# ANALYSIS OF THE NEGATIVE IMPACTS OF COFFEE HUSK ON THE LOCAL ENVIRONMENT OF ETHIOPIA

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**Abstract:** Among the many by-products of coffee production, coffee husk is produced in large quantities in coffee-producing countries like Ethiopia. Apart from that, the husk highly pollutes environment since the majority of coffee-processing industries dispose it into open air where the compounds contained in coffee husks represent threat to environment. Analysis of the detrimental effects of coffee husks on the environment. In the present work, five concentrations of husk extracts (5%, 10%, 15%, 20%, and 25%) mgl-1 were experimentally analysed for extractable phenolic, chlorogenic acid (CGA), caffeine, tannin, and trigonelline, respectively, for coffee husk collected from Buno Bedele and Illubabor zones of the Oromia Region Government, Ethiopia. The coffee husk contained 56% of chlorogenic, 58% of caffeine, and 60% of total extractable tannins. The findings showed incrementally increasing acidic elements that have an environmental impact.

**Keywords:** Caffeine, chlorogenic, tannins, UV/Vis Spectrophotometry, coffee husk

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## INTRODUCTION

Being its original birthplace and the world's fifth-largest producer of coffee [1], Ethiopia is one of the main Arabica coffee-growing countries. In Ethiopia, coffee processing enterprises generate a significant amount of coffee, which is mainly an agricultural waste accounting for around 30-50% of the coffee produced by weight every year[2] [3]. This husk is burned in an open field or disposed of in a nearby watercourse. As the local and the global demand for coffee is increasing, its processing intensity and the consequent environmental influence are also increasing. Tables 1 and 2 show the amount of coffee production and increasing production trend from the year 2016 to 2021 in the Buno-Bedelle and Illubabor zones of the Oromia region, in Ethiopia, which are selected to study the environmental impact of coffee husks. In both zones, the coffee production is increased, though with no uniform rate. Correspondingly, the waste of the coffee husk is also increasing.

**Table 1.** Buno Bedele zone coffee production.

| Year | Production (t) | Increase (t) | Increase (%) |
|---|---|---|---|
| 2016 | 31,963 | - | - |
| 2017 | 46,142 | 14,179 | 30.73 |
| 2018 | 51,923 | 5,781 | 11.13 |
| 2019 | 53,668 | 1,745 | 3.25 |
| 2020 | 56,789 | 3,121 | 5.50 |
| 2021 | 59,559 | 2,770 | 4.65 |

**Table 2.** Illubabor zone coffee production

| Year | Production (t) | Increase (t) | Increase (%) |
|---|---|---|---|
| 2016 | 34,963 | - | - |
| 2017 | 56,142 | 21,219 | 37.79 |
| 2018 | 61,943 | 5,801 | 9.37 |
| 2019 | 63,868 | 1,925 | 3.01 |
| 2020 | 66,898 | 3,030 | 4.74 |
| 2021 | 69,679 | 2,686 | 4.23 |

Source: Buno Bedele zone Agricultural Bureau.

Figure 1 shows the disposal mechanism of coffee husk in Ethiopia, indicating how this waste is managed after being processed and causing environmental pollution. The husk becomes very stinky during rainy seasons and washed down to water bodies like rivers and lakes [4] [5]. The coffee Improper garbage disposal results in a number of serious health problems for human beings and other mammals such as respiratory issues, dizziness, eye irritation, stomach discomfort, nausea, and even it can affect plants and soil.

**Figure 1. Coffee husk disposal system.**

Many studies discovered useful the antimicrobial [6], antioxidants [7], anti-inflammatory [7], and anti-obesity benefits of low-calorie drinks. Furthermore, the environmental consequences of substances like caffeine, chromogenic acid, and tannins that are discharged into the atmosphere through minimal garbage (husk) are very harmful [8].

Caffeine is poisonous to aquatic organisms, mammals and certain plants [9], flora [10], and microorganism growth [11]. A soluble phenol called chromogenic acid is created when quince acid and coffee acid are esterified [12].

With a focus on the stages which lead towards the first development of solid residues, Figure 2 shows a schematic review of the coffee fruit post-harvest processing procedures. Since the coffee washing process consumes a large amount of water containing a lot of carbon, thus the polluted water has a significant environmental effect.

