INTERNATIONAL JOURNAL OF MULTIDISCIPLINARY RESEARCH AND ANALYSIS

ISSN(print): 2643-9840, ISSN(online): 2643-9875

Volume 08 Issue 05 May 2025

DOI: 10.47191/ijmra/v8-i05-36, Impact Factor: 8.266

Page No. 2597-2604

Unveiling the Secrets of Arabica Coffee: How Cultivation Methods Impact Quality and Chemical Composition

I Nyoman Gde Surendra Atmaja[1], I Nyoman Rai[2], I Made Sukewijaya[3]

[1]Student of Master of Dryland Agriculture Study Program, Faculty of Agriculture, Udayana University, Denpasar, Bali, Indonesia
[2]Agronomy and Horticulture Laboratory, Faculty of Agriculture, Udayana University, Denpasar, Bali, Indonesia
[3]Agroecotechnology Study Program, Faculty of Agriculture, Udayana University, Denpasar, Bali, Indonesia
Corresponding Author- I Nyoman Rai

ABSTRACT: Arabica coffee (Coffea arabica L.) is one of the most valuable plantation commodities, significantly contributing to the global coffee trade. Kintamani Arabica coffee, cultivated in Bali, Indonesia, is known for its unique flavor profile and is primarily grown using an intercropping system with citrus trees. However, variations in cultivation methods may impact the physical characteristics and phytochemical composition of coffee beans. This study aims to analyze the physical properties and phytochemical content of Arabica coffee cultivated under monoculture and intercropping systems. A purposive sampling method was used to collect Arabica coffee cherries from different plantations in Kintamani. Physical properties such as weight, length, width, and defect percentage were observed, while phytochemical analysis was conducted on both green bean and roasted coffee samples using maceration extraction with ethanol as a solvent. Antioxidant activity was measured using the DPPH method, and caffeine content was analyzed via UV-Vis spectrophotometry. The results indicate that the intercropping system produces coffee with superior physical characteristics and a lower defect rate compared to monoculture and non-intensive cultivation. Phytochemical analysis confirmed the presence of flavonoids, tannins, saponins, alkaloids, and caffeine, with weak antioxidant activity. Monoculture coffee beans exhibited higher flavonoid and caffeine content, whereas intercropping increased tannin and flavonoid levels post-roasting. These findings highlight the importance of cultivation methods in determining coffee quality. Future research should explore the phytochemical properties of other plant parts, such as leaves and stems, to provide a more comprehensive understanding of Arabica coffee's bioactive compounds.

KEYWORDS: arabica coffee, cultivation methods, phytochemicals, intercropping, kintamani

I. INTRODUCTION

Coffee is one of the leading plantation commodities with high economic value, primarily due to its role as an export commodity. One of the coffee varieties highly demanded in the global market is Arabica coffee (Coffea arabica L.), renowned for its distinctive flavour profile. Arabica coffee accounts for 65% of global coffee production and is preferred for its superior beverage quality and lower caffeine content than Robusta [1]. Indonesia is recognized as a producer of high-quality Arabica coffee, offering various unique regional varieties such as Gayo, Toraja, Kintamani, and Java.

Bali Province is one of the Arabica coffee-producing regions, with a plantation area of 11,459.59 hectares and a production volume of 3,671 tons in 2022. Bangli Regency, particularly Kintamani District, has the largest Arabica coffee plantation area in Bali and has held a Geographical Indication (GI) certification since 2008. Kintamani Arabica coffee commands a high market value in the global trade, enhancing its reputation and competitiveness in local and international markets. Coffee-producing regions in Bali Province are also part of the Geographical Indication Protection Society (MPIG), which provides legal protection for coffee products from these regions, ensuring better market competitiveness [2].

One of the unique aspects of Kintamani Arabica coffee lies in its cultivation technique. Unlike other Arabica coffee varieties, this coffee is grown using an intercropping system, initially with shade trees such as Erythrina, but now more commonly combined with citrus trees. This intercropping system offers mutual benefits, as the taller citrus trees provide the 60% shade required by coffee plants, while the coffee plants contribute nutrients to the citrus trees. The intercropping method with citrus enhances the coffee's distinctive flavour characteristics, including the absence of significant defects, citrus acidity, low bitterness, and a strong, high-quality citrus aroma [3].

Despite its high market value, Kintamani Arabica coffee has relatively low productivity. Coffee production in Kintamani varies significantly, with some farmers achieving suboptimal yields. This discrepancy is attributed to varying levels of knowledge and implementation of cultivation techniques that adhere to Good Agricultural Practices (GAP) principles [4]. Differences in cultivation practices may influence coffee beans' physical characteristics and chemical composition, particularly secondary metabolites that play a crucial role in determining the coffee flavour and quality.

