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Research Article

Analysis of Variations in Matcha Components Across Different Brands on the Tunisian Market

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Abstract

Matcha is a powdered green tea from the *Camellia sinensis* L. plant, intended for both hot and cold drinking. Selecting the right matcha is crucial to its manufacture. This study organoleptically and physicochemically evaluated three types of matcha tea powder, measuring color (Lab*), water content, water solubility index, water holding capacity, pH, ∘Brix, as well as protein and lipid contents. In addition, flavonoids, total polyphenols and antioxidant activity were assessed. Matcha M1 showed the best antioxidant performance and the highest protein content (27,656 ± 0,134%), significantly higher than M2 and M3. It also showed the highest luminosity (L*), followed by M3, while M2 had the lowest luminosity. M1's pH was also the lowest (5,623 ± 0,025), contributing to better microbiological stability. M1 was preferred by consumers in sensory evaluation.

This study clarified that matcha can exhibit significant flavor differences between brands and provided a theoretical basis for the selection and application of matcha in tea products.

Keywords: Matcha (*Camellia sinensis*); Total polyphenols; Organoleptic evaluation; Antioxidant activity; Protein content

Introduction

Tea, one of the world's most widely consumed beverages, has been used for centuries for its health benefits, stimulating power and medicinal properties in the prevention of various diseases [1].

Among its most notable effects are its antioxidant, bacteriostatic, anti-cancer, anti-obesity, anti-diabetic, anti-cardiovascular, anti-infectious, anti-neurodegenerative properties and its ability to regulate lipid metabolism [1].

Matcha, a form of powdered green tea from the *Camellia sinensis* plant, is particularly appreciated worldwide for its high content of bioactive compounds, such as polyphenols, tannins and catechins [2].

It is particularly rich in catechins, notably (-)-epicatechin, (-)-epigallocatechin, (-)-epicatechin-3-gallate and (-)-epigallocatechin-3-gallate (EGCG), which exhibit marked antioxidant activity and beneficial physiological effects, including neuroprotection, an inhibitory effect on fat accumulation, blood sugar reduction and regulation of hypersensitivity [3-5]. Matcha, rich in these catechins, also offers protective effects on neuronal cells, reduces cholesterol and inhibits fat accumulation [6].

A unique feature of matcha is its cultivation method, which involves shading the tea bushes for around three weeks before harvesting, thereby increasing the production of bioactive compounds [7].This process modifies the chemical composition of the leaves, increasing theanine and caffeine content, while reducing that of catechins. This creates a higher proportion of compounds responsible for the 'umami' taste, in contrast to sun-grown teas, which are more bitter due to the catechins [7].

Matcha is particularly rich in polyphenols, active compounds responsible for its health benefits, including antioxidant, antiviral and anti-inflammatory properties, as well as stimulation of immune and detoxification processes [7].

These polyphenols represent up to 30% of the dry weight of green tea [8], and their regular consumption is associated with a reduced risk of chronic diseases, such as cancer, by delaying the onset of risk factors associated with these pathologies [9].

The benefits of matcha and its chemical composition depend on several factors, including the origin of the plants, the duration of shading, the infusion method and preparation conditions, such as temperature and time [7].

Growing interest in its biological properties and chemical composition is fuelling its popularity with consumers and in the food and nutritional supplement industries. Due to its low calorie content and vegetarian and vegan nature, matcha meets the current trend for natural, healthy foods [7].

In addition to its consumption in beverages, matcha powder is also used in the confectionery industry as food coloring and in capsule form [7].

It is important to note that not all matcha teas are equivalent, due to a number of factors. This is why this study focused on analyzing the nutritional composition of green matcha powder by analyzing samples of three brands available on the Tunisian market. The aim is to gain a better understanding of their nutritional profile and make an in-depth comparison.

Materials and Methods

Materials

The research material consisted of three matcha green tea powders, sourced from products on the Tunisian market. The products were stored at 4°C in individual 100 g packs.

