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Research Article

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Impact of Storage Conditions on Moisture Content and Colour Characteristics of Roasted Arabica Coffee Using Imaging Techniques

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Abstract

Coffee, specifically Coffea arabica, is highly valued for its quality, aroma, and flavor. Understanding the factors affecting coffee quality is essential for farmers, industry players, and consumers. One key factor is the storage conditions, including air exposure, light, moisture, and temperature. Moisture content (MC) and color are commonly used indicators of coffee quality. This study analysed MC and colour trends of dark and medium roasted Arabica ground coffee stored under various conditions (cold vs. room temperature, airtight vs. non-airtight, and opaque vs. transparent) over a 10-week period. The results showed that the MC increased under all conditions. For dark roast, the lowest MC was observed in cold, airtight, transparent storage, whereas the highest was observed in room-temperature, non-airtight, opaque storage. For medium roast, the lowest MC occurred in cold, airtight, opaque storage, and the highest occurred in room-temperature, non-airtight, transparent storage. Color analysis using RGB imaging provided reliable grayscale values consistent with visual observations, although the trends fluctuated and were not strictly increasing or decreasing. Nevertheless, the method effectively distinguished roast levels, with dark roast showing lower grayscale values than the medium roast. A relationship between MC and color was also observed, where a higher MC corresponded to higher grayscale values (slightly brighter appearance). Overall, this study highlights the impact of storage conditions on MC and color, offering insights for improving coffee storage practices to maintain quality and freshness.

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1. Introduction

Coffee wins many hearts with its delicious taste and aroma. In the last three decades, the number of coffee drinkers has increased, especially in Asia (from the central to the eastern portion represented by Japan) and the Arabian Peninsula. The "discovery" of coffee by these populations has led to a 2% annual consumption growth rate, which is above the world's vegetative growth (Vegro & de Almeida, 2020). However, statistics made by the Department of Statistics Malaysia (DOSM) reported that Malaysia consumed 800,000 60 kg bags of coffee between 2021 and 2022 (Department of Statistics Malaysia [DOSM], 2022; Ramanathan & Ali, 2021).

However, coffee purchases depend on the taste and quality preferences of the buyer and consumer. Although coffee now has various brewing recipes, such as latte, espresso, white coffee, mocha, and cappuccino, the original green coffee beans (GCB) may taste different based on the type of coffee bean, the horticulture used in its production, water used to make it, and how the beans are stored, ground, brewed, extracted, and fermented. These factors can affect the flavors of a cup of coffee, including the roasting degree (Hernandez et al., 2017; Souza, 2008; Tipler, 2013). Roasting is the process of converting green coffee beans into roasted beans using heat treatment. According to Halim-Lim et al. (2022), the roasting of coffee beans has significant effects on various aspects of coffee beans, including their physical and chemical properties, color, aroma, and flavor. This process is responsible for aroma through processes such as pyrolysis, the Maillard reaction, Strecker degradation, and caramelization (Thammarat et al., 2018), producing hundreds of volatile compounds (Cotter & Hopfer, 2018a, Ku Madihah et al., 2013; Saud & Salamatullah, 2021).

The darkening of coffee color during roasting is influenced by the intricate interactions of the Maillard reaction, caramelization, and physical transformations within the coffee beans as they are subjected to heat. When it comes to colour, roasted coffee is commonly categorized into light, medium, and dark roast levels (Nasution & Andayani, 2017). This distinction is based on the resulting color of the beans after roasting, and because color is frequently used as the basis for consumers' initial assessment of quality, it serves as a critical indication of perceived quality (Yeager et al., 2022). As depicted in Figure 1, the color of coffee beans before and after roasting is compared, demonstrating how the color darkens as the roasting temperature increases.

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Figure 1. Arabica (a) green coffee beans, (b) medium roasted beans and (c) dark roasted beans (Tarasov et al., 2022).

In addition to color, variations in physical properties, such as density, expansion index, texture, weight loss, and moisture content (MC), have also been highlighted in the roasting process (Fiore et al., 2006). Among these properties, moisture content is a critical parameter for the entire coffee production chain and is frequently studied in relation to the quality of coffee. Within this context, it has been reported that the moisture content of raw or unprocessed coffee beans is normally between 45% and 55%, dropping by as much as 10% to 12% after processing and drying, and losing another 2% after roasting (Boot, 2020). Maintaining an appropriate moisture content is crucial. High-moisture (more than 12% wet basis) green coffee can spoil from bacteria, mold, or yeast, especially if the seed is not deactivated. In contrast, if the moisture content of the beans drops below 9%, the beans shrink and become distorted, giving the impression that the coffee is of poor quality (Gautz et al., 2008). Therefore, understanding the effects of roasting on moisture content and its interplay with other physical and chemical properties is crucial.

However, it is essential to recognize that color and moisture content are influenced not only by the roasting process itself but also by subsequent storage methods. The conditions under which coffee is stored, whether for transportation or home storage, as well as temperature, humidity, and exposure to oxygen, significantly impact the color and moisture content, ultimately shaping the overall quality of the final brew. Traditionally, jute sacks have been used to store coffee beans; however, owing to their inability to maintain favorable conditions, many studies have been conducted to overcome this problem. For instance, Tripetch & Borompichaichartkul (2019a) compared the effects of packaging materials for GCB, specifically high-density polyethylene (HDPE) bags and jute sacks. The study revealed that HDPE bags were more effective in preserving moisture content, color, and chlorogenic acid in GCB during storage than jute sacks. Another study by Smrke et al. (2022) examined different packaging methods on GCB, including airtight canisters, original packages with tape, original packages with a clip, and a package with an integrated screw cap. The findings demonstrated that the

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storage method using a package with an integrated screw cap performed the best, preserving freshness for a longer period than other packaging methods.

Furthermore, the storage temperature and relative humidity were investigated. Ross et al. (2006) conducted an experiment to determine the sensory changes in ground coffee beans stored at room temperature and freezing temperatures. The results indicated that significant sensory differences were detected in coffee prepared from freshly ground beans compared to that stored for two weeks at room temperature. Similarly, differences were observed in coffee prepared from beans stored for one or two weeks in a freezer. This highlights the importance of controlling the storage conditions to maintain the freshness and sensory characteristics of coffee. This is also supported by producers of these specialty coffees, who typically advise consumers to consume their products within a few weeks to appreciate certain scents that can easily disappear with storage (Cotter & Hopfer, 2018a).

To analyze the moisture content and color of coffee after roasting or during storage, traditional methods such as sensory analysis rely on subjective human judgment and may be unreliable. However, advancements in technology have revolutionized the evaluation process. Computer vision and image processing algorithms have emerged as powerful tools for the objective assessment of various food characteristics, including size, shape, color, and texture (Du & Sun, 2004). By analyzing the pixel values in images, precise evaluations of food quality can be achieved. Furthermore, the applications of imaging technique analyses have increased for many decades, not only for coffee (Albahry et al., 2017; Arboleda et al., 2018; Caporaso et al., 2022; Faridah et al., 2011; Hernandez et al., 2017; Nasution et al., 2019; Nasution & Andayani, 2017; Pinheiro Claro Gomes et al., 2022; Reis et al., 2013; Tolessa et al., 2016; Tugnolo et al., 2019; Yusmanizar et al., 2019) but also for other agricultural food product quality analysis; fruits and vegetables (Chu, X. et al., 2022; Gastélum-Barrios et al., 2011; Mehl et al., 2004; Mohd Ali et al., 2021; Pu & Sun, 2015; Rajkumar et al., 2012; W. Wang et al., 2012; Ye et al., 2018), grains (Bao et al., 2001; Bendig et al., 2014; Neuman et al., 1989), meats (Elmasry et al., 2012; Xiong et al., 2017), eggs (Thipakorn et al., 2017; Yao et al., 2022) and many more for a non-destructive method. These technologies enable accurate monitoring of moisture content and color variations, ensuring effective quality control and delivering a superior coffee product to consumers. Therefore, this project specifically focuses on examining coffee with different roasting levels, with color and moisture content as the parameters analyzed, under different storage conditions.

Ensuring high-quality coffee is essential for maximizing consumer satisfaction and commercial value; however, freshness deterioration due to staling remains a major concern. Coffee quality is strongly influenced by roasting, which drives key chemical reactions affecting flavor, aroma, and sensory properties, as well as storage conditions such as exposure to light, air, moisture, and heat. Among the key quality indicators, color and moisture content (MC) play critical roles. However, existing studies have rarely integrated these parameters into a single experimental framework. In addition, most research has focused on green coffee beans (GCB), limiting our understanding of how

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storage conditions affect roasted coffee quality. Previous studies have predominantly used the Lab* color space, with limited exploration of RGB and grayscale analyses during storage.