Research on coffee cultivation in Indonesia has compared monoculture and intercropping systems. Intercropping coffee with other crops, such as areca palm, is more beneficial and productive than monoculture, with a land equivalent ratio 2.39 [5]. A study in North Sumatra indicated that shaded coffee farming accounts for 32% of total Arabica production and provides ecological benefits for land conservation [6]. Additionally, research in Dairi Regency revealed that intercropped Arabica coffee exhibits 25.5% higher productivity and generates 48.2% higher income than monoculture [7]. However, further studies are required to explore the quality of coffee produced under these two systems.

Research has shown that coffee beans' physical and sensory quality is influenced by genetic traits, cultivation practices, and growing environment [8]). A study on Gayo Arabica coffee found that higher altitudes (1,500-1,700 m) yield better physical quality and flavour profiles compared to lower altitudes (1,000-1,500 m) [8,9]. Both altitude ranges produce speciality-grade coffee, but higher elevations correlate with increased flavour complexity and overall quality [9]. These findings highlight the importance of optimal cultivation practices and environmental conditions in producing high-quality coffee.

Phytochemical analysis is an essential method for identifying plant bioactive compounds [10]. Various studies have reported variations in phytochemical content within Arabica coffee beans. For instance, phytochemical tests on green bean extracts of Aceh Gayo Arabica coffee confirmed the presence of alkaloids, tannins, phenolics, flavonoids, triterpenoids, and glycosides [11]. Meanwhile, phytochemical screening of roasted Arabica coffee bean extracts from Wamena and Moanemani, Papua, identified alkaloids, flavonoids, terpenoids, saponins, and tannins [12].

Arabica coffee is also known for its high antioxidant content, derived from polyphenols, a group of micronutrients found in various food sources. One of the primary secondary metabolites within polyphenols is flavonoids, which are highly soluble in polar solvents [13]. Phytochemicals, as secondary metabolites, are significant in defining coffee characteristics [14]. The chemical composition of coffee, including its antioxidant activity, is influenced by cultivation methods [15]. Therefore, this study aims to examine the phytochemical content of Kintamani Arabica coffee cultivated under monoculture and intercropping systems.

This study aims to identify the physical properties and phytochemical composition of Kintamani Arabica coffee cultivated using monoculture and intercropping systems. Understanding the impact of cultivation methods on coffee's physical attributes and phytochemical composition is crucial for determining optimal agricultural strategies. The findings of this study are expected to provide scientific recommendations for farmers to adopt more effective and sustainable cultivation techniques to enhance the quality, productivity, and competitiveness of Kintamani Arabica coffee in both domestic and international markets.

II. METHODS

This study employs a purposive sampling technique for site selection, focusing on kintamani as the centre of arabica coffee production in bali. Arabica coffee fruit samples from monoculture plantations (mo), intercropping with citrus (ts), and non-intensively managed plantations (ti) were collected using simple random sampling. The coffee cherries used were fully ripe (red). This study aims to answer two research questions: whether the difference in cultivation methods results in distinct physical characteristics of arabica coffee cherries and whether the difference in cultivation methods leads to variations in the phytochemical compounds of arabica coffee.

The observation of the physical properties of coffee cherries includes colour, weight, shape, length, and width. Phytochemical testing was conducted on both green beans and roasted coffee beans. The green bean processing followed the wet processing method with fermentation for 12 hours, while the coffee beans were roasted at 200°c for 11 minutes to produce roasted beans. Phytochemical analysis was performed using the maceration method with ethanol as a solvent. Antioxidant activity was tested using the dpph method, while caffeine content was analyzed using uv-vis spectrophotometry.

The study was conducted from june to november 2024 in three villages in kintamani: catur, batukaang, and mengani. The testing was conducted at the food analysis laboratory of ftp and the integrated research laboratory of fmipa, udayana university. The equipment included a digital balance, spectrophotometer, rotary evaporator, and blender. The research materials included arabica coffee cherries, ethanol, dpph solution, and various chemical reagents. The research variables included quantitative variables such as weight, length, width, flavonoids, tannins, antioxidant activity, and caffeine content, while qualitative variables included colour, shape, saponins, and alkaloids.

