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RESEARCH ARTICLE **PHYTOCHEMISTRY**

Comparative Analysis of Phenolic Compounds in Coffee Prepared by American and Arabic Brewing Methods

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ABSTRACT

Coffee's high antioxidant ability is attributed to its abundance of minerals and bioactive substances including caffeic acid, chlorogenic acid, and other phenolic compounds. Phenolic molecules with high nutritional value, are decomposed by the high temperatures that coffee beans are exposed to in order to produce volatile aromatic chemicals, the concentration of this active compounds are affected by the type of preparation method. The aim of this study was comparing the difference between Arabic and American coffee preparing methods in term of phenolic compounds quantity among different twelve coffee brands collected from Libyan market. Folin–Ciocalteu assay was used in quantification of phenolic compounds in all samples. The results of this study show that the preparing method have significant role in determining the phenolic content of coffee. The Arabic preparation method, which involves boiling the water with coffee, resulted in a significant reduction in Total Phenolic Compounds (TPC) compared to the American method for all samples. On average, the TPC of the all coffee samples with two different preparation methods arranged between 225.545 to 508.096 mg GAE /L. Generally, the findings show that the American preparing method is more effective in producing phenolic compounds, although the degree of this effect differs among coffee brands.

دراسة مقارنة للمركبات الفينولية في القهوة المحضرة بالطريقة العربية والأمريكية

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الكلمات المفتاحية
القهوة
المركبات الفينولية
فولين-سيوالتو
حمض الغاليك
طرق التحضير

الملخص

تُعزى الخصائص المضادة للأكسدة والتاثيرات العلاجية للقهوة إلى وفرة المعادن والمواد النشطة بيولوجيًا، بما في ذلك حمض الكافيين وحمض الكلوروجينيك ومركبات فينولية أخرى. تتحلل هذه المركبات الفينولية ذات القيمة الغذائية العالية بفعل درجات الحرارة المرتفعة التي تتعرض لها حبوب البن، مُنتجةً مواد كيميائية عطرية متطايرة، ويتأثر تركيز هذه المركبات النشطة بطريقة التحضير. هدفت هذه الدراسة إلى مقارنة الفرق بين طريقتي تحضير القهوة العربية والأمريكية من حيث كمية المركبات الفينولية في اثنتي عشرة علامة تجارية مختلفة من القهوة جُمعت من السوق الليبية. استُخدم اختبار فولين لتحديد كمية المركبات الفينولية في جميع العينات. تُظهر نتائج هذه الدراسة أن لطريقة التحضير دورًا هامًا في تحديد محتوى القهوة من المركبات الفينولية. أدت طريقة التحضير العربية، التي تتضمن غلي الماء مع القهوة، إلى انخفاض ملحوظ في إجمالي المركبات الفينولية مقارنةً بالطريقة الأمريكية في جميع العينات. في المتوسط، تراوحت نسبة المركبات الفينولية الكلية في جميع عينات القهوة المحضرة بطريقتين مختلفتين بين 225.545 و 508.096 ملغ مكافئ حمض الغاليك/لتر. وبشكل عام، تُظهر النتائج أن طريقة التحضير الأمريكية أكثر فعالية في إنتاج المركبات الفينولية، على الرغم من اختلاف درجة هذا التأثير بين أنواع القهوة المختلفة..

Introduction

Since coffee is the most important product, it is likely the most commercially significant agricultural crop and the most consumed beverage worldwide [1]. Recent studies have linked regular coffee drinkers to a lower chance of developing chronic illnesses, such as cancer. Numerous potential health effects were linked to coffee drinking because of their anti-inflammatory and chemopreventive effects. The shrinkage of inflammation as result of administration of coffee was suggested as result of the antioxidative properties of specific ingredients of coffee [2]. Moreover, recent studies suggests that consumption of coffee is associated with a minimization of the risk for kidney, liver, breast and colorectal cancers, to a minor extent, whereas, it is unrelated to pancreas, prostate and ovary cancers [3]. Caffeine is the main ingredient in coffee and is considered a strong stimulant of the central nervous system and mood elevator; its use is linked to hepatoprotective benefits and a lower risk of developing Alzheimer's and Parkinson's diseases [4, 5].

