Nutritional Profile and Health Properties of Turmeric and Curcumin Extract: a Comparative Analysis

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Abstract

Turmeric has been used as a traditional medicine in Southeast Asian countries and can serve as a spice, food preservative, and coloring agent. Turmeric owes its unique properties and color to curcuminoids, biologically active substances that encompass curcumin, de-methoxycurcumin, and bis-demethoxycurcumin. The purpose of the study was to investigate the nutritional properties of turmeric and curcumin extract, as potential dietary supplements for poultry nutrition. Turmeric was characterized by a content of 7.89 % crude protein, 4.61 % crude fiber, 1.76 % crude fat, and 7.47 % ash. The proximate composition of curcumin extract showed lower values when compared to turmeric. The chromatographic analysis of vitamin E isomers revealed α-tocopherol of 1.97 mg/kg in turmeric vs 8.09 mg/kg in curcumin, γ-tocopherol of 3.01 mg/kg in turmeric vs 10.4 mg/kg in curcumin, and δ-tocopherol of 13.84 mg/kg, while in curcumin was not detected. The antioxidant yellow pigments lutein and zeaxanthin were in higher amounts in curcumin extract, which was also characterized by an increased concentration of total polyphenols (76.50 mg/g GAE). Turmeric had higher levels of flavonoids (47.42 mg/g vs 24.71 mg/g). The outcomes of this study can serve as a foundation for developing innovative food products by using poultry nutrition and harnessing the potential benefits of this ancient spice.

Keywords: Antioxidant potential, bioactive compounds, nutritional quality, white grape pomace.

1. Introduction

Numerous plant species possess the remarkable ability to biosynthesize and store valuable substances that can have economic and health benefits. These substances include waxes, dyes, polyphenols, essential oils, flavors, and fragrances, among others. Over the past decade, there has been an increasing demand for natural products in response to environmental concerns and consumer preferences for natural sources of nutritional, medicinal, and cosmetic products. As a result, the industry of natural products and research in the fields of medicinal, aromatic, and cosmetic plant extracts have experienced steady and significant expansion [1].

Curcuma longa L., popularly known as turmeric or golden spice, is a member of the Zingiberaceae family. It has been used in Asia since ancient times as a condiment, preservative, flavoring, and coloring agent, as well as a traditional remedy for various diseases [2]. There are over 70 varieties of turmeric that are known, produced, and marketed, and they may differ in their chemical properties [3]. Turmeric is commercially available as a powder from the rhizome. The most significant bioactive component present in turmeric is a phenolic compound known as curcumin, belonging to the curcumin class, which constitutes about 2-9% of the entire composition [4]. This compound accounts for 70-75% of the curcumin class, followed by demethoxycurcumin (10–25%) and bisdemetoxicurcumin (5–10%). The distinctive yellow color of turmeric is attributed to

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these compounds, whose composition can vary based on factors such as soil conditions, geographical origin, and processing methods [5].
Turmeric possesses various bioactivities like antidiabetic and cardioprotective effects [6], as well as antioxidant, anti-inflammatory, antibacterial, antifungal, antidiabetic, insecticidal, and larvicidal effects [7]. The pharmacological effects of turmeric can be attributed to its phytoconstituents, which include phenylpropanoids, terpenoids, flavonoids, steroids, and volatile oils [8]. The pigment curcumin (bis-α, β-unsaturated β-diketone) has been used to treat various ailments, having significant positive effects, such as antioxidant and anti-inflammatory effects [9]. Chemically, it is a diarylheptanoid that consists of two aromatic rings with two hydroxyl and two methoxyl groups. The phenolic ring is joined by an aliphatic unsaturated carbon chain that has two carbonyl groups at C-3 and C-5 [10].
Several studies investigated the impact of turmeric powder, essential oil, and its active components on livestock, suggesting that turmeric has the potential to enhance digestive enzyme activities, improve liver function, and reduce serum cholesterol levels [11, 12], improving performance and egg quality of laying hens. In other studies, it has been reported that chickens that consumed 5g/kg turmeric flour had improved energy efficiency and feed conversion ratio. In addition, layers fed with a diet supplemented with turmeric powder showed an improvement in serum concentration of total cholesterol and liver function as compared to the control group [13]. Moreover, the supplementation of 5% turmeric powder in the diet of laying quails showed an increase in egg production and egg quality [14].
The present study aimed to conduct a comparative analysis of the nutritional profile and health properties of turmeric and curcumin extract, to evaluate their potential as dietary supplements for poultry nutrition.

2. Materials and methods

2.1. Plant Material

The experimental material consisted of powder from rhizomes of turmeric (*Curcuma longa* L) and powder of curcumin extract, which were purchased from a local store (Plafar S.A.).

