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Virgin Coconut Oil as a Performance Enhancer for Beeswax Candles

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ABSTRACT

Paraffin wax is derived from petrochemicals, which release harmful substances when burned as candles. Beeswax serves as a natural and renewable alternative for making candles, offering cleaner burning that is safe for humans. The beeswax was mixed with virgin coconut oil (VCO) of 0 wt% to 55 wt% by weight at a temperature ranging from 75 °C to 85 °C. The resulting mixture was then cooled down in a glass container that had a wick installed. The wick was then burned to assess the candle's performance. Beeswax candles have the slowest burning rate compared to other candles on the market. The best mixing temperature for melting and blending both materials without altering composition is 75 °C. Additionally, the incorporation of VCO in beeswax candle production can enhance performance by up to 35.4 % due to the reduction of the melting point, which increases the diffusion of wax into the wick.

1. INTRODUCTION

Candles were invented by ancient Romans back in 3000 B.C. using a wick that was dipped into melted tallow until the desired thickness was achieved, known as the dipping method. The candle-making process advanced in the 18th century when high-quality wax from sperm whale oil (spermaceti) was used during the whaling industry era. In 1850, James Young developed paraffin wax, which replaced spermaceti and led to the mass production of candles due to its high quality and commercial viability [1]. While candles were initially used for light and heat, as technology became more accessible, their function shifted to being used in celebrations, relaxation, and ceremonies. Candles can create a pleasant environment, and their light provides better protection to the retina than incandescent light bulbs, fluorescent lamps, and warm-light light emitting diodes [2].

The energy source for candles is wax. When pure wax candles burn, they release a high density of ultrafine particles, up to 241,000 particles/cm[3], which can affect the air quality in homes [3]. These particles, which account for 65% of indoor pollutants, are the result of various activities including cooking [4,5]. The main component of these particles is carbon dioxide (CO_2), which is a harmful pollutant but can be mitigated with a good ventilation system. In addition, there are trace amounts of acrolein, naphthalene, acetaldehyde, and formaldehyde present in the air from burning candles, which can cause various health complications and nuisances [3,5]. It's worth noting that 85% of the raw materials used to produce candles is paraffin wax [1,6].

The combustion of paraffin wax candles can produce hazardous substances such as alkenes, benzene, and toluene, which can pose a threat to human health [5,7]. Katsumi et al. (2016) found that prolonged inhalation of vaporized paraffin from burned candles can lead to lipoid pneumonia, which is similar to the condition observed in individuals using a spray lubricant as a liniment [8]. As a precautionary measure, it is advisable to opt for candles made from natural materials such as soy wax and beeswax, while avoiding low-quality candles and those made from paraffin or artificial materials [7,9]. It is worth noting that although soy wax produces cleaner-burning candles and is renewable and biodegradable, it can also generate acrolein, a toxic substance that can irritate the eyes and affect the respiratory system of both humans and animals [2,10,11]. On the other hand, beeswax candles are known for producing minimal smoke and odour and have the slowest burning rate compared to paraffin wax and soy wax due to the long chain wax ester they contain [2,11,12].

Coconut oil is a vegetable oil that can be used as fuel to replace diesel but the problem arises from its high viscosity because it contains fatty acid and glycerol [13]. The high viscosity can slow down the combustion process because of the slowed down of the fluid [14]. During combustion, the fatty acids are burned before glycerol. The fatty acid tends to produce separate flames of different boiling points. The process energy released from glycerol needs a high rate of combustion process and tends to slow the flame propagation [13]. The current study aims to assess the VCO as the performance-enhancer for beeswax candles.

2. EXPERIMENTAL PROCEDURES

2.1 Materials

Beeswax, VCO, and cotton wick. All materials were kept in a desiccator and used as received without any additional purification.

2.2 Candle Preparation

Approximately 100 g of beeswax was melted in water bath at 65 °C for 20 minutes. VCO (0 -115g) was added to melted beeswax and stirred at 65 °C to 85°C until its well-mixed before it was poured into a glass container (5 cm x 5 cm x 3.5 cm) with a wick (a cotton strip with a metal disk connected to one-end) held in the center. The candle was left for 6 hours at room temperature for the candle to be hardened. The candle's performances were tested by burning the candle completely in a closed environment under normal conditions. All experimental were repeated twice to ensure the reproducibility.

3. RESULTS AND DISCUSSION

3.1 Effect of Mixing Temperature

The beeswax consists of esters (71%), hydrocarbons (15%), free acids (8%), and other compounds (6%). These properties are altered when the wax is overheated or heated for a prolonged period, leading to degradation and loss of ester [15-17]. When mixing VCO with beeswax, the solid wax needs to be melted before being combined with VCO. The different mixing temperatures of VCO with beeswax are presented in Fig. 1, showing that the burning rate of the candles is not affected by mixing temperatures below 75°C. Higher mixing temperatures can reduce mixing time, but the candles burn faster due to the formation of surface foam from rapid heating of the materials [18].