The phenolic acids, particularly chlorogenic acid (CGA), are gaining significant interest due to their anti-inflammatory and antioxidant effects. Chlorogenic acid (CGA), prevalent in foods like coffee and tea, is known for its strong antioxidant

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properties. Caffeoyl quinic acid (CQA) is an important polyphenol in coffee because it makes up a large part of the polyphenolic content of coffee. Coffee beans contain about 10 g/100 g of CGA, while 3-CQA is frequently the most prevalent variant in different plant sources. The term CGA encompasses a range of hydroxyl cinnamic esters and their isomeric forms. The diversity of CGA types helps coffee extracts achieve their complex functionality [6, 7]. In addition, coffee's high antioxidant ability is also attributed to its abundance of minerals and bioactive substances [8], including caffeic acid, chlorogenic acid, and other phenolic compounds [9, 10]. The scientific term for coffee is *Coffea*, which is a member of the Rubiaceae family. It native to tropical and southern Africa as well as tropical Asia, these plants categorized as shrubs or small trees. Coffee's high caffeine content is well-known and has had a significant role in its appeal on a global scale. [11]. As the extent of roasting rises, coffee beverages' total phenolic and flavonoid content and antioxidant activity decrease [12]. Similarly, coffee roasting temperatures can change the caffeine level of beverages, even though caffeine has a high melting point [13]. As a result, antioxidant molecules with high nutritional value are decomposed by the high temperatures that coffee beans are exposed to in order to produce volatile aromatic chemicals [14]. Antioxidant activity of coffee beverages is meaningfully decreased by degradation of these molecules, and because of their excessive heat stability, a proportional rise in caffeine levels can be seen [15]. Economically , Coffee is exceptionally important product, it providing substantial income for producing countries, it is a vital source of economic activity in underdeveloped countries because of its worldwide supply chain, which sustains jobs from cultivation to export [16,17]. .Even with the prevalent consumption of coffee in Libya, there is limited research on the phenolic content of commercially available coffee brands and the effect of different preparation techniques on these compounds. This study aims to quantify the phenolic content of coffee samples that were collected from the Libyan market and evaluate the impact of the type of preparation methods on the quantity of these bioactive compounds. By answering questions about the variability of phenolic content and the effects of preparation techniques, this research seeks to improve coffee consumption for enhanced health benefits.

Methodology

Sample Collection

A comparative analysis was conducted using Twelve widely consumed brands of coffee were purchased from supermarkets in Tripoli, Libya. The brands were chosen to represent a variety of commercially existing products. Samples names were as in Table (1).

Preparation Methods

To evaluate the impact of the type of preparation method, two preparation techniques were compared:

Arabic coffee Method (Decoction method): 10 g of each coffee sample was added to 170 mL of cold distilled water. The mixture was boiled for 10 minutes. Following a 1-minute cooling, the beverage was decanted to isolate the liquid for analysis.

Table 1: samples brand names

Sample no	Sample brand
Sample 1	Kaiser
Sample 2	Isam
Sample 3	Alkalel.
Sample 4	Alkalej.
Sample 5	Dubai.
Sample 6	Alalem.
Sample 7	Hatem.
Sample 8	Aljondi.
Sample 9	Albraa.
Sample 10	Alemn.
Sample 11	Alamed.
Sample 12	Balla.