The research procedure consisted of several stages. First, arabica coffee cherries were collected from three plantations: monoculture, intercropping with citrus and non-intensively managed plantations. Next, extraction was conducted using the maceration method with 80% ethanol (1:4), followed by concentration using a rotary evaporator and an oven at a specific temperature. The physical properties analysis included identifying the colour, weight, shape, length, and width of coffee cherries, referring to ipgri, and assessing coffee bean quality based on the indonesian national standard (sni) 01-2907-2008. The phytochemical analysis involved testing for flavonoids using hcl and mg powder, tannins using a 1% fecl3 solution, and saponins through the shaking test. Alkaloids were analyzed using wagner, mayer, and dragendorff reagents. Antioxidant activity was measured using the dpph method and ic50 values, while caffeine content was analyzed using the parry method and uv-vis spectrophotometry.

RESULTS AND DISCUSSION

The colour and shape variables of the fruit observed directly in the field in various cultivation methods show that the colour of the coffee fruit from the three methods tends to be similar, namely red. However, based on the average of each cultivation method, coffee cultivated in monoculture has a more dominant red colour than intercropping and non-intensive cultivation methods, as shown in Figure 1.

The results of the study on the physical properties of Arabica coffee fruit in various cultivation methods also showed that the fruit shape tends to be round in all three methods: monoculture, intercropping, and non-intensive cultivation. Meanwhile, other physical variables in the form of quantitative data, namely fruit weight, fruit length, and fruit width, were analyzed using analysis of variance, which was then continued with the Least Significant Difference (LSD) test at a significance level of 5%. The results of the variance analysis showed that the variables of fruit weight, fruit length, and fruit width had very significant differences based on the cultivation method applied.