Physico-chemical analysis

pH

The pH of 2.5% matcha green tea aqueous solutions and designed functional beverages was measured by the potentiometric method using a laboratory pH probe (KDD002) to an accuracy of 0.01 units at room temperature (20°C) [10].

Soluble solids content (°Brix)

The soluble solids content (°Brix) of 2,5% matcha green tea aqueous solutions and designed functional beverages was measured using an automated digital refractometer was used (Brix-20ATC) [10].Results (expressed in %) were read off the sugar scale at room temperature (20°C).

Water content

The moisture content of matcha was determined by weighing approximately 1 g of matcha powder, and then measured using an MB 35 halogen desiccator [11].

Lipid content

Samples of 4,5 g matcha were weighed into a cartridge. The flask containing the solvent was connected to the Soxhlet apparatus, and a return cooler was installed above it [7].

The solvent was brought to the boil. The vapors entered the cooler, condensed, then filled the part of the apparatus containing the sample to be extracted [7].

When a certain level was reached, the solvent was automatically returned to the bottle below. Extraction time was 6 hours. The solvent was removed by drying at 130°C to constant weight. Fat percentage was calculated from dry weight [7].

Protein content

Samples of 0,5g raw material were weighed into flasks. Next, 15 mL of concentrated sulfuric acid and a catalyst were added, and the mixture was mineralized [7]. The mineralized sample was alkalized with 40% sodium hydroxide to convert the ammonium salt to ammonia by distillation [7].

Separated ammonia was determined by reaction with hydrochloric acid (0,1 M) and titration with sodium hydroxide (0,1 M) in the presence of a Tashiro indicator [7]. A conversion factor of 6.25 was used to convert nitrogen to total protein [7].

Color

A 1 g sample of Matcha was analyzed for L*, a* and b* parameters using a chromameter (MINOLTA, CR300, JAPAN) [11].

Techno-functional properties

Solubility index

0,2 g of sample were mixed with 10 ml of distilled water, then incubated in a water bath at 80°C for 30 minutes [11].After centrifugation at 4500 rpm for 10 minutes at 25°C, the supernatant was placed in a dish of known weight and dried in an oven at 105°C for 24 hours [11].

Water absorption capacity

1 g of matcha tea powder was weighed using an analytical balance. Next, 50 mL of distilled water was added, mixed in the centrifuge tube, then centrifuged for 15 minutes at 10000 rpm. Excess water was removed, the water-absorbing powder weighed and the water retention capacity expressed in g/g (grams of water per gram of powder) [10].

Phytochemical analysis

Flavonoid content

1 g of sample was added to 50 mL of distilled water heated to 95°C for 45 min. The mixture was then filtered and the supernatant collected [11].

A 1 mL aliquot was diluted tenfold with distilled water. To this solution, 0,15 mL of 5% $NaNO_3$ was added, and the mixture rested for 6 minutes [11].

Next, 0,15 mL of 10% $AlCl_3$ was added, followed by incubation for 6 minutes. Finally, 2 mL of 4% NaOH was added, and the mixture rested for 15 minutes. Absorbance was measured at 510 nm [11].

Phenol content

The same extract as for flavonoids was diluted tenfold with distilled water. A 0,1 ml aliquot was mixed with 500 µL of Folin-Ciocalteu reagent and 4 ml of 7,5% sodium carbonate solution, then homogenized. The mixture was incubated in the dark for 1 hour, then its absorbance measured at 725 nm [11].

DPPH radical scavenging activity

A 0,1 ml aliquot of the sample extracts used for flavonoid analysis was added to 3,9 ml of 0,1 mM DPPH solution in methanol, then allowed to stand in the dark for 15 minutes [11].

The absorbance of the mixture at 515 nm was measured. Antioxidant activity was expressed in terms of inhibition concentration (IC_{50}) [11].

Human sensory panel test

Matcha tea plant samples were subjected to a hedonic test. Sensory evaluation involved 35 untrained panelists (48% men and 52% women). Panelists were recruited from tea consumers who agreed to taste matcha samples.