This represents a significant research gap, as RGB and grayscale approaches may offer complementary and, in some contexts, more practical advantages than the conventional Lab* color space. Unlike Lab*, which requires controlled calibration and specialized instruments, RGB analysis is directly compatible with digital imaging systems, enabling rapid, cost-effective, and real-time monitoring of colour changes. Furthermore, grayscale analysis simplifies color information into intensity variations, which can enhance the sensitivity to subtle surface changes, such as oil migration, browning, and degradation during storage. These features make RGB and grayscale particularly suitable for scalable, non-destructive quality assessment and potential industrial applications using machine vision systems.

Therefore, this study aimed to provide a comprehensive evaluation of roasted coffee quality under different storage conditions by analyzing (i) moisture content trends, (ii) color trends using RGB-based grayscale values, and (iii) the relationship between MC and color. This integrated approach seeks to enhance our understanding of the quality changes in roasted coffee during storage. During this project, the experiment was highly dependent on the commercially available coffee products. The roasted coffee beans and ground coffee used in this study were obtained from market suppliers, where the roasting and grinding processes were performed externally. As a result, detailed roasting profiles, including temperature and time, were not accessible because of the proprietary confidentiality maintained by the manufacturers.

Nevertheless, the samples were categorized according to their declared roast levels (e.g., light, medium, and dark), which serve as practical indicators of roasting intensity and are commonly used in coffee research. Variations in roasting conditions may influence structural properties, such as porosity and moisture absorption behavior. Therefore, future studies are recommended to incorporate controlled roasting conditions to enable more precise analysis of the relationship between roasting parameters and coffee quality changes during storage

2. Material and Methods

2.1 Sample Preparation

Three kilograms (3 kg) of Degayo Coffee were purchased from Global Coffee Resources Sdn. Bhd. The coffee variety is Arabica, which originates from Ratawali, Gayo, Aceh Province, Indonesia. Both coffee samples (1.5 kg each of dark and medium roast) were purchased in ground form and standardized to the same particle size prior to analysis (Figure 2).

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Figure 2. (a) Dark roasted coffee. (b) Medium roasted coffee.

2.2 Storage

The storage preparation was performed at the Biomaterials Processing Laboratory, Department of Biological and Agricultural Engineering, University Putra Malaysia starting from 13th March to May 26, 2023. Cold temperature and room temperature storage conditions (24 º C) were set up for the dark and medium roasted coffee samples in the same laboratory, where the cold room had a constant temperature of 5°C. Airtight and non-airtight labels were applied to the different containers following their storage conditions, each containing opaque and transparent packs, as the storage example shown in Figure 3.

Figure 3. Airtight (left) and non-airtight containers (right) with transparent (top) and opaque packets (bottom).

Airtight containers ensured minimal air content by zip-locking both transparent and opaque packets, whereas non-airtight containers were left unzipped. Meanwhile, the labels are easier to understand, as shown in Figure 4, where the label names are written as in Table 1.

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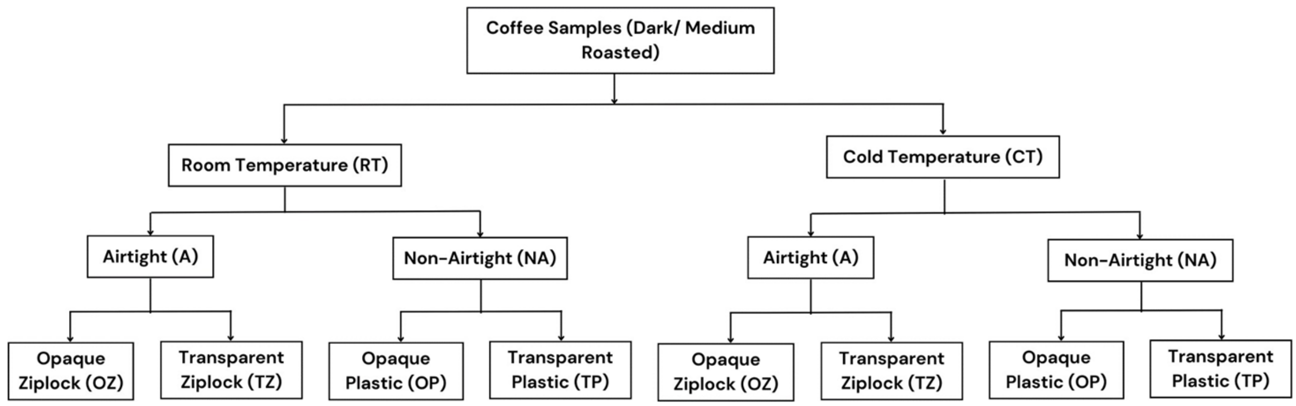

Figure 4. Flowchart of storage.

Table 1. The labels name for different roasting levels.

Samples	Label Names for Different Roasting Level	
	Dark Roasted	Medium Roasted
1	DR-RT-A-TZ	MR-RT-A-TZ
2	DR-RT-A-OZ	MR-RT-A-OZ
3	DR-CT-A-TZ	MR-CT-A-TZ
4	DR-CT-A-OZ	MR-CT-A-OZ
5	DR-RT-NA-TP	MR-RT-NA-TP
6	DR-RT-NA-OP	MR-RT-NA-OP
7	DR-CT-NA-TP	MR-CT-NA-TP
8	DR-CT-NA-OP	MR-CT-NA-OP

This experiment consists of 3 set of 16 samples containing approximately 60 g ground coffee, hence in each container 3 packs of samples are kept in their respective storage kinds for a period of 10 weeks. 60 g of samples are divided into 3 categories which, 30 g of them are used for moisture content (3 g for every week), 3 g (same sample for every week) and the remaining coffee are left for loss preparation during sample handling throughout the analysis.

2.3 Moisture Analysis

The moisture content (MC) of the samples was determined weekly using a moisture analyzer (A&D MX-50 Moisture Analyzer, A&D Weighing, Japan). The instrument operates based on thermogravimetric analysis, where samples are heated using a halogen lamp, and the MC is calculated from the mass difference before and after drying. For each measurement, approximately 3 g of the sample was weighed and evenly distributed on the sample pan. The analysis was conducted using the standard mode (STANDARD-MID) at a temperature of 120 °C. Moisture content was expressed on a wet basis (wb), and both moisture content (%) and analysis time were recorded for each sample

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throughout the storage period (AOAC, 2005). This procedure was used to evaluate the trend of the moisture content under different storage conditions.

2.4 Image Acquisition

The schematic diagram of the image acquisition system is shown in Figure 5. Images were captured using a webcam (Logitech C922 Pro HD Stream Webcam, Logitech, Malaysia), with specifications summarized in Table 2.

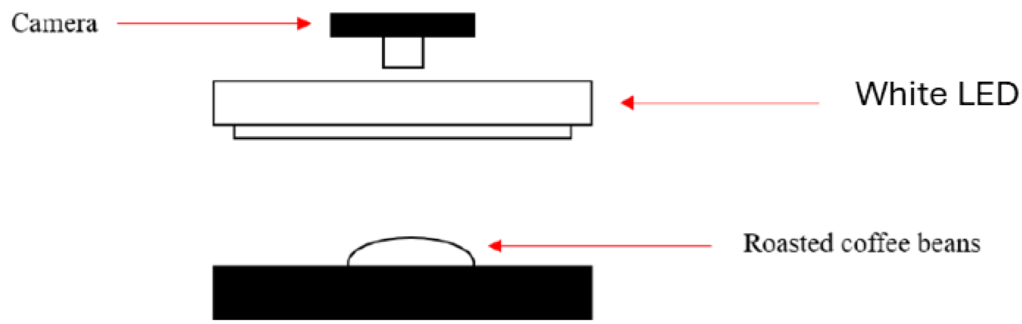

Figure 5. Schematic diagram of the imaging system using a White LED light.

Table 2. The specifications of webcam camera (C922 Pro HD Stream Webcam, Logitech, Malaysia).

Details		Values
Specifications	Max Resolution	1080p/30 fps - 720p/ 60 fps
	Camera mega pixel	3
	Focus type	Autofocus
	Lens type	Glass
	Built-in mic	Stereo
	Mic range	Up to 1 m

White LED lighting was used as the light source. The camera was mounted with the LED at a height of 8 cm above the sample. Coffee samples were placed on white paper as the background, with pixel intensity values ranging from 245 to 254 to ensure consistency prior to image acquisition. The entire setup was enclosed in a box covered with a black cloth to eliminate interference from external light sources.

The image acquisition settings were configured using the Logitech Camera application to ensure consistent image quality. Parameters such as autofocus, white balance, brightness, sharpness, contrast, and tint were fixed throughout the experiment (Table 3). In addition, the brightness was controlled using a lighting controller (ANG-4000-CH4-24V-A1, TMS Lite Sdn. Bhd., Malaysia) was set at 3 V. All settings were maintained constant for the 10-week experimental period. The captured images were

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stored in JPEG format with a resolution of 1080 × 1080 pixels. A total of 48 samples (three sets of coffee samples) were recorded weekly, resulting in 480 images being analyzed over the 10-week period.

Table 3. Setting values for RGB images in the Logitech Camera application.

