3	Less bright

Samples with a higher proportion of soy wax (9:1) consistently exhibit a "Bright" appearance, while those with an increasing ratio of waste cooking oil show decreasing brightness, characterized by descriptions such as "Less dim" for the 8:2 ratio and "Less bright" for the 7:3 ratio. This indicates a correlation between the candle's composition and its perceived luminosity, suggesting a potential relationship between soy wax and waste cooking oil in sustainable candle manufacturing.

3.4 Soot characterization

Burning of a candle will release gases to the surrounding which can affect indoor air quality. Thus, it is crucial to study the soot produced during the burning. In this paper, volatile organic compounds (VOC) and particulate matter 2.5 (PM2.5) of the soot were studied in order to assess its environmental and health impact. VOCs, such as formaldehyde and benzene, are linked to a number of harmful health impacts, such as irritated respiratory tracts and worsened asthma symptoms. PM2.5, or fine particles, can cause respiratory and cardiovascular issues because of their deep lung penetration. PM2.5 is defined as particles with a diameter of 2.5 micrometers or less. Knowing the emissions from candles makes it easier to evaluate how they affect human health and indoor air quality [10].

The measurements of VOC and PM2.5 presented in Figure 4 and Figure 5 provide valuable insights into the environmental impact of different ratios of soy wax to waste cooking oil in candle formulations. The VOC results reveal a trend where the 9:1 ratio exhibits the highest average total VOC emissions at 0.093 ppm, followed closely by the 8:2 ratio at 0.089 ppm, and the 7:3 ratio shows the lowest average total VOC emissions at 0.087 ppm. This suggests that burning candles with a larger percentage of soy wax could result in more VOC emissions.

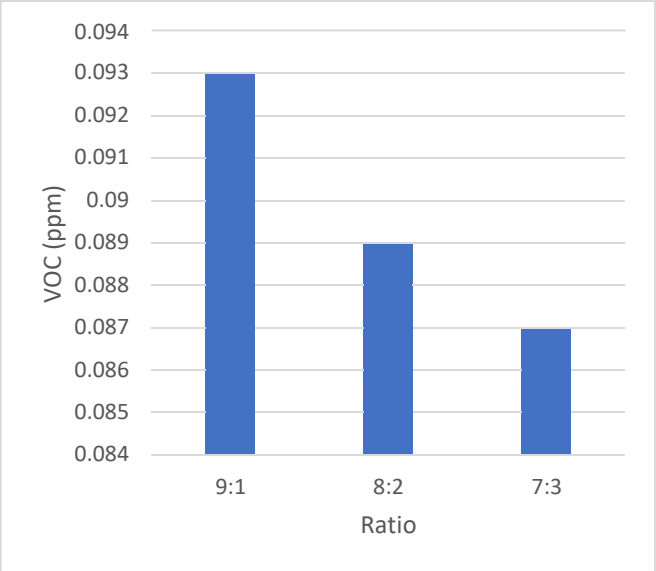

Figure 4: Average of Total VOC (ppm)

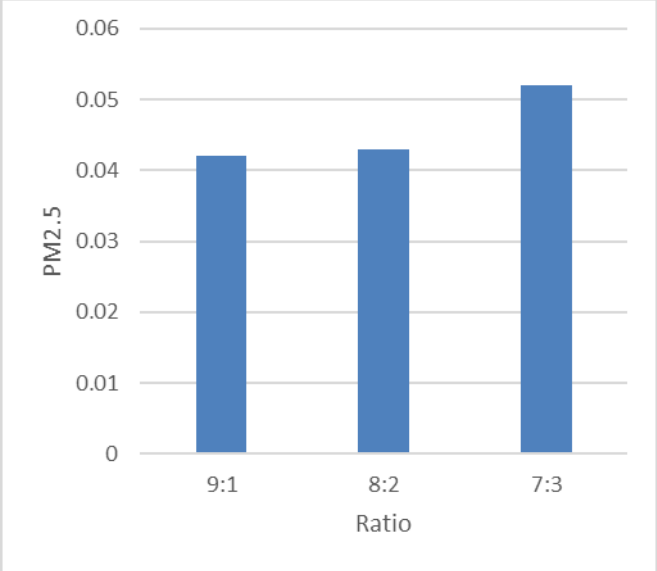

Figure 5: Average of Total PM2.5

There is an interesting difference when comparing these VOC values with the PM2.5 data. With an average of 0.052, the 7:3 ratio, which showed the lowest average total VOC emissions, shows an increase in PM2.5 concentrations. Conversely, the 9:1 and 8:2 ratios, characterized by higher VOC emissions, show lower average PM2.5 concentrations at 0.042 and 0.043, respectively. This discrepancy could be caused by the complex interactions between different chemical constituents during burning.

The detected amounts of PM2.5 are far lower than the allowable limits established by environmental regulations, indicating that the candles are within acceptable limits for both environmental and health standard. The allowable limit of PM2.5 in Malaysia is 35 µg/m³ for the 24-hour mean. Going above this limit can be extremely dangerous for one's well-being, particularly for children, the elderly, or people with a history of respiratory or cardiovascular disease. Increased lung and heart disease symptoms, as well as respiratory conditions including bronchitis and asthma, have been linked to elevated PM2.5 levels.

In addition to having an adverse effect on health, elevated levels of PM2.5 can cause haze, reduce visibility, and harm the ecosystem by degrading the quality of the soil, water, and vegetation. [11]. The VOC and PM2.5 measurements contribute to a comprehensive understanding of the environmental impact of different soy wax to waste cooking oil ratios in candle formulations. The contrasting trends in emissions highlight the complexity of candle combustion and emphasize the need for a holistic approach to sustainable candle manufacturing.

4.0 CONCLUSION

In conclusion, the candle produced from waste cooking oil and soy wax, particularly with 9:1 ratio has good potential to be utilized as an environmental-friendly alternative to conventional candles. Besides showing a satisfactory performance in terms of lifespan and light abilities, this candle produces gas emissions with minimal impact on human health and the environment as the amount of VOC and PM2.5 emitted by the candle is far below the permissible limit. The usage of waste cooking oil in this study to produce candles is also beneficial to mitigate the current issue on improper disposal of waste cooking oil.

ACKNOWLEDGEMENT

The authors would like to express sincere gratitude to Politeknik Tun Syed Nasir Syed Ismail, and the Ministry of Higher Education, Malaysia, for providing the laboratory facilities in order to complete this research.

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