The samples were brewed and served. Panelists evaluated a series of room-temperature tea infusions and were given the opportunity to cleanse their palate between each test by chewing cookies and drinking water. A hedonic evaluation was performed using a linear scale with scores from 1 to 7, from 1 (extremely unpleasant/very low) to 7 (extremely pleasant/very high) [11].

Statistical analysis

All experiments were repeated at least three times. Results were subjected to a one-factor analysis of variance at 95% significance level, with SPSS software, using the one-factor ANOVA test, and Excel was used for the radar presented for sensory analysis.

Results and Discussion

Physico-chemical analysis

pH

pH is an essential parameter for assessing food quality and shelf life. It is also one of the main obstacles that microbial flora must overcome in order to develop [12]. Indeed, human pathogenic microorganisms rarely thrive in acidic pH environments [12].

Figure 1 presents the different matcha teas tested on the market based on their pH. The lowest pH was observed in tea M1, with a value of 5,623 ± 0,025. In contrast, the pH values of teas M2 and M3 were significantly higher, with respective values of 5,927 ± 0,033 and 5,933 ± 0,005.

Indeed, Najman., *et al.* (2023) [10] confirmed that a low pH increases the stability of the powders tested by inhibiting the growth of micro-organisms (e.g. bacteria or yeast) and offering protection against decomposition during storage, based on work carried out on 10 matcha teas.

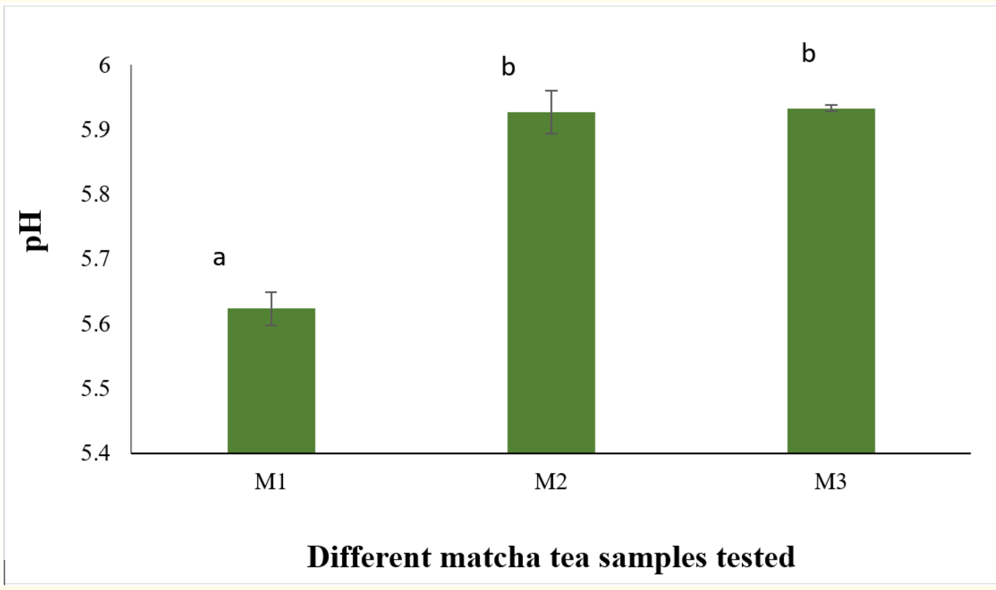

Figure 1: pH of matcha tea samples tested.

Different letters indicate the significant difference between the three samples at p < 0,05.

Soluble solids content (°Brix)

Brix level is an indicator of sugar concentration: the higher the Brix level, the higher the sugar content [13].

Table 1 presents an assessment of the different Matcha teas available on the market, based on their soluble solids content (°Brix).

The lowest average content was observed in M1 tea, with a value of 1,167 ± 0,006%, which is significantly lower than those of M2 and M3 teas, with contents of 1,227 ± 0,012% and 1,233 ± 0,006% respectively.