Settings	RGB Imaging
Auto focus	53
Auto white balance	Maximum
Brightness	154
Sharpness	189
Contrast	198
Tint	80

2.5 Image Processing

To analyze the color trend, grayscale values were extracted from the images. A summary of the image processing steps is shown in Figure 6. A summary of the image processing steps is shown in Figure 6. The conversion from RGB to grayscale was performed using the rgb2gray function in MATLAB (MathWorks, USA), which applies a standard, luminance-based transformation. This method computes the grayscale intensity as a weighted sum of the red, green, and blue channels, where greater emphasis is given to the green component to reflect human visual perception. Grayscale conversion can be expressed as follows:

$$\text{Grayscale} = 0.299R + 0.587G + 0.114B$$

where R, G, and B represent the intensity values of the respective color channels. The resulting grayscale images were subsequently used to evaluate the changes in the brightness and surface characteristics of the coffee samples throughout the storage period.

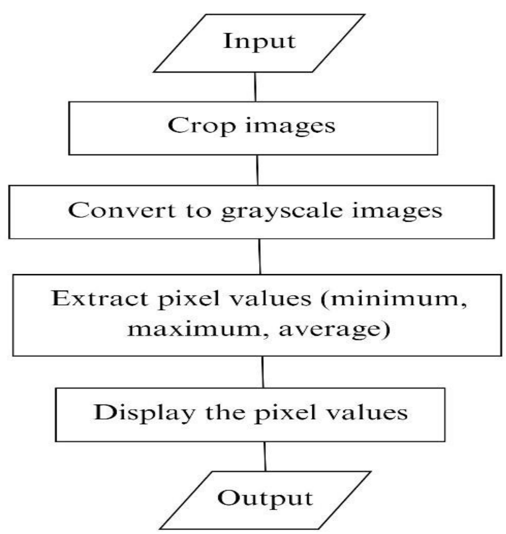

Figure 6. Flowchart of the image processing.

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2.6 Data Analysis

All data for the moisture content and grayscale values were recorded and analyzed using Microsoft Excel. Statistical analysis was performed using one-way analysis of variance (ANOVA) to evaluate the significant differences between groups. For moisture content, one-way ANOVA was applied to compare the mean values between different roasting levels (dark and medium) and storage conditions. Similarly, ANOVA was conducted on the grayscale values obtained from the RGB image analysis to assess the differences among the experimental conditions. The significance level of $p < 0.05$ was used to determine statistically significant differences.

3. Results and Discussion

3.1 Moisture Content

In this study, moisture content (MC) data were collected over a 10-week period. However, owing to inconsistencies in the sampling intervals, the analysis was conducted based on cumulative days (total of 68 days) rather than fixed weekly intervals.

Overall, dark roasted coffee generally exhibits a lower MC than medium roasted coffee owing to the longer roasting duration and greater moisture loss (Corrêa et al., 2016; Gotch, 2023). Despite this, all samples showed a consistent increase in MC during storage, regardless of the roasting level or storage condition. Initially, it was expected that the MC would decrease at room temperature because of heat exposure and increase under cold conditions. However, the MC increased under both conditions. This behavior can be attributed to the hygroscopic nature of coffee, which absorbs moisture from its surrounding environment until equilibrium is reached (Wintgens, 2004; Yousuf et al., 2022). Similar observations were reported by Corrêa et al. (2016), who found that MC increased in both whole and ground roasted coffee during storage, independent of temperature.

Although moisture absorption is natural, a rapid increase in MC is undesirable as it may accelerate quality deterioration and promote microbial growth, including mold formation. Therefore, this study focused on identifying storage conditions that result in the lowest and highest MC throughout the storage period.

3.1.1 Dark Roasted Coffee

The storage conditions were compared by examining the temperature, airtightness, and transparency. Dark roasted coffee stored at room temperature in non-airtight opaque containers (DR-RT-NA-OP) exhibited the highest moisture content (MC), whereas coffee stored at cold temperatures in airtight transparent containers (DR-CT-A-TZ) showed the lowest MC (Figure 7).

The results indicate that coffee stored at room temperature had a higher MC than coffee stored under cold conditions, despite the higher ambient temperature. This is attributed to the influence of relative humidity, as coffee absorbs moisture from humid air owing to its hygroscopic nature.

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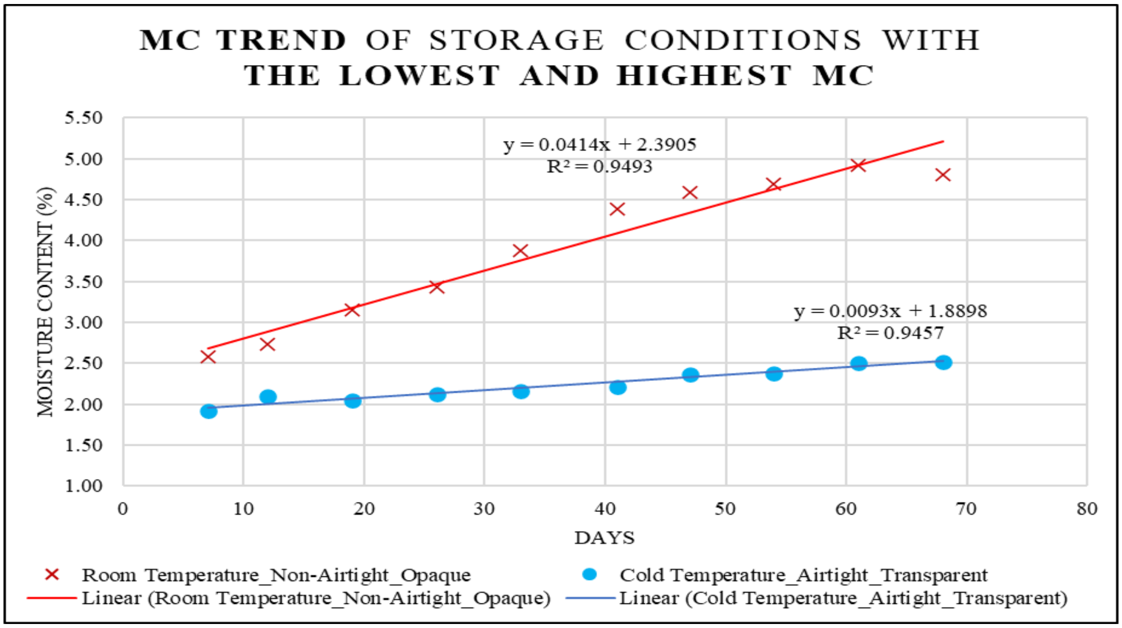

Figure 7. MC trend of storage conditions with the lowest and highest MC for dark roasted coffee.

Coffee stored at room temperature exhibited higher MC than cold-stored samples, likely due to the influence of relative humidity, as coffee absorbs moisture from the humid air (Junior et al., 2014; Gloess et al., 2013). Airtightness also played a significant role; non-airtight containers allow continuous interaction with ambient air, increasing moisture absorption. Transparency influenced MC differently: opaque containers were more prone to internal condensation, promoting moisture circulation, while transparent containers allowed light and heat penetration, reducing condensation

Slope analysis indicated that DR-RT-NA-OP had a steeper slope (0.041) than DR-CT-A-TZ (0.009), reflecting faster moisture absorption under room temperature, non-airtight, and opaque conditions. The corresponding R^2 values (0.949 and 0.946) confirmed the strong linear relationship between storage duration and MC.

3.1.2 Medium Roasted Coffee

Medium roasted coffee exhibited trends similar to those of dark roasted coffee, with the primary difference observed in the effect of transparency. Storage under room temperature, non-airtight, transparent conditions (MR-RT-NA-TP) resulted in the highest moisture content (MC), whereas cold temperature, airtight, opaque storage (MR-CT-A-OZ) produced the lowest MC (Figure 8).

Similar to dark roast, the MC of medium roast coffee increased at room temperature compared to cold storage. Interestingly, transparent containers showed higher MC than opaque containers for medium roasting. Light penetration increases the internal temperature, raising the moisture-holding capacity of air inside the container and accelerating moisture absorption by the coffee. Slope analysis confirmed faster MC uptake in MR-RT-NA-TP (0.0474) than in MR-CT-A-OZ (0.011), with a strong

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linear correlation for MR-RT-NA-TP (R^2 = 0.984) and a weaker correlation for MR-CT-A-OZ (R^2 = 0.683), likely due to mid-storage fluctuations.