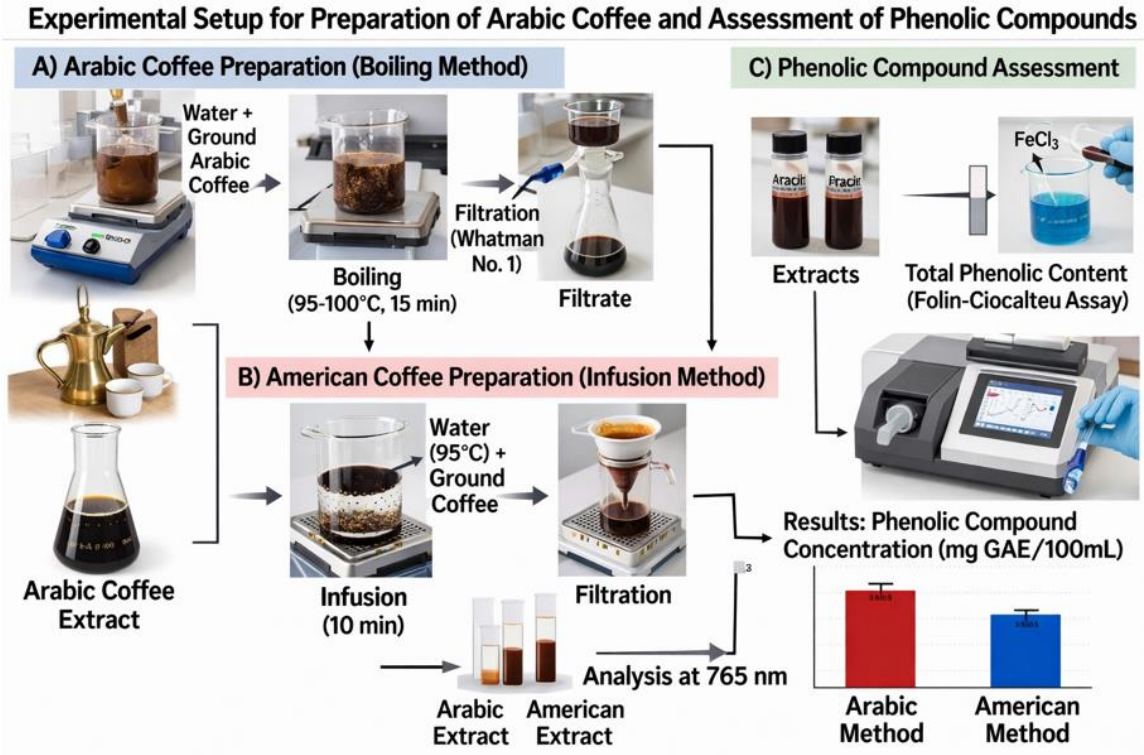

Figure 1: Experimental procedure workflow

American Method (Infusion method): Quantity of 10 grams of each coffee sample was introduced into 170mL aliquot of boiled distilled water, the total water-contact duration, was consistently maintained at approximately 10minutes. Following filtration, the resulting clear filtrate was collected directly for following analytical procedures [18].

Quantification of Phenolic Compounds

Assay Procedure

The total phenolic content (TPC) of the coffee samples were determined using the Folin–Ciocalteu method [19]. In test tubes, 0.5 mL of the coffee sample was mixed with 2.5 mL of 10% (v/v) Folin-Ciocalteu reagent. Then, after 5 minutes at room temperature, 2.0 mL of 20% (w/v) sodium carbonate (Na_2CO_3) solution was added. The tubes were vortexed and incubated in the dark at room temperature for 60 minutes. The absorbance of the resulting blue complex was measured at 725 nm using a UV-Vis spectrophotometer against a reagent blank

Calibration Curve

A standard curve was prepared using gallic acid (concentration range: 10–50 µg/mL). Results were stated as milligrams of Gallic Acid Equivalents per liter of coffee brew (mg GAE/L). All measurements were performed in triplicate.

Results

All samples were subjected to Folin-Ciocalteu assay for determination of phenolic compounds among two preparations methods. Significant variability in TPC was observed among the twelve brands.

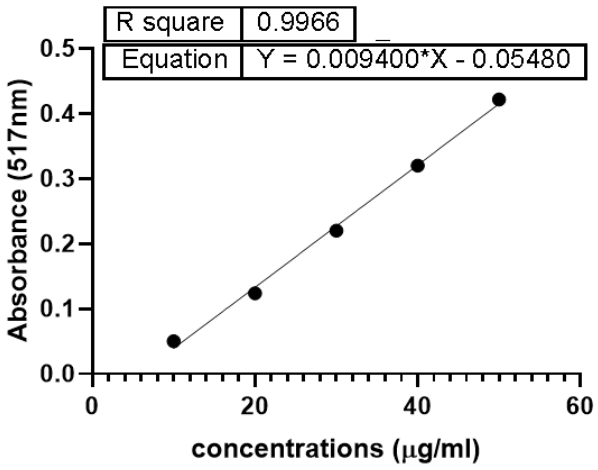

Figure 2: Different concentrations of Gallic acid

Galic acid calibration curve

The calibration curve showed a high linearity with an R^2 value of 0.9966, (Figure 2) showing good correlation between Gallic acid concentration and absorbance. Gallic acid used as a standard to quantify the total phenolic compounds in the coffee samples. Different concentration of Gallic acid (10 -50µg/ml) with Folin working reagent**.**