The concentration of soluble solids (°Brix) reflects, among other things, the amount of carbohydrates present in the solutions tested. Compared with other sweetened beverages, matcha has a lower sugar content, making it an interesting option for diabetics or those on weight-loss diets [10].

Analysis	Different types of matcha tea		
	M1	M2	M3
Moisture content (%)	6,375 ± 0,004 ^{a}	6,870 ± 0,411 ^{b}	7,190 ± 0,068 ^{b}
Lipid content (%)	7,340 ± 0,216 ^{b}	5,662 ± 0,199 ^{a}	5,488 ± 0,222 ^{a}
Protein content (%)	27,656 ± 0,134 ^{c}	22,439 ± 0,159 ^{b}	17,550 ± 0,358 ^{a}
Brix (%)	1,167 ± 0,006 ^{a}	1,227 ± 0,012 ^{b}	1,233 ± 0,006 ^{b}

Table 1: Proximal composition of matcha tea powders.

Different letters indicate the significant difference between the three samples at p < 0,05.

Moisture content

As shown in table 1, matcha teas showed significant differences ($p \leq 0{,}05$), with values ranging from 6,375 ± 0,004% to 7,190 ± 0,068%. The highest water content was observed in Matcha M3, while M1 tea showed a significantly lower water content compared to the other matcha teas.

The variations observed in the water content of the different matcha teas can be explained by several factors, not least the difference in shade between the growing plots.

Indeed, the shade of the plots can influence the water content of the tea leaves, which has a direct impact on the water activity in the matcha.

Teas grown under shade tend to develop leaves with biological characteristics that allow faster dehydration, which can result in lower moisture values.

On the other hand, teas from unshaded plots may have a higher water content, affecting their water activity [11].

In addition to shading, other factors may also explain these variations, such as differences in the production process, growing conditions, water quality, as well as the specific characteristics of tea cultivars [11].

These differences may result from various aspects of production and cultivation practices, contributing to moisture variation and, consequently, to the durability and microbiological safety of matcha teas [11].

Color

Color is a key attribute influencing consumer preference for food products, including matcha, and is also an important indicator of its quality. According to the results of the color difference measurement (Table 2), the matcha tea sample with the highest and most significant brightness (L*) is M1, followed by M3, while M2 has the lowest brightness.

The ‘a*’ value represents the degree of red-green color, where a positive value indicates a red hue and a negative value a green hue.

The lowest, and most significant, value of ‘a*’ is observed in M2, followed by M1, while M3 has the highest value of ‘a*’, indicating a redder hue. The ‘b*’ value represents the degree of yellow-blue color, with a positive value indicating a yellow hue and a negative value a blue hue.

The highest significant ‘b*’ value is found in M1, followed by M2, while M3 has the lowest ‘b*’ value, suggesting a bluer hue.

These color variations can be explained by several factors. Firstly, chlorophyll content may play an important role. Studies have shown that teas with a higher chlorophyll content, such as those from certain matcha varieties, tend to have a more pronounced green color, which may explain the observed differences in color values.

Indeed, a high ratio of chlorophyll a to chlorophyll b may be an indicator of a greener matcha color, contributing to variations in observed color intensity [14].

In addition, shading of the cultivation plots could also explain these color variations. The results show that the higher the shading percentage, the lower the ‘a*’ value, indicating a more intense green color in shaded plots. This phenomenon is also observed in the ‘b*’ values, where increasing shading seems to favor bluer hues. Studies have shown that the chlorophyll content of tea leaves grown under shade is generally higher than those grown in full sun, which could positively influence color [15].

In addition, matcha from heavily shaded plots tends to have lower luminosity, which could be associated with higher chlorophyll content and darker color [16].

In summary, variations in matcha color can be explained by factors such as shade and chlorophyll content, which influence the color and brightness of the final product. Teas grown under shade generally have a greener color and lower brightness, due to their higher chlorophyll content. These variations can also result from differences in growing and processing practices, and are important elements to consider when assessing matcha quality.

Protein content

In our study, the highest total protein content of matcha was M1 at 27,656 ±0,134% and the lowest was M3 through M2 at 17,550 ± 0,358% and 22,439 ± 0,159% respectively (Table 1).