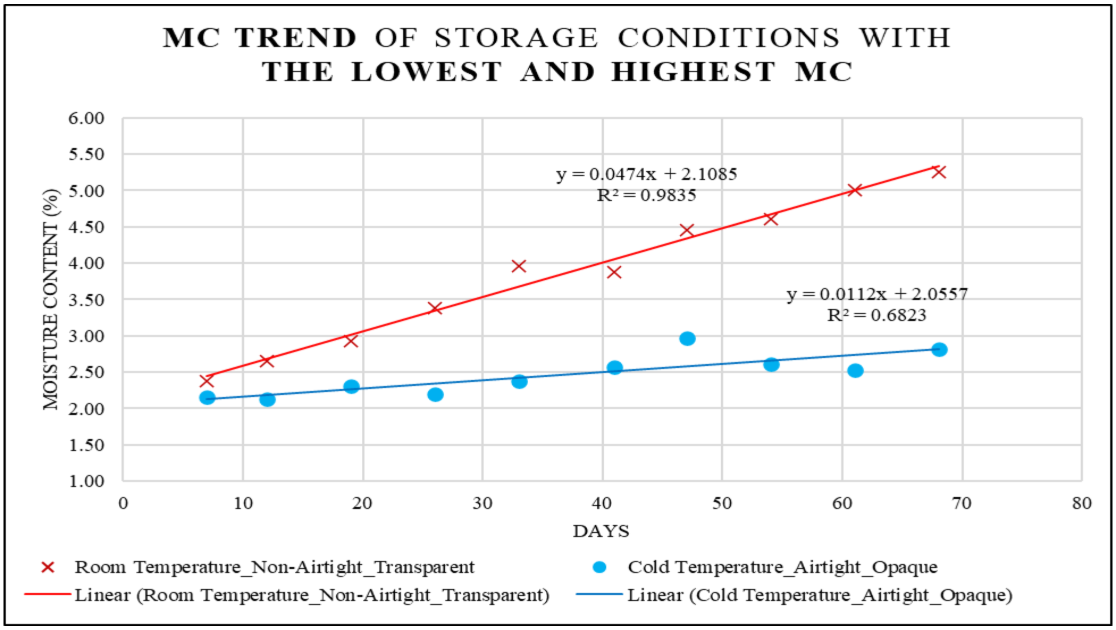

Figure 8. MC trend of storage conditions with the lowest and highest MC for medium roasted coffee.

Similar to dark roast, the MC of medium roast coffee increased at room temperature compared to cold storage. Interestingly, transparent containers showed higher MC than opaque containers for medium roasting. Light penetration increases the internal temperature, raising the moisture-holding capacity of air inside the container and accelerating moisture absorption by the coffee. Slope analysis confirmed faster MC uptake in MR-RT-NA-TP (0.0474) than MR-CT-A-OZ (0.011), with strong linear correlation for MR-RT-NA-TP (R^2 = 0.984) and weaker correlation for MR-CT-A-OZ (R^2 = 0.683), likely due to mid-storage fluctuations.

3.1.3 Dark Vs Medium Roasteed Coffee

Coffee roasting subjects beans to varying heat intensities, thereby altering their physical and chemical properties (Gabriel-Guzmán et al., 2017). Structural changes during roasting increase bean porosity, particularly at darker roast levels, which may facilitate faster moisture absorption compared to medium-roasted coffee (Al-Shemmeri et al., 2024). In contrast, medium-roasted coffee retains a denser structure, which may slow down moisture uptake. Consequently, the roasting level is expected to influence the moisture content (MC) during storage. Figures 9 and 10 illustrate the MC trends of dark and medium roasted coffee at different storage temperatures over the 10-week period. Figures 9 and 10 compare the MC of dark and medium roasted coffee at different storage temperatures.

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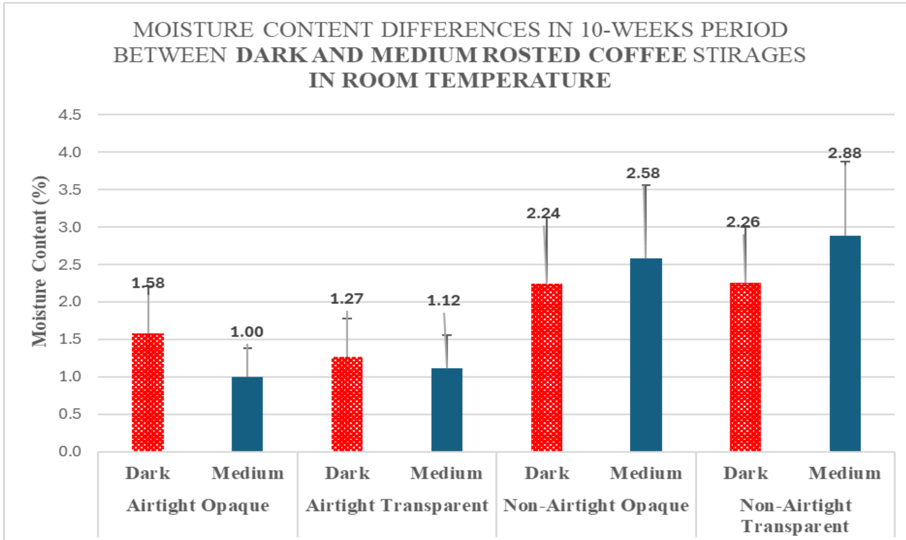

Figure 9. MC differences in 10-weeks period between dark and medium roasted coffee storages in room temperature.

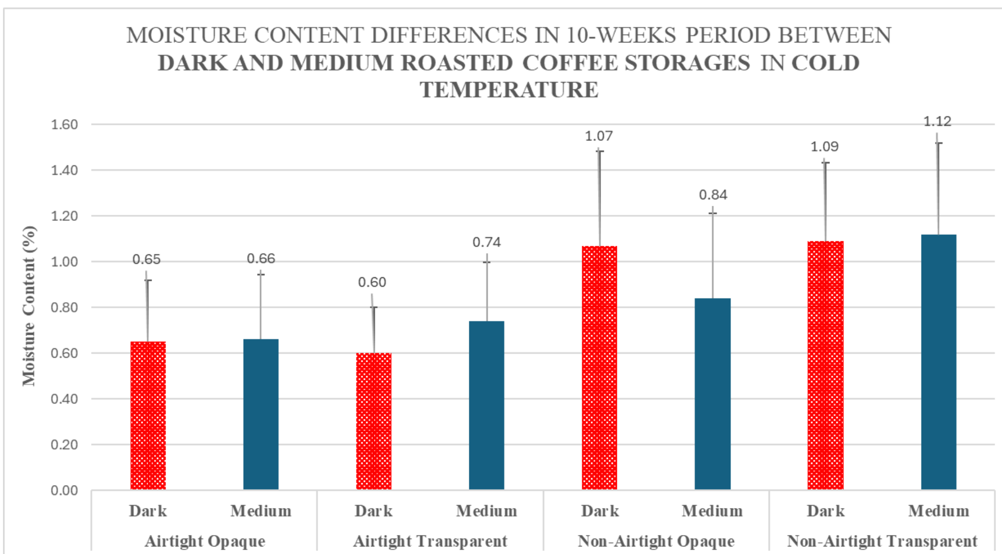

Figure 10. MC differences in 10-weeks period between dark and medium roasted coffee storages in cold temperature.

At room temperature, dark roasted coffee exhibited higher MC in airtight opaque and airtight transparent containers (1.58% and 1.27%, respectively) than medium roasted coffee (1.00% and 1.12%). However, in non-airtight opaque and transparent containers, medium roasted coffee showed higher MC (2.58% and 2.88%) than dark roasted coffee (2.24% and 2.26%, respectively). One-way ANOVA confirmed that these differences were statistically significant ($p < 0.001$), indicating that both roasting

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level and storage conditions substantially influenced the moisture content. These results demonstrate that only specific storage options led to higher MC for dark roasted coffee at room temperature.

In cold storage, dark roasted coffee had a slightly higher MC only in non-airtight opaque containers (1.07% vs. 0.84%). For the other conditions—airtight opaque, airtight transparent, and non-airtight transparent—medium roasted coffee exhibited higher MC values (0.66%, 0.74%, and 1.12%) than dark roasted coffee (0.65%, 0.60%, and 1.09%). Despite these variations, one-way ANOVA confirmed that the differences in MC between roasting levels were statistically significant across all conditions ($F = 10.562$, $p < 0.001$), highlighting the role of roasting degree in the moisture absorption behavior.

Overall, the differences in MC between the roasting levels and storage conditions were relatively small (0.01%–0.58%), suggesting minor effects on the overall storage quality. Notably, the 10-week storage period may have limited the observed variations, and longer durations could amplify these differences.

One-way ANOVA (Table 4) was conducted to evaluate the significance of the differences in MC between dark and medium roasted coffee. The F-value (10.562) exceeded the critical F-value (1.736), and the p-value (8.94×10^{-17}) was effectively zero, indicating a statistically significant difference between groups.

Table 4. The result of one-way ANOVA for moisture content of dark and medium roasted coffee.

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	50.871	15	3.391	10.562	8.94E-17	1.736
Within Groups	46.238	144	0.321			
Total	97.109	159				

In conclusion, the analysis confirms that dark and medium roasted coffee exhibit significantly different moisture contents under varying storage conditions, with dark roasted coffee generally absorbing moisture faster due to its higher porosity.