Quantification of phenolic compounds in coffee brands

This data displayed in Table 2 and Figure 3 compares phenolic quantity in several coffee brands measured by American and Arabic methods, revealing significantly higher values with the American method across all sample The Arabic preparation method, which involves boiling coffee with water, consistently led to lower total phenolic content (TPC) in all samples compared to the American method. Across all coffee brands, these procedures resulted in a significant reduction in TPC compared to the American method for all samples. TPC values for both Arabic and American preparation methods for all coffee brands ranged from 225.5 ± 1.1 to 508.1 ± 0.19 mg GAE/L. For the Arabic method the lowest TPC was observed in brand Albraa (225.545 ±1.1 mg GAE/L) while higher TPC observed in the brand Dubai (370.4 ±0.19 mg GAE/L). While the American method produced a higher value of 508.1 ± 0.19 mg GAE/L for the Isam brand and lowest value of 293.2 ±0.29 for Alalem brand as a presented in Table2 Figure 3. This pattern was observed consistently across other brands of coffee. These results show that coffees phenolic compound quantification is significantly impacted by the preparation technique.

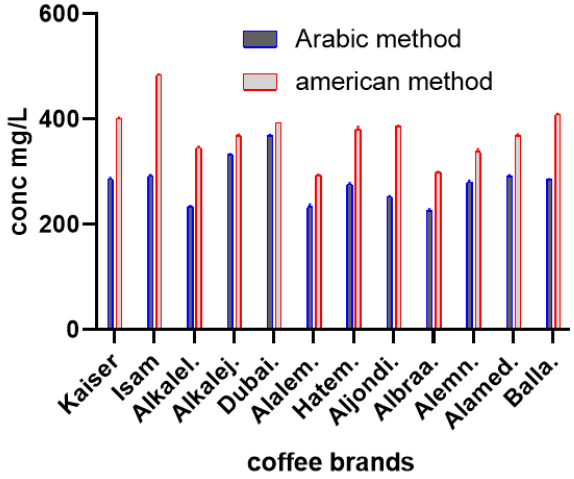

Figure 3: Phenolic content of different coffee samples with different preparation methods, TPC values differed significantly between preparation methods, The data points represent the mean with± SD from three independent experiments (n=3, P-value < 0.05)

Table 2: Phenolic content of different coffee samples with different preparation methods

Sample name	Phenolic content mg GAE/L (*Arabic method)*	Phenolic content mg GAE/L (American method)
Kaiser	286.810 ±0.19	401.616 ±0.11
Isam	293.336 ±0.94	508.096 ±0.19
Alkalel.	235.619 ±0.11	346.409 ±0.12
Alkalej.	336.544 ±0.10	367.413 ±0.20
Dubai.	370.439 ±0.19	392.796 ±1.01
Alalem.	236.252 ±0.99	293.233 ±0.29
Hatem.	279.334 ±0.11	380.993 ±0.40
Aljondi.	252.725 ±0.10	386.577 ±0.29
Albraa.	225.545 ±1.1	299.817 ±0.11
Alemn.	281.298 ±0.19	337.081 ±0.48
Alamed.	290.104 ±1.04	365.510 ±0,20
Balla.	285.099 ±1.9	411.769 ±0.99

Discussion

Phenolic compounds such as chlorogenic acids (CGA) and associated compounds are considered the main constituents of the phenolic fraction of green coffee beans, reaching levels up to 14% (dry matter basis) [20]. These compounds have a number of valuable health effects attributed to their effective antioxidant activity as well as hypoglycemic, hepatoprotective, and antiviral activities. Caffeoylquinic acids, dicaffeoylquinic acids, p-coumaroylquinic acids, feruloylquinic acids, and mixed diesters of caffeic and ferulic acids with quinic acid are the main groups of CGA found in green coffee beans [21]. Phenolic compounds and CGA may be hydrolyzed or degraded into low molecular weight compounds through processing of coffee [22]. While coffee is known for its stimulating properties due to containing caffeine, it also contains other bioactive compounds, which are phenolic compounds, with chlorogenic acids being the most abundant [23]. The main aim of this study was the quantification of phenolic compounds among twelve commercial coffee brands that were collected from the Libyan market and the study of the effect of preparation method on the quantity of phenolic compounds in the coffee samples.