2.2. Proximate analysis

The proximate composition of the turmeric and curcumin was determined as follows: crude protein (ISO 5983-2/2009) by Kjeldahl method (Kjeltec auto 1030 Tecator Instruments, Höganäs, Sweden), crude fat (SR ISO 6492/2001) by continuous solvent extraction (Soxtec 2055 Foss Tecator, Höganäs, Sweden), crude fiber by the method with intermediary filtration (Fibertec 2010 System Foss Tecator, Höganäs, Sweden), dry matter (ISO 6496/2001) and ash (ISO 2171/2010) using the gravimetric method and a Nabertherm calcination furnace (Nabertherm GmbH, Lilienthal, Germany).

2.3. Minerals analysis

The levels of copper, iron, manganese, zinc, and calcium were analyzed using flame atomic absorption spectrometry (FAAS). The samples were prepared through microwave digestion (Berghof, Eningen, Germany) and tested using Thermo Electron SOLAAR M6 Dual Zeeman Comfort equipment (Cambridge, UK). Phosphorus levels were measured using a colorimetric method and a UV-Vis spectrometer (Jasco V-530, Japan Servo Co. Ltd., Tokyo, Japan).

2.4. Fatty acids determination

The fatty acids profile of turmeric and curcumin were determined using a gas chromatograph Perkin Elmer Clarus 500 (Massachusetts, United States). The fatty acids present in the samples underwent a two-step process: first, they were converted into methyl esters and then separated on a TRACE TR-Fame capillary chromatographic column featuring a highly polar stationary phase (Thermo Electron, Massachusetts, United States), and with dimensions of 60 m × 0.25 mm × 0.25 µm film. The detection of fatty acids was carried out using a flame ionization detector (FID), and their identification and quantification were achieved by reference to standard chromatograms.

2.5. Liposoluble antioxidants

The extraction of liposoluble antioxidants from turmeric and curcumin was performed after a saponification step that involved a hydrolysis of samples with an ethanolic potassium hydroxide solution, in a water bath and for 30 minutes at 80 °C. The extraction was performed with petroleum ether.
Xanthophylls (lutein, zeaxanthin, astaxanthin and cantaxanthin) were analyzed using a HPLC method and a liquid chromatograph (Perkin Elmer

200 series, Shelton, CT, USA) with a UV detector (detection at 450 nm). The chromatographic conditions involved a mobile phase of 10 % water, 15 % methanol and 75% acetone at a flow rate of 0.5 mL min^{-1} and a C18 reversed-phase column (5 µm, 250 × 4.60 mm i.d.) (Nucleodur, Macherey-Nagel, Germany).
The determination of vitamin E isomers was assessed using a liquid chromatograph (Vanquish Thermo-Electron Corporation, Waltham, MA) and a PDA-UV detector at wavelength 292 nm. The chromatographic conditions involved a mobile phase of 4% water and 96% methanol, at a flow rate of 1.5 mL min^{-1} and a C18 reversed-phase column (5 µm, 250 × 4.60 mm i.d.) (Thermo-Electron Corporation, Waltham, MA).

2.6. Watersoluble antioxidants

The measurement of the total polyphenols (TPC) content in a sample was conducted through the Folin–Ciocalteu's spectrophotometric method, which was described previously (Untea et al., 2020). To determine the total phenol content, a calibration curve of gallic acid was used, and the results were expressed in milligrams of gallic acid equivalents per gram of dried sample (mg GAE/g).
The determination of total flavonoid content was performed using the aluminum chloride colorimetric method. In a 10 mL volumetric flask, 1 mL of methanolic extract of turmeric or curcumin was mixed with 4 mL of aluminum chloride ($AlCl_3$) and incubated at room temperature for 15 minutes. Subsequently, the absorbance of the resulting orange-yellow solution was measured at 410 nm against the blank using a UV-VIS spectrophotometer (Jasco V-530, Japan Servo Co. Ltd., Tokyo, Japan). The calibration curve was assessed with quercetin as standard, and the flavonoid content was expressed as mg Quercetin equivalents (QE) per gram.