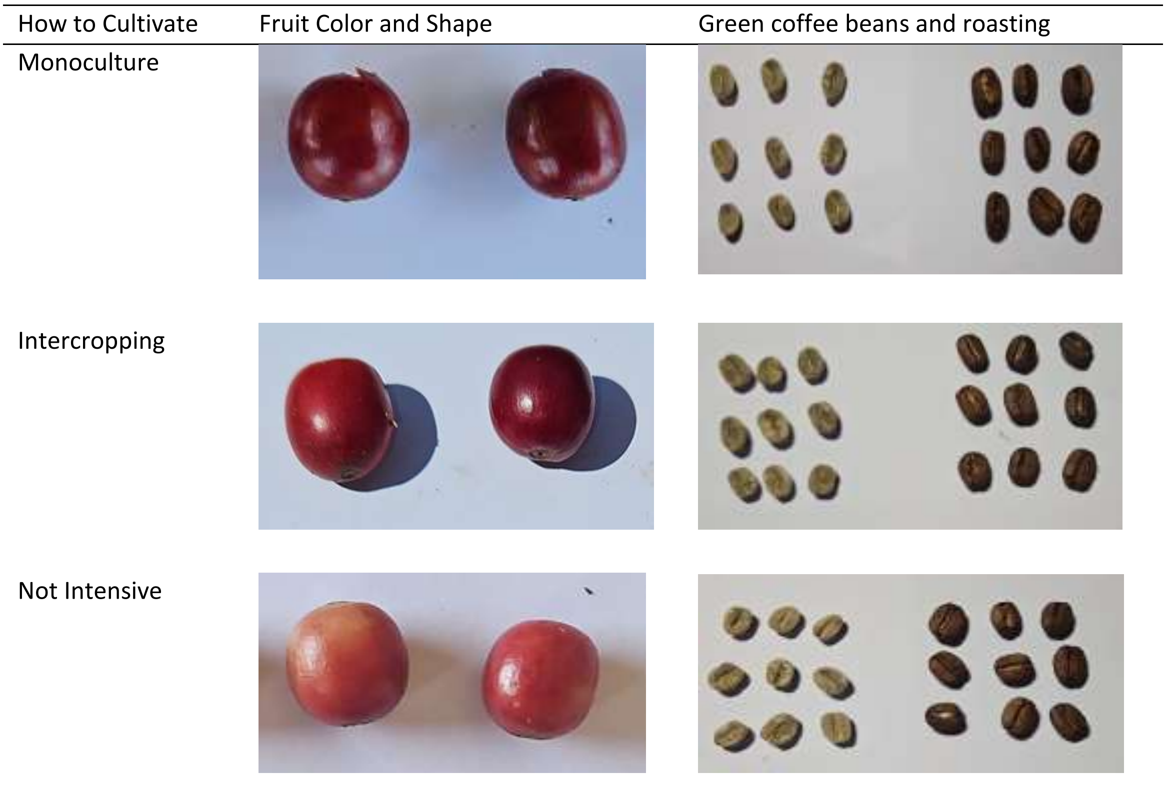

Figure 1. Physical Characteristics of Arabica Coffee Fruit and Beans

Table 1 shows that the intercropping cultivation method produces the highest fruit weight, 2.529 g, with the most significant fruit length reaching 16.617 mm and the largest fruit width of 15.537 mm. In addition, the table also shows that differences in cultivation methods significantly affect fruit weight, with the highest value obtained in the intercropping method (2.529 g). These results significantly differ from the monoculture and non-intensive cultivation methods, each with a fruit weight of 2.284 g and 2.022 g. The fruit length variable in the intercropping cultivation method also showed the highest value, namely 16.617 mm, which was significantly different compared to the monoculture method (16.388 mm) and non-intensive cultivation (16.133 mm). The highest fruit width was found in the intercropping cultivation method with a value of 15.537 mm, which was significantly different from other methods. Meanwhile, the lowest fruit width was obtained in the non-intensive cultivation method, with a value of 14.442 mm.

Table 1. The effect of arabica coffee plant cultivation methods on fruit weight, fruit length, and fruit width.

Treatment	Fruit Weight	Fruit Length	Fruit Width
Intercropping	2,529 a	16,617 a	15,537 a
Monoculture	2,284 b	16,388 b	15,043 b
Not Intensive	2,022 c	16,133 c	14,442 c
LSD 5%	0.074	0.206	0.207

Information:
Numbers followed by the same letter in the same treatment and column indicate no significant difference based on the Least Significant Difference (LSD) test at the 5% level.

The fruit weight variable is the most important variable in identifying the physical properties of Arabica coffee fruit in various cultivation methods in this study. The results showed that the intercropping cultivation method produced the highest fruit weight, 2.529 g. Compared to the non-intensive cultivation method, there was a decrease in coffee fruit weight of 20.047%, so the weight of coffee fruit in the non-intensive method became 2.022 g. The highest fruit weight in the intercropping method was in line with other variables, namely the longest fruit length (16.617 mm) and the largest fruit width (15.537 mm). The relationship between fruit weight and fruit length shows a significant correlation with a correlation value of 1.00. At the same time, the relationship between fruit weight and fruit width also has a very close correlation with a value of 0.999. The results of this study, which show a close relationship between fruit weight and fruit length and width, align with the research of Yuwana et al. (2014).

The study stated that fruit weight is positively and very closely correlated with the length, width, and thickness of rice coffee beans, where the more significant the weight of the coffee beans, the greater the length, width, and thickness of the rice coffee beans.In addition, Edowai and Tahoba (2018) stated that the intercropping cultivation method affects the quality of coffee fruit by improving plant health, providing more diverse sources of nutrients, maintaining soil moisture, and reducing stress on coffee plants. Better soil moisture also improves fruit growth and makes coffee taste richer and more balanced.

Table 2. General test results for arabica coffee bean quality requirements

Characteristics	**Monoculture**	**Intercropping**	**Not Intensive**	**Standard Limits**	**Unit**
Water content	10.3	10.2	10.3	12.5 max	%
Live Insects	None	None	None	None	
Total Defect Value	1.0	0.7	6.0	11	%
Foreign object	0.0	0.0	0.0	0.5 max	%
Rotten and Moldy Smelling Seeds	None	None	None	None	
Conclusion	Quality I	Quality I	Quality I		

Table 3. Results of special conditions test for arabica coffee bean quality

Sample Type	**Test Results**	**Percentage (%)**	**Conclusion**	**Condition**
Monoculture	Passes 6.5 mm diameter sieve, does not pass 6 mm diameter sieve	2.12	Currently	Max pass 5%
Intercropping	Passes 6.5 mm diameter sieve, does not pass 6 mm diameter sieve	2.11	Currently	Max pass 5%

Not Intensive	Passes 6 mm diameter sieve, does not pass 5 mm diameter sieve	5.09	Small	Max pass 5%

In addition to conducting physical observations of coffee berries directly in the field, this study also conducted quality tests of coffee beans in the form of green beans using various cultivation methods. Coffee bean quality tests were carried out based on the Indonesian National Standard (SNI) 01-2907-2008 concerning coffee bean standards, which classify the quality of coffee beans into general quality requirements and special quality requirements.Table 3 shows the results of the general requirements test for coffee bean quality, where monoculture, intercropping, and non-intensive cultivation methods are all classified into quality 1. Meanwhile, the results of the unique requirements test for Arabica coffee bean quality shown in Table 3 show that the non-intensive cultivation method produces small coffee beans. In contrast, those cultivated using monoculture and intercropping methods produce medium-sized coffee beans. Therefore, the quality test shows that coffee beans cultivated using monoculture and intercropping methods are included in the quality category 1, classified as medium-sized beans.