In fact, this variation could be explained by the difference in shade of the different matcha teas, as Manikharda and colleagues (2023) [11] have shown that shade has a significant impact on the protein content of different matcha teas.

In comparison, similar amounts can be found in 100 g of tofu (14 g) and buckwheat (13 g). Proteins are one of the key dietary macronutrients, with structural, building, metabolic, transport, immune and repair functions [7].

Proteins are subject to anabolic and catabolic processes. They are a component of body tissues, hormones and cells. In addition, proteins have been shown to have beneficial effects on wound healing, nutritional status and the prevention and treatment of malnutrition [7].

Physiological conditions with increased protein requirements include cancer, aging, inflammation, heart failure, chronic obstructive pulmonary disease, chronic kidney disease, dialysis treatments, malnutrition and physical activity [7].

The dietary recommendations for adults developed by the National Center for Nutrition Education (Narodowe Centrum Edukacji Żywieniowej) suggest a protein intake of 0,9 g per kilogram of body weight, while ESPEN's dietary recommendations for the elderly indicate a protein intake in the range of 1 g to 1,5g per kilogram of body weight, in addition to individualized intakes based on existing pathologies [7].

The search for a readily available source of diversified protein becomes essential, especially for those following such diets [7]. Matcha appears to be an excellent nutritional choice to supplement dietary protein deficiencies [7].

Lipid content

As shown in table 1, which presents the different matcha teas tested on the market according to their lipid content, there was a significant increase in lipid content between the different matcha teas.

The lowest mean lipid value was recorded in M3, with a mean content of 5,488 ± 0,222%, while the highest mean value was recorded in M1, with a mean of 7,340 ± 0,216%. The mean value observed in M2 was 5,662 ± 0,199%.

Lipids play an important role in plants, limiting evapotranspiration and serving as energy reserves. In the human body, lipids perform several essential functions: they act as carriers for vitamins A, D, E and K, and are involved in various biological processes such as coenzymes, antioxidants, vision, reproduction, etc. [7].

Fats are a basic nutrient and source of energy for the human body. The recommended daily intake of fats varies according to age, energy needs, co-morbidities and individual metabolism. Fats provide not only energy, but also essential fatty acids (EFAs), and serve as precursors for the production of biologically active compounds. However, excessive fat intake can have adverse health effects, including obesity, lipid abnormalities, cardiovascular disease and certain malignant cancers [7].

Techno-functional properties

According to figure 2, the water solubility index of the matcha powders tested was lowest for M1, with a value of 17,393 ± 0,219%.

In contrast, the water solubility index of the powders was highest for M3, with a value of 17,593 ± 0,785%. However, this difference between the different matchas remains insignificant.

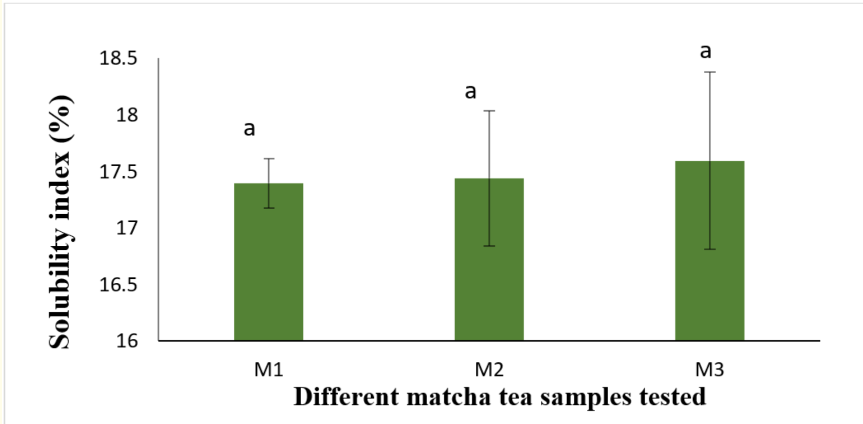

Figure 2: Solubility index of matcha tea samples tested.
Different letters indicate the significant difference between the three samples at p < 0,05.