2.7. Antioxidant Activity Analysis

The antioxidant capacity of turmeric and curucumin extracts was assessed by using four different spectrophotometric methods for the determination of DPPH, ABTS, antioxidant capacity, and iron chelating ability. For DPPH, the calibration curve was performed using 6-hydroxy-2,5,7,8 tetramethylchroman-2-carboxylic acid (Trolox) and a spectrophotometer (Jasco V-530, Japan Servo Co.Ltd., Japan), results being expressed as mmol Trolox equivalents/kg sample. The scavenging potential of plant extracts against ABTS radical was determined by measuring the absorbance at 734 nm (Jasco V-530, Japan Servo Co.Ltd., Japan) using ethanol as blank. The evaluation of the total antioxidant capacity of the extract by phosphomolybdenum method was assessed by measuring the absorbance of the samples at 695 nm, with results being expressed as ascorbic acid equivalents.
The chelation of ferrous ions by turmeric and curcumin extracts was estimated. Briefly, 1 mL methanolic extract (1:10, w/v) was mixed with 1.6 mL deionized water in a 10 mL volumetric flask. A volume of 0.06 mL of 2 mM FeCl2 solution was added and allowed to stand at room temperature for 3 min, when 0.12 mL of 5 mM ferrozine solution was added. The mixture was vigorously shaken and then allowed to stand at room temperature for 10 minutes. Subsequently, the absorbance of the purple-colored complex formed was measured at 562 nm using a UV-VIS spectrophotometer (JASCO V 530, Japan Servo Co.Ltd., Japan) by comparing it to a blank sample. The results were expressed as mg disodium ethylenediamine tetra-acetic acid (EDTA-Na2) equivalents per g sample (equiv. mg EDTA/g).

Statistical Analysis

All measurements were performed in triplicate. The data obtained were analyzed by one-way ANOVA, followed by Tukey test ($p = 0.05$), using the XLSTAT software (Addinsoft, Paris, France) and Prism-GraphPad software v. 9.1.2 (San Diego, CA, USA). A lack of statistically significant differences between the examined groups is indicated by similar letters.

3. Results and discussion

Proximate composition and mineral content

The results regarding the proximate composition of the turmeric and curcumin are shown in Table 1. It was shown that turmeric had significantly higher ($p < 0.05$) values for crude protein, crude fat, crude fiber, and ash, compared to curcumin extract. Close values were reported by Ikpeama et al. [16], who found 9.40 % crude protein and 4.60 % crude fiber in turmeric powder. Turmeric is a good source of energy with a high carbohydrate (approximately 42 g/100 g), that facilitates the digestion and absorption of other nutrients. The percentage of native starch found in C. longa (22%) is comparable to the amount of starch found in potatoes. However, the starch in C. longa

has a more organized and crystalline structure, and a triangular shape with smooth surfaces [17].

Mineral analysis of both turmeric and curcumin powder was performed (Table 1). Iron was, quantitatively, the most abundant mineral in the analyzed samples. Turmeric is noteworthy for its capacity to enhance iron uptake, a vital element crucial for immune function, cognitive development, temperature regulation, and metabolic processes. In a study conducted by Erdoğan and Erbaş [18], different values were reported for the minerals contained in turmeric: 175 mg/kg iron, 2 mg/kg copper, 19 mg/kg manganese, and 3 mg/kg zinc.

Table 1. The proximate composition and mineral content in turmeric and curcumin powders

Item	Turmeric	Curcumin	SEM	p-Value
Crude protein (g/100 g)	7.89 b	0.94 a	1.56	<0.0001
Crude fat (g/100 g)	1.76 b	0.45 a	0.30	0.001
Crude fibre (g/100 g)	4.61 b	0.73 a	0.87	<0.0001
Ash (g/100 g)	7.47 a	0.57 a	1.55	<0.0001
Minerals				
Copper (mg/kg)	3.12 b	1.01 a	0.48	0.0002
Iron (mg/kg)	491.25 b	131.74 a	80.55	<0.0001
Manganese (mg/kg)	66.21 b	15.21 a	11.45	<0.0001
Zinc (mg/kg)	14.67 b	2.84 a	2.70	0.001

Means in rows followed by the same letter are not significantly different at the 5% level of probability ($p < 0.05$)

Fatty acid profile

The individual fatty acid content of turmeric powder is shown in Table 2.

Table 2. Fatty acids profile of turmeric powder (g/100 g Total FAs)

Fatty acids	C:D	Turmeric
Butyric acid	C 4:0	3.52
Caproic acid	C 6:0	14.99
Caprilic acid	C 8:0	1.47
Nonadecanoic acid	C 9:0	0.55
Capric acid	C 10:0	1.09
Lauric acid	C 12:0	2.39
Myristic acid	C 14:0	3.38
Myristoleic acid	C 14:1	1.36
Pentadecanoic acid	C 15:0	0.34
Pentadecenoic acid	C 15:1	5.83
Palmitic acid	C 16:0	7.97
Palmitoleic acid	C 16:1	1.79
Heptadecanoic acid	C 17:0	18.12
Heptadecenoic acid	C 17:1	4.51
Stearic acid	C 18:0	13.40
Oleic acid	C 18:1	8.01
Linoleic acid	C 18:2n6	7.28
Arachidic acid	C 20:0	0.19
α Linolenic acid	C 18:3n3	2.00
Octadecatetraenoic acid	C18:4n3	0.66
Eicosadienoic acid	C20(2n6)	0.38
Eicosatrienoic acid	C20(3n6)	0.21
Eicosatrienoic acid	C20(3n3)	0.30
Arachidonic acid	C20(4n6)	0.17
Σ SFA		67.41
Σ MUFA		21.49
Σ PUFA		11.00
Σ n-3		2.960
Σ n-6		8.040
n-6/n-3		2.718
PUFA/SFA		0.163

C:D, carbon number: double bounds number; SFA, saturated fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids. The relative concentration of each fatty acid is reported as a gram of fatty acids/100 g of total fatty acids.