The fundamental difference in Table 3 is seen in the number of coffee bean defects. The non-intensive cultivation method has the highest percentage of defects, which is 6%, while the intercropping method has the lowest number of defects, 0.7%. This shows that the intercropping cultivation method produces coffee beans with lower defects than the non-intensive method. This condition is caused by the absence of fertilization in the non-intensive cultivation method, so the nutrients needed for the fruit formation process are not met. As a result, the coffee fruit formation process is not optimal, which leads to an increase in the number of defective coffee beans after processing, so the quality of the coffee decreases.

According to SNI 01-2907-2008, defective coffee beans are classified into 20 criteria: black beans, brown beans, single-holed beans, multiple-holed beans, and others. According to [16], black coffee beans are generally caused by diseases that attack coffee berries, while pest attacks, especially insects, usually cause hollow beans. In addition, broken beans generally occur due to the harvest of young coffee berries, so during the peeling process (pulping), the beans become broken. Based on the observation results, the intercropping cultivation method produces the best physical properties of coffee beans and better coffee bean quality compared to monoculture and non-intensive cultivation methods.

The antioxidant activity test (IC50) results on green bean coffee beans showed that the monoculture cultivation method produced the highest value, 513.0750 ppm, as shown in Table 4. In contrast, the lowest value was found in the non-intensive cultivation method, which was 329.9520 ppm. After roasting, the IC50 level decreased by 52.41%, or 244.1601 ppm in monoculture coffee beans. The decrease also occurred in coffee beans that were cultivated non-intensively, with a decrease of 39.87%, so that the IC50 level became 198.4167 ppm after the roasting process.

According to research by [17] the decrease in antioxidant activity during the roasting process occurs due to the degradation of phenolic compounds, flavonoids (quercetin and kaempferol), chlorogenic acid, and caffeic acid due to heating. In addition, according to [18], higher antioxidant activity is indicated by a lower IC50 value, where the antioxidant capacity is categorized as very strong at 50 ppm, vigorous at 50–100 ppm, moderate at 101–150 ppm, and weak at more than 150 ppm. Based on the results of this study, all samples tested had IC50 values above 150 ppm, so both Arabica coffee beans in the form of green beans and those that have been roasted are included in the category of weak antioxidant activity.

The highest flavonoid content test results in this study were shown by green coffee beans cultivated in monoculture, with a flavonoid content of 1,904.47 mg/100 g, as shown in Table 4. In contrast, the lowest value was found in Arabica coffee beans cultivated non-intensively, with a flavonoid content of 1,603.96 mg/100 g. After the roasting process, the highest flavonoid content was found in coffee beans cultivated using the intercropping method, with a content of 748.63 mg/100 g, which decreased by 53.91% from the flavonoid content in green beans cultivated using the same method. A similar decrease also occurred in the sample with the lowest flavonoid content, namely coffee beans from the non-intensive cultivation method, which decreased by 64.65% after the roasting process.

The decrease in flavonoid levels during the roasting process is in line with research by [19] which states that bioactive flavonoid compounds will be damaged at temperatures above 50°C. High temperatures can cause changes in the structure of active compounds so that the flavonoid content in coffee extract decreases. This is also supported by research by [20] which states that flavonoids are metabolites that are thermolabile, meaning they are not resistant to temperatures above 50°C. The optimal flavonoid extraction process is carried out at temperatures below 50°C, while flavonoid levels tend to decrease at higher temperatures.

Table 4. The effect of cultivation methods and treatment of green bean and roasting coffee samples on the number of IC50, flavonoids, tannins, saponins, and alkaloids

Sample Code	IC 50 (ppm)	Flavonoid (mg/100 g)	Tannin (mg TAE/100g)	Saponins	Alkaloid
Monoculture green bean	513,0750	1,940.47	1,862.17	Positive (+)	Positive (+)
Intercropping green bean	418,1403	1,624.25	1,820.37	Positive (+)	Positive (+)
Not Intensive green bean	329,9520	1,603.96	1,879.53	Positive (+)	Positive (+)
Monoculture roasting	244,1601	641.72	2,258.10	Positive (+)	Positive (+)
Intercropping roasting	203,6149	748.63	2,508.60	Positive (+)	Positive (+)
Not Intensive roasting	198,4167	567.02	2,142.31	Positive (+)	Positive (+)