In terms of water absorption capacity (Figure 3), the matcha samples tested showed the highest value in M2, which retained an average of 3,323 ± 0,413 g of water per gram of powder, although the differences between samples were not significant. In contrast, M3 had the lowest water absorption capacity, with a value of 3,173 ± 0,172 g/g.

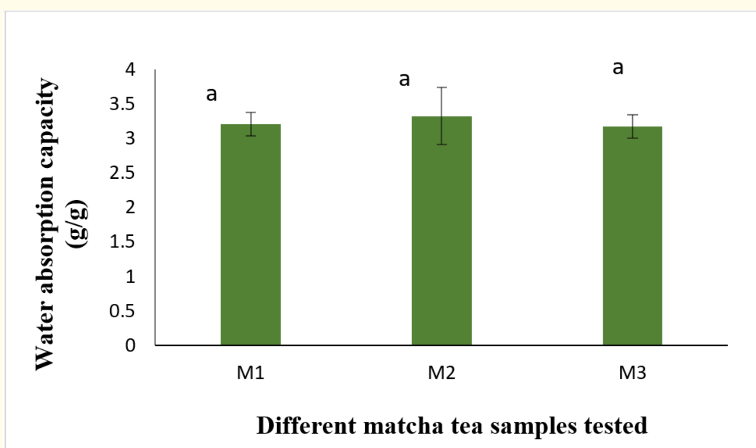

Figure 3: Water absorption capacity of matcha tea samples tested.
Different letters indicate the significant difference between the three samples at p < 0,05.

In fact, water solubility appeared to be influenced by matcha particle size. Furthermore, the shading process was thought to soften tea leaves due to leaf thinning [16], resulting in finer lamellae and palisade-like tissues, thus facilitating matcha grinding.

Our results concur with those of Manikharda., *et al*. (2023) [11], who detected no significant difference between samples subjected to varying shading intensities. This observation is in line with that of Topuz., *et al*. (2014) [17], who found no significant difference in green tea powder particle size as a function of shading intensity.

However, particle size also appears to be influenced by leaf tissue tenderness and other factors during the production process, such as the sieving method. Particle agglomeration could also contribute to reduced matcha powder solubility [11].

However, particle size was also influenced by leaf tissue tenderness and other conditions during the production process, such as the sieving method. Agglomeration could also contribute to the low solubility of matcha powder [11].

Phytochemical analysis

Polyphenol content

Matcha teas have a high polyphenol content (**t**able 3), with a significant difference observed between sample M1 and the others. M1 has the highest value, with an average of 58,847 ± 6,988 mg/g, followed by M3 at 25,740 ± 0,767 mg/g, while M2 has an average of 23,137 ± 0,337 mg/g.

One possible reason for this significant variation in polyphenol content between the different matcha teas lies in their production methods. Matcha tea can be grown in the shade or in direct sunlight. Photosynthesis, a key factor in the production of secondary metabolites, plays an important role in this difference. These metabolites fall into various categories and follow complex biosynthetic pathways [18].

The polyphenols present in green tea are derived from processes that begin with photosynthesis, which is involved in the glycolysis reaction where glucose is converted to pyruvate. Subsequent oxidation of pyruvate transforms it into acetyl-CoA, which is then converted into malonyl-CoA by the enzyme acetyl-CoA carboxylase. Malonyl-CoA is at the origin of polyketide synthesis, ultimately leading to the production of phenols and flavonoids [18].

Flavonoid content

Matcha teas also showed notable flavonoid content. Sample M1 showed the highest concentration significantly, with an average of 48,003 ± 0,273 mg/g, followed by M3 with an average of 30,117 ± 1,345 mg/g, and finally M2 with an average content of 28,840 ± 0,229 mg/g (Table 3).

