Arabic coffee residue: Oil Content and Prospects for recycling in Kuwait

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Abstract:

Arabic coffee is a daily traditional drink in Kuwait and Arabian Peninsula countries. Scientific studies indicated the presence of oil in this coffee waste. The oil extracted from coffee has many health and industrial uses. This study evaluates Arabic coffee consumption in Kuwait through a survey and then studies oil extraction efficiency from the waste coffee ground. Results of the cross-sectional survey showed that most study participants consume Arabic coffee at least four times a week, and about half of the respondents were prompt to keep the waste for further treatment. Experimental extraction showed that the amount of oil isolated from plain coffee waste was higher when no additives were added. Cardamom and other coffee additives work as emulsifiers to enhance oil leaching in coffee preparation; in other words, less oil is left in the spent coffee grounds.

Keywords: Arabic Coffee, waste, Kuwait, Coffee oil

1. Introduction[1]

In the Middle East and Arabian Peninsula countries, Arabic coffee is traditionally named (*Gahwa);* it is commonly called the welcoming drink. Drinking *Gahwa* is a routine behavior in most Arab countries. It is a drink brewed from *Arabica* coffee beans and consumed heavily in the Arabian Gulf countries. The difference between Arabic coffee and other Western coffee is distinguished by its pre-cooking method. Pre-cooking is roasting and grinding the raw green beans. The roasting process affects the beans' physical and chemical properties; the water and caffeine content are affected, hence changing the flavor. Scientific evidence shows that the more coffee beans are roasted, the more the caffeine and water content decreases. The heating process does not induce significant changes in the composition of fatty acids and oil elements extracted (Van Cuong et al., 2014; Raba et al., 2018; Alqarni et al., 2018).

One distinguishing physical properties of Arabic coffee (*Gahwa*) is its color. The color changes with the level of roasting, starting from pale green to dark brown. This color difference is due to roasting, which takes place only briefly, keeping the content of caffeine and water high. Moreover,

[1] Part of this paper has been presented in the GCC 1st Engineering Symposium organized by Kuwait University on November 30-31 in Kuwait.

the grinding is usually coarse ground, meaning large gains similar to bread crumbs. In this level of grinning, hot water can only bind to the outside part of the grinds, and then it seeps from the outside to the inside gradually; therefore, a relatively long time of coffee extraction by boiling is needed. The coarse grinding has light extraction of the flavors and enables drinking more than one cup of this type of coffee, a way suitable for Arabic hospitability.

Coffee is a functional food due to its high quantity of compounds with antioxidant and other biologically beneficial properties (Alamri et al., 2022). Arabic coffee was listed as one of the "World Intangible Cultural Heritage" by UNESCO in 2015 and was heavily presented in the "World Cup 2022" held in Qatar. Arabic coffee has different flavors depending on the additives related to the geographical region. Main flavors include cardamom, cloves, saffron, and coffee whitener. Preparing *Gahwa* is easy and is done daily in most homes in the Arabian Gulf area; water is boiled, coffee grounds are added, boiled on low heat for some time, flavors are added, and finally, the mixture is simmered for a couple of minutes. The cooked coffee mixture must be filtered before serving in a unique pot called *Dallah* or any thermos flask. The serving cups are specially designed for this beverage with standard oval or round cups with a capacity of around 30 ml each. Arabic coffee is served with dates to add a sugary taste to the bitter coffee drink. Figure 1 shows a typical Arabic coffee set.

Figure 1: Arabic coffee set, Dallah, cubes, and dates.

Commercial nutrition studies state that a small cup of brewed coffee is almost free of any calories or fat (Zelman, 2021); however, other scientific chemical studies indicate a percent of oil that appears in the drinkable coffee and its waste (see for example, Speer & Kölling -Speer, 2006; Raba et al.2018 و). Lipids, considered coffee oil, were detected in significant amounts in coffee, ranging from 0.2% in household coffee to 2% in espresso (Speer & Kölling-Speer, 2006). The lipid fraction of coffee is composed mainly of triacylglycerols, sterols, and tocopherols. Arabic coffee has an average content of moisture, crude proteins, total lipids, carbohydrates, and ash of

around 6.99, 10.95, 6.13, 22.12, and 4.16%, respectively (Alamri et al., 2022 and Nogain & Gowri, 2013).