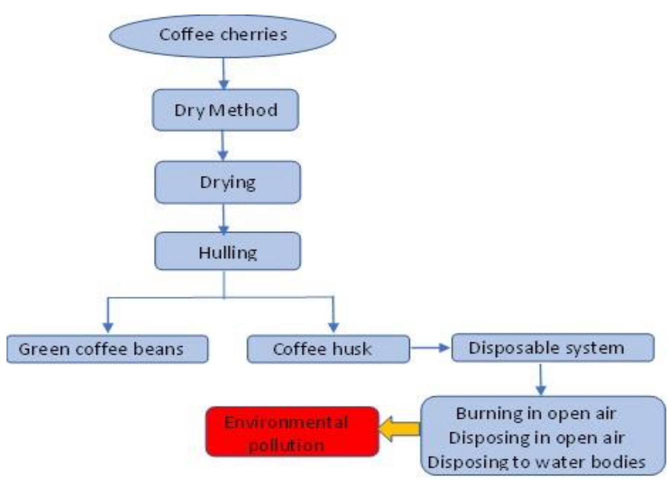


**Figure 2. The procedures involved in the manufacture of coffee husk.**

Coffee husks are composed of 58-85% of super molecule, 8-11% of proteins, 0.5-3% of lipids, 3-7% of minerals, and small quantity of bioactive compounds, like caffeine (~1%), chlorogenic acid (~2.5%) and other tannins (~5%)[12] [13] [14]. Several studies have been carried out for coffee husks re-utilization, for instance as a substrate for biogas [15] [16], and alcohol production [17], biosorbents for cyanide [18], Elimination of heavy metals into liquid solutions using adsorbent materials [19], Removing colours from aqueous solutions using biosorbents [17] [19], bio sorbents for defluorination of water [18], bio sorbents for lead (II) [20], for extraction to retrieve reactive compounds or to transform into fuel pellets [17].
Although it isn't properly used, Ethiopia produces a significant amount of such processing-related trash each year. Additionally, coffee husks may also ideal to a greater directly use as a substrate for the cultivation of edible mushrooms [21] or composites [22], Husk and [23], the fabrication of briquettes [24], the generation of bio-ethanol [25], and the manufacturing of vinegar [26]. manufacturing of particleboard and biogas. Lastly coffee husk waste can be converted into value adding products and create job opportunities for farmers, industries and small-scale enterprises.
To undertake an experimental examination of coffee is the goal of this research husks with a focus on the negative impacts on the environment. The study is conducted using five solutions (5%, 10%, 15%, 20%, and 25%) for extractable phenolics, chlorogenic acid, caffeine, tannin, and trigonelline, respectively.

## 2. MATERIALS AND METHODS

The southwest of Ethiopia, namely Buno Bedele and Ilubabor, was where coffee specimens (Coffee Arabica) was gathered. Coffee husks have been cleaned with diluted water, dried or otherwise displayed in an oven set at 105 OC for 24 hours, and then handled with 10% NaOH to remove undesired components from the fibers. Finally, the pH of the fibers was adjusted by treating the fibers once more with 3% H2SO4 after the 10% NaOH treatment. Using a research lab electric mill (DIETZ7311) with sieve diameters of 0.150 mm and 0.125 mm, coffee husks were collected, cleaned, dried, and milled before having their chemical makeup examined.

### 2.1. Preparation of Dilutions

For the experimental work, five solutions were prepared: i.e., 5, 10, 15, 20, and 25%. According on that procedure of, they were created by adding methanol [27].

### 2.2. UV/Vis Photometer Laboratory Test

Victimization caused absorbance. photometer for UV/Vis for observations, a twin beam UV/Vis photometer from Maalab Scientific instruments with a 1 cm quartz cuvette shell was utilized. Equipment from the lab, including a water tube, an autoclave, and a stirrer, was utilized in conjunction with the photometer and its PC.
In order to carry out the spectrophotometric check process, a liquid caffeine stock solution was prepared by dissolving 2.91 mg of caffeine in 100 ml of liquid. In order to get an accurate reading of the caffeine's working solutions, the sock solution was carefully diluted with deionized water. In a similar manner, the stock solution of caffeine was read by dissolving 1.45 mg of caffeine in 50 ml of chloride and then diluting it to a series of 25 ml normal meter flasks. This process was repeated three times. Each sample of coffee was tested three times, and the results were used to determine the average value, the variation, and the relative variance.

### 2. 3. Total Phenolic Compounds Extraction

The coffee husk was pulverized using either a professional blender or a milling cutter equipment. The powder was passed through a test sieve with a mesh 80 and mesh 100, which correspond to a particle size of 0.125 mm and 0.150 mm, respectively. In a beaker, 25 millilitres of deionized water were used to dissolve 100 milligrams of coffee husk powder. This mixture was then diluted to a volume of 50 millilitres using more deionized water. After that, the solutions were stirred constantly while they were heated in a water bath at a temperature of 100 degrees Celsius for two hours. When making the standard solution, an amount of pure chlorogenic acid (CGA) (Aldrich-Sigma, Germany) weighing exactly 100 mg was purchased commercially, carefully weighed using an electronic balance, and then mixed in 500 ml of deionized water to make the stock standard solution. A magnetic hot plate stirrer was used in a very dark room to facilitate the uniform dissolution of the solution. This was done to reduce the amount of light that interacted with the substance being dissolved. A series of ordinary solutions were read from the stock solution (5, 10, 15, 20, and 25%) $mgL^{-1}$ for CGA in deionized water, and each measurement was immediately done; therefore, the absorbance of each series was measured. The concentration of CGA in the stock solution was expressed as $mgL^{-1}$.
*Beer-law Lambert's guided series solutions*. 20 mg of sieved coffee husk powder was dissolved in 50 ml of de-ionized water. The solutions were swirled for one hour using a hot plate magnetic stirrer and heated slightly to enhance CGA solubility, and then filtered to remove particulates. Liquid-liquid CGA extraction followed filtering. Chlorogenic acid and tannins are extracted using similar processes as coffee husk caffeine. This approach included liquid-liquid extraction and absorption monitoring.
To prevent caffeine, tannin, and CGA spectral overlaps in the 300 - 700 nm wavelength region, dichloromethane liquid–liquid extraction was created. A 100 ml solutions of specimen were created by combining the produced specimen solutions (50 mL solution) with 50 mL dichloromethane. After 30 minutes of stirring, a layer with caffeine as the top layer and CGA as the bottom layer developed. A double beam UV/Vis spectrophotometer (Maalab, India) was used to determine the absorption of the CGA from the residue that was gathered and quantified. The concentrations of the CGA was estimated utilizing the brew Lambert's Law at the maximum wavelength. The CGA quantities in low husk were determined by using the following equations after the CGA caffeine and phenol concentrations were derived from the absorbance of the observed specimen solutions accordance with brewage Lambert's Law at most wavelength.

