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The effects of extraction time on coffee waste oil using non polar solvent

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KEYWORDS

Coffee Waste
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ABSTRACT

Abstract. The coffee waste grounds oil, a by-product of the coffee industry, is gaining recognition for its potential in industrial and environmental applications. This study aims to determine the effects of extraction time for waste coffee oil. The waste is collected from the local coffee shop nearby. The waste coffee was extracted using Soxhlet extraction by n-polar solvent which is n hexane. The extraction time was varies from 2 hours to 6 hours. These findings shows the optimum extraction time is 5 hours that produces highest oil yield, 11.97% with the characteristics oil coffee with specific gravity 0.876 g/mL. This study contributes to sustainable waste management and creative uses for coffee waste by addressing the environmental impact and potential for useful applications.

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1.0 INTRODUCTION

Coffee is one of the world's most favorite beverages, with millions of cups consumed daily (1–5). Due to this phenomenon, the production and consumption of coffee generate a significant amount of by-products, primarily in the form of used coffee grounds, coffee chaff (the outer skin of coffee beans), and coffee husks. These waste materials from coffee used to be trash and end up in landfills. These waste materials are also the most significant contributors to greenhouse gas emissions, particularly methane contribute to significant effect on global warming (6–8).

Coffee waste has different parts, each with its own special uses. Table 1 shows the physical components of coffee waste, while Table 2 shows the chemical components of coffee waste (9).

Table 1 : The Physical Components of Coffee Waste

COMPONENT	PROPERTIES	PRODUCT APPLICATION
Spent Coffee Ground	i. The most recognizable component of coffee waste ii. These grounds have a coarse, granular texture iii. It includes small solid particles; which retain the	i. Natural exfoliate; helping to remove dead skin cells and promote smoother skin ii. Odour absorbent; helping freshen the air

	aroma and colour of coffee	
Coffee Chaff	i. Lightweight and papery material. ii. It has a fibrous, flaky texture and can vary in colour from pale to dark, depending on the roast level iii. It contains traces of the coffee bean's silverskin, which can impart some flavour.	i. Garden fertilisers; to control soil temperature, keep moisture in the soil and discourage weed growth. ii. Lightweight filler: it has textural and insulating properties and can be used as lightweight filler in a variety of products.
Coffee Silverskin	i. It is a thin, papery membrane that covers the coffee bean before roasting	i. Potential flavouring; contributing to coffee flavour and aroma
Coffee Wastewater	i. Liquids component; containing organic matter, suspended solids, and potentially harmful chemicals	i. Biogas production; can serve as a renewable energy source ii. Nutrient-rich irrigation; can be used as nutrient-rich irrigation for crops, enhancing soil fertility

Table 2 : The Chemical Components of Coffee Waste

COMPONENT	PROPERTIES	PRODUCT APPLICATION
Coffee Oils	i. A complex mixture of organic compounds; includes lipids(fats) and triglycerides	i. Flavour extracts; coffee oils can be extracted to create natural flavour extracts used in the food and beverage industry ii. Aromatherapy; can be used in aromatherapy products for their pleasant and calming scents
Phenolic Compounds	i. Antioxidants such as chlorogenic acids, caffeine acid, and polyphenols.	i. Nutraceuticals; can be used in nutraceutical and dietary supplements for potential health benefits ii. Food preservation; some phenolic compounds can be employed in food preservation due to their antioxidant properties
Carbohydrates	i. Contains carbohydrates, including cellulose, hemicellulose, and pectin.	i. Composting; for composting, enriching soil ii. Biofuel production; it can be processed to produce biofuels, contributing to renewable energy sources
Protein and Amino Acids	i. Contains proteins, which consist of various amino acids	i. Nutritional supplements ii. Flavour enhancers; it can be used as flavour enhancers in food products
Lipids and Fatty Acids	i. Lipids and fatty acids are	i. Biodiesel production; it can be

	found in coffee waste, especially in SCG. ii. Contribute to the oiliness and body of coffee iii. Play a role in both the flavour and texture of the brew	processed into biodiesel, a renewable and eco-friendly fuel source. ii. Food additives: in controlled quantities, some fatty acids can be used as food additives
Volatile Organic Compounds	i. Contains a wide range of volatile organic compounds, which contribute to coffee's aromatic qualities ii. Include aldehydes, ketones and esters, which are responsible for the complex and distinct aroma of coffee.	i. Aromatization; it can be used in aromatization processes for enhancing scents in perfumes, air fresheners, and candles ii. Flavour development; in the food industry, volatile compounds contribute to flavour development in various products
Caffeine	i. Stimulant compound	i. Cosmetics; reducing puffiness and promoting circulation ii. Pharmaceutical formulations.