Table 4 shows the results of tannin levels in this study, the highest of which was shown in green bean Arabica coffee beans that were not cultivated intensively, which was 1,879.53 mg TAE/100 g. In contrast, the lowest tannin levels were found in green bean Arabica coffee beans that were cultivated by intercropping, which was 1,820.37 mg TAE/100 g. The tannin levels in roasted coffee beans increased when compared to green bean Arabica coffee beans. The highest levels of roasted Arabica coffee beans were found in coffee beans cultivated by intercropping with a value of 2,508.60 mg TAE/100 g; there was an increase in tannin levels of 37.81% from green bean coffee beans, while the lowest tannin levels in roasted Arabica coffee beans were found in coffee beans that were cultivated non-intensively, which was 2,142.31 mg TAE/100 g, where this level also increased by 13.98% from green bean coffee beans. According to research by Suhaila et al. (2023), the right temperature will produce optimal tannin. Generally, the solubility of the extracted active ingredients becomes optimal for the extract as the temperature increases. However, the increase in extraction temperature needs to be considered because tannin production will decrease if the extraction temperature is too high. It was stated in his research that at a temperature of 40^0C, the amount of tannin was 158.43 mg/g-1 and increased at a temperature of 45^0C by 166.88 mg/g-1, then decreased at a temperature of 50^0C by 129 mg/g-1 and when the temperature rose to 55^0C the amount of tannin increased by 215.72 mg/g-1. Furthermore, the amount of tannin decreased at a temperature of 60^0C by 190.38 mg/g-1.

This study only tested the phytochemical content of saponins and alkaloids with qualitative tests, so it only found out whether or not there was phytochemical content in coffee beans, both green beans and roasted ones, in different cultivation methods. Table 5.6 shows the results of saponin and alkaloid analysis in this study produced positive values (+) from all cultivation methods carried out; this means that green bean Arabica coffee beans and roasted Arabica coffee beans in all cultivation methods contain phytochemical compounds saponins and alkaloids. [21] stated that to determine the presence of saponin content is indicated by the formation of stable foam in the tested sample. The semi-polar chemical properties of saponins make this compound easily soluble in water and fat. Thus, the existence of compounds in cell membranes has the potential to prevent or inhibit the division or replication of pathogenic bacterial cells in the body. Saponins can modulate bacterial genetic material so that the bacterial cell reproduction process is damaged [22].

Meanwhile, alkaloids are the most abundant secondary metabolite compounds that have nitrogen atoms, which are found in plant tissues. Alkaloids play a role in metabolism and control development in plant life systems. Most alkaloid compounds come from plants, especially angiosperms. Alkaloids can be found in various parts of plants, such as flowers, seeds, leaves, twigs, roots and bark [23].

Table 5. The influence of cultivation methods and differences in treatment of coffee bean samples g*red bean*and roasting againstCaffeine levels.

Sample ID	Method	Unit	Caffeine Content
Monoculture green bean	Spectrophotometry	%	1,471
Intercropping green bean	Spectrophotometry	%	1,009

Not Intensive green bean	Spectrophotometry	%	1,215
Monoculture roasting	Spectrophotometry	%	1,891
Intercropping roasting	Spectrophotometry	%	1,427
Not Intensive roasting	Spectrophotometry	%	1,489

Caffeine is a methylxanthine alkaloid compound (purine base) in the form of white crystals [24]. The results of the study presented in Table 5 show that the highest caffeine content in green bean coffee beans is found in Arabica coffee beans cultivated using the monoculture method, with a value of 1.471%. Meanwhile, the lowest caffeine content in green bean coffee beans was found in Arabica coffee beans cultivated using the intercropping method, which was 1.009%.

The caffeine content in roasted coffee beans increased compared to Arabica coffee beans in the form of green beans. The highest caffeine content in roasted Arabica coffee beans was found in coffee cultivated using the monoculture method, with a value of 1.891%, which showed an increase in caffeine content of 28.55% from green bean coffee beans. Meanwhile, the lowest caffeine content in roasted Arabica coffee beans was found in coffee cultivated using the intercropping method, which was 1.427%, which also increased by 41.43% compared to the caffeine content in green bean coffee beans.

Based on research conducted by [25], the roasting process significantly affects the caffeine content in green and roasted coffee beans. The higher the roasting level, the higher the caffeine content in the coffee beans. The study reported that the caffeine content in coffee beans that underwent medium roasting reached 1.48%. In line with these findings, [25] research also stated that increased caffeine levels in roasted coffee beans can occur due to evaporation of water content and acidic compounds, such as chlorogenic acid, during the roasting process. The temperature and time factors of the roasting process are thought not to cause evaporation of caffeine, fat, and minerals. Therefore, with the reduction in water content and acidic compounds due to evaporation, the caffeine content in coffee beans becomes higher.