The thermo-oxidative stability of oil extracted from *Arabica* green beans has been proven to be high up to 270 °C (Raba et al., 2018). Therefore, any heat treatment of the beans during the preparation stage is not expected to change the properties of the lipid fraction. This stability will encourage many industrial applications and usage of this oil after its extraction. Oil extracted from coffee has many health and industrial uses. Health benefits include, among others, antioxidants (Nosari et al., 2015) and pharmaceuticals (Al-Asmari et al., 2020). Some industrial uses are an antifoaming agent (Ishwarya & Nisha, 2021) and biodiesel manufacturing (Thoppil & Zein, 2021).

Coffee oil exists in a significant amount in its waste. Spent coffee ground (SCG) is currently considered a waste; however, it can be converted into more valuable products. In literature, the oil content of SCG ranges from 11 to 20% (Passadis et al., 2020); however, the extracted amount can be much lower according to the extraction method and gain size. The vast consumption of Arabic coffee in the Arabian Gulf countries can encourage oil extraction from coffee waste on a large scale. The first part of the work will present a survey study on Arabic coffee consumption in Kuwait and the preliminary potential of recycling its waste by identifying the public's desire. The second part will explore the oil content of SCG experimentally.

2. Uses of Spent Coffee Waste

Waste generated from food is increasing worldwide, even in underdeveloped countries. Recycling and valorization of this waste is a must now. Consequently, there is an urgent need for practical and innovative ideas for using SCG and its valuable products, thus increasing sustainability for this small household waste and the large-scale coffee industry. Valuable products from SCG are enormous since the composition of SCG is very complex; Leow et al. (2021) listed 24 chemical substances in the oil extracted from this type of waste. Studies on coffee waste and Arabic coffee are diverse, and the literature reported in ScienceDirect has increased significantly between 2000 and 2021, as shown in Figure 2, indicating a good potential for coffee waste in different industrial and medical areas.

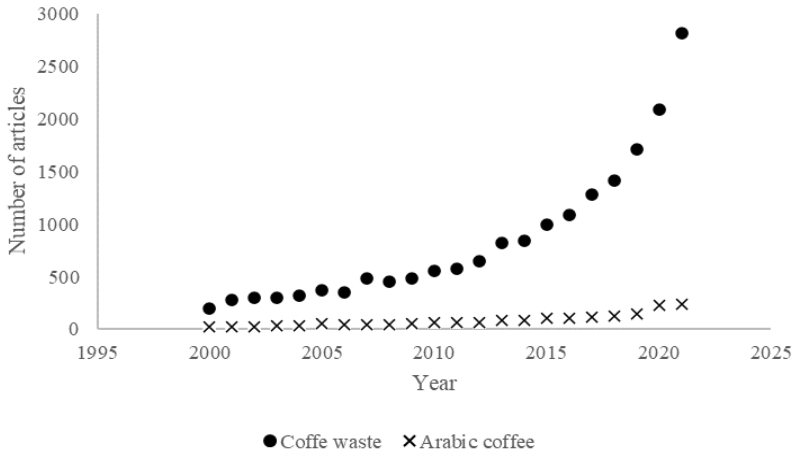


Figure 2: Number of articles about coffee waste reported in ScienceDirect

Many opportunities exist to extract valuable products from SCG waste material instead of burying them in landfills. The opportunities can be as simple as exfoliating beauty material to remove heavy metals and dyes from aqueous solutions (Tokimoto et al., 2005). Other applications include utilization in animal feed (Givens & Barber, 1986), production of organic compost or as fertilizer (Kasongo et al., 2011), solid fuel (Yulin Hu et al., 2022), feedstock for activated carbon production (Alves et al., 2019), bioethanol production (Choi et al., 2012 & Passadis et al., 2020), and as a biomaterial in the pharmaceutical industry, in the food industry and in the furniture industry (Leow et al., 2021). For the beauty industry, the high lipid fraction of coffee oil can enhance the skin lipids and enhance hydration together with the oil being antioxidant, anti-inflammatory, antimicrobial, antiviral, anti-aging, anti-cancer, anti-cellulite, and sunscreen (Santos et al., 2021).