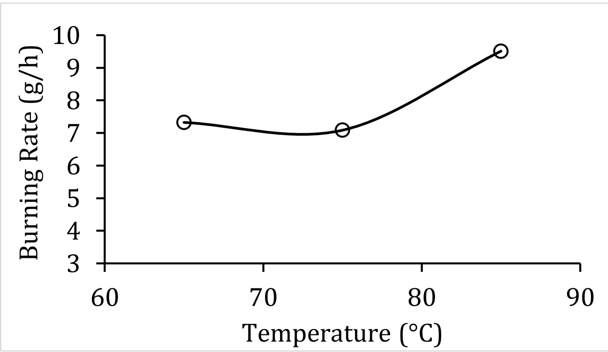

Fig. 1. Effect of mixing temperature of 40 wt% of VCO with beeswax between 65 °C to 85°C.

3.2 Effect of VCO Loading

The combustion of candles depends on several parameters, including the fuel, amount of air, and volume of released combustion gas. The fuel for the candle is a mixture of beeswax and VCO, which liquefies when the wick is burned and is moved by capillary action towards the wick's surface, where evaporation occurs. The evaporation near the wick's surface creates a saturation gradient that is sustained by the liquid capillary motion, resulting in a self-sustaining flame [19,20]. During combustion, the wick's surface is exposed to air, and particulate matter and gaseous products are released. Soot is produced when there is a lack of air [19]. Fig. 2 shows that increasing the VCO loading can improve the candle's performance by up to 34.5%. The slows down of the burning rate because VCO reduces the beeswax's melting point, resulting in increased diffusion of liquid fuel into the wick [21]. The candle's wick is also observed to maintain a steady length, indicating that the candle is consumed slowly [20]. However, after a 50 wt% of VCO loading, the burning rate has not changed significantly, but the candle becomes too soft which cannot maintain the shape.

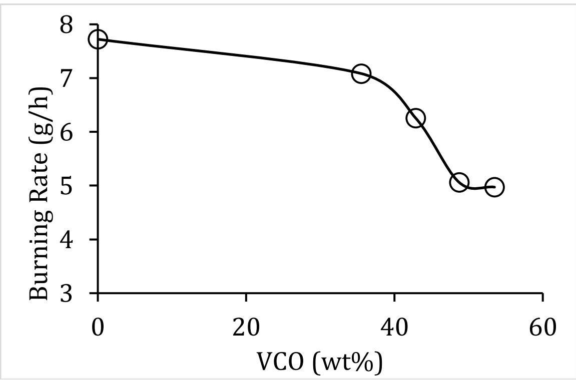

Fig. 2. Performance of candle with varying VCO from 0 wt% to 55 wt%.

4. CONCLUSION

The candle made from beeswax burns cleanly without emitting any harmful gases. The temperature at which VCO is mixed with beeswax can impact the candle's performance by altering the wax's composition. The optimal mixing temperature is 75°C, as it reduces the time required for melting and blending without compromising the candle's performance. Additionally, adding VCO can improve the candle's performance by up to 35.4% by slowing down its burning rate.

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REFERENCES

[1] J.-H. Jou, C.-H. Wu, Y.-T. Su, Z.-K. He, and D. K. Dubey, "Unveiling the mythical candles," *Building and Environment*, vol. 169, p. 106565, 2020. Doi: 10.1016/j.buildenv.2019.106565.

[2] J. A. Furlong, J. D. Haelssig, and M. J. Pegg, "Impact of candle wicks and fuels on burning rate, flame shape, and melt pool diameter," *Journal of Combustion and Flame*, vol. 249, p. 112628, 2023. Doi: 10.1016/j.combustflame.2023.112628.

[3] M. E. Ojewumi, O. O. Olanipekun, O. R. Obanla, E. O. Ojewumi, and R. S. Bassey, "Production of candle from oil extract of a legume- soybean," *International Journal of Engineering and Advanced Technology*, vol. 9, pp. 1-7, 2019. Doi: 10.35940/ijeat.B2382.129219.

[4] V. R. M. Chandrasekaran, S. Periasamy, S.-P. Chien, C.-H. Tseng, and P. J. Tsai, "Physical and psychological stress along with candle fumes induced cardiopulmonary injury mimicking restaurant kitchen workers," *Current Research in Toxicology*, vol. 2, pp. 246-253, 2021. Doi: 10.1016/j.crtox.2021.07.001.