$$A = \mathcal{E}\times c\times l \qquad (1)$$

A is the solution's absorption, in this case, c is molar concertation of solute ($mole/m^3$), ε is mola Decade absorbance ratio ($m^2\ mole^{-1}$) and l is optical path length (m). For a certain chemical at a specific wave length, the molar presented here provides absorption coefficient coefficient is constant and is more often stated as epsilonmax, when absorption is at its highest, the molar absorptivity.

**2.4 Statistical Analysis**

In order to forecast the likelihood of ethanolic extract concentrations increasing. Concentrations of ethanolic extract were the predictor variable. (5, 10, 15, 20, and 25%). Triple examinations of a technological nature was performed. The information was analysed utilizing the ANOVA and Turkey ($p > 0.05$) methods utilizing IBM SPSS software. To make certain the information was normal, the Shapiro-Wilk check were using. According to this analysis a correlation is significant at 0.01 level (2-tailed).

## 3. RESULTS

Coffee waste (husk) will have severe ecotoxicological effects [8] on the environment [27]. Information for contents of extractible phenolic compound within the coffee husk (CH) are shown in Table 3. The samples indicate that coffee husk has a high level of the above mentioned phenolics, what is expected because the role of those metabolites in protection against external threats [25]. The bleached samples are lower in amount than the unbleached. Bleaching is a pre-treatment used in the deactivation of polyphenol oxidize enzymes, which are accountable for oxidation potential. On the other hand, it promoted the breakdown of CH compounds, which is an indication that these phenolic compounds were sensitive to the temperature that was applied when bleaching [25]. The amounts of chlorogenic acid, caffeine, and tannin increased by 56%, 58%, and 60%, respectively. As shown in Table 3, the water was used in the process of extracting the various chemicals for the investigation, ethanol and Dichloromethane solvent mixture. The results show that the extracted caffeine amount is higher than the other compounds in the coffee husk. Chlorogenic acid and caffeine acid were the phenolic compounds found in both preparations in greater concentrations [28]. The chlorogenic acids and associated metabolites, that make up the majority of the phenolic compounds in coffee husk, are those that have received the most attention in the literature [29]. Chlorogenic, gallic, and caffeic acids, which are compatible with the substances found in this research, have been discovered and measured in a number of investigations employing coffee husks [28] [30].

**Table 3.** Extractable phenolics, chlorogenic acid, caffeine, tannin and trigonelline in 100 g of coffee husks.

| Sample | CGA (mg/100 g) | Tanni (mg/100 g) | Caffeine (mg/100 g) | Trigonelline (mg/100 g) |
|---|---|---|---|---|
| **Coffee husk** | 43.09±0.16 | 96.06±0.14 | 101.10±0.12 | 120.22 ± 0.16 |

**3.1. The Study of Absorption Spectra**

In the beginning, a research was carried out to evaluate the efficacy of procedures for creating a processed binary chemical extract from a randomized husk specimen. All spectra indicated a maximal at the anticipated alkaloid absorbance peak, according to the initial spectrometric observations performed on the binary compound extract without accounting for alkali. The wavelengths were studied at intervals of 300 – 700 nm for determining the presence of alkaloid spectrophotometrically. The wavelength of a single strong absorption measured under UV lighting fluctuates at $\lambda_{max}$ = 301 nm, and the wavelengths were tested at intervals of 300 – 700 nm for the determination of CGA. As demonstrated in Figure 3, the UV light has a wavelength of one strong absorbance at $\lambda_{max}$ = 298 nm.