SCG contains a vital substance, caffeine, which is in high demand worldwide for memory, mood enhancement, and headache relief. The caffeine content in coffee oil can reach up to 6.37%, depending on the extraction solvent (Leow et al., 2023). Moreover, SCG is attractive as an energy source because of its high calorific value of around 22.3 MJ/kg, similar to coal and wastepaper (Głowacki et al., 2020). Experimental methods for oil extraction are diverse; the Soxhlet extractor is the traditional method; however, it has some disadvantages, such as the extensive usage of organic flammable solvents and long preparation and extraction time. Therefore, other methods were developed, such as supercritical carbon dioxide (high pressure and temperature) and ultrasound-assisted extraction. Ultrasound-assisted extraction is assisted by ultrasound waves, and this has proved to increase oil yield with less time and under lower temperatures. Rocha et al. (2014) applied ultrasound-assisted extraction on SCG to extract the oil for further conversion to biodiesel and ethanol; the yield was 12% with a composition rich in palmitic and linoleic acids. One industrial application of coffee oil extraction is currently being applied in *Bio-Bean*, a recycling waste company based in London. Founded in 2013, *Bio-bean* has committed to delivering a local renewable heat alternative through coffee-derived biofuels and biomass pellets. To date, neither the biofuel nor the biomass pellet is on the market, and they have yet to publish a patent on their extraction process.

3. Consumption of Arabic Coffee in Kuwait

Arabic coffee is served daily in Arabic communities; some studies indicate that people tend to consume 1-2 cups every day (El Shabrawy & Felimban, 1993), while others consume a total of half a cup of Arabic coffee every day (Jalloun & Alhathlool, 2020). To the authors' knowledge, most studies on the consumption of Arabic coffee present its health effects (see Jalloun & Alhathlool, 2020; Albar et al., 2021), and no studies were done on this particular type of coffee waste. A cross-sectional study was conducted in Kuwait between August and September 2021 to understand Arabic coffee consumption; 508 persons responded to a questionnaire. The number of respondents included in this study was considered a representative sample of Kuwait's population. The questionnaire was designed, distributed, and collected through Google Forms. It consisted of questions on demographics and personal perspectives about drinking and waste treatment of Arabic coffee in Kuwait. Data were analyzed to obtain descriptive statistics that can assist in future plants for Arabic coffee waste collections.

The participants were randomly selected, and the age average was 40.43 (St.d 13.56). Participants were stratified according to gender, residential area, and nationality. Gender was defined as male/female, and residential areas were defined as the six governorates in Kuwait. Knowing the residential area is vital since some governorates are heavily populated with a sizeable social-cultural category called *Bedouin*, having the origin of nomadic tribes. These Kuwaiti *Bedouins* consume Arabic coffee much more than Kuwaitis of other origins. For nationality, it was sufficient to consider either Kuwaiti or non-Kuwaiti (expatriates). The demographic data is shown in Table 1 below.

Table 1: Demographic data from the cross-sectional study

	Mean	**Standard Deviation**
Age (years)	40.431	13.558
Gender	**Frequency**	**Percent**
Female	340.000	66.929
Male	168.000	33.071
Governorate	**Frequency**	**Percent**
Al-Aasma	224.000	44.094
AlAhmedi	47.000	9.252
AlJahra	25.000	4.921
AlFarwaniya	52.000	10.236
Hawalli	97.000	19.094
Mubarak AlKabeer	63.000	12.402
Nationality	**Frequency**	**Percent**
Kuwaiti	469.000	92.323
Non-Kuwaiti	39.000	7.677

Although expatriates account for about 70% of Kuwait's 4.3 million population (World Population Review, 2022), most participants were Kuwaitis, forming 92.3% of responders; they were more encouraged to participate in the survey due to their daily usage and/or familiarization of the Arabic coffee. Non-Kuwaitis are mainly from Asia and Africa (Indians and Egyptians); they have other daily drinks, such as American or Turkish coffee. Moreover, most participants (44%) are from Al-Asimah (The capital) governorate since it has the highest Kuwaiti to expatriates ratio.

On average, the weekly rate of household/family consumption of Arabic coffee is 492 g consumed more than four times a week. If the average family in Kuwait has 5.7 members (ArcGSI, 2022), then the individual annual consumption is around 4.5 kg. This number is slightly higher than other coffee consumption studies (see, for example, Allafi et al., 2020) because this number represents the Arabic coffee prepared at home in a special thermos for the consumption of family members and guests. Usually, it is only partially consumed. We care more about this number than the actual coffee intake due to its relation to coffee waste.

The coffee is homemade by 91% of the respondents due to its close relation to traditional hospitality and daily lifestyle. Unfortunately, most responders threw coffee waste disposal in the regular trash, with an alarming percentage of 84.05%. The other percent needs to learn the disposal procedure because other people, including other family members or workers at coffee shops, prepare Arabic coffee and dispose of the residue. More than half of the participants (58%) are

willing to collect and deliver the Arabic coffee residue without any financial return. The other 42% had a different vision about the residue; 20% were willing to collect the residue but not to deliver it, and 15% had yet to decide on the collection and delivery of the residue; it is a new concept for them. Only 7% refused the whole idea and will not make any effort. Figure 3 shows these numbers.