The finding of this comparative study (Table 2 and Figure 3) shows a considerable difference in phenolic compound quantities between the twelve commercial coffee brands that were prepared by American and Arabic methods. The American method constantly yielded higher phenolic concentrations, with increases ranging from 9.17% to 73.21%. These findings suggest that the American method generally serves as a more efficacious technique for the extraction of phenolic compounds from the coffee matrix. This conclusion is supported by previous research; notably, a study by Costa et al. (2017) comparing American (filter), Turkish, and espresso preparations also reported a significantly larger total phenolic content in American-style filtered coffee. The extent of these methodological differences is particularly notable in brands such as Isam and Kaiser Brands, where the American method detected around 40-65% more phenolic. These outcomes raise important queries about adjustment in phenolic compound quantification and focus on the possible consequences for quality assessment and comparative nutritional studies. Several technical factors could be responsible for these observed variations in phenolics among all the different samples. Extraction effectiveness is the main reason, as in the American method, more severe extraction environments (e.g., temperature, longer duration, or improved solvent systems) might improve phenolic compound release from the sample matrix [24]. This is mainly related to bound phenolic formulas, which need hydrolytic conditions for quantification. In addition, this variance can be attributed to intrinsic product features such as roast degree, particle size (grind) profile, geographical origin, and blend composition [25], all of which interact with extraction procedures. Nevertheless, the absolute phenolic concentrations measured in this study, which range in the hundreds of mg GAE/L, remain consistent with values reported in the broader literature for brewed coffee [26]. Additionally, another important factor that could have a considerable effect is the spectrophotometric interference; the variances in the chromogenic reaction (likely Folin-Ciocalteu based on typical phenolic assays) can result from variations in reagent preparation, temperature control, reaction time, or wavelength selection. The Arabic method might be affected by interference from other components like reducing sugars, ascorbic acid, or other non-phenolic reducing agents. Determination of phenolic content through different coffee brands and preparation methods showed important differences, emphasizing the critical impact of brewing technique on the extraction of these bioactive compounds. As calculated by the Folin-Ciocalteu assay, the results reveal that the ideal method for phenolic extraction is not general but appears to be dependent upon the specific coffee product. When prepared using the traditional Arabic method, which is characterized by long boiling, Brand Dubai yielded the maximum phenolic concentration (370.439) mg of Gallic Acid Equivalents per liter). In contrast, preparation by the American method (a standardized drip technique) produced a noticeably different result. For the American method, Brand Isam displayed the maximum phenolic content, reaching 508.096 mg GAE/L. The health impact of this study is that it presents valuable dietary information for coffee consumers: they should select the American preparation technique, as this method better preserves these valuable compounds that have antioxidant and neuroprotective benefits. Moreover, this research recommends educating consumers to alter the traditional Arabic/Turkish method (boiling coffee in water), which has lower phenolic content, to the American method, which preserves the high content of phenolic components.

Conclusion

The results of this study show that the preparing method have significant role in determining the phenolic content of coffee. Among all assessed coffee brands, the American preparation method produced higher concentrations of phenolic compounds compared with the traditional Arabic method. These differences suggest that extraction effectiveness is powerfully affected by methodological factors such as extraction time, water temperature, and brewing mechanics. Generally, the findings show that the American preparing method is more effective in producing phenolic compounds, although the degree of this effect differs among coffee brands. Such inconsistency is likely attributable to different factors such as roast degree, inherent variances in bean components, and grind features. The study highlights the importance of preparation methods in shaping the chemical composition and potential antioxidant capacity of coffee beverages.

Future work

Future research should focused on linking preparing parameters to individual health requirements and genetic profiles. This involves moving from *in vitro* antioxidant quantification to in-depth metabolomics and human bioavailability studies that display how different preparation methods influence on the absorption and physiological impact of coffee's bioactive compounds.

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