Spent coffee grounds have various applications; for example, are not only excellent at absorbing odours but also serve as a source of natural exfoliation for skincare (10). Coffee is well known as a cosmetic ingredient, particularly due to the presence of phenolic compounds, such as chlorogenic acids, and caffeine. Caffeine is widely used in cosmetic formulations due to its photoprotector and anti-aging properties, as well as lipolytic action in cellulitis, and hair regrowth (11). Coffee chaff, which is like the shell of the coffee beans, can be put in lightweight things or in gardens to help plants grow. Additionally, wastewater generated in the coffee processing industry contains organic matter that can be converted into biogas or used for nutrient-rich irrigation. It's in these diverse components that the true value of coffee waste becomes evident.

According to Statista Research Department in 2022, Malaysia produces an estimated 48,000 metric tons of coffee waste which primarily consists of spent coffee grounds and chaff. Statistics of coffee consumption worldwide from 2012/13 to 2021/22 with a forecast to 2022/23 is shown in Figure 1.

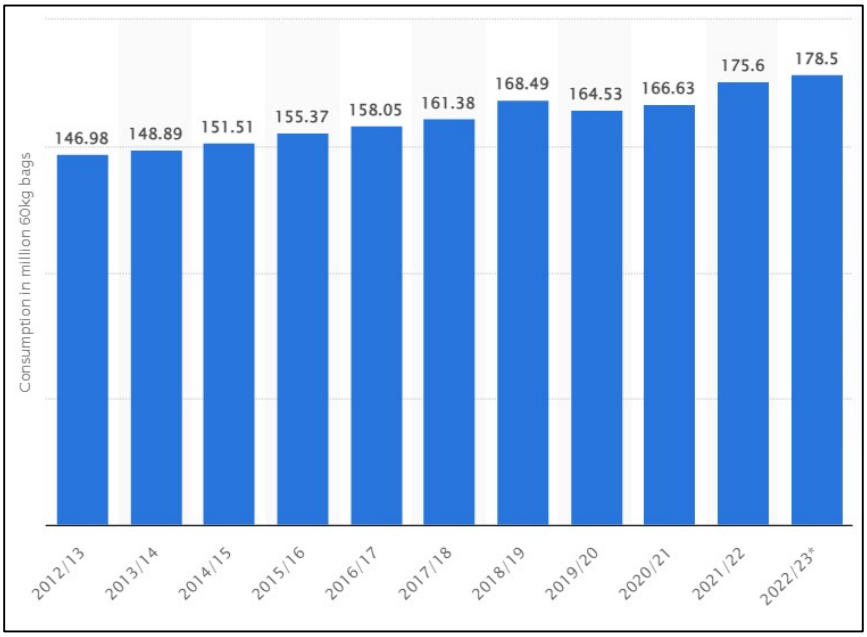

Figure 1: Statistics coffee consumption worldwide from 2012/13 to 2021/22 with a forecast to 2022/23 [Source: Statista Search Department, (2023)]

These by-products were ignored and disposed of as waste, which added to environmental problems like methane emissions and clogged landfills (12,13). The decomposition of coffee waste in landfills creates an acidic leachate (liquid) which can damage the surrounding soil that also generates greenhouse gases (14–16). These gases have a further effect on environment and contribute to climate change (17). The underutilization of coffee waste is a wasted opportunity for sustainable waste management and resource optimization (18). Waste coffee represents a promising resource for the coffee oil production. The oil content in the coffee source varies from 11 to 20% depending on its types (19,20). Additionally, coffee oil is naturally rich in antioxidants (21), contributing to its stability and preventing rapid composition. Its low saponification levels help maintain the oil's viscosity, ensuring it doesn't easily solidify (22).

Growing awareness of the potential that coffee waste holds has been observed in recent years. Creative ways to repurpose coffee waste and turn it into a valuable resource are being investigated by researchers and environmentalist. For instance, a group of researchers investigated the potential waste coffee grounds as valuable biodiesel (23–25). Their studies found that the properties waste coffee biodiesel within the limit of ASTM standards. (26) examined the utilization of oil extracted from spent coffee ground for the production of polyhydroxyalkanoates (PHB). Moreover, owing to its substantial surface area, porous structure, and rich organic compound content, waste coffee grounds oil serves as an ideal medium for effective candle formulation (27). A few parameters affected the waste coffee solid liquid extraction such as the temperature, the nature of solvent, the extraction time and the feed ratio of solid liquid (28). This research focuses on extraction time of solid liquid extraction in order to obtain the optimal yield of coffee oil that meet the characteristic of its.