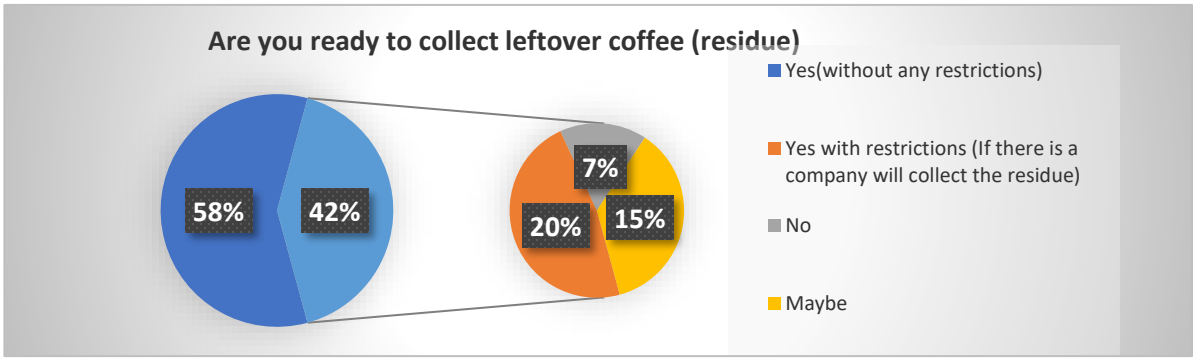


Figure 3: Association between respondents' demographic data and Arabic coffee waste collection.

4. Experimental Methodology

This experimental part is based on recovering coffee oil from different SCG; therefore, different types of SCG were collected after brewing different Arabic coffee samples; the difference comes from the additives. Most Arabic coffee is usually prepared at home with additives like cardamom, and some come in commercial packages with more additives. Although instant Arabic coffee exists, it has limited consumption, and its production plants exist outside Kuwait. Therefore, collection facilities should be set up within residential areas to collect spent coffee grounds if a plant is to be set for oil extraction. Currently, samples of SCG are being provided for free. However, in the case of industrial recoveries, the cost of SCG should be considered for transportation and storage under a controlled environment since it is a wet material susceptible to mold formation.

Samples used in this study are three types of SCG taken from three types of coffee:

- Pure Arabic coffee (PAC)
- Arabic coffee with cardamom only (ACC)
- Commercial Arabic coffee with a mix of flavoring additives (COM)

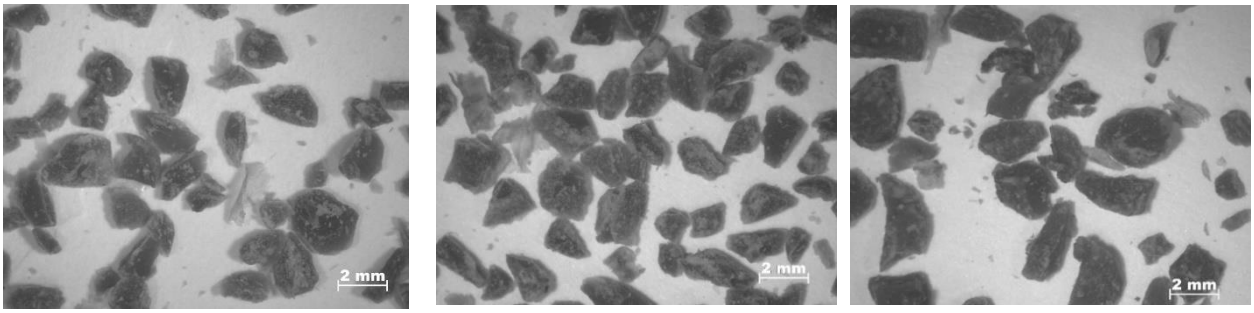
The first sample is pure Arabic coffee without additives, which is rarely used for consumption. However, it is considered a reference for the other two samples. The second type is the most consumed since cardamom is the most added spice. The third type is commercial coffee, which is becoming popular among young coffee consumers. This commercial coffee has different additives of spices and taste posters, mainly cloves, saffron, flavors, and coffee whitener.