Flavonoids and catechins are the main substances found in green tea. They are produced via the shikimate pathway, which begins with photosynthesis. The shikimate pathway starts with erythrose-4-phosphate and phosphoenolpyruvate, which are converted to chorismate, the precursor of many aromatic secondary metabolites. Shikimate pathways are closely linked to numerous aromatic amino acids such as L-tryptophan, L-phenylalanine and L-tyrosine [18].

Indeed, the variation in polyphenol and flavonoid concentrations in matcha is influenced by a multitude of factors, including shade and geography. For example, matcha from South Korea has higher concentrations of caffeine and kaempferol, while organically grown teas harvested in spring or summer have higher levels of phenolic acids such as sinapic acid and ellagic acid [19].

One explanation for this variation in flavonoid and polyphenol content between matcha samples could be linked to their cultivation processes. Indeed, some matcha teas, grown in the shade, limit photosynthesis, which has an impact on chemical composition. Factors such as temperature, pH, oxygen availability and the presence of metal ions also influence these differences [20].

Leaf qualities, plantation altitude and geographical conditions also play a key role in varying levels of bioactive compounds. For example, fresher green tea leaves grown at lower altitudes have higher antioxidant activity and contain higher levels of total phenols than those grown at higher altitudes and older [21].

Post-harvest storage, growing method and harvesting season also play a crucial role. Teas stored for extended periods tend to have reduced levels of these active compounds [19]. Furthermore, the intensity of shading affects the chemical composition of matcha, with more intense shading leading to lower concentrations of phenolic and flavonoid compounds. Catechin derivatives, the major phenolic compounds in tea, are present in greater quantities in young leaves than in mature leaves.

In addition, Manikharda., *et al.* (2023) [11] observed that shade intensity affects the chemical composition of Matcha. More intense shading leads to lower concentrations of phenolics and flavonoids. Catechin derivatives, which are major phenolic compounds in tea, are found in greater quantities in young leaves than in mature leaves.

The activity of the PAL (phenylalanine ammonia lyase) enzyme, involved in catechin biosynthesis, is particularly influenced by shading conditions and temperature variations. Shading alters the dynamics of this enzyme, favoring catechin production under specific conditions, notably with cooler temperatures and reduced light, which influences the chemical composition and antioxidant properties of matcha [22].

Thus, it is clear that geographical conditions and shade treatment play a central role in the variation of polyphenol and flavonoid concentrations in matcha, profoundly influencing its properties and benefits.

Antioxidant activity

IC_{50} is a key parameter for comparing the free radical scavenging potential of different foods and for assessing the impact of processing methods on the levels of bioactive compounds responsible for health benefits [23].

In order to compare different matcha teas in terms of antioxidant potential, the results of DPPH radical capture tests were expressed as IC_{50} values.

It should be noted that a low IC_{50} value indicates high biological activity. Analysis of the data showed that IC_{50} values were significantly ($p \leq 0,05$) lower in the M1 samples than in the other samples, as shown in table 3.

Indeed, the beneficial effect of tea on health is mainly attributed to its antioxidant activity. As shown in table 3, a higher IC_{50} concentration is associated with a lower total flavonoid and polyphenol content.

In addition, Manikharda., *et al.* (2023) [11] demonstrated that antioxidant activity varies in different matcha teas as a function of shading level, which increases from 0% to 90%, resulting in a higher IC_{50} concentration.

Analysis	Different types of matcha tea		
	M1	M2	M3
Polyphenol content (mg/g)	58,847 ± 6,988^{b}	23,137 ± 0,337^{a}	25,740 ± 0,767^{a}
Flavonoid content (mg/g)	48,003 ± 0,273^{b}	28,840 ± 0,229^{a}	30,117 ± 1,345^{a}
IC_{50} (mg/ml)	0,056 ± 0,001^{a}	0,079 ± 0,003^{b}	0,075 ± 0,004^{b}

Table 3 : Polyphenol, flavonoid content, and IC_{50} of different matcha teas.

Different letters indicate the significant difference between the three samples at $p < 0,05$.