2.0 METHODOLOGY

2.1 Materials and equipment

Waste coffee obtained from local coffee shop. Solvent n-hexane 95% manufactured by Sigma Aldrich. The equipment used SOXHLET extractor.

2.2 Preparation of Waste Coffee for extraction

This process is obtained to remove moisture from waste coffee grounds. Firstly, the sample used will be collected at only one coffee shop. This is to prevent different types of coffee grounds from being used as sample and to prevent errors from occurring. Then, the collected waste coffee grounds will be subjected to drying in an oven at 105°C to eliminate moisture, which primarily ranged from 18% to 45% by weight. The formula for calculating the moisture content is presented in Eq. (2.1).

$$Moisture\ Content\ = \left(\frac{w - d}{w}\right) x\ 100 \tag{2.1}$$

Where:

w = Wet weight (g)

d = Weight after drying (g)

2.3 Extraction of Waste Coffee Oil

The oil is extracted using a Soxhlet process, and non polar solvent, hexane, a low-boiling solvent, is employed and subsequently recovered via a simple batch distillation process with a reflux condenser. The Soxhlet device is maintained at a temperature range of 65 – 70°C. Initially, 20g of the sample is weighed and placed into the extractor, with the sample enclosed in filter paper shaped like a cup. A condenser is affixed to the extractor and connected to a water tap. Following the process, the oil is separated from the organic solvent through a rotary vacuum evaporator, dried at 60°C, and its weight is determined. This entire setup is repeated, with variations in extraction times ranging from 2, 3, 4, 5, and 6 hours as indicated in Table 3. The yield is calculated based on the dry weight of the sample, expressed as a percentage by using Eq (2.2).

$$Oil\ yield\ = \frac{Mass_{\ oil}}{Mass_{\ WCG}} \times\ 100\% \tag{2.2}$$

Where:

Mass $_{oil}$ = Weight of extracted oil (g)

Mass $_{WCG}$ = Weight of waste coffee grounds (g)

Table 3 : Tabulated data for extraction

Time of Extraction (hr)	Mass Coffee Ground (g)	Volume of Solvent (ml)
0	60	250
2	60	250
3	60	250
4	60	250
5	60	250
6	60	250

2.4 Specific Density

The specific density, a crucial physical parameter, plays a vital role in assessing the quality and purity of oil. It is defined as the ratio of the weight of a given substance to the weight of an equal volume of water, both measured at the same temperature. The mathematical formula of specific density as shown in equation (2.3).

$$Spesific\ Density = \frac{Mass_{oil}}{Volume} \times 100\% \quad (2.3)$$

3.0 RESULTS AND DISCUSSION

3.1 Moisture Content

For all samples collected, the weight of coffee was measured for each day for 5 days. Then the moisture content was calculated using the equation 2.1 as indicated in Figure 2. It shows the highest moisture content at day 1 which is 33.6%. Overall, the moisture content is reduced and reach steady state value starting day 4 at 33.5%. This moisture content value is suitable for oil extraction using non polar solvent as stated in the previous literature (29).

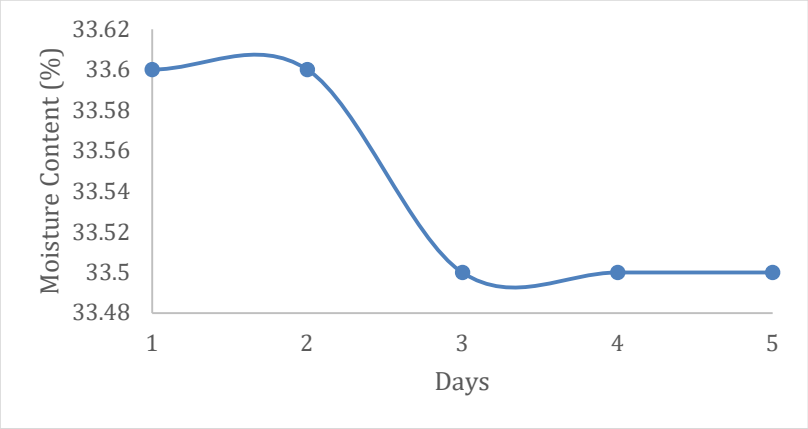

Figure 2 : The moisture content of coffee waste at different days

3.2 Oil Yield

This study examines the effects of extraction time using n hexane as solvent. Coffee oil extraction using non polar solvent hexane was tested for different extraction time range 2 hours to 6 hours. It was observed to increase with time but it was determined that prolonging the extraction time beyond 5 had no significant benefit. Notably, the most substantial oil yield, 11.97% was achieved after 5 hours extraction time. It clearly shown, 5 hours is optimum extraction time for coffee waste, whereas longer extraction time has less accessible surface area and fewer compounds to extract.