The coffee sample is first brewed at different times, which is typical for Arabic coffee in the Arabian Peninsula. The SCG is collected, then dried, and then oil is extracted using n-hexane as a solvent. The steps are explained below:

1- Three types of Arabic coffee are weighed and then brewed in water for two different cooking times, 15 and 25 minutes.
2- The coffee is drained, and SCG is collected and weighed.
3- The SCG was kept in an oven for drying at 105°C for 24 hours, followed by cooling in a glass container over silica gel.
4- The dried SCG is photographed under the microscope to observe grain size and shape differences.
5- 10 g of the dried SCG sample was placed in a round bottom flask of the Soxhlet apparatus and extracted for 1.5 hr using 250 mL n-hexane since it gives maximum oil extraction (Passadis et al., 2020).
6- The extraction process was repeated three times, and all the outlets from the extraction were collected in one container.
7- The oil is separated from the solvent by distillation in a rotary evaporator.

5. Results

The first part of the results is the SCG images; the microscope images of coffee are attractive and give us important information about coffee grains. A Zeiss Stemi 2000-C ® microscope was used to take the images of the three samples. The images are shown in Figures 4-a to 4-c below, with a scale bar added.



(a) *(b)* *(c)*

Figure 4: Microscopic image of spent Arabic coffee (a) plain (b) with cardamom (c) commercial

To estimate particle size, the Fiji software was used on the images; this software automatically sizes and counts particles. The size average from images was 2.2, 2.3, and 3 mm for PAC, ACC, and COM, respectively. This size represents extra-coarse gride size, which has the consistency of breadcrumbs. Extra coarse coffee grounds take a long time to release their flavor, which justifies the slow brewing methods and relatively long processing time. Other than size, the three types of Arabic coffee differ in color; the more additives, the darker the color. Typical additives that have a significant effect on color are saffron and cloves.

Every gram of Arabic coffee results in around 3 grams of SCG due to saturation with water; this water content is slightly lower than that of other coffee waste with smaller grain sizes.

Głowack et al. (2020) reported a range of 4.4 to 3.9 for finely ground coffee for mocha coffee. Assuming that half of the Kuwaiti families consume Arabic coffee at 492 g a week, more than 2,800 tonnes of wet SCG waste are generated yearly. This massive amount of waste is currently buried in municipal landfills, producing methane, carbon dioxide, and other organic compounds, i.e., more air pollution.

Oil extraction results are listed in Table 2, with the type of Arabic coffee in the first column, the cooking time in the second column, and the mass percent of oil recovered relative to the dried SCG. Results show that increasing cooking time will reduce the oil content in the SCG; in other words, it increases the oil content of coffee and enhances the flavor. Moreover, it is observed that coffee additives indirectly enhance the flavor by transferring the coffee oil into the liquid. The higher oil content of plain coffee (PC) waste than the other two with additives (ACC and COM) was interesting; therefore, we could suggest that the additives catalyze oil leaching from the SCG to the liquid coffee. Cardamom acts like an emulsifier (helps oil and water to blend); this was revealed in other studies. Jafarizadeh-Malmiri et al. (2022) studied a composite nano-emulsion consisting of ginger, cinnamon, and cardamom essential oil, which proved effective. Durak et al. (2017) considered cardamom a *functional coffee additiv*e with observed synergistic interactions affecting flavor and biological activities. More emulsifiers can be found in the coffee whitener, which some people like to add while brewing coffee. This whitener has some mono and triglycerides that are considered emulsifiers.

Table 2: Results of oil extraction from spent coffee ground

Sample	Cooking time	% oil recovered
Plain Arabic coffee	15 min	4.91
	25 min	3.49
Arabic coffee with cardamom	15 min	3.44
	25 min	3.33
Commercial Arabic coffee	15 min	3.22
	25 min	3.05

It was found that the percentage of oil recovered is less than in other studies; Passadis et al. (2020) reported 12.89% after 4 hours of extraction, Al-Hamamre et al. (2012) reported 15.28% after 30 min hexane extraction, and Leow et al. (2021) reported 10% after 24 hours extraction. This lower oil recovery can be attributed to the relatively high brewing time and the large grain size of the Arabic coffee; however, the oil content is still significant.

6. Conclusion & recommendation

Results of this work have shown that spent coffee ground from Arabic coffee is a valuable source of coffee oil that is highly affected by coffee additives. The oil has a lot of commercial uses, and if the spent coffee ground is collected efficiently, the oil leaching process would have an economic potential. Overall, there is a potential social driving force for the collection of Arabic coffee residue in the state of Kuwait, and this will probably increase if the following can be done:

- Providing refrigerated collecting machines near the well-known supermarket.

- Promoting cosmetic and food products containing coffee oil.
- Encouraging people and coffee shops to deliver their SCG.

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