3.1.4 Summary of Moisture Analysis

This study evaluated the effect of storage conditions on the moisture content (MC) of dark and medium roasted coffee over 10 weeks. Temperature and airtightness influenced the MC similarly for both roasting levels, whereas transparency had a more notable impact. The lowest MC was observed in DR-CT-A-TZ (dark roast) and MR-CT-A-OZ (medium roast), whereas the highest MC was observed in DR-RT-NA-OP (dark roast) and MR-RT-NA-TP (medium roast). Overall, transparent and airtight containers under cold storage minimized moisture absorption, whereas room temperature and non-airtight storage promoted higher MC.

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The differences in MC between dark and medium roasts were generally small, ranging from 0.01% to 0.58%, with the dark roast being more porous and slightly faster at absorbing moisture. One-way ANOVA confirmed significant differences between the roasting levels ($F = 10.56$, $p < 0.001$), indicating that the roasting degree affects the moisture absorption behavior.

Some observed fluctuations in the MC, especially during cold storage, were attributed to external factors such as surface condensation, uneven moisture distribution within packets, and variations in sampling techniques. Standardized sampling and consistent measurement procedures are recommended to reduce these effects and ensure reliable MC readings.

In conclusion, storage temperature, airtightness, and container transparency all influence moisture content, with transparency playing a particularly important role. Proper storage under cold, airtight, and controlled light conditions is essential for maintaining coffee quality during storage.

3.2 Color Analysis

Color analysis was performed by extracting grayscale values from RGB images using MATLAB (R2023a, The MathWorks Inc., USA). Images were captured over 10 weeks (totaling 70 days, accounting for variable intervals between 3 and 11 days), and cumulative days were used to standardize the analysis, similar to the moisture study. Grayscale values were used to generate graphs illustrating color trends over the storage period, allowing for the comparison of imaging techniques to identify the most reliable method for detecting changes.

During storage, a gradual darkening of coffee was observed, consistent with Ktenioudaki et al. (2019), who reported similar color degradation in stored strawberry. Moisture content also influenced color, as evaporating water caused the coffee grounds to appear darker. Each sample was imaged in three sets, and the pixel values were extracted from each set to monitor the color changes over time.

3.2.1 Dark Roasted Coffee

The grayscale values extracted from the RGB images ranged from 5 to 16 and did not show a strictly increasing or decreasing trend. However, all storage conditions displayed a consistent pattern: a sharp increase in pixel values at week 3, followed by a decline and stabilization until week 10 (Figure 11).

Weekly visual comparisons of DR-CT-A-TZ and DR-RT-NA-OP revealed that, at week 3 (day 21), the images appeared brighter than those of other weeks. Corresponding grayscale values confirmed this, with DR-CT-A-TZ reaching 15 (highest among other days, which ranged 8–10) and DR-RT-NA-OP also showing the peak brightness with values between 8–11 (Tables 5 and 6). These observations indicate that RGB imaging aligns well with grayscale analysis, confirming its reliability for monitoring coffee color during storage.

Slight increases in brightness at week 3 were likely due to variations in storage conditions, inconsistent measurement intervals, and minor fluctuations in light intensity during imaging.

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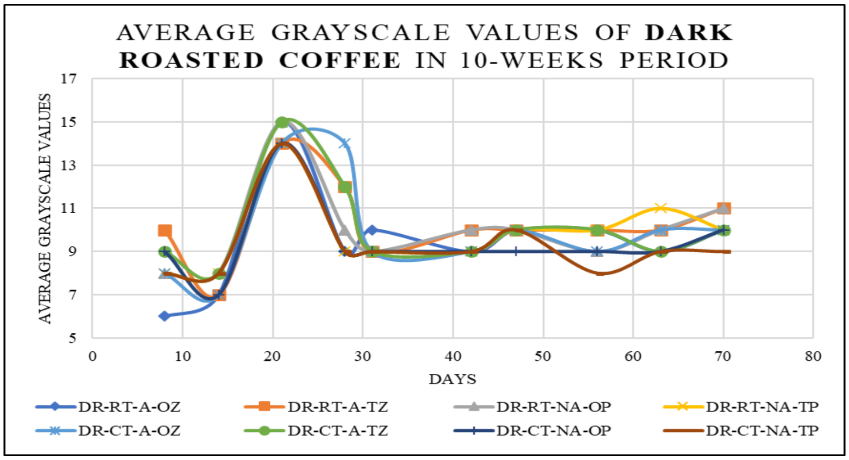

Figure 11. Average grayscale values for all storage conditions of dark roasted coffee throughout the storage period using RGB imaging.

Table 5. The RGB images comparison of DR-CT-A-TZ with the average grayscale values.

Set	Storage Period									
	Day 8	Day 14	Day 21	Day 28	Day 31	Day 42	Day 47	Day 56	Day 63	Day 70
1	9	8	15	9	10	9	10	10	9	9
2	9	8	16	10	10	9	10	10	10	10
3	9	7	13	16	8	8	11	10	8	10
Average	9	8	15	12	9	9	10	10	9	10

Table 6. The RGB images comparison of DR-RT-NA-OP with the average grayscale values.

Set	Storage Period									
	Day 8	Day 14	Day 21	Day 28	Day 31	Day 42	Day 47	Day 56	Day 63	Day 70
1	8	9	15	10	9	10	10	9	12	12
2	9	8	14	10	10	9	10	9	9	12
3	7	8	15	10	9	11	11	9	9	10
Average	8	8	15	10	9	10	10	9	10	11

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Comparing storage conditions with the lowest and highest moisture content (MC), coffee stored in DR-CT-A-TZ (cold, airtight) exhibited darker grayscale values than coffee stored in DR-RT-NA-OP (room temperature, non-airtight, opaque) at the end of 70 d (Figure 12). However, the difference was minimal, with only a one-unit variation. Both storage conditions showed similar trends throughout the storage period, with identical grayscale values on days 14, 21, 31, and 47.

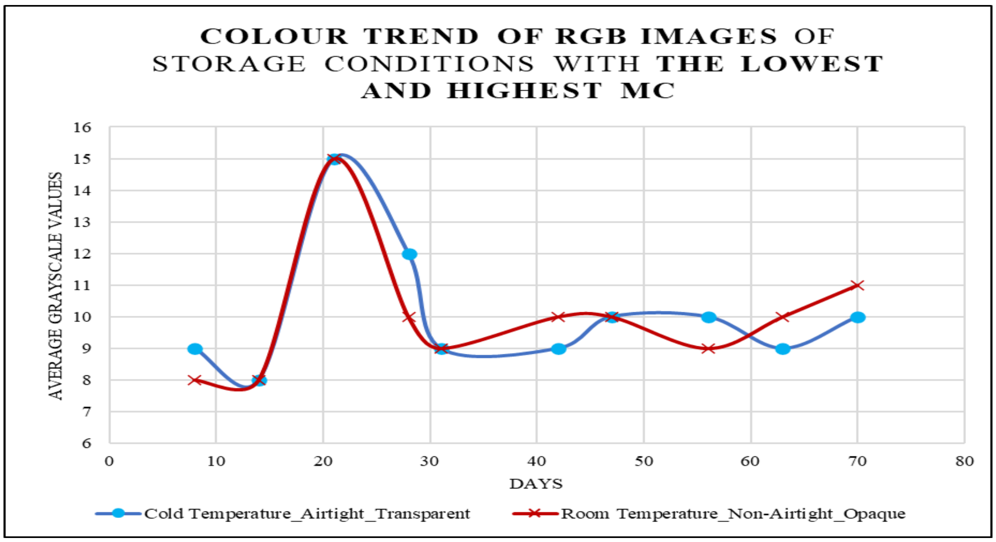

Figure 12. Color trends of RGB images of storage conditions with the lowest and highest MC for dark roasted coffee.

3.2.2 Medium Roasted Coffee

Similar to dark roasted coffee, the grayscale values extracted from the RGB images of medium roasted coffee generally peaked around week 3 (day 21). However, the color trends for medium-roasted coffee showed greater variability. For example, MR-RT-A-TP and MR-CT-A-OZ peaked at week 5 (day 31), whereas MR-RT-A-OZ and MR-RT-NA-TP exhibited two peaks at days 21 and 31 (Figures 13 and 14). The average grayscale values ranged from 8 to 17, which was slightly higher than that of dark roasted coffee.

Weekly image visualization of MR-CT-A-OZ (lowest MC) and MR-RT-NA-TP (highest MC) confirmed these trends (Tables 7 and 8). Variability in grayscale values across replication sets—e.g., 16, 15, and 11 for MR-CT-A-OZ—indicates that fluctuations in light intensity during imaging affected colour measurements. Peaks at days 21 and 36 in MR-RT-NA-TP were influenced by averaging the differences across the replication sets (grayscale values: 16, 11, 17 and 12, 19, 15, respectively). Despite these fluctuations, RGB imaging accurately reflected visual color changes, confirming its reliability in assessing coffee color trends.

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Table 7. The RGB images comparison of MR-CT-A-OZ with the average grayscale values.