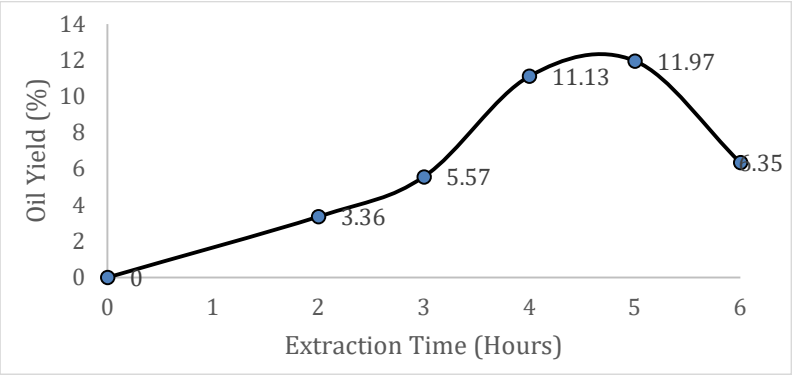

Figure 3 : The oil yield obtained for different extraction time

3.3 Specific Density

The specific density of coffee oil is typically expressed in grams per milliliter (g/ml). There are several factors affected the coffee oil specific density such type coffee bean used, the time and method extraction, and the level of refinement. The specific density value of extraction using hexane solvent for various time of extraction as shown in Figure 4.

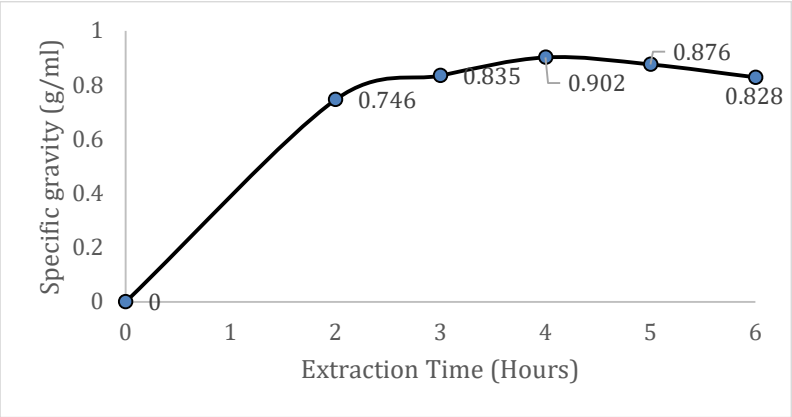

Figure 4 : The specific density for value for different extraction time

The specific density value ranged from 0.746 g/ml to 0.828 g/ml. It is observed the specific density value obtained increased with longer extraction time up to 4 hours, which is 0.902 g/ml. The longer extraction time onwards, the specific density value is decrease to 0.876 mg/L and 0.828mg/L. The optimum extraction time is 5 hours that yield specific density 0.876mg/L which is in good agreement with previous literature (30).

4.0 CONCLUSIONS

In conclusion, the investigation into the physicochemical properties of coffee oil, focusing on specific density, oil yield, and moisture content, has yielded significant insights into its qualitative and quantitative aspects. The specific density, a key indicator of purity and quality, underscores the intrinsic characteristics of coffee oil, distinguishing it from other vegetable oils and suggesting its suitability for various applications. The oil yield, quantitatively determined, reflects the efficiency of extraction methods and the potential economic viability of coffee oil production. Moisture content, a critical parameter for storage stability and quality preservation, further delineates the shelf life and usability of the oil. Collectively, these parameters not only facilitate a comprehensive understanding of coffee oil's physicochemical properties but also highlight its potential in industrial, nutritional, and pharmacological applications. Overall, this study suggests the optimum extraction time is 5 hours that produces highest oil yield, 11.97% with the characteristics oil coffee with specific density 0.876 g/mL.This study paves the way for future research aimed at optimizing extraction processes, enhancing oil quality, and expanding the application horizon of coffee oil in diverse sectors.

Author Contribution

Aidatul.A : Conceptualization, methodology, investigation, visualisation, writing and editing. Aniyyah.N.M.S: Investigation, supervision and editing. Author: Conceptualization, Supervision, Methodology, writing and editing. Norazlina.H : editing. Lili.S.H : editing

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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