The GC analysis of fatty acids in turmeric powder showed that from the unsaturated fatty acids, oleic acid had the highest content, followed by pentadecanoic acid. Among the saturated fatty acids, heptadecanoic acid registered the highest concentration and was followed by caproic and stearic acid. In line with these results, Paul et al. [19] also observed that oleic acid was the major unsaturated fatty acid from turmeric extract, and concluded that the percentage of oleic acid was similar to that found in olive oil and safflower oil. In the past few years, there has been a notable focus on oleic acid (OA), the predominant monounsaturated fatty acid (MUFA) in everyday diets. Increasing evidence suggests that diets high in monounsaturated OA may offer favorable effects on body composition, potentially aiding in the management and prevention of obesity [20]. While OA demonstrates promise in weight management, its efficacy in obesogenic environments warrants deeper investigation.

Total polyphenols and antioxidant capacity

The rhizomes of C. longa serve as a rich source of phytochemicals, containing 21.54 mg/g GAE total polyphenols (Figure 1). Curcumin extract registered a higher content of total polyphenols (76.50 mg/g GAE), while turmeric powder had an increased concentration of total flavonoids (47.42 mg/g flavonoids in turmeric vs 24.71 mg/g in curcumin). However, in the commonly commercialized dry powder form, turmeric exhibits a reduction of approximately 42% in total phenolic compounds compared to its fresh counterpart [21]. The higher temperatures employed in the drying process have a pronounced impact on the extraction yield and curcuminoid content, leading to greater losses of volatile substances, pigment degradation, and reduced yields compared to lower temperature methods. Conversely, microwave drying has emerged as the optimal technique for producing dry C. longa, as it minimizes the degradation of phenolic compounds compared to lyophilization. Exposure of curcumin to elevated temperatures, oxygen, and light accelerates its degradation, thereby hindering process efficiency and limiting the application of turmeric in food products [22].

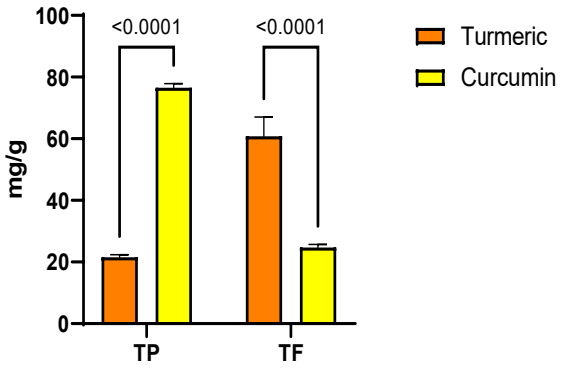

Figure 1. Watersoluble antioxidants in turmeric and curcumin (TP – total polyphenols, mg/g GAE; TF – total flavonoids, mg/g)

The main phenolic compounds present in C. longa include demethoxycurcumin and bisdemethoxycurcumin, which are rich in curcumin (the main active compound). The high content of curcumin in these rhizomes, associated with the intensity of the orange color, shows high antioxidant activity and superior health-promoting properties [23]. Plant phenolics play crucial roles in determining functional quality, color, and flavor, while also serving as potent singlet oxygen quenchers and free radical scavengers, thereby mitigating molecular damage. The health-promoting effects of phenolics primarily stem from their antioxidant properties, as the radicals generated following hydrogen or electron donation are resonance stabilized, rendering them relatively stable [24].

Considering the variations among the extensive array of test systems accessible, the outcomes of a single antioxidant assay can merely provide a simplified indication of the antioxidant capacity of plants. Hence, employing a strategy involving multiple assays during screening is strongly recommended. While numerous methods exist for assessing antioxidant activity, only a few of them are capable of effectively evaluating both hydrophilic and lipophilic species [25]. To facilitate a more comprehensive comparison of results and encompass a broader spectrum of potential applications, the in vitro antioxidant activity of turmeric powder was evaluated using methods such as free radical scavenging activity using ABTS and DPPH radical, total antioxidant capacity using the phosphomolybdenum method, and performing an iron chelation assay.

Table 3. Antioxidant capacity of turmeric and curcumin powders

Item	Turmeric	Curcumin	SEM	p-Value
Iron chelation	1.31 a	6.46 b	1.15	<0.0001
ABTS	320.50 b	