Set	Storage Period									
	Day 8	Day 14	Day 21	Day 28	Day 31	Day 42	Day 47	Day 56	Day 63	Day 70
1	10	8	10	11	16	11	11	11	10	12
2	10	8	10	10	15	11	12	10	12	11
3	10	9	10	10	11	10	12	11	12	12
Average	10	8	10	10	14	11	12	11	11	12

Table 8. The RGB images comparison of MR-RT-NA-TP with the average grayscale values.

Set	Storage Period									
	Day 8	Day 14	Day 21	Day 28	Day 31	Day 42	Day 47	Day 56	Day 63	Day 70
1	12	10	16	13	12	12	11	11	13	13
2	10	10	11	13	19	13	11	11	13	13
3	14	10	17	12	15	11	11	12	14	13
Average	12	10	15	13	15	12	11	11	13	13

Comparing storage conditions, coffee stored in cold, airtight, and opaque conditions (MR-CT-A-OZ) exhibited a slightly darker color than coffee stored in room temperature, non-airtight, and transparent conditions (MR-RT-NA-TP), with only a one-unit difference in grayscale values over the storage period (Figure 15).

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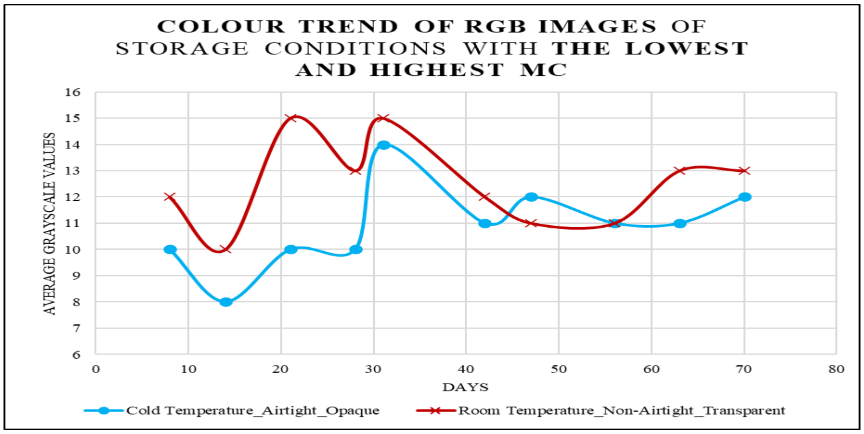

Figure 15. Color trends of RGB images of storage conditions with the lowest and highest MC for medium roasted coffee.

3.2.3 Dark VS Medium Roasted Coffee

Dark roasted coffee exhibits a darker color than medium roasted coffee, as reflected by lower pixel values in RGB imaging. Table 9 shows that the minimum pixel value for dark roasted coffee was 6, compared to 8 for medium roasted coffee, while the maximum average pixel value was higher for medium roasted coffee (17 vs. 15), indicating a brighter appearance.

Table 9. Minimum and maximum average pixel values of dark and roasted coffee for RGB imaging.

Average Pixel Value	Roasting Level	
	Dark roasted	Medium Roasted
Minimum	6	8
Maximum	15	17

One-way ANOVA (Table 10) confirmed a significant difference in the average pixel values between the two roasting levels. The F-value of 2.535 exceeded the critical F-value of 1.736, and the p-value of 0.0023 was below the 0.05 significance threshold, providing strong evidence to reject the null hypothesis. Thus, both the descriptive statistics and ANOVA results indicate that dark roasted coffee is significantly darker than medium roasted coffee, validating the observed color differences.

Table 10: The result of one-way ANOVA for grayscale value of dark and medium roasted coffee.

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	126.575	15	8.4383	2.535	0.00229	1.736
Within Groups	479.4	144	3.3292			
Total	605.975	159				

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In conclusion, based on the results of the one-way ANOVA, there was a significant difference in the average pixel values between the dark- and medium-roasted coffee samples. The low p-value and F-value exceeding the critical value provide strong evidence against the null hypothesis of no difference.

3.2.4 Summary of Colour Analysis

Color analysis was performed by extracting grayscale values from the RGB images. The results showed fluctuations rather than a clear increasing or decreasing trend over the 70-day storage period. The initial hypothesis expected a decrease in grayscale values (darker color) due to enzymatic browning, alongside non-enzymatic processes such as caramelization and the Maillard reaction, which contribute to the characteristic color and flavor of coffee (Sandman, 2021; Motoda, 1982). Cooler, airtight, and opaque storage conditions were expected to slow browning, whereas room temperature, non-airtight, and transparent conditions were predicted to accelerate color darkening owing to higher oxygen exposure, water activity, and temperature (Ross et al., 2006). However, only marginal differences in color were observed between the storage conditions. A key challenge is data fluctuation, which is primarily caused by inconsistent light intensity during imaging. For example, in week 4 of DR-RT-A-TZ, set 1 had a grayscale value of 18, whereas sets 2 and 3 had values of 8 and 9, respectively (Figure 16). These variations affected the weekly averages, obscuring clear trends. Similar issues were observed for medium-roasted coffee.

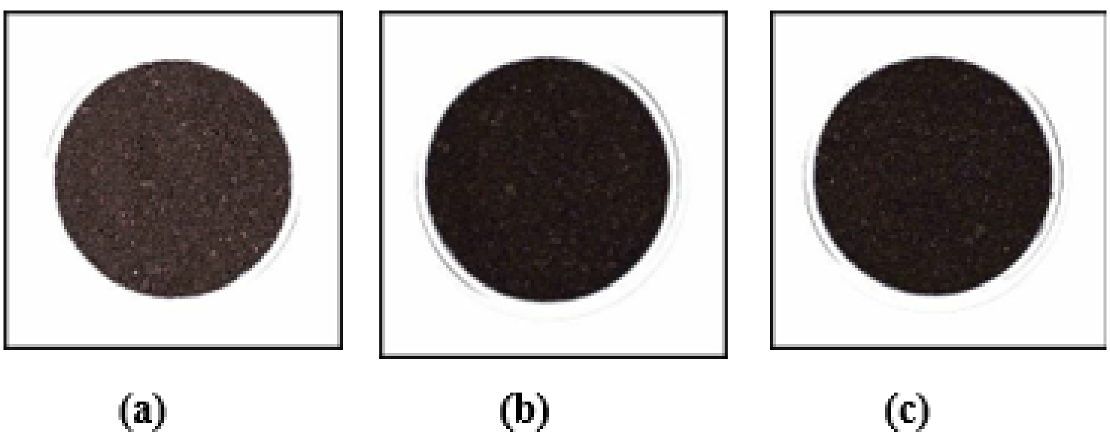

Figure 16. The comparison of RGB images of dark medium-room temperature-airtight-transparent (DR-RT-A-TZ) during week 4 which a) is set 1, b) set 2 and c) set 3.

Additionally, the short storage duration and irregular intervals between image captures (ranging from 3 to 11 days) contributed to the instability of the grayscale values. Despite these fluctuations, RGB imaging remained effective in reflecting general color changes, although precise trend interpretation was limited by experimental constraints.

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3.3 Relationship of Moisture Content and Colour

Analyzing the relationship between moisture content (MC) and color across all storage conditions was challenging due to fluctuations in both datasets. No clear increasing or decreasing trend was observed, making the combined MC-color graphs difficult to interpret. Additionally, prior research on the color changes of differently roasted coffees under varied storage conditions is limited, and most studies use the Lab* color space on green coffee beans rather than RGB/grayscale on ground roasted coffee (Dmowski & Dąbrowska, 2014; Ismail et al., 2014; Smrke et al., 2022; Tripetch & Borompichaichartkul, 2019a).

Moisture analysis over 68 d showed that the MC increased for all storage types. For dark roasted coffee, DR-CT-A-TZ had the lowest MC, whereas DR-RT-NA-OP had the highest. For medium roasted coffee, MR-CT-A-OZ had the lowest MC, whereas MR-RT-NA-TP had the highest. These fluctuations were attributed to minor human errors, such as inconsistencies in measurement, timing, or sampling.

Color analysis using grayscale values from RGB images over 70 days revealed similar trends, although fluctuations occurred, particularly during the mid-storage period. The RGB imaging results aligned with the visual observations, confirming their reliability. When comparing storage conditions with the lowest and highest MC, higher MC corresponded to slightly higher grayscale values, indicating marginally brighter coffee, whereas lower MC showed slightly darker color. The difference in the grayscale values was minimal, typically only one unit.

Additionally, RGB imaging effectively distinguished between dark- and medium-roasted coffee, with dark-roasted coffee exhibiting lower pixel values (darker color) than medium-roasted coffee. Data fluctuations due to inconsistent light intensity and variable intervals between measurements were noted and discussed in this study.

In summary, despite minor fluctuations, MC and RGB imaging consistently reflect storage effects, showing that coffee with higher moisture tends to appear slightly brighter, and the roasting level significantly affects color intensity.