Sensory evaluation

Figure 4 shows the results of the sensory evaluation carried out on three matcha green teas. The analysis revealed significant differences between the samples, in terms of color, appearance, aroma, taste and overall acceptability. These criteria have enabled us to better understand consumer preferences and the perceived quality of each matcha tea.

In terms of color, M1 stood out significantly for its intensity of green, obtaining a high score, followed by M2. In contrast, M3 scored the lowest in terms of greenness, indicating a significant difference in the visual quality of the teas between M1, M2 and M3. Significant differences were thus observed between all samples. This variation could be attributed to differences in growing conditions or tea leaf processing.

In terms of aroma evaluation, M1 again scored significantly higher, suggesting a fresher, more complex aroma. M3 took second place, while M2 received the lowest score, indicating a less developed aroma and potentially less attractive to tasters. Significant

Figure 4: Evaluation of the organoleptic characteristics of the different matcha teas.

differences were thus observed between all samples. This could be linked to a variation in the quality of the leaves used to make matcha, or to a different transformation process.

In terms of taste quality, M1 stands out significantly, being considered to have the most delicate and savory taste. M3 comes next, while M2 is considered slightly less appreciated. There is a noticeable difference between M1 and the other samples, but no significant difference between M2 and M3. These results imply that M1 is considered to have the most pleasant and balanced taste.

In terms of matcha appearance, M1 stands out significantly as having the best color, creaminess and presentation. M3 follows, while M2 is considered slightly less attractive. There is a noticeable difference between M1 and the other samples, but no discernible difference between M2 and M3. These results suggest that M1 is perceived as having the most pleasing appearance.

Because of its bright color, pleasant aroma and refreshing taste, M1 was rated significantly higher than the other samples in terms of overall acceptability. Although considered satisfactory, M2 and M3 showed no discernible differences from each other and received more moderate evaluations than M1.

A possible reason for the significant differences between the various matcha teas could be the shading. In fact, Manikharda., *et al*. (2023) [11], found that shading treatment significantly improves matcha acceptance. The cultivation and processing methods play a crucial role in influencing the sensory quality of matcha teas.

Conclusions

The research results presented above, relating to the evaluation of the physico-chemical and bioactive characteristics of various types of matcha tea available on the Tunisian market, can be used as a basis for selecting the product offering the most suitable characteristics for the design of functional foods.

In all analyses, sample M1 was selected as the best, particularly in terms of pH, Brix, lipids, proteins and luminosity (L*). Indeed, M1 showed the highest and most significant luminosity, followed by M3, while M2 showed the lowest luminosity. In terms of polyphenols, antioxidant activity and flavonoids, M1 also showed superior results.

Based on the results obtained, the M1 matcha green tea sample, characterized by the most desirable bioactive properties, was selected for further research. This sample can be used to develop the composition of functional foods, which can be recommended to a wide range of consumers according to their individual needs or expectations. Thanks to its high protein content in an easily accessible form, M1 could meet the needs of a large group of consumers, including athletes or those with increased protein requirements.

These properties are crucial, as they enable matcha green tea powder to be used as a source of bioactive ingredients in the design of functional foods and other food products. Tests carried out revealed a high content of total polyphenols and flavonoids, bioactive compounds known for their health benefits.

Functional foods represent a constantly evolving market segment, influencing health and contributing to the prevention of civilization diseases. Today, many functional products are enriched with proteins, pre- and probiotics, polyunsaturated fatty acids and antioxidants, including polyphenols. Because of the multiple health benefits of matcha green tea, it is particularly relevant to integrate this product into the daily diet, as an addition to various food products such as breads, pastries or desserts, thus maximizing its nutritional benefits.

Compliance with Ethical Standards

Conflict of Interest

The authors declare that they have no competing interests.

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Ethics Approval and Consent to Participate

Not applicable.

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Contributions

Dely Maissa wrote the main manuscript text ; Mankai.Melika reviewed the manuscript and made corrections and Mnasser Hassouna supervised the work. All authors read and approved the final manuscript.

Data Availability

The datasets of the present study are available online from the corresponding author upon reasonable request.

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