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IMPACT OF DIFFERENT ROASTING TEMPERATURES ON THE CHEMICAL COMPOSITION, CAFFEINE CONTENT, ACRYLAMIDE CONTENT, PHENOLIC CONTENT, AND ANTIOXIDANT POTENTIAL OF ROBUSTA COFFEE

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ABSTRACT: The chemical composition, caffeine content, acrylamide content, phenolic content, antioxidant potential, browning index, and volatile compound separation using GC–MS were investigated in this study for the three most popular roasting temperatures of Robusta coffee: light (210 ºC; 20 min), medium (230 ºC; 20 min), and dark (240 ºC; 20 min). Light-roasted coffee scored the highest in moisture content and crude protein and the lowest in ether extract and crude fibre, all of which were significant ($p < 0.05$). With the exception of quercetin, the roasting procedure—specifically, dark roasting—has decreased the levels of kaempferol, caffeine, trigonelline, and hydroxymethylfurfural in both green and roasted coffee samples. Acrylamide levels were lowest in medium-roasted coffee (0.44 mg/100 g) and highest in light-roasted coffee (0.55 mg/100 g). The browning index rises with rising roasting temperature. Light-roasted coffee showed the highest free total phenolic content, the lowest DPPH activity, and the lowest levels of condensed tannins and flavonoid compounds. 126 volatile compounds were discovered and semi-quantified in the dark-roasted coffee using GC-MS. All things considered, this study showed that although rigorous roasting would reduce the quantity of phenolic compounds in coffee beans, it would maintain or even boost their antioxidant capacity. Commercial light-roasted coffee beans have relatively better nutritional value. Our findings may help resolve past disputes and provide useful proof for coffee production in the food sector..

Key words: Coffea Robusta, GC-MS, antioxidants, flavonoids, roasting, nutritional value.

INTRODCTION

Coffee has become one of the most popular drinks in the globe due to its extraordinary rise in consumption in recent years(**Acquaticci et al., 2023; Klaidaeng et al., 2023**). When it comes to caffeinated preferences, the *Coffeaarabica* variety is most prevalent and is known to give the beverage exceptional quality attributes. Unlike the Coffeacanephora species, coffee produced from *C. arabica* beans is valued for its smooth flavour and sophisticated sensory qualities. But in the marketplace, this culinary brilliance frequently results in a higher price tag(**Chindapam et al., 2019; Hall et al., 2022; Poisson et al., 2017**).Additionally, the world of coffee is full of subtleties that include a wide range of kinds, depending on factors like variety selection, processing methods, roasting levels, brewing methods, and even the adding of complementary components(**Poltronieri& Rossi, 2016; Mehaya& Mohammad, 2020; Pereira et al., 2021; Worku et al., 2023**).

Through physicochemical and structural changes in the food matrix, roasting and other thermal processes are crucial for increasing the bioavailability of constituents and educating the digestibility and palatability of food

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products(**Baggenstoss et al., 2008; Sruthi et al., 2021: Cortés-Macías et al., 2023**).Notably, coffee properties including antioxidant activity and phenolic component content are largely determined by the degree of roasting(**Freitas et al., 2023**).Nonetheless, there is still disagreement on how roasting affects the bioactive substances in coffee. According to some research, phenolic components may be depleted by high roasting temperatures, which would lower the antioxidant activity of the beverage. Conversely, because some phenolic compounds are heat-resistant and because roasting produces new non-phenolic chemicals, milder roasting tends to maintain antioxidant activity(**Van der Werf et al., 2014; Mehaya& Mohammad, 2020; Wu et al., 2022: Freitas et al., 2023)**.

Phenolic chemicals, particularly chlorogenic acids, which are more prevalent in unroasted coffee beans, are intimately linked to the inherent bioactivity of coffee (**Pimpley et al., 2020**). The majority of coffee preparations, however, use beans that have been roasted, which drastically changes the bioactivity of coffee by lowering phenolic chemicals and producing products of the Maillardreaction(**Alongi&Anese, 2018; Alongi et al., 2019; Alongi et al., 2021; Anese et al., 2023**).Coffee includes caffeine, which is recognised for its energising properties, in addition to chlorogenic acids. Along with epidemiological investigation, coffee utilization may be linked with a lesser incidence of type 2 diabetes(**Akash et al., 2014; Shahinfar et al., 2021**)and cancer(**Silva et al., 2022**).These positive effects are mostly ascribed to caffeine, trigonelline, and chlorogenic acids (CGAs)(**Li et al., 2023**).

A crucial step in the coffee processing process, roasting has a direct impact on the product's quality attributes, such as colour, flavour, and aroma. Coffee beans' unique characteristics are a result of the Maillard reaction, caramelisation, and oxidation of specific polyphenolic chemicals brought on by heat during roasting(**Aguiar et al., 2016; Sruthi et al., 2021**).The thermal breakdown of sugars through the Maillard reaction or caramelisation, however, can also result in the production of 5-hydroxymethylfurfural (5-HMF), which can also cause the breakdown of proteins, polysaccharides, caffeine, trigonelline, and CGAs(**Chaichi et al., 2015; Lopes et al., 2020 Mehaya& Mohammad, 2020; Freitas et al., 2023**).

A key step in the production of coffee is roasting, which is a dry heating process. Different roasting disorders, such as temperatures that typically range between 160 and 240°C and exposure times to heat of 8 to 25 minutes, produce a variety of flavour profiles, from light to medium and dark roasts(**Park et al., 2023; Sruthi et al., 2021**).Selecting the right roasting profile is crucial to getting the flavour you want and is a key factor in determining the end product's quality. In order to facilitate the performance of a biological investigation in the nest stage, the current study compares the differences in chemical composition, antioxidant activity, colour qualities, and fragrance volatile chemicals in Robusta coffee at three different roasting degrees.

MATERIALS AND METHODS

Chemical and reagents

Chemicals which included the Folin–Ciocalteu reagent, sodium carbonate anhydrous, hydrated sodium acetate, hexahydrate aluminium chloride, vanillin, and 2,2'-diphenyl-1-picrylhydrazyl (DPPH). Gallic acid and quercetin served as the standards for the antioxidant assay were obtaind from Sigma-Aldrich Deionized water were used to preparation of all reagents.

Plant material

Green coffee beans(Robusta coffee) were purchased from Misr Café Company in 10th of Ramadan city, Egypt. Beans that were uniform in size and defect-free were roasted.

Roasting conditions

50 g of green coffee beans were roasted in the roasting drum of a laboratory-scale electric rotating drum roaster (PRE 1Z; Probat-Werke von GimbomMaschinenfabrik GmbH, Germany) with a 100 g capacity. The conditions selected for each experiment were 210, 230, and 240 degrees Celsius, for 20 minutes. Before being analysed, the roasted coffee was stored in an airtight jar in the refrigerator after being

thoroughly ground in a coffee grinder (model GVX212, Krupps, Essen, Germany) with a 0.30 mm screen size. While the coffee was roasting, temperature variations in the roasting drum were observed.

Chemical analysis

A proximate chemical analysis of roasted coffee powder was conducted to determine its crude protein, moisture content, ether extract, crude fibre, and ash content were determined according to **AOAC (2010)** . By subtracting the total percentages of crude protein, ether extract, crude fibre, and ash content from 100, the nitrogen-free extract was calculated by difference.

Determination of acrylamide

A gas chromatograph fitted with a flame ionisation detector was used to test acrylamide at 260 ºC (**Wendie et al., 2005**). In addition to an injector temperature of 260 ºC, helium gas as a carrier gas at constant pressure, and an oven temperature that varied from 100 ºC (maintained for 0.5 minutes) to 200 ºC at a rate of 15 ºC per minute, an RTX-5 column (30 m length, 0.2 5 mm I.D. 0.25 m film thickness) was used.