4. Conclusion

This study successfully investigated the trends of moisture content (MC) and color in dark and medium roasted coffee under various storage conditions and examined the relationship between MC and color. Moisture analysis showed a consistent increase across all storage types, confirming that exposure to ambient conditions accelerates moisture uptake during storage. Dark roasted coffee had the lowest MC in cold, airtight, transparent storage (DR-CT-A-TZ) and the highest at room temperature, non-airtight, opaque storage (DR-RT-NA-OP). Similarly, medium roasted coffee stored in cold, airtight, opaque containers (MR-CT-A-OZ) retained a lower MC, whereas samples at room temperature, non-airtight, transparent packaging (MR-RT-NA-TP) absorbed the most moisture. One-way ANOVA confirmed significant differences in MC between roasting levels and storage treatments,

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indicating that both intrinsic (roast level) and extrinsic (storage) factors meaningfully influenced moisture dynamics.

Colour analysis using grayscale values extracted from RGB images revealed trends consistent with visual observations and expected roasting effects: dark roasted coffee consistently displayed lower pixel values (darker colour) than medium roasted samples. Storage conditions with higher MC corresponded to slightly brighter grayscale values, although the magnitude of this effect was limited, likely due to the early stage of staling within the 10-week period of storage. Despite fluctuations caused by variations in lighting intensity and measurement intervals, RGB imaging reliably differentiated subtle color changes between roasting levels and storage conditions. This supports the applicability of accessible imaging tools, such as the MATLAB rgb2gray conversion algorithm, for the non-destructive monitoring of surface color changes, which correlate with physical changes occurring during storage.

From a practical perspective, these findings offer actionable guidance for coffee producers and consumers. Optimal storage—specifically cold, airtight, and opaque packaging—was effective in minimizing moisture uptake and color shifts for up to approximately 8–10 weeks, suggesting this timeframe as a reasonable guideline for maintaining roasted coffee quality under typical ambient conditions. In contrast, storage at room temperature or in non-airtight/transparent containers accelerated quality degradation, which may lead to faster staling, loss of flavor and aroma, and reduced consumer satisfaction. By adopting the recommended storage practices, stakeholders can extend the usable shelf life of roasted coffee, mitigate quality loss, reduce waste, and enhance overall product value.

For future research, longer storage periods are recommended to capture more pronounced changes in the MC and color. Standardized data collection protocols, measurement of relative humidity, initial MC measurements, and careful control of lighting during imaging are suggested to improve the accuracy. Additionally, exploring other color models, such as CIELab and HSI, alongside chemical and sensory analyses, could provide a more comprehensive understanding of coffee quality during storage.

Overall, this study highlights the potential of RGB imaging for monitoring coffee quality and provides insights into the effects of storage conditions on the moisture content and color of roasted coffee.

5. AI Writing Statement

The author employed a generative artificial intelligence tool (ChatGPT, (GPT-5.3)) solely for linguistic refinement. No part of the data analysis, interpretation, or conclusions was generated by artificial intelligence; these remain entirely the author's original work.

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6. References

AOAC (2005). Official Methods of Analysis, 18th Edition, Method 925.10: Moisture in Coffee. Association of Official Analytical Chemists, Gaithersburg, MD, USA.

Albahry, A., von Hörsten, D., Pawelzik, E., & Mörlein, D. (2017). Rapid prediction of moisture content in intact green coffee beans using near-infrared spectroscopy. Foods, 6(5), 1–11. https://doi.org/10.3390/foods6050038

Al Shemmeri, M.; Fryer, P.; Farr, R.; Lopez Quiroga, E. (2024). Development of coffee bean porosity and thermophysical properties during roasting. Journal of Food Engineering, 378, 112096. DOI:10.1016/j.jfoodeng.2024.112096.

Arboleda, E. R., Fajardo, A. C., & Medina, R. P. (2018). An image processing technique for coffee black beans identification. 2018 IEEE International Conference on Innovative Research and Developm ent, ICIRD 2018, 1–5. https://doi.org/10.1109/ICIRD.2018.8376325

Bao, J. S., Cai, Y. Z., & Corke, H. (2001). Prediction of rice starch quality parameters by near-infrared reflectance spectroscopy. Journal of Food Science, 66(7), 936–939. https://doi.org/10.1111/j.1365-2621.2001.tb08215.x

Bendig, J., Bolten, A., Bennertz, S., Broscheit, J., Eichfuss, S., & Bareth, G. (2014). Estimating biomass of barley using Crop Surface Models (CSMs) derived from UAV-Based RGB Imaging. Remote Sensing, 6(11), 10395–10412. https://doi.org/10.3390/rs61110395

Boot, W. (2020). Moisture of green coffee beans. Giesen Coffee Roaster. https://www.giesen.com/moisture-of-green-coffee-beans/

Caporaso, N., Whitworth, M. B., Cui, C., & Fisk, I. D. (2018). Variability of single bean coffee volatile compounds of Arabica and robusta roasted coffees analysed by SPME-GC-MS. Food Research International, 108, 628–640. https://doi.org/10.1016/j.foodres.2018.03.077

Caporaso, N., Whitworth, M. B., & Fisk, I. D. (2022). Prediction of coffee aroma from single roasted coffee beans by hyperspectral imaging. Food Chemistry, 371. https://doi.org/10.1016/j.foodchem.2021.131159

Chu, X., Miao, P., Zhang, K., Wei, H., Fu, H., Liu, H., Jiang, H., & Ma, Z. (2022). Green banana maturity classification and quality evaluation using hyperspectral imaging. Agriculture, 12(4), 530. https://doi.org/10.3390/agriculture12040530

Corrêa, P. C., de Oliveira, G. H. H., de Oliveira, A. P. L. R., Vargas-Elías, G. A., Santos, F. L., & Baptestini, F. M. (2016). Preservation of roasted and ground coffee during storage. Part 1: Moisture content and repose angle. Revista Brasileira de Engenharia Agricola e Ambiental, 20(6), 581–587. https://doi.org/10.1590/1807-1929/agriambi.v20n6p581-587

Cotter, A. R., & Hopfer, H. (2018a). The effects of storage temperature on the aroma of whole bean arabica coffee evaluated by coffee consumers and hs-spme-gc-ms. Beverages, 4(3). https://doi.org/10.3390/beverages4030068

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Department of Agriculture. (2019). Potensi penanaman kopi liberica di malaysia. https://doamy.blogspot.com/2019/01/potensi-penanaman-kopi-liberica-di.html

Department of Statistics Malaysia. (2022). Food balance sheet Malaysia 2021. Department of Statistics Malaysia.

Dmowski, P., & Dąbrowska, J. (2014). Comparative study of sensory properties and colour in different coffee samples depending on the degree of roasting.

Du, C. J., & Sun, D. W. (2004). Recent developments in the applications of image processing techniques for food quality evaluation. Trends in Food Science and Technology, 15(5), 230–249. https://doi.org/10.1016/j.tifs.2003.10.006

Elmasry, G., Barbin, D. F., Sun, D.-W., & Allen, P. (2012). Meat quality evaluation by hyperspectral imaging technique: an overview. Critical Reviews in Food Science and Nutrition, 52(8), 689–711. https://doi.org/10.1080/10408398.2010.507908

Faridah, Gea O. F. Parikesit, & Ferdiansjah. (2011). Coffee bean grade determination based on image parameter. TELKOMNIKA, 9(3), 547–554.

Fiore, A. G., Severini, C., Romaniello, R., & Peri, G. (2006). Study of physical properties of coffee beans during roasting: Application of hyperspectral image analysis. Proceedings of the 21st International Conference on Coffee Science, Montpellier, France.

Gabriel-Guzmán, M., Rivera, V. M., Cocotle-Ronzón, Y., García-Díaz, S., & Hernandez-Martinez, E. (2017). Fractality in coffee bean surface for roasting process. Chaos, Solitons and Fractals, 99, 79–84. https://doi.org/10.1016/j.chaos.2017.03.056

Gautz, L. D., Smith, V. E., & Bittenbender, H. C. (2008). Measuring coffee bean moisture content. www.hawaiiag.org/hdoa/admin-

Gotch, N. (2023). Dark Roast vs Medium Roast. The Darkest Roast. https://thedarkestroast.com/dark-roast-vs-medium-roast/

Halim-Lim, S. A., Wan-Mohtar, W. A. A. Q. I., Surapinchai, S., & Azizan, N. A. Z. (2022). Optimum condition of roasting process of liberica coffee towards the local and international preference. Food Research, 6(3), 115–123. https://doi.org/10.26656/fr.2017.6(3).340

Hernandez, M. C., Romero, D., Torres, H., Miranda, J., & Hernandez-Lopez, A. E. (2017). X-ray fluorescence analysis of ground coffee. Journal of Nuclear Physics, Material Sciences, Radiation and Applications, 5(1), 25–34. https://doi.org/10.15415/jnp.2017.51003

Ismail, I., Anuar, M. S., & Shamsudin, R. (2014). Physical properties of liberica coffee (Coffea liberica) berries and beans. http://www.pertanika.upm.edu.my/

Junior, A. T., Guimarães, L. E., Filho, E. F., Castro, B. DE, Medeiros Del Ponte, E., & Dionello, R. G. (2014). physicochemical quality of maize grain stored with different moisture contents in airtight and non-airtight environments. (Issue 13). http://www.abms.org.br

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Available online:
http://journal.ipb.ac.id/index.php/jtep
DOI: 10.19028/jtep.014.1.81-107

Ktenioudaki, A., O'Donnell, C. P., & do Nascimento Nunes, M. C. (2019). Modelling the biochemical and sensory changes of strawberries during storage under diverse relative humidity conditions. Postharvest Biology and Technology, 154, 148–158. https://doi.org/10.1016/ j.postharvbio. 2019.04.023

Ku Madihah, K. Y., Zaibunnisa, A. H., Norashikin, S., Rozita, O., & Misnawi, J. (2013). Optimization of roasting conditions for high-quality Robusta coffee. In International Food Research Journal (Vol. 20, Issue 4).