[5] P. Kapalo, A. Estokova, and O. Voznyak, "The carbon dioxide generation rate from burning of candle and its effect on room ventilation," *IOP Conference Series: Materials Science and Engineering*, vol. 1252, p. 012011, 2022. Doi: 10.1088/1757-899X/1252/1/012011.

[6] M. Derudi, S. Gelosa, A. Sliepcevich, A. Cattaneo, and R. Rota, "Emissions of air pollutants from scented candles burning in a test chamber," *Atmospheric Environment*, vol. 55, pp. 257-262, 2021. Doi: 10.1016/j.atmosenv.2012.03.027.

[7] A. Estokova and P. Kapalo, "Investigation of the thermal properties of candle wax material," *IOP Conference Series: Materials Science and Engineering*, vol. 1252, p. 012013, 2022. Doi: 10.1088/1757-899X/1252/1/012013.

[8] H. Katsumi, M. Tominaga, M. Tajiri, S. Shimizu, and Y. Sakazaki, "A case of lipid pneumonia caused by inhalation of vaporized paraffin from burning candles," *Respiratory Medicine Case Reports*, vol. 19, pp. 166-168, 2016. Doi: 10.1016/j.rmcr.2016.10.001.

[9] Z. Nazir, A. Habib, T. Ali, H. Ghouri, and M. A. Haque, "The unknown risks of scented candles! What science has to say: an editorial," *Annals of Medicine and Surgery*, vol. 86, pp. 16-17, 2023. Doi: 10.1097/MS9.0000000000001524.

[10] C. Lau, H. Fiedler, O. Hutzinger, K. H. Schwind, and J. Hosseinpour, "Levels of selected organic compounds in materials for candle production and human exposure to candle emissions," *Chemosphere*, vol. 34, pp. 1623–1630, 1997. Doi: 10.1016/s0045-6535(97)00458-x.

[11] K. Rezaei, T. Wang, and L. A. Johnson, "Combustion characteristics of candles made from hydrogenated soybean oil," *Journal of the American Oil Chemists' Society*, vol. 79, pp. 803-808, 2002. Doi: 10.1007/s11746-002-0562-y.

[12] P. M. Fine, G. R. Cass, and B. R. T. Simoneit, "Characterization of fine particle emissions from burning church candles," *Environmental Science & Technology*, vol. 33, pp. 2352–2362, 1999. Doi: 10.1021/es981039v.

[13] H. Saroso, I. N. G. Wardana, R. Soenoko, and N. Hamidi, "Burning characteristics of coconut oil vapour-air mixtures at premixed combustion," *Advanced Studies in Theoretical Physics*, vol. 7, pp. 941-956, 2013. Doi: 10.12988/astp.2013.3884.

[14] J. H. Mandei, Y. F. Assah, M. Edam, and N. P. Kumolontang, "Utilization of virgin coconut oil that has been extracted in phenolic compounds as resource of diethanolamide surfactant," *IOP Conference Series: Materials Science and Engineering*, vol. 1115, p. 012073, 2021. Doi: 10.1088/1757-899X/1115/1/012073.

[15] W. F. Tinto, T. O. Elufioye, and J. Roach, "Chapter 22 Waxes," *Pharmacognosy*, pp. 443-55, 2017. Doi: 10.1016/B978-0-12-802104-0.00022-6.

[16] J. Menezes and K. A. Athmaselvi, "Chapter 5 Report on edible films and coatings," *Food Packaging and Preservation*, pp. 177-212, 2018. Doi: 10.1016/B978-0-12-811516-9.00005-1.

[17] A. Bihonegn, "Physicochemical properties of Ethiopian Beeswax, the case of South Wollo zone Amhara region," *International Journal of Agricultural Sciences and Food Technology*, vol. 3, pp. 61-66, 2017. Doi: 10.17352/2455-815X.000024.

[18] Eshete and Eshetie, "A Review on crude beeswax mismanagement and loss: Opportunities for collection, processing and marketing in Ethiopia," *Research Journal of Food and Nutrition*, vol. 2, pp. 4-12, 2018. Doi: 10.22259/2637-5583.0204002.

[19] J. Guzialowska-Tic, "Description of raw materials for manufacturing candles and grave candles and their influence on the environment," *CHEMIK*, vol. 67, p. 10, 2013.

[20] M. P. Raju and J. S. Tien, "Modelling of candle burning with a self-trimmed wick," *Combustion Theory and Modelling*, vol. 12, pp. 367-388, 2008. Doi: 10.1080/13647830701824171.

[21] M. Agarwal, B. Kuldeep, A. P. John, K. Maheshwari, and R. Dohare, "Experimental study on novel phase change composites for thermal energy storage," *Journal of Thermal Analysis and Calorimetry*, vol. 147, pp. 7243-7252, 2021. Doi: 10.1007/s10973-021-11023-7.