Browning index

The absorption of the five-fold diluted coffee brew solution at 420 nm was calculated using a spectrophotometer UV–Vis (Labomed Inc., USA). This index measures the amount of melanoidins and other brown compounds created during the caramelisation and Maillard processes (**Chung et al. 2013**).

Color measurements

To assess the colour computation for roasted coffee, a chromameter (CR 400) was utilised. According to the International Commission of Illumination (CIE), the documents were displayed as L*, a*, and b*, which stand for revealed light and managed chromatic, respectively, red–green and yellow–blue axes.

Determination of Phytochemicals

Extraction of free and bound phenolic Compounds

Free phenolic components were extracted from coffee samples using the methods described by **Peng et al. (2019),** with some modifications. Following a thorough 1:10 (w:w) mixing of coffee powder and 70% ethanol, the mixture was homogenised for 30 seconds at 10,000 rpm using an Ultra-Turrax T25 Homogeniser (IKA, Staufen, Germany). After that, it was incubated in a shaking incubator (ZWYR-240 incubator shaker, Labwit, Ashwood, VIC, Australia) for 12 hours at 120 rpm and 4°C. A Hettich Refrigerated Centrifuge (ROTINA380R, Tuttlingen, Baden Württemberg, Germany) was then used to centrifuge the mixture for 15 minutes at 4°C and 5000 rpm. The supernatant fluid was filtered using a 0.45 μm syringe filter (Thermo Fisher Scientific Inc., Waltham, MA, USA) to get free phenolic extracts. A modified version of **Phan et al, (2019)** was used to extract the bound phenolic compounds from the samples. The silt underwent alkaline hydrolysis with the addition of 2 M NaOH and an hour of shaking incubator incubation at 200 rpm. Using concentrated HCl to change pH 2.0 for acid hydrolysis, 2 M NaOH was used to bring the pH back to 7.0. The models were then blended with 70% ethanol and incubated for 60 minutes to disperse the unconfined bound phenolic compounds into the organic diluent phase. The mix was centrifuged for 20 minutes at 4°C at 8000 rpm. The supernatant fluid was collected and filtered via a syringe filter as bound phenolic extracts. Both free and bound phenolic extracts were stored at -20°C until they were prepared for additional analysis.

Quantification of phenolic compounds and antioxidant assays

Sample preparation

All assessed analyses for phenolic compounds (TPC, TFC, and TCT) and the measurement of total antioxidant capacity (DPPH, ABTS, FRAP, •OH-RSA, FICA, and RPA) were detected according adapted to fit the spectrophotometer (Multiskan® Go microplate photometer) and 96-well plate (Costar, Corning, NY, USA) (Thermo Fisher Scientific, Waltham, MA, USA), per Suleria et al. (2020) and **Ali et al. (2021).**

Determination of total phenolic content (TPC)

The total phenolic compounds in coffee beans were measured as gallic acid using the

Folin–Ciocalteu technique, with some variations based on **Mussatto et al. (2011).** To put it briefly, a plate was coated with 200 µl of water, 25 µl of Folin-Ciocalteu reagent solutions, and 25 µl of sample extract or standard. The plate was then incubated at 25°C for five minutes. Following the addition of 25 µl of 10% (w/w) sodium carbonate, the mixture was incubated for an hour under the like disorders. Gallic acid (0–200 µg/ml) was expended as the calibration curve, and water calculated as the blank. The absorbance was measured at 765 nm, and the outcomes were reported as mg gallic acid equivalents (GAE) per (mg GAE/g) ± standard deviation (SD).

Determination of total flavonoid content (TFC)

The total flavonoid concentration of coffee was established as mg quercetin by **Ali et al. (2021).** Simply said, 120 µl of a 50 g/L sodium acetate solution, 80 µl of sample extract, and 80 µl of 2% aluminium chloride were added to a plate. After that, the plate was incubated in the dark at 25°C for 2.5 hours. Quercetin (0–50 µg/ml) was used as the standard curve, and water was used as the blank. Absorbance was measured at 440 nm, and the samples' final flavonoid content was stated as mg quercetin equivalents (QE) per g (mg QE/g) ± SD.

Determination of total condensed tannins (TCT)

The total amount of condensed tannins in coffee beans using the vanillin sulphuric acid method according to **Ali et al. (2021)** . To put it briefly, 25 µl of sample extract, 150 µl of vanillin solution, and 25 µl of 32% sulphuric acid were placed on a plate. After that, the plate was incubated in the dark at 25°C for 15 minutes. The blank and standard curves were made using water and catechin (0–1 mg/ml), respectively. Using the absorbance, which was deliberate at 500 nm, the final concentration of condensed tannins was computed as mg catechin equivalents (CE) per g (mg CE/g) ± SD.

DPPH antioxidant assay

The coffee beans' capacity to scavenge free radicals by transforming from purplish to yellowish was evaluated as a preliminary test using the modified DPPH assay, which was based on **Nebesny and Budryn's (2003)** methodology. To put it briefly, a plate was coated with 40 µl of sample extract or standard and 260 µl of 0.1 mM DPPH solution. The plate was then incubated at 25°C for 30 minutes. Trolox (0–200 µg/ml) and water were used for the standard curve and blank, respectively. The absorbance was calculated at 517 nm, and the outcomes were displayed as mg Trolox equivalents (TE) (mg TE/g) ± SD.

Estimation of Flavonols (Quercetin and Kaempferol)

Sample Preparation

One gramme of a finely ground tea leaf sample was put into a 250 mL flask with a circular bottom. 40 mL of 60% aqueous methanol was followed by 5 mL of 6M hydrochloric acid (HCL). The mixture was refluxed at the boiling temperature for two hours prior to filtering in a 50 mL volumetric flask. After cooling, 60% methanol in water was added to the filtrate to mark it. A 0.45 µ membrane filter was used to filter the sample before it was put into the HPLC (**Kingori et al, 2021**).

Standards Preparation

Stock solutions containing 200 µg/mL of myricetin, quercetin, and kaempferol were prepared in ethanol at room temperature (20˚C to 25˚C). Working standard solutions for each individual standard were diluted between 0 and 100 µg/mL and passed through a 0.45 µ filter membrane prior to being injected into the HPLC.

HPLC analysis

The Shimadzu LC 20 A series of HPLC systems, which featured a binary pump with vacuum degasser (DGU-20A5R), thermostated column compartment (CTO-10AS vp), auto sampler (SIL 20 ATHT), and photo diode array detector (SPD-20MA), were produced by the Shimadzu Corporation in Kyoto, Japan. The C18-phenyl reversed-phase column, which had dimensions of 4.6 × 250 mm and 5 µ, was maintained at 25˚C. Mobile phases A and B were 0.1% aqueous acetic acid and HPLC-grade acetonitrile, respectively. A gradient elution system was run at 0.01 minutes, 10% B; 30

minutes, 55% B; 35 minutes, 50% B; and 38 to 40 minutes, 10% B. The mobile phase flow rate was 1.0 mL/min, and the injection volume was 20 µL. The eluents were located and analysed at 370 nm.

Analysis of caffeine, trigonelline, and furfural contents

The method modified by **Vignoli et al. (2014)** was used to test roasted coffee samples for caffeine, trigonelline, and hydroxymethylfurfural. High performance liquid chromatography (HPLC) was performed using a Thermo Scientific Accela LC system (diode array detector (DAD), autoinjector, and Accela pump) (Thermo Fisher Scientific, Austin, TX), and the reverse phase Lichrospher 100 RP-18 (250 × 4.6 mm, particle size of 5 µm, pore size 10 nm) (Merck, Germany) as the column used for the separation. The mobile phase consisted of methanol (B) and water (A). At intervals of 0–6 minutes (90% A and 10% B), 6–7 minutes (90–80% A and 10–20% B), 7–23 minutes (80% A and 20%), 23–24 minutes (80–0% A and 20–100% B), 24–25 minutes (0–90% A and 100–10% B), and lastly, 25–26 minutes (90–80% A and 10% B), the elution was conducted. The injector and column were at 25 ◦C and 40 ◦C, respectively, and the injection volume was 1 µL (partial loop) with a flow rate of 1 mL/min. Peaks were discovered at wavelengths of 272 nm. Caffeine, trigonelline, and HMF were identified using a calibration curve and a standard injection.

Assessment of volatiles compounds

Volatile chemicals were separated using gas chromatography mass spectrometry (Hewlett-Packard 6890 GC/HP 5973 MS Agilent Technologies). The oven program was increased from 40 to 200 ºC with a starting and holding duration of 5 ºC min_1 at 5 and 45 minutes, respectively. Helium was used as the carrier gas. The requirements for GC-MS were outlined by **Buffo and Cardelli-Freire (2004).** According to GC-MS conditions, the column gas flow rate was 1 mL min_1. A 70 eV ionising force, a mass range of 30–330 amu, an interface temperature of 280 ºC, and a scanning rate of 2.2 scan sec-1 were the parameters. One microlitre of injection was used in split-less mode. Using the WILEY and NIST mass spectral (MS) libraries to compare mass spectra to known volatile compounds.

Statistical analysis

According to **McClave and Benson (1991),** analysis of variance was used to statistically examine the collected data. Software for one-way analysis of variance (ANOVA) was applied to all of the data. Duncan's new multiple range tests were used to differentiate significant treatment means. At $p < 0.05$, differences were deemed significant.

RESULTS AND DISCUSSION

Proximate Chemical Composition

The approximate chemical composition of the different coffee roasting grades were displayed in Table 1. The results show that light-roasted coffee (LRC) has the maximum levels of moisture content (3.62%) and crude protein (12.26%) and the lowest levels of crude fibre (24.80%) and ethyl ether extract (9.50%). Samples of dark-roasted coffee (DRC) have the highest ether extract (10.58%), crude fibre (27.30%), and ash content (4.78%), whereas the lowest moisture content (2.74%) and crude protein (11.26%) are seen in these samples. There was a highly significant difference between the coffee samples in all items **Nogaim and Gowri (2013)**, they discovered that the mean levels of crude proteins, total lipids, moisture, carbohydrates, and ash in Arabic coffee were 10.95, 6.13, 6.99, 22.12, and 4.16%, respectively, which is consistent with our findings. Additionally, **Vasconcelos et al. (2007)** discovered that while protein concentrations stayed consistent throughout roasting levels, after roasting, the amount of ash and oil reduced and increased significantly, most likely due to differences in variety and growing conditions.

Table 2 shows the colour characteristics, browning index, and acrylamide content at various roasting settings. Acrylamide levels were lowest in MRC (0.44 mg/100 g) and highest in LRC (0.55 mg/100 g). **Adimas et al. (2024)** claim that roasting creates toxic compounds like acrylamide. When asparagine's amino group and the carbonyl source go through

a Maillard reaction, acrylamide is usually created during high-temperature cooking methods like baking, roasting, and frying. Statistical analysis show a highly significant different between three different coffee bean VS. roasting temperature .It's crucial to remember that with a mild roastcoffee (MRC), the acrylamide level surpasses greatest values and then reduces as the roasting temperature rises. The idea of formation in the early phases of the Maillard process is consistent with this result. The quantities of acrylamide in ground, instant, and powdered coffee varied from 150 to 327 µg/kg (**Bortolomeazzi et al., 2012**). Since acrylamide has been demonstrated to have a mutagenic effect on lab animals in multiple studies and by the International Agency for Research on Cancer, it may be carcinogenic to people. To determine the acceptable amount of acrylamide in coffee products, more investigation is needed. The Food and Drug Administration stated that the acceptable intake for fries is 0.077 mg/kg. MRC has 1 g/100 g of acrylamide, but DRC had 0.5 g/100 g, according to **Granby &Fagt (2004).** Furthermore, medium-roasted espresso had nearly 25% less acrylamide than dark-roasted coffee, according to **Alves et al. (2010).** Coffee that was slow-roasted, or roasted at little temperatures for a long time, had less acrylamide than coffee that was roasted at high temperatures for a short time, according to **Soares et al. (2009).KuMadihah et al. (2013)** state that the lowest amounts of acrylamide (0.23 mg/100 g) are obtained when Arabic coffee is roasted for 26 minutes at 180 ºC.

Acrylamide content, Browning index(BI) and color characteristics in light, medium, and dark coffee

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Table 2 displays the variations in the BI, L*, a*, and b* values. Coffee that was dark-roasted had the highest browning index (1.98), whereas coffee that was light-roasted had the lowest (0.58). The L* value, which measures the coffee's whiteness, inclines to reduction significantly ($p < 0.05$) as the roasting temperature rises. The redness of roasted coffee is represented by the value a*, which inclines to rise during the roasting process. The roasted coffee's b* value, or degree of yellowness, boosted at lesser roasting temperatures (210 ºC; 20 min), while it drastically decreased at higher roasting temperatures (240 ºC; 20 min). Colour development is one of the factors that are commonly used to determine the level of roasting and one indicator of the final product's quality (**Shan et al., 2016**). Although a variety of processes occur during roasting, the main

Table 1.Effect of roasting temperatures on chemical composition (% in dry matter) of Robusta coffee.

Components %	Light coffee (210 ºC)	Medium coffee (230 ºC)	Dark coffee (240 ºC)
Moisture	3.62±0.20[a]	3.16±0.25[b]	2.74±0.33[c]
Ether extract	9.50±0.18[c]	10.36±0.12[b]	10.58±0.16[a]
Crude protein	12.26±0.35[a]	12.08±0.30[b]	11.26±0.42[c]
Crude fiber	24.80±0.44[c]	26.70±0.32[b]	27.30±0.38[a]
Ash	4.42±0.03[c]	4.55±0.06[b]	4.48±0.05[a]

Values (means ± SD) with different superscript letters are statistically significantly different ($p \leq 0.05$)

Table 2. Effect of roasting temperatures on acrylamide content, color characteristics and browning index of Robusta coffee

Items		Light coffee (210 ºC)	Medium coffee (230 ºC)	Dark coffee (240 ºC)
Acrylamide(mg/100 g)		**0.55±0.05[a]**	**0.44±0.02[c]**	**0.48±0.03[b]**
Browning index (420 nm)		**0.58±0.03[c]**	**1.22±0.05[b]**	**1.98±0.04[a]**
Color	**L***	**51.40±1.2[a]**	**44.30±1.3[b]**	**35.80±1.14[c]**
	a*	**12.60±0.77[c]**	**16.90±0.68[b]**	**17.12±0.82[b]**
	b*	**30.14±0.50[a]**	**28.70±0.72[b]**	**27.20±0.78[c]**

Values (means ± SD) with different superscript letters are statistically significantly different ($p \leq 0.05$).

reactions that result in colour and brown compounds include the Maillard reaction and the oxidative polymerisation or breakdown of phenolic molecules. The BI quantities the cleanliness of the browning since roasting causes both enzymatic and non-enzymatic browning. Similarly, **Yen et al. (2005)** located that roasted coffee had a higher BI than aqueous extracts of soluble discarded coffee grounds. The L* number indicates how white the roasted coffee. The L* value inclines to reduce significantly ($p < 0.05$) at higher roasting temperatures, which may be due to the production of brown compounds via non-enzymatic browning (**Wang et al., 2011; Shan et al., 2016**). The redness (a* value) of the roasted coffee inclined to rise with roasting temperature.**Gökmen&Senyuva (2006)** discovered a relationship between the CIE a* colour value and the amount of acrylamide in coffee. **Alves et al. (2010)** found that compared to light coffee, dark and medium-roasted coffee had reduced amounts of acrylamide. At the lower roasting grade (210 ºC; 20 min), the b*value (degree of yellowness) of the roasted coffee boosted; however, at the higher roasting grade (240 ºC; 20 min), it dramatically decreased. According to **Afoakwa et al. (2014),** when roasting time increases, the b-value rises due to the thermal oxidation of polyphenols and the production of Maillard produces.

Phenolic, flavonoids and tannins content

The study of the Phenolic, flavonoids and tannins contents data for coffee beans is shown in Table 3. All of shows the free phenolic compound values were greater than the bound values, with the exception of TCT. Significant changes ($p < .05$) were observed in the phenolic content of coffee beans with different roasting levels. The highest TPC value (36.40 mg G AE/g) was found in light-roasted coffee beans, which were followed by medium-roasted (33.80 mg GAE/g) and dark-roasted (28.70 mg GAE/g). these results were in line with (**Cho et al., 2014; Król et al., 2020**). Following heavy roasting, TPC can drop as a result of direct breakdown of polyphenolic compounds, especially the very thermally unstable chlorogenic acids found in coffee beans, at temperatures exceeding 80°C (**Hecimovic et al., 2011; Król et al., 2020**). Partially bound phenolic compounds found in the plant matrix may be released during heat processing when cellulose elements break down (**Cho et al., 2014; Mehari et al., 2020**). In contrast to bound TPC values, it leads to a relatively higher level of free TPC values by promoting the accumulation of free phenolic compounds, which stops the substantial drop. The bound TPC value also revealed a similar pattern and significant fluctuations, indicating that the total bound phenolic compounds decreased from 29.70 mg GAE/g to 21.30 mg GAE/g as the roasting degree increased. However, the presence of Maillard reaction produces, especially melanoidins, must be contemplated because of their interaction with the Folin-Ciocalteu reagent, which may cause them to somewhat rise the value of TPC (**Pérez-Hernández et al., 2012).**

When compared to bound phenolic, the data for free phenolic compounds demonstrated a reversal trend, with the free TFC and TCT values rising from 2.54 mg QE/g and 3.22 mg CE/g to 1.98 mg Q E/g and 8.40 mg CE/g. As the roasting degree rose, these variations became more noticeable. Similar results showed that the amount of total flavonoids and tannins was directly correlated with the degree of roasting (**Hecimovic et al., 2011; Odzakovic et al., 2016; Król et al., 2020**). More and more bound phenolic compounds were liberated as the roasting temperature rose, improving the free TFC and TCT while reasonably lowering the bound phenolic compounds.. Proper roasting can break down compressed tannins into lesser molecular mass flavonoids, such as anthocyanin, which could raise the free TFC value a little. However, the great heat defiance of tannins may be somewhat decreased at temperatures below 210°C (**Van Cuong et al., 2014: Ahmad et al., 2018**). While flavan-3-ol is the monomer of condensed tannins that belong to flavonoids, gallic acid is a component of hydrolysable tannins that belong to nonflavonoids**(Mehari et al, 2020**). Therefore, contacts with proteins and sugars through thermal processing, along with the isomerisation and polymerisation of polyphenolic compounds, may lead to the formation of a range of compounds, including gallic acid complexes, quinolactones, and flavan-3-ols complexes, which may increase TPC and TCT (**Kim et al., 2011; Król et al., 2020**).

It is clear that when the roasting level increased, the DPPH radical scavenger activities drastically decreased, in line with **Herawati et al. (2019).** In contrast, Colombian Arabica coffee beans that were medium-roasted (233 ºC/3 min) had the most antioxidant activity, whereas dark coffee (240 ºC/3 min) had the lowest, according to **Del Castillo et al. (2002).Giuffrè et al. (2018)** found that reducing antioxidant molecules is consistent with a more intense roasting method where the antioxidants are degraded during heating. The breakdown of the bioactive molecules during roasting is consistent with the heat instability of antioxidant chemicals (**Vignoli et al., 2014**). However, as the roasting grade increases, considerable amounts of Maillard and Strecker reaction products are created to improve the total antioxidant characteristics and assistance balance for phenolic damages in antioxidant activity (**Ludwig et al., 2014)**

Quantitative levels of quercetin, kaempferol caffeine, trigonelline, and HMF in green, and dark coffee

The levels of kaempferol and quercetin in light, medium, dark, and green coffee are shown in Table 4. Quercetin (35.60 mg/g) and kaempferol (33.20 mg/g) were the two primary flavonols identified in green coffee under the chromatographic conditions of the study. Examining the effects of roasting these two components for 20 minutes at 240°C revealed that the quercetin concentration rose to 47.70 mg/g.

Table 3.Effect of roasting temperatures on phenolic, flavonoids content and antioxidant activity of Robusta coffee

Antioxidant assays	Light coffee (210 ºC)	Medium coffee (230 ºC)	Dark coffee (240 ºC)
	Free Phenolic		
TPC (mg GAE/g)	36.40±0.35^{a}	33.80±0.55^{b}	28.70±0.72^{c}
TFC (mg QE/g)	2.54±0.02^{b}	1.25±0.03^{c}	1.98±0.05^{a}
TCT (mg CE/g)	3.22±0.08^{c}	5.60±0.22^{b}	8.40±0.12^{a}
DPPH (mg TE/g)	172.00±1.2^{a}	166.20±1.3^{b}	154.60±1.5^{c}
	Bound Phenolic		
TPC (mg GAE/g)	29.70±0.62^{a}	24.60±0.74^{b}	21.30±0.85^{c}
TFC (mg QE/g)	1.12±0.04^{a}	0.92±0.06^{c}	1.06±0.04^{b}
TCT (mg CE/g)	13.24±0.36^{a}	7.35±0.22^{b}	4.66±0.42^{c}
DPPH (mg TE/g)	75.20±1.02^{c}	83.60±0.78^{b}	86.20±1.11^{a}

Values (means ± SD) with different superscript letters are statistically significantly different ($p \leq 0.05$).

Table 4. Flavones compounds [Quercetin,kaempferol, Caffeine, trigonelline, and hydroxymethylfurfural (HMF)] content in Robustacoffee affected by roasting at 240 ºC/20 min

Components (mg/g)	Greencoffee	Dark coffee (240 ºC)
Quercetin	35.60 ±0.75^{b}	47.70±0.58^{a}
Kaempferol	33.20±0.54^{a}	0.00±0.00^{b}
Caffeine	23.60±0.92^{a}	13.80±0.1.04^{b}
Trigonelline	2.45±0.84^{a}	0.78±0.33^{b}
HMF	0.00±0.00	0.00±0.00

Values (means ± SD) with different superscript letters are statistically significantly different ($p \leq 0.05$).

Furthermore, no kaempferol was detected in the roasted samples, suggesting quercetin to be the more abundant of the two macromolecules. This finding generates a lot of interest for additional research because epidemiological studies have indicated a possible association between kaempferol-containing meals and a decreased risk of developing a range of ailments, including cardiovascular diseases and cancer (**Kolb et al, 2020**). These results are consistent with previous research on the flavonoid concentration of green and roasted coffee (**Król et al., 2020**).

GC/MS analysis of dark roasted arabica coffee beans:

The gas chromatograms of the volatile ingredients of the dark-roasted arabica coffee beans utilised in this study are shown in Table 5 and Figure 1. In general, the dark-roasted arabica coffee beans were discovered to include 126 distinct compounds. They are separated into the eleven chemical classes listed below: Alcohols, ethers, esters, trimethylsilanes, amines, terpenoids, ketones, hydrocarbons, acids, aldehydes, and sec-butyl nitrites The range of 0.17 to 13.17% was composed of the following substances: 3-Hexadecene, (Z), E-14-Hexadecenal (11.19%), E-15-Heptadecenal, 5-Octadecene, (E)-, 5-Eicosene, (E)- (13.17%), and E-15-Heptadecenal, 5-Octadecene, (E)- (12.19%) Along with the other known components, Di-2-benzothiazole disulfane has the lowest percentage (0.17%). Coffee beans' major volatile component content increased in tandem with the level of severe roasting. These substances included furans, furanic compounds, acetic acids, and a few heterocyclic nitrogen compounds that were found in preceding study (**Somporn et al., 2011, Hertz-Schunemann et al., 2013; Caporaso et al., 2018**). After roasting, acetic acid was the greatest common organic acid in roasted coffee beans, probably as a result of the breakdown of saccharides, especially sucrose (**Diviš et al., 2019**). Fructose is created during roasting when sucrose hydrolyses and any leftover water evaporates. It then proceeds through Lobry-de-Bruynvan-Eckenstein rearrangement to produce 2,3-endiol. The production of 1-deoxyglucosone, an acid precursor that may ultimately result in the formation of acetic acid, occurs when these sugars undergo thermal dehydration (**Yeretzian et al., 2014**). Similar to acetic acid, coffee beans' concentration of furan and furanic compounds significantly increased after they were roasted. Carbohydrates and amino acids are two frequent precursors that are present in green coffee beans in comparatively high proportions (**Chaichi et al., 2015**). The caramel scent of roasted coffee beans may be partially attributed to furans, such as 2-furanmentaol (furfuryl alcohol), which are produced during roasting when sucrose, ribose, or deoxyosones react with amino acids (cysteine or methionine) (**Hertz-Schunemann et al., 2013: Caporaso et al., 2018**). Furanic compounds, such 5-methylfurfural and furfural, which come from two distinct routes, may also have an impact on coffee scent (**Chaichi et al., 2015**). According to **Caporaso et al. (2018),** one originates from the Amadori rearrangement products, specifically deoxyribose, which is subjected to dehydration, cyclisation, and polymerisation after the Maillard reaction. Furanic compounds can also be produced by thermally oxidising ascorbic acid, furfuryl alcohol, and polyunsaturated fatty acids **(Chaichi et al., 2015: Caporaso et al., 2018**). Accordingly, increasing the roasting degree from light to dark may boost the synthesis of furfuryl alcohol and considerably raise the concentration of 5-methylfurfral and furfural, which is in line with the results of this investigation.

Based on Table 3, a clustering was found in the pyrazine group because 2,5-dimethylpyrazine and 2,6-dimethylpyrazine have distinct functional group locations but come from the same Maillard process (**Lee et al., 2016**). During roasting, the pyrazine content remained relatively consistent, with a few variations. At temperatures above 250°C, pyrazines would be incorporated into the molecule and reduced in melanoidins, according to some other studies (**Schenker et al., 2002**). As the degree of roasting grew, so did the propensity for the typical roasting products identified in this study, pyrroles and pyridines. Roasted coffee beans use a similar method to create pyrazine and these two group compounds. The Strecker reaction between aldoses (aldehydes) andalkylamines (aminoketones) would then involve additional

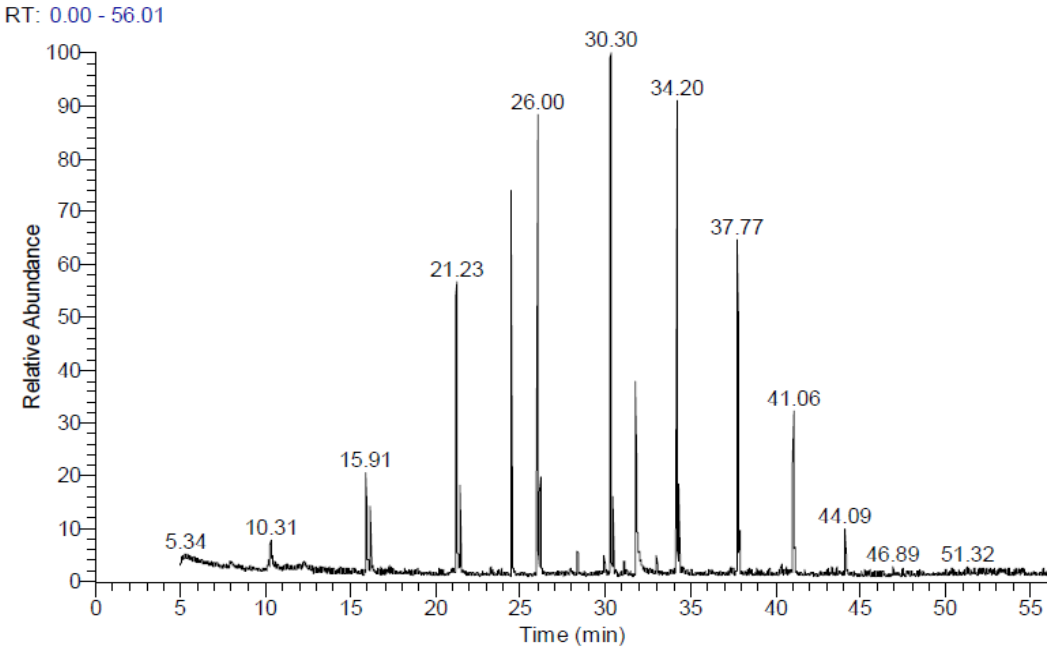

Fig.1: GC/MS analysis of dark roasted Robusta coffee beans

Fig.2: Robusta coffee, green, light, medium, and dark and its brew

Table 5 . The percentage of volatile compounds in dark roasted Robusta coffee beans

Peak No.	RT (Min.)	MW	MF	Area %	Identified Compounds
1	5.11	402	$C_{22}H_{26}O_7$	0.20	7-Methoxy-3-methyl-2-(4-Hydroxy-3-methoxyphenyl)-5-(2-hydroxy-1-acetoxypropyl)benzofuran
2	5.11	402	$C_{22}H_{26}O_7$	0.20	7-Methoxy-3-methyl-2-(4-Hydroxy-3-methoxyphenyl)-5-(1-hydroxy-2-acetoxypropyl)benzofuran
3	5.11	198	$C_8H_{13}F_3O_2$	0.20	6,6,6-Trifluoro-5-hydroxy-2,2-dimethyl-3-hexanone
4	7.94	732	$C_{25}H_{54}N_4Si_3U$	0.48	{[Uranium-(pentamethyl cyclopentadienyl)]-tris[(trimethylsilylamino)-1',2'-ethylideneamino]}
5	7.94	362	$C_{22}H_{22}N_2O_3$	0.48	2-Acetyl-3-(2-cinnamido) ethyl-7-methoxyindole
6	7.94	166	$C_2H_2Cl_4$	0.48	Ethane, 1,1,2,2-tetrachloro-(CAS)
7	10.16	140	$C_9H_{16}O$	0.26	*Cyclononanone (CAS)*
8	10.16	176	$C_{10}H_{21}Cl$	0.26	*Decane, 3-chloro-*
9	10.16	140	$C_{10}H_{20}$	0.26	*1-Decene (CAS)*
10	10.32	128	C_9H_{20}	1.10	Heptane, 2,3-dimethyl (CAS)
11	10.32	170	$C_{12}H_{26}$	1.10	Undecane, 2-methyl- (CAS)
12	10.32	128	C_9H_{20}	1.10	Hexane, 2,3,5-trimethyl-
13	12.26	364	$C_{20}H_{28}O_6$	0.46	*Phorbol*
14	12.26	608	C36H48O8	0.46	*2,4,6,8-Tetradecatetraenoic acid, 9a-(acetyloxy)-1a, 1b,4,4a, 5,7a,7b,8,9,9a-decahydro-4a, 7b-dihydroxy-3-(hydroxymethyl)-1,1,6,8-tetramethyl-5-oxo-1H-cyclopropa[3,4]benz[1,2-e] azulen-9yl ester, [1aR-(1aà,1bá,4aá,7aà,7bà,8à,9á,9aà)]-*
15	13.50	364	$C_{21}H_{32}O_5$	0.18	*Acetic acid, 4,5-dihydroxy-10,13-dimethyl-3-oxohexadecahydrocyclopenta[a] phenanthren-17-yl ester*
16	13.50	492	$C_{22}H_{23}F_3N_6O_4$	0.18	*N-(2,4-dimethoxypHenyl)-6-morpholin-4-yl-N' (4-trifluoromethoxyphenyl)-[1,3,5]Triazine-2,4-diamine*
17	13.68	196	$C_{10}H_{16}N_2O_2$	0.27	*Acethydrazide, N2-[1-(2,3-dihydro-6-methylpyran-2-yl)ethylideno]-*
18	13.68	326	$C_{20}H_{26}N_2O_2$	0.27	*Aspidofractinin3-ol, 17-methoxy-, (2à,5à)-(CAS)*
19	13.68	228	$C_{10}H_{12}O_4S$	0.27	*1-(Phenylsulfonyl)-4-hydroxybutan-2-one*
20	15.26	642	$C_{32}H_{36}Br_2O_4$	0.18	*3,3'''-Dibromo-2,2', 2'',2'''-tetramethoxy-5,5', 5'',5'''-tetramethylquarterphenyl*

Peak No.	RT (Min.)	MW	MF	Area %	Identified Compounds
21	15.26	640	$C_{43}H_{36}N_4O_2$	0.18	*5,15-Bis(3-methoxyphenyl)-10-phenyl-20-propylporphyrin*
22	15.26	640	$C_{42}H_{40}O_6$	0.18	*15,11-metheno-11H-tribe nzo[c,g,n][1,6]dioxacyclo pentadecin-7-carboxaldeh yde, 22-ethoxy-19-(2-ethoxy-3-formyl-5-methylphenyl)-5,21-dihydro-9,13,17-trimethyl*
23	15.67	634	$C_{36}H_{58}O_5S_2$	0.20	*Lanostane-7,11-dione, 3,18-bis(Acetyloxy)-, cyclic 7-(1,2-ethanediylmercaptole), (3á,20.xi.)-(CAS)*
24	15.67	630	$C_{21}H_8Cl_4F_6N6O_2$	0.20	*2,2-Bis[4-[(4,6-dichloro-1,3,5-triazin-2-yl) oxy]phenyl]-1,1,1,3,3,3-hexafluoropropane*
25	15.92	168	$C_{12}H_{24}$	2.91	*Cyclododecane (CAS)*
26	15.92	196	$C_{14}H_{28}$	2.91	*Cyclotetradecane*
27	15.92	168	$C_{12}H_{24}$	2.91	*3-Dodecene, (E)-*
28	16.14	256	$C_{14}H_{24}O_4$	2.03	*Oxalic acid, allyl nonylester*
29	16.14	170	$C_{12}H_{26}$	2.03	*Dodecane (CAS)*
30	16.14	506	$C_{36}H_{74}$	2.03	*Hexatriacontane (CAS)*
31	17.25	635	$C_{18}H_{10}Br_5N$	0.17	*(4-Bromophenyl)bis(2,4-dibromophenyl) amine*
32	17.25	220	$C_9H_{13}Cl_O4$	0.17	*Rehmaglutin D*
33	17.25	428	$C_{31}H_{56}$	0.17	*Pentacosane, 13-phenyl-*
34	21.00	428	$C_{31}H_{56}$	0.26	*Pentacosane, 13-phenyl-*
35	21.00	288	$C_{17}H_{17}ClO_2$	0.26	*3-tert-Butyl-5-chloro-2-hydroxybenzophenone*
36	21.23	168	$C_{12}H_{24}$	6.99	*5-Undecene, 4-methyl-*
37	21.23	168	$C_{12}H_{24}$	6.99	*5-Undecene, 4-methyl-, cis/trans*
38	21.23	182	$C_{13}H_{26}$	6.99	*3-Tridecene, (E)*
39	21.43	254	$C_{18}H_{38}$	2.21	*Dodecane, 2,2,4,9,11,11-hexamethyl-(CAS)*
40	21.43	310	$C_{22}H_{46}$	2.21	*Docosane (CAS)*
41	21.43	155	$C_9H_{17}NO$	2.21	*3-Octen-2-one, 4-(methylamino)-(CAS)*
42	23.26	346	$C_{22}H_{34}O_3$	0.39	*Pregan-20-one, 2-hydroxy-5,6-epoxy-15-methyl*
43	23.26	592	$C_{36}H_{36}N_2O_6$	0.39	*3',4'-Dihydro-Stephasubine*
44	24.44	206	$C_{14}H_{22}O$	9.98	*2-tertButyl-4-isopropyl-5-methylphenol*
45	24.44	206	$C_{13}H_{18}O_2$	9.98	*3,4-Dihydro-2H-1,5-(3"-t-butyl) benzodioxepine*
46	24.44	206	$C_{16}H_{14}$	9.98	*15-methyltricyclo[6.5.2 (13,14).0(7,15)]pentadeca-1,3,5,7,9,11,13-heptene*
47	26.00	224	$C_{16}H_{32}$	11.19	*3-Hexadecene, (Z)*
48	26.00	238	$C_{16}H_{30}O$	11.19	*E-14-Hexadecenal*
49	26.16	198	$C_{14}H_{30}$	2.19	*Tetradecane (CAS)*
50	26.16	226	$C_{16}H_{34}$	2.19	*Hexadecane (CAS)*
51	27.74	471	$C_{21}H_{45}NO_3Si_4$	0.17	*Epinephrine-tetraTMS*

Peak No.	RT (Min.)	MW	MF	Area %	Identified Compounds
52	27.74	457	$C_{20}H_{43}NO_3Si_4$	0.17	*2-trimethylsilylamino-1-trimethylsilyloxy-1-(3',4'-bis(trimethylsilyloxy)-phenyl)ethane*
53	27.74	0	N/A	0.17	*Cystine, TBS 2x*
54	27.98	362	$C_{26}H_{50}$	0.31	*Cyclohexane, 1,1'-dodecylidenebis[4-methyl-*
55	27.98	126	C_9H_{18}	0.31	*Cyclohexane, 1-ethyl-2-methyl-, trans-(CAS)*
56	28.36	198	$C_{14}H_{30}$	0.61	*Tetradecane (CAS)*
57	28.36	212	$C_{15}H_{32}$	0.61	*Pentadecane*
58	28.36	240	$C_{17}H_{36}$	0.61	*Heptadecane (CAS)*
59	29.91	238	$C_{12}H_{11}ClO_3$	0.72	*Methyl-5-(4-Chlorophenyl)- 4-pentenoate*
60	29.91	238	$C_{16}H_{11}Cl$	0.72	*2-(1-Chloroethenyl) phenanthrene*
61	29.91	238	$C_9H_{11}ClN_6$	0.72	*6-Chloro-3-(3,5-dimethylpyrazol-1yl) pyridazine-4, 5-diamine*
62	30.30	252	$C_{17}H_{32}O$	13.17	*E-15-Heptadecenal*
63	30.30	252	$C_{18}H_{36}$	13.17	*5-Octadecene, (E)-*
64	30.30	280	$C_{20}H_{40}$	13.17	*5-Eicosene, (E)-*
65	30.43	156	$C_{11}H_{24}$	1.99	*Octane, 2,4,6-trimethyl-*
66	30.43	184	$C_{13}H_{28}$	1.99	*Decane, 2,6,8-trimethyl-*
67	30.92	266	$C_{18}H_{34}O$	0.18	*11-Octadecenal (spectrum disagrees) (CAS)*
68	30.92	268	$C_{17}H_{32}O_2$	0.18	*3-Cyclopropylcarbonyloxy tridecane*
69	30.92	282	$C_{18}H_{34}O_2$	0.18	*3-Cyclopropylcarbonyloxy tetradecane*
70	31.09	710	$C_{36}H_{54}O_{14}$	0.36	*Card-20(22)-enolide, 3-[(2,6-dideoxy-4-O-á-D-glucopyranosyl-3-O-methyl-á-D-ribo-hexopyranosyl)oxy]-5,14-dihydroxy-19-oxo-, (3á,5á)-*
71	31.09	1780	$C_{94}H_{180}N_4O_{26}$	0.36	*Permethylated and reduced product of degradation product from H3-glycolipid By L-L-fucosidase and by B-galactosidase*
72	31.09	214	$C_{12}H_{26}OSi$	0.36	*1-Methyl-1-(4-methylpentyloxy)-1-silacyclohexane*
73	31.76	194	$C_{13}H_{22}O$	6.25	*(2R*,3S*)-3-Butyl-2-ethenyl-2-methylcyclohexanone*
74	31.76	194	$C_8H_{10}N_4O_2$	6.25	*Caffeine (CAS)*
75	32.61	193	$C_{10}H_{11}NO_3$	0.26	*1-Indolinecarboxaldehyde, 2-hydroxy-5-methoxy-*
76	32.61	448	$C_{16}H_{20}N_2O_9S_2$	0.26	*Glucobrassicin*
77	33.00	276	$C_{17}H_{24}O_3$	0.65	*7,9-ditertbutyl-1-oxaspiro[4.5]deca-6,9-diene-2,8-dione*
78	34.20	252	$C_{17}H_{32}O$	12.19	*E-15-Heptadecenal*
79	34.20	252	$C_{18}H_{36}$	12.19	*5-Octadecene, (E)-*

Peak No.	RT (Min.)	MW	MF	Area %	Identified Compounds
80	34.31	236	$C_{11}H_{24}O_3S$	2.21	*Sulfurous acid, isohexyl-2-pentyl ester*
81	34.31	282	$C_{20}H_{42}$	2.21	*Eicosane (CAS)*
82	34.31	212	$C_{15}H_{32}$	2.21	*Dodecane, 2,6,10-trimethyl(CAS)*
83	37.37	399	$C_{20}H_{18}ClN_3O_2S$	0.31	*7-[2-(4-chlorophenyl)-2-oxoethoxy]- 9-methylsulfanyl-8-aza-spiro[4.5]deca-6,9-diene-6,10-dicarbonitrile*
84	37.37	260	$C_{14}H_{12}OS_2$	0.31	*2-Butanoylbenzodithiophene*
85	37.37	278	$C_{14}H_{18}N_2O_4$	0.31	*2-Acetylamino-3-phenylpropionic acid, 1-carbamoylethyl ester*
86	37.51	656	$C_{42}H_{72}O_5$	0.24	*Lipo-3-episapelin A*
87	37.51	582	$C_{41}H_{58}O_2$	0.24	*.psi.,.psi.Carotene, 3,3',4,4'-tetradehydro-1', 2'-dihydro-1-hydroxy-1-'methoxy-*
88	37.51	582	$C_{41}H_{58}O_2$	0.24	*OH-Spirilloxanthin*
89	37.77	280	$C_{20}H_{40}$	8.56	*9-Eicosene, (E)-*
90	37.77	280	$C_{20}H_{40}$	8.56	*5-Eicosene, (E)-*
91	37.86	226	$C_{16}H_{34}$	1.20	*Hexadecane*
92	37.86	282	$C_{20}H_{42}$	1.20	*Eicosane (CAS)*
93	38.56	644	$C_{41}H_{40}O_7$	0.19	*5"-(1,1-Dimethylethyl)-2, 2',2",2"',2""-pentamethoxy[1,1':3',1":3",1"':3"' .1""-quinquephenyl]-3,3""-dicarboxyaldehyde*
94	38.56	644	$C_{45}H_{32}N_4O$	0.19	*2-Hydroxymethyl-5,10,15,20-tetraphenylporphyrin*
95	38.56	878	$C_{57}H_{98}O_6$	0.19	*Trilinolein*
96	40.30	462	$C_{25}H_{42}N_4O_4$	0.22	*2-Nonadecanone-2,4-D. N.P.H.*
97	40.30	304	$C_{17}H_{20}O_5$	0.22	*Acetyloxyparthenin*
98	40.30	384	$C_{17}H_{32}O_4Si_3$	0.22	*Benzeneacetic acid, à,4-bis[(trimethylsilyl)oxy]-, trimethylsilyl ester (CAS)*
99	40.38	502	$C_{32}H_{54}O_4$	0.17	*7,8-Epoxylanostan-11-ol, 3-acetoxy*
100	40.38	332	$C_{14}H_8N_2S_4$	0.17	*Di-2-benzothiazole disulfane*
101	41.06	336	$C_{24}H_{48}$	4.76	*Cyclotetracosane*
102	41.06	280	$C_{20}H_{40}$	4.76	*3-Eicosene, (E)-*
103	43.31	298	$C_{16}H_{18}N_4O_2$	0.32	*2,4-Diamino-5-[3,4-cyclopentylidenedioxybenzyl]pyrimidine*
104	43.31	216	$C_{15}H_{20}O$	0.32	*Curzerene*
105	43.31	216	$C_{16}H_{24}$	0.32	*Tricyclo[8.6.0.0(2,9)]hexadeca-3,15-diene, trans-2,9-anti-9,10-trans-1,10-*
106	43.76	566	$C_{41}H_{58}O$	0.21	*.psi.,.psi.Carotene, 3,4-didehydro-1,2-dihydro-1-methoxy-*
107	43.76	566	$C_{41}H_{58}O$	0.21	*Anhydrorhodovibrin*
108	43.76	584	$C_{41}H_{60}O_2$	0.21	*.psi.,.psi.Carotene, 3,4-didehydro-1,1', 2,2'-tetrahydro-1'-hydroxy-1-methoxy-*

Peak No.	RT (Min.)	MW	MF	Area %	Identified Compounds
109	44.09	442	$C_{22}H_{45}Cl_3Si$	1.73	*Silane, trichlorodocosyl-*
110	44.09	242	$C_{16}H_{34}O$	1.73	*1-Decanol, 2-hexyl-*
111	45.33	785	$C_{44}H_{84}NO_8P$	0.17	*3,5,9-Trioxa-5-phosphaheptacos-18-en-1-aminium, 4-hydroxy-N, N,N-trimethyl-10-oxo-7-[(1-oxo-9-octadecenyl)oxy]-, hydroxide, inner salt, 4-oxide, (R)-*
112	45.33	785	$C_{44}H_{84}NO_8P$	0.17	*Ethanaminium, 2-[[[2,3-bis[(1-oxo-9-octadecenyl)oxy]propoxy] hydroxyphosphinyl]oxy]-N, N,N-trimethyl, hydroxide, inner salt, (R)-(CAS)*
113	45.33	622	$C_{27}H_{28}Br_2O_5S$	0.17	*Bromthymol Blue*
114	46.90	364	$C_{26}H_{52}$	0.27	*Eicosane, 2-cyclohexyl-*
115	46.90	364	$C_{26}H_{52}$	0.27	*Cyclohexane, (1-hexyltetradecyl)-*
116	50.41	610	$C_{27}H_{30}O_{16}$	0.18	*Lucenin 2*
117	50.41	430	$C_{27}H_{42}O_4$	0.18	*2-(-3-Acetoxy-4,4,10,13,14-pentamethyl-2,3,4,5,6,7,10,11,12,13,14,15,16,17-tetradecahydro-1H-cyclopenta[a]phenanthren-17-yl)-propioni*
118	50.41	430	$C_{27}H_{42}O_4$	0.18	*Propanoic acid, 2-(3-acetoxy-4,4,14-trimethylandrost-8-en-17-yl)-*
119	52.21	536	$C_{28}H_{40}O_{10}$	0.19	*9-Desoxo-9-xacetoxy-3,8,12-tri-O-acetylingol*
120	52.21	496	$C_{27}H_{52}O_4Si_2$	0.19	*9,12,15-Octadecatrienoic acid, 2,3-bis[(trimethylsilyl)oxy] propyl ester, (Z,Z,Z)-*
121	52.79	520	$C_{27}H_{36}O_{10}$	0.17	*4H-Cyclopropa[5',6']benz [1',2':7,8]azuleno[5,6-b] oxiren-4-one, 8,8a-bis(acetyloxy)-2a-[(acetyloxy)methyl]-1,1a, 1b, 1c,2a,3,3a,6a,6b,7,8,8a-dodecahydro-6b-hydroxy-3a-methoxy-1,1,5,7-tetramethyl, [1aR-(1aà,1bá,1cà,2aà,3aá,6aà,6bà,7à, 8á,8aà)]-*
122	52.79	506	$C_{27}H_{38}O_9$	0.17	*3,9-Epoxypregnan-14-ol-20-one, 3,11,18-triacetoxy*
123	52.89	554	$C_{40}H_{58}O$	0.20	*Rhodopin*
124	52.89	598	$C_{34}H_{38}N_4O_6$	0.20	*Hematoporphyrin*
125	53.72	536	$C_{28}H_{40}O_{10}$	0.20	*9-Desoxo-9-x-acetoxy-3,8,12-tri-O-acetylingol*
126	53.72	460	$C_{25}H_{32}O_8$	0.20	*Prednisolone hemisuccinate*

amino acids, resulting in heterocyclization and the creation of several volatile compounds with potent scents, including pyrroles, pyridines, and pyrazines (**Caporaso et al., 2018**). Pyridine may also be produced by the breakdown of trigonelline (**Hertz-Schunemann et al., 2013**). Therefore, toasting too much would reduce the amount of pyridine. The degree of intensive roasting in this investigation likewise increased the phenol content tendency. The breakdown of caffeoylquinic acid and ferulic acid, which are created when chlorogenic acids break down during exothermic roasting, is most likely what causes the synthesis of phenol in roasted coffee beans (**Caporaso et al., 2018**). Coffee beans' volatile chemical concentration may generally rise with proper high-intensity roasting, which is beneficial for the development of coffee bean flavour (**Wu et al, 2022**).

Conclusions

The current study's findings demonstrated that commercial light-roasted coffee beans had a significantly higher amount of total phenolic compounds and antioxidant potential. The dark-roasted had higher levels of condensed tannins and total flavonoids. The commercial light-roasted coffee beans, however, fared better overall in terms of phenolic content and antioxidant potential. Using GC-MS, 122 volatile compounds were identified and quantified in all dark-roasted coffee beans. In conclusion, coffee beans would contain fewer phenolic compounds as roasting intensifies. Even after intensive roasting, coffee beans' antioxidant qualities may be maintained or even improved to some extent because new molecules with remarkable antioxidant activity are created. Light-roasted coffee beans have the most varied phenolic components and relatively outstanding aroma characteristics.

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تأثير درجات حرارة التحميص المختلفة علي التركيب الكيميائي، ومحتوى الكافيين، ومحتوى الأكريلاميد، والمحتوى الفينولي، وإمكانية مضادات الأكسدة لقهوة الروبوستا

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في هذه الدراسة، تم دراسة التركيب الكيميائي، ومحتوى الكافيين، ومحتوى الأكريلاميد، والمحتوى الفينولي، وإمكانية مضادات الأكسدة، وفصل المركبات المتطايرة باستخدام كروماتوغرافيا الغاز- (GC-MS) لدرجات حرارة التحميص الثلاث الأكثر شيوعًا لقهوة روبوستا: الفاتحة (210 درجة مئوية؛ 20 دقيقة)، والمتوسطة (230 درجة مئوية؛ 20 دقيقة)، والداكنة (240 درجة مئوية؛ 20 دقيقة). سجلت القهوة المحمصة الفاتحةأعلى نسبة في محتوى الرطوبة والبروتين الخام، وأقل نسبة في مستخلص الأثير والألياف الخام، وكانت جميعها ذات دلالة إحصائية ($p < 0.05$). باستثناء الكيرسيتين، أدت عملية التحميص – وتحديدًا التحميص الداكن – إلى خفض مستويات الكايمبفيرول والكافيين والتريجونيلين والهيدروكسي ميثيل فورفورال في عينات القهوة الخضراء والمحمصة. كانت مستويات الأكريلاميد أقل ما يمكن في القهوة متوسطة التحميص (0.44 ملجم/100 جرام) وأعلى ما يمكن في القهوة خفيفة التحميص (0.55 ملجم/100 جرام). يرتفع مؤشر التلون البني browning index مع زيادة درجة حرارة التحميص. أظهرت القهوة خفيفة التحميص أعلى محتوى إجمالي حر من الفينول، وأقل نشاط لـ DPPH، وأقل مستويات من التانينات المكثف ومركبات الفلافونويد. تم اكتشاف 126 مركبًا متطايرًا وقياسها جزئيًا في القهوة داكنة التحميص باستخدام كروماتوغرافيا الغاز- (GC-MS). بعد دراسة جميع الجوانب، أظهرت هذه الدراسة أنه على الرغم من أن التحميص الدقيق سيقلل من كمية المركبات الفينولية في حبوب البن، إلا أنه سيحافظ على قدرتها المضادة للأكسدة أو حتى يعززها. تتميز حبوب البن التجارية خفيفة التحميص بقيمة غذائية أفضل نسبيًا. قد تساعد نتائجنا في حل النزاعات السابقة وتقديم دليل مفيد لإنتاج القهوة في قطاع الأغذية.

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