Mehl, P. M., Chen, Y.-R., Kim, M. S., & Chan, D. E. (2004). Development of hyperspectral imaging technique for the detection of apple surface defects and contaminations. Journal of Food Engineering, 61(1), 67–81. https://doi.org/10.1016/S0260-8774(03)00188-2

Mohd Ali, M., Hashim, N., & Shahamshah, M. I. (2021). Durian (Durio zibethinus) ripeness detection using thermal imaging with multivariate analysis. Postharvest Biology and Technology, 176, 111517. https://doi.org/10.1016/j.postharvbio.2021.111517

Motoda, S. (1982). Enzymic treatment of cocoa, coffee and tea with polyphenol oxidase.

Nasution, T. H., & Andayani, U. (2017). Recognition of roasted coffee bean levels using image processing and neural network. IOP Conference Series: Materials Science and Engineering, 180(1). https://doi.org/10.1088/1757-899X/180/1/012059

Nasution, T. H., Rumansa, M., & Lukman Adlin, H. (2019). Designing the quality of coffee bean detection application using Hue Saturation Intensity. IOP Conference Series: Materials Science and Engineering, 648(1). https://doi.org/10.1088/1757-899X/648/1/012036

Neuman, M. R., Sapirstein, H. D., Shwedyk, E., & Bushuk, W. (1989). Wheat grain colour analysis by digital image processing ii. wheat class discrimination. Journal of Cereal Science, 10(3), 183–188. https://doi.org/10.1016/S0733-5210(89)80047-5

Pinheiro Claro Gomes, W., Gonçalves, L., Barboza da Silva, C., & Melchert, W. R. (2022). Application of multispectral imaging combined with machine learning models to discriminate special and traditional green coffee. Computers and Electronics in Agriculture, 198. https://doi.org/10.1016/ j.compag.2022.107097

Pu, Y.-Y., & Sun, D.-W. (2015). Vis–NIR hyperspectral imaging in visualizing moisture distribution of mango slices during microwave-vacuum drying. Food Chemistry, 188, 271–278. https://doi.org/ 10.1016/j.foodchem.2015.04.120

Ramanathan, R., & Ali, N. (2021). Coffee consumption and sustainability in Malaysia. Journal of Food Products Marketing, 27(5), 345–360.

Rajkumar, P., Wang, N., EImasry, G., Raghavan, G. S. V., & Gariepy, Y. (2012). Studies on banana fruit quality and maturity stages using hyperspectral imaging. Journal of Food Engineering, 108(1), 194–200. https://doi.org/10.1016/j.jfoodeng.2011.05.002

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 Available online:
http://journal.ipb.ac.id/index.php/jtep
DOI: 10.19028/jtep.014.1.81-107

Reis, N., Franca, Adriana. S., & Oliveira, Leandro. S. (2013). Performance of diffuse reflectance infrared Fourier transform spectroscopy and chemometrics for detection of multiple adulterants in roasted & ground coffee.

Ross, C. F., Pecka, K., & Weller, K. (2006). Effect of storage conditions on the sensory quality of ground arabica coffee. Journal of Food Quality, 29(6), 596–606. https://doi.org/10.1111/j.1745-4557.2006.00093.x

Sandman. (2021). Enzymatic and non-enzymatic browning. The Food Untold. https://thefooduntold.com/food-science/enzymatic-and- non-enzymatic-browning/

Saud, S., & Salamatullah, A. M. (2021). Relationship between the Chemical Composition and the Biological Functions of Coffee. Molecules, 26(24), 7634. https://doi.org/10.3390/molecules26247634

Smrke, S., Adam, J., Mühlemann, S., Lantz, I., & Yeretzian, C. (2022). Effects of different coffee storage methods on coffee freshness after opening of packages. Food Packaging and Shelf Life, 33. https://doi.org/10.1016/j.fpsl.2022.100893

Thammarat, P., Kulsing, C., Wongravee, K., Leepipatpiboon, N., & Nhujak, T. (2018). Identification of volatile compounds and selection of discriminant markers for elephant dung coffee using static headspace gas chromatography—mass spectrometry and chemometrics. Molecules, 23(8). https://doi.org/10.3390/molecules23081910

The MathWorks Inc. (2023). MATLAB (R2023a).

Thipakorn, J., Waranusast, R., & Riyamongkol, P. (2017). Egg weight prediction and egg size classification using image processing and machine learning. 2017 14th International Conference on Electrical Engineering/Electronics, Computer, Telecommunication and Information Technology (ECTI-CON), 477–480. https://doi.org/10.1109/ECTICon.2017.8096278

Tipler, A. (2013). Coffee Characterization Using Clarus SQ 8 GC/MS, TurboMatrix HS Trap and GC SNFR Olfactory Port.

Tolessa, K., Rademaker, M., De Baets, B., & Boeckx, P. (2016). Prediction of specialty coffee cup quality based on near infrared spectra of green coffee beans. Talanta, 150, 367–374. https://doi.org/10.1016/j.talanta.2015.12.039

Tripetch, P., & Borompichaichartkul, C. (2019a). Effect of packaging materials and storage time on changes of colour, phenolic content, chlorogenic acid and antioxidant activity in arabica green coffee beans (Coffea arabica L. cv. Catimor). Journal of Stored Products Research, 84. https://doi.org/10.1016/j.jspr.2019.101510

Tugnolo, A., Beghi, R., Glovenzana, V., & Guidetti, R. (2019). Characterization of green, roasted beans, and ground coffee using near infrared spectroscopy: A comparison of two devices. Journal of Near Infrared Spectroscopy, 27(1), 93–104. https://doi.org/10.1177/9067033519825665

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Vegro, C. L. R., & de Almeida, L. F. (2020). Global coffee market: Socio-economic and cultural dynamics. In L. F. de Almeida & E. E. Spers (Eds.), Coffee Consumption and Industry Strategies in Brazil (pp. 3–19). Woodhead Publishing. https://doi.org/10.1016/B978-0-12-814721-4.00001-9

Wang, W., Li, C., Tollner, E. W., Gitaitis, R. D., & Rains, G. C. (2012). Shortwave infrared hyperspectral imaging for detecting sour skin (Burkholderia cepacia)-Infected Onions. Journal of Food Engineering, 109(1), 38–48. https://doi.org/10.1016/j.jfoodeng.2011.10.001

Wintgens, J. N. (Ed.). (2004). Coffee: growing, processing, sustainable production. Wiley. https://doi.org/10.1002/9783527619627

Xiong, Z., Sun, D.-W., Pu, H., Gao, W., & Dai, Q. (2017). Applications of emerging imaging techniques for meat quality and safety detection and evaluation: A Review. Critical Reviews in Food Science and Nutrition, 57(4), 755–768. https://doi.org/10.1080/10408398.2014.954282

Yao, K., Sun, J., Chen, C., Xu, M., Zhou, X., Cao, Y., & Tian, Y. (2022). Non-destructive detection of egg qualities based on hyperspectral imaging. Journal of Food Engineering, 325, 111024. https://doi.org/10.1016/j.jfoodeng.2022.111024

Ye, D., Sun, L., Tan, W., Che, W., & Yang, M. (2018). Detecting and classifying minor bruised potato based on hyperspectral imaging. Chemometrics and Intelligent Laboratory Systems, 177, 129–139. https://doi.org/10.1016/j.chemolab.2018.04.002

Yeager, S. E., Batali, M. E., Lim, L. X., Liang, J., Han, J., Thompson, A. N., Guinard, J. X., & Ristenpart, W. D. (2022). Roast level and brew temperature significantly affect the colour of brewed coffee. Journal of Food Science, 87(4), 1837–1850. https://doi.org/10.1111/1750-3841.16089

Yusmanizar, Setiasih, I. S., Nurjanah, S., Muhaeimin, M., Nurhadi, B., Rosniawaty, S., & Munawar, A. A. (2019). Fast and non-destructive prediction of moisture content and chologenic acid of intact coffee beans using near infrared reflectance spectroscopy. IOP Conference Series: Materials Science and Engineering, 506(1). https://doi.org/10.1088/1757-899X/506/1/012033

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