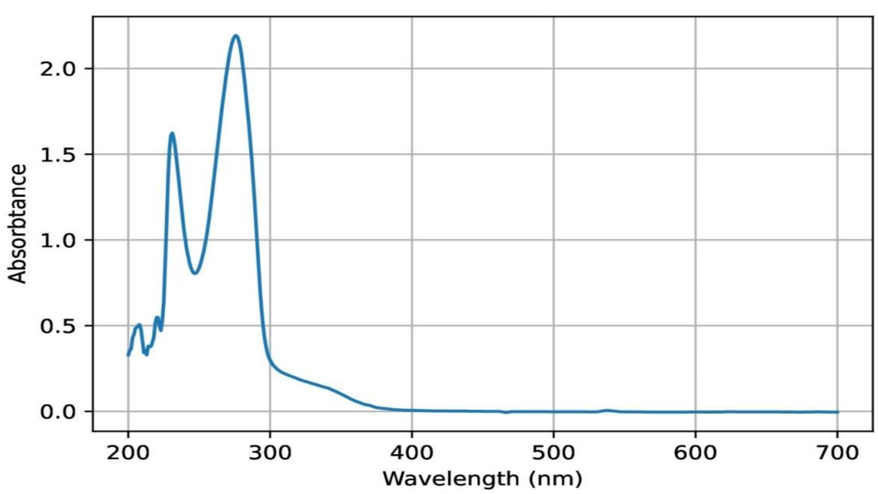


**Figure 3. UV/Vis spectrum of caffeine in dichloromethane.**

### 3.1.1. Determination of Caffeine in Dichloromethane Extracts

Since the chlorogenic acid is fixed by the solutions of 0.1M sodium hydroxide, the trigonelline acid and phenol that are occasionally found in coffee husk in association with alkaloids are totally removed by these extraction techniques. Trigonelline, caffeic acid, chlorogenic acid, and phenol acid are insoluble in methylene chloride. As shown in Figure 4, the UV/Vis spectra of alkaloid in methylene chloride extracts were found to be specific. This was determined through an examination of the ultra-violet absorption spectra of methylene chloride extracts, which revealed that all of the spectra contain a maximum absorption of 298 nm peak that square measure an equivalent as alkaloid. As a result of the fact that the spectrophotometric analysis of the alkaloid in methylene chloride extracts did not reveal any meddlesome peaks, Caffeine is an emerging pollutant that is harming the environment and human health. When the concentration of alkaloid was changed from 2.5 $x10^{-5}$ to 1.25 x $10^{-4}$ weight unit $dm^{-3}$, a linear operating rise in absorbance was detected. Similarly, absorbance measurements were assigned to 1.0 $10^{-4}$ typical alkaloid clarity obtained by diluting a stock resolve with weight unit $dm^{-3}$ alkaloid sensitivity 25 ml methylene chloride. As seen in Figure 4, the maximum absorption occurred at $\lambda_{max}$= 301 nm.

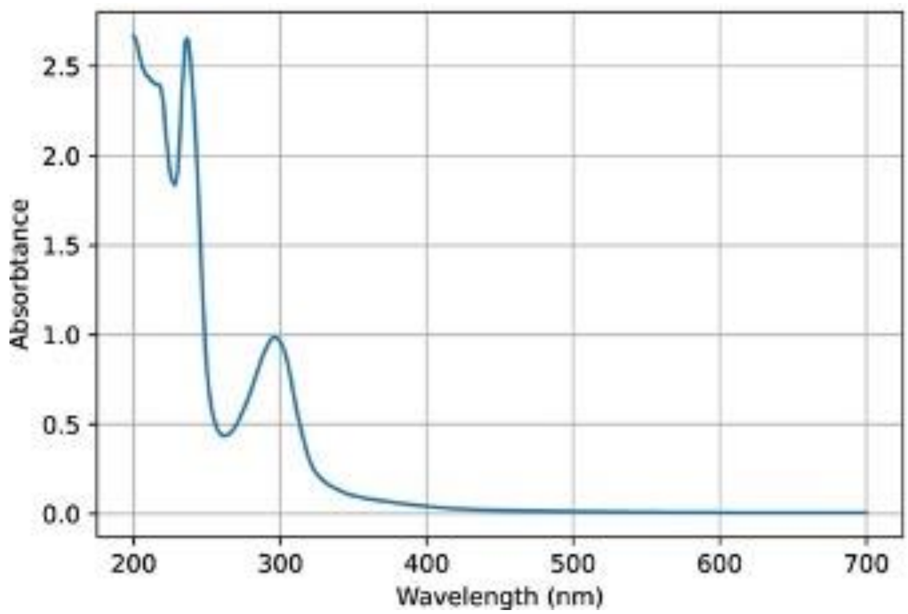


**Figure 4. UV/Vis spectrum of CGA in Dichloromethane.**

For the purpose of determining the concentration range in which chlorogenic acid exhibits linearity between absorption power and concentration, standard solutions of chlorogenic acid were prepared at a variety of concentrations. The activity modifier that was employed was an aqueous solution of 0.1M sodium hydroxide to eliminate interfering bands. The overlapping bands begin to resolve after 0.1M NaOH was added in a dropwise fashion. When additional drops were added to the solution containing the aqueous extract of coffee husk, there was a change in the spectra bands. The results obtained are as follows: 0.321 mol $dm^{-3}$, 0.306 mol $dm^{-3}$, and 0.33 mol $dm^{-3}$.

### 3.1.2. Determination of tannin in aqueous extracts

For possible usage as an alternative resource for composite materials, tannin extract from coffee husk waste biomass has been proven to be very promising. Water, ethanol, and dichloromethane are used as solvents to obtain them. The most prevalent phenolic element in all of these extracts was tannic acid, which is mostly composed of phenols. According to a technique suggested by, the amount of condensed tannins was determined [31].

As caffeine concentrations ranged from 2.5 $x10^{-5}$ to 1.25 x $10^{-4}$ mol $dm^{-3}$, absorbance increased linearly. Similarly, absorbance was measured with 1.0 $10^{-2}$ mol $dm^{-3}$ A typical caffeine solution is made by diluting a stock caffeine solution with 25 millilitres of dichloromethane. Figure 5 presents the findings, which indicate that the highest absorption occurred at $\lambda_{max}$ = 300 nm.

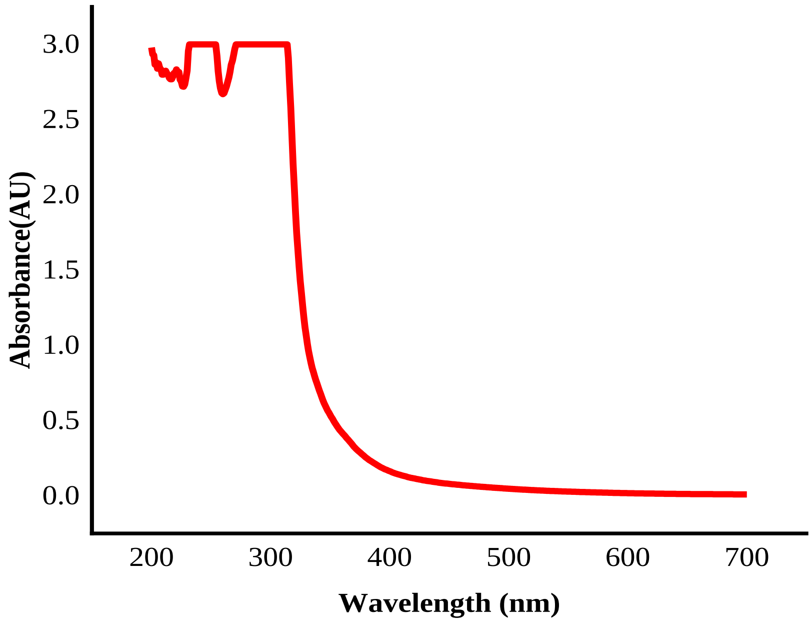


**Figure 5. Spectrums of aqueous tannin preparations in coffee husk's absorption fibre**

**3.2. Calibration Curves**

The standardizing of sample concentrations is achieved by graphing absorption points curve for alkaloid in methylene chloride was created. Each value in the standardization graphs was the average of three replicates. The molar decadic absorption factor constant was determined using the slope of the standardizing curves, Ɛ. The caffeine extracted from coffee husk had an impact on the environment. Using the phenolic extract's absorption measurements as a basis caffein acid, comparison was done with the standard solution, with r = 0.9975. The analysis of phenolic compounds is presented in Figure 6. Assessing absorbance versus the concentration of phenolic compounds, chlorogenic, and tannin acid has been assessed. The increased total phenolic content recovered in this research was most likely caused by the higher concentration of chlorogenic acid found in the chemical makeup of coffee husks, which is a water-soluble phenolic compound with antioxidant properties [32] [33].

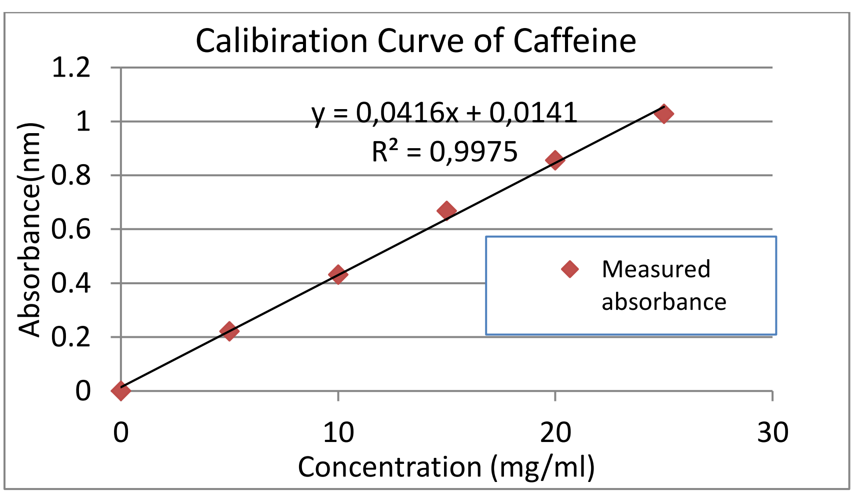


**Figure 6. Caffeine content against absorption in dichloromethane, plotted.**

The negative impact through particular analyses including liquid-liquid solution and Soxhlet, the characteristics of the phenolic content in coffee husk were identified. Graphics were created to show the relationship among this and coffee husk as a result. absorbance ad concentration, which was used to assess the negative impacts of coffee husk. Figure 7 shows that the graph presented correlations between absorbance and concentration of chlorogenic with r = 0.9942. As depicted this a linear correlation is observed with identical slope as the case of the absorbance of caffeine.

In Figure 8, the analysis phenolic content and antioxidant activity were linearly linked, with r = 0.997. The results of the research show that the parameters utilized to get the extracts only slightly impacted the antioxidant activities assessment, which showed a substantial positive association with the quantity of phenolic components due to the greater amount of phenolic components.

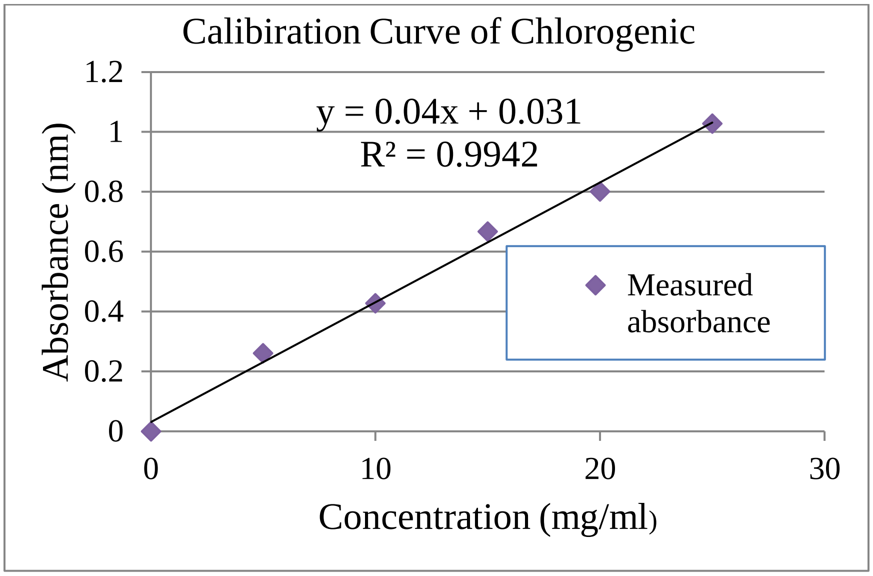


**Figure 7. Plot of concentration versus absorbance of chlorogenic in Dichloromethane.**

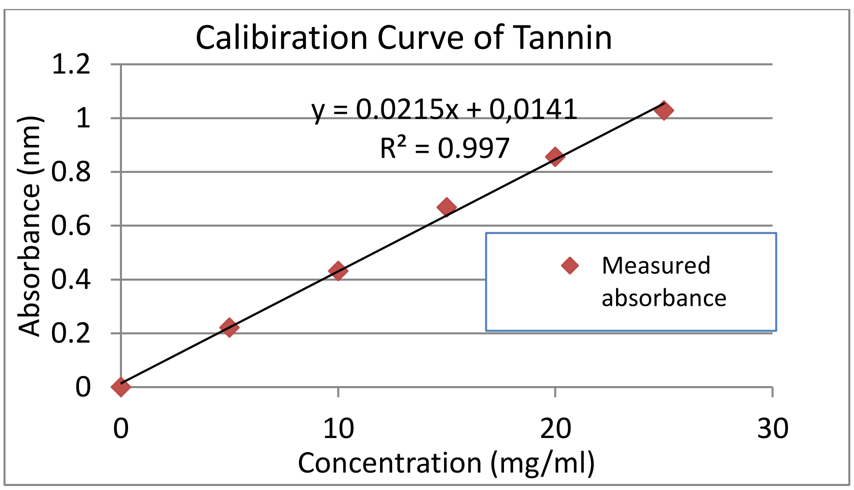


**Figure 8. Plot of concentration versus absorbance of tannin in Dichlomethane.**

Beer's rule held true for alkaloid solutions prepared in deionized water and methylene chloride at concentrations ranging from $2.5 \times 10^{-5}$ to $1.25 \times 10^{-4}$ weight unit $dm^{-3}$. The coefficient relationship revealed a reasonable alkaloid concentration and absorbance are correlated linearly. A $2.5 \times 10^{-5}$ weight unit $dm^{-3}$ normal alkaloid resolution was employed in each solvent to determine the exactitude and detection limit. For three replicate measurements of alkaloid in water and methylene chloride, the relative variance was 4.21% and 3.23%, respectively. For water and methylene chloride, the limit of detection was 2.10 mg/l and 1.63 mg/l, respectively, calculated as three times the blanks variation split by the slopes of the equation. The established Spectrophotometric approach was evaluated on actual materials for phenolic, chlorogenics, and determining alkaloids in husk. A drop-wise solution of 0.1 M NaOH was applied to the binary compound extracts. Comparisons between the results of the defined technique and the literature extraction approach were made. Deionized water is used to dissolve the band square measurement that can be observed clearly inside the spectral bands of coffee husk samples.

## 4. CONCLUSIONS

This article reports the study conducted on experimental analysis of coffee husk using five solutions, i.e., 5%, 10%, 15%, 20%, and 25% for extractable phenolics, chlorogenic acid, caffeine, tannin, and trigonelline, respectively. The work is motivated by the fact that Due to the availability of bioactive chemicals with antioxidant effect, using coffee husk as a raw material for extraction is a helpful strategy. Additionally, using coffee husks gives this particular waste additional value while helping to reduce agro-industrial waste. A research like this one shown that will be possible to develop coffee husk management system and specify environmental damage caused by coffee husk, such as human health, soil acidity, air pollution, plants, and water pollution. The coffee husk was analysed by in this procedure, approaches for measuring absorption of liquid-liquid were applied. Based on the study reported above, the following conclusions can be drawn:

- The reuse of coffee processing by-products reduces the negative environmental impact.
- Blanching coffee husks improved the procedure of examining the acids in the coffee husk.
- The samples showed that coffee husk has higher acidic contents, and the results verified the unfavourable effects of coffee husk, improving by 56%, 58%, and 60%, respectively.
- According to the results of the experiment work, coffee husk has high amount of caffeine, chlorogenic, and tannin acid which can bring impacts to the environment.
- Phenolic compounds extraction from coffee husk can be obtained by liquid-liquid solution.

**Author Contributions**

Berhanu Amena carried out the concept, experimental work, data analysis, and writing for the whole project. Holm Altenbach, Getachew Tibba, and Hirpa Lemu's review and revision, Holm Altenbach and Getachew Tibba oversaw the project the whole time.

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**Data Availability Statement**

The corresponding author may provide the data used in this research upon request.

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**Conflicts of Interest**

The author (s) disclosed possible any conflicts of interest that may have arisen during the article's research, writing, or publishing.

## REFERENCES

i. Woldesenbet,A. G.; Woldeyes, B.; Chandravanshi, B. S. Characteristics of wet coffee processing waste and its environmental impact in Ethiopia. Int. J. Res. Eng. Sci. 2014, vol. 2, pp. 1–5.

ii. Huang, L.; Mu, B.; Yi, X.; Li, S.; Wang, Q. Sustainable Use of Coffee Husks For Reinforcing Polyethylene Composites J. Polym. Environ. 2018, vol. 26, pp. 48–58, doi: 10.1007/s10924-016-0917-x.

iii. Murthy, P. S.; Madhava Naidu, M. Sustainable management of coffee industry by-products and value addition - A review Resour. Conserv. Recycl. 2012 , vol. 66, pp. 45–58, 2012, doi: 10.1016/j.resconrec.2012.06.005.

iv. Gedefaw, M. Assessing The Current Status Of Solid Waste Management Of Gondar Town Ethiopia Int. J. Sci. Technol. Res. 2015, vol. 4, pp. 28–36.

v. Mengist Hailemariam, A. A. Solid waste management in Adama , Ethiopia : Aspects and challenges Integr. Dev. Water Supply Sanit. 2014, vol. 8, pp. 670–676.

vi. Meckelburg, N. et al. Antibacterial effect of coffee: Calcium concentration in a culture containing teeth/biofilm exposed to Coffea Canephora aqueous extract Lett. Appl. Microbiol. 2014, vol. 59, pp. 342–347, doi: 10.1111/lam.12281.

vii. Jia, H. et al. Coffee intake mitigated inflammation and obesity-induced insulin resistance in skeletal muscle of high-fat diet-induced obese mice Genes Nutr. 2014, vol. 9, doi: 10.1007/s12263-014-0389-3.

viii. Fernandes, A. S. et al. Impacts of discarded coffee waste on human and environmental health Ecotoxicol. Environ. Saf. 2016, vol. 141, pp. 30–36, doi: 10.1016/j.ecoenv.2017.03.011.

ix. Mohanpuria, P.; Yadav, S. K. Retardation in seedling growth and induction of early senescence in plants upon caffeine exposure is related to its negative effect on Rubisco Photosynthetica 2009, vol. 47, pp. 293–297, doi: 10.1007/s11099-009-0045-0.

x. Miyashira, C. H.; Tanigushi, D. G.; Gugliotta, A. M.; Santos, D. Y. Influence of caffeine on the survival of leaf-cutting ants Atta sexdens rubropilosa and in vitro growth of their mutualistic fungus Pest Manag. Sci. 2012, vol. 68, pp. 935–940, doi: 10.1002/ps.3254.

xi. Sledz, W. et al. Antibacterial activity of caffeine against plant pathogenic bacteria Acta Biochim. Pol. 2015, vol. 62, pp. 605–612, doi: 10.18388/abp.2015_1092.

xii. Toschi, T. G.; Cardenia, V.; Bonaga, G.; Mandrioli, M.; Rodriguez-Estrada, M. T. Coffee silverskin: Characterization, possible uses, and safety aspects J. Agric. Food Chem. 2014, vol. 62, pp. 10836–10844, doi: 10.1021/jf503200z.

xiii. Blinová, L.; Sirotiak, M.; Bartošová, A.; Soldán, M. Review: Utilization of Waste From Coffee Production Res. Pap. Fac. Mater. Sci. Technol. Slovak Univ. Technol. 2017, vol. 25, pp. 91–101, doi: 10.1515/rput-2017-0011.

xiv. Gouvea, B. M.; Torres, C.; Franca, TA. S.; Oliveira, L. S.; Oliveira, E. S. Feasibility of ethanol production from coffee husks Biotechnol. Lett. 2009, vol. 31, pp. 1315–1319, doi: 10.1007/s10529-009-0023-4.

xv. Akinbomi, J.; Brandberg, T.; Sanni, S. A; Taherzadeh, M. J. Development and Dissemination Strategies for Accelerating Biogas Production in Nigeria BioResources 2014, vol. 9, pp. 5707–5737, doi: 10.15376/biores.9.3.

xvi. Sahu, O. Bioethanol Production by Coffee Husk for Rural Area Adv. Res. J. Biochem. Biotechnol. 2014, vol. 1, pp. 1–5.

xvii. Janissen, B.; Huynh, T. Chemical composition and value-adding applications of coffee industry by-products: A review Resour. Conserv. Recycl. 2018, vol. 128, pp. 110–117, doi: 10.1016/j.resconrec.2017.10.001.

xviii. Blinová, L.; Sirotiak, M.; Bartošová, A.; Soldán, M. Faculty of Materials Science and Technology in Trnava Review : Utilization of Waste From Coffee Production Res. Pap. 2017, vol. 25, pp. 91–102, doi: https://doi.org/10.1515/rput-2017-0011.

xix. Önal, E.; Uzun, B. B.; Pütün, A. E. Bio-oil production via co-pyrolysis of almond shell as biomass and high density polyethylene Energy Convers. Manag. 2014, vol. 78, pp. 704–710, doi: 10.1016/j.enconman.2013.11.022.

xx. Wan Ngah, W. S.; Hanafiah, M. A. K. M. Removal of heavy metal ions from wastewater by chemically modified plant wastes as adsorbents: A review Bioresource Technology 2008, vol. 99, pp. 3935–3948, doi: 10.1016/j.biortech.2007.06.011.

xxi. Chala, B.; Oechsner, H.; Latif, S.; Müller, J. Biogas potential of coffee processing waste in Ethiopia Sustain. 2018, vol. 10, pp. 1–14, doi: 10.3390/su10082678.

xxii. Salomone, R.; Life cycle assessment applied to coffee production : investigating environmental impacts to aid decision making for improvements at company level 2003, vol. 1, pp. 295–300.

xxiii. Husk, C.; Alemu, F. Cultivation of Shiitake Mushroom ( Lentinus edodes ) on 2015, vol. 3, pp. 64–70, doi: 10.11648/j.jfns.20150302.16.

xxiv. Miito, G. J.; Banadda, N. A short review on the potential of coffee husk gasification for sustainable energy in Uganda F1000Research, 2017, vol. 6, pp. 1–13, doi: 10.12688/f1000research.10969.1.

xxv. Cangussu, L. B.; Melo, J. C.; Franca, A. S. Chemical Characterization of Coffee Husks , a By-Product of Coffea arabica Production 2021, Vol.10, pp. 3125, doi: 10.3390/foods10123125 .

xxvi. Rebollo-Hernanz, M.; Zhang, Q.; Aguilera, Y.; Martín-Cabrejas, M. A.; de Mejia, E. G. Relationship of the phytochemicals from coffee and cocoa by-products with their potential to modulate biomarkers of metabolic syndrome in vitro Antioxidants, 2019, vol. 8, doi: 10.3390/antiox8080279.

xxvii. Nia, B.; Frah, N.; Lekbir, A.; Benhmed, K. Assessment of toxicity on the basis of total phenolic content in oleander leaves (Nerium oleander L.) against Myzus persicae (Sulzer, 1776) (Hemiptera: Aphididae) Acta Agric. Slov. 2018, vol. 111, pp. 265–270, doi: 10.14720/aas.2018.111.2.02.

xxviii. Silva, M. de O.; Honfoga, J. N. B.; de Medeiros, L. L.; Madruga, M. S.; Bezerra, T. K. A. Obtaining Bioactive Compounds from the Coffee Husk (Coffea arabica L.) Using Different Extraction Methods Molecules 2020, vol. 26, doi: 10.3390/molecules26010046.

xxix. Andrade, K. S.; Gonalvez, R. T.; Maraschin, M.; Ribeiro-Do-Valle, R. M.; Martínez, J.; Ferreira, S. R. S. Supercritical fluid extraction from spent coffee grounds and coffee husks: Antioxidant activity and effect of operational variables on extract composition 2012, Talanta, vol. 88, pp. 544–552, doi: 10.1016/j.talanta.2011.11.031.

xxx. Murthy, P. S.; Naidu, M. M. Recovery of Phenolic Antioxidants and Functional Compounds from Coffee Industry By-Products Food Bioprocess Technol. 2012, vol. 5, pp. 897–903, doi: 10.1007/s11947-010-0363-z.

xxxi. Broadhurst, R. B.; Jones, W. T. Analysis of condensed tannins using acidified vanillin J. Sci. Food Agric. 1978, vol. 29, pp. 788–794, doi: 10.1002/jsfa.2740290908.

xxxii. Sato, Y. et al. Itagaki, S.; Kurokawa, T.; Ogura, J.; Kobayashi, M.; Hirano, T.; Sugawara, M.; Iseki, K. In vitro and in vivo antioxidant properties of chlorogenic acid and caffeic acid Int. J. Pharm. 2011, vol. 403, pp. 136–138, doi: 10.1016/j.ijpharm.2010.09.035.

xxxiii. Rodrigues, N. P.; Bragagnolo, N. Identification and quantification of bioactive compounds in coffee brews by HPLC-DAD-MSn J. Food Compos. Anal. 2013, vol. 32, no. 2, pp. 105–115, doi: 10.1016/j.jfca.2013.09.002.