CONCLUSION

Based on the research and discussion results, the intercropping cultivation system produces better physical characteristics and coffee quality compared to monoculture and non-intensive cultivation methods. The intercropping system affects Arabica coffee cherries' weight, length, and width, resulting in coffee beans with a lower defect rate than other cultivation methods. In addition, the green and roasted Arabica coffee beans' phytochemical content from different cultivation methods shows the presence of flavonoids, tannins, saponins, alkaloids, and caffeine, with weak antioxidant activity. Green beans from monoculture cultivation produced the highest flavonoid and caffeine contents, while the highest tannin content in green beans was found in coffee cultivated non-intensively. Roasted Arabica coffee beans from monoculture cultivation produced the highest caffeine content, while the highest flavonoid and tannin contents were found in roasted Arabica coffee beans cultivated through intercropping. This study is limited to identifying Arabica coffee fruit's physical characteristics and phytochemical content based on different cultivation methods. Therefore, future research is recommended to examine other parts of the coffee plant, such as leaves and stems, to gain a more comprehensive understanding of the overall characteristics of the coffee plant. Furthermore, the findings of this study can serve as a reference for farmers, researchers, and the coffee industry in determining the optimal cultivation method to enhance the quality of Arabica coffee. Future research should also conduct a more in-depth analysis of the relationship between environmental factors, cultivation methods, and phytochemical content to provide more specific recommendations for improving the quality and benefits of Arabica coffee.

REFERENCES

1) Deribe, H. (2022). Spices production in Ethiopia: a review. *Agricultural Reviews*, *43*(2), 186-192.
2) Udayana, I. G. B. (2017). Marketing strategies arabica coffee with information technology in Kintamani District Bangli. *International Research Journal of Engineering, IT and Scientific Research*, *3*(3), 93-102.
3) Asiah, N., Epriyani, C., Kurnia, A., Ramadhan, K., Hidayat, S. G., & Apriyantono, A. (2022). Profil Kopi Arabika Kintamani Bali.
4) Widia, I. W., & Duniaji, A. S. (2016). Laporan pelaksanaan rencana aksi pengembangan industri agro kopi di Propinsi Bali tahun 2016. *Bali: Dinas Perindustrian dan Perdagangan Propinsi Bali dan Fakultas Teknologi Pertanian Universitas Udayana*.
5) Nasamsir, N., & Harianto, H. (2018). Pertumbuhan dan produktivitas lahan tumpang sari tanaman pinang (Areca catechu l.) dan kopi (Coffea sp.). *Jurnal Media Pertanian*, *3*(2), 61-71.
6) Saragih, J. R. (2018). Aspek ekologis dan determinan produksi kopi arabika spesialti di Wilayah Dataran Tinggi Sumatera Utara. *Jurnal wilayah dan lingkungan*, *6*(2), 74-87.

7) S. M. Silitonga, Salmiah, and L. Sihombing, “Analisis komparasi tingkat pendapatan usahatani kopi dengan berbagai pola tanam (monokultur dan polikultur) di Kabupaten Dairi Kecamatan Sumbul Desa Tanjung Beringin,” J. Soc. Econ. Agric. Agribusiness, vol. 2, no. 3, pp. 1–15, 2013.
8) Purba, P., Sukartiko, A. C., & Ainuri, M. (2020). Analisis mutu fisik dan citarasa kopi indikasi geografis arabika gayo berdasarkan ketinggian tempat. *Jurnal Tanaman Industri dan Penyegar*, *7*(2), 83-92.
9) Muiz, K., Nilahayati, N., Nasruddin, N., Jamidi, J., & Hafifah, H. (2024). Analisis Kualitas Fisik Dan Cita Rasa Kopi Arabika (Coffea arabica L.) Pada Dua Rentang Ketinggian. *Jurnal Agrium*, *21*(3), 258-265.
10) Kumalasari, M. L. F., & Andiarna, F. (2020). Uji fitokimia ekstrak etanol daun kemangi (Ocimum basilicum L). *Indonesian Journal for Health Sciences*, *4*(1), 39-44.
11) Handoko, A. P., Lutfiyani, D., & Selvester, M. (2020). Uji fitokimia ekstrak biji hijau kopi arabika (Coffea Arabica L) aceh gayo. In *Seminar Nasional Riset Kedokteran* (Vol. 1, No. 1).
12) Mangiwa, S., & Maryuni, A. E. (2019). Skrining fitokimia dan uji antioksidan ekstrak biji kopi sangrai jenis arabika (Coffea arabica) asal Wamena dan Moanemani, Papua. *Jurnal Biologi Papua*, *11*(2), 103-109.
13) Ajhar, N. M., & Meilani, D. (2020). Skrining fitokimia dan uji aktivitas antioksidan dari ekstrak etanol biji kopi arabika (Coffea arabica) yang tumbuh di daerah gayo dengan metode DPPH. *Pharma Xplore: Jurnal Sains dan Ilmu Farmasi*, *5*(1), 34-40.
14) Walid, M., & Putri, D. N. (2023). Skrining senyawa metabolit sekunder dan total fenol kopi robusta (Coffea canephora Pierre ex A. Froehner) di Daerah Petungkriyono Pekalongan. *Pena: Jurnal Ilmu Pengetahuan dan Teknologi*, *37*(1), 1-10.
15) Wigati, E. I., Pratiwi, E., Nissa, T. F., & Utami, N. F. (2019). Uji Karakteristik Fitokimia dan Aktivitas Antioksidan Biji Kopi Robusta (Coffea Canephora Pierre) Dari Bogor, Bandung dan Garut dengan Metode DPPH (1,1-diphenyl-2-picrylhydrazyl). FITOFARMAKA: Jurnal Ilmiah Farmasi, 8(1), 53–59. https://doi.org/10.33751/jf.v8i1.1172
16) Setyani, S., Subeki, S., & Grace, H. A. (2018). Evaluation of Defect Value and Flavour Robusta Coffee (Coffea canephora L.) Pro-duced by Small and Medium Industri Sector of Coffee in Tanggamus District. *Jurnal Teknologi & Industri Hasil Pertanian*, *23*(2), 103-114.
17) Acidri, R., Sawai, Y., Sugimoto, Y., Handa, T., Sasagawa, D., Masunaga, T., Yamamoto, S., & Nishihara, E. (2020). Phytochemical Profile and Antioxidant Capacity of Coffee Plant Organs Compared to Green and Roasted Coffee Beans. *Antioxidants*, *9*(2), 93. https://doi.org/10.3390/antiox9020093
18) Kurniawan, M. F., Nasution, A. M., & Hapsari, D. R. (2024). Karakteristik Sensori Kopi Arabika Varietas Sigagar Utang Berdasarkan Pengolahannya Menggunakan Quantitative Descriptive Analysis (QDA). *Jurnal Ilmu Pangan dan Hasil Pertanian*, *7*(2), 204-218.
19) Ulhusna, F. A. (2022). The Profil Fitokimia Dan Aktivitas Antioksidan Ekstrak Air Daun Tegetes erecta L. *Jurnal Jeumpa*, *9*(1), 690-694.
20) Syafriana, V., Ramadhani, L. A., Helma, F., Ningsih, W., & Suyatno, S. (2024). Antibacterial Activity of Ethanol Extracts of Sempur Air (Dillenia suffruticosa) and Akar Kaik-kaik (Uncaria cordata) Leaves Against Shigella dysentriae and Salmonella typhimurium. *Journal of Tropical Pharmacy and Chemistry*, *8*(1), 86-92.
21) Mangiwa, S., & Maryuni, A. E. (2019). Skrining fitokimia dan uji antioksidan ekstrak biji kopi sangrai jenis arabika (Coffea arabica) asal Wamena dan Moanemani, Papua. *Jurnal Biologi Papua*, *11*(2), 103-109.
22) Ngginak, J., Apu, M. T., & Sampe, R. (2021). Analisis kandungan saponin pada ekstrak seratmatang buah lontar (Borassus flabellifer Linn). *BIOEDUKASI: Jurnal Pendidikan Biologi*, *12*(2), 221-228.
23) Maisarah, M., & Chatri, M. (2023). Karakteristik dan fungsi senyawa alkaloid sebagai antifungi pada tumbuhan. *Jurnal Serambi Biologi*, *8*(2), 231-236.
24) Aryadi, M. I., Arfi, F., & Harahap, M. R. (2020). Literature review: Perbandingan kadar kafein dalam kopi Robusta (Coffea canephora), kopi Arabika (Coffea arabica) dan kopi Liberika (Coffea liberica) dengan metode spektrofotometri UV-Vis. *Amina*, *2*(2), 64-70.
25) Putri, M. K., & Dellima, B. R. E. M. (2022). Analisis Kadar Kafein dalam Green Bean dan Roasted Bean Kopi Robusta (Coffea canephora) Temanggung Menggunakan Spektrofotometer UV: Analysis of Caffeine Levels in Green Bean and Roasted Bean of Robusta Coffee (Coffea canephora) Temanggung Using UV Spectrophotometer. *Jurnal Sains dan Kesehatan*, *4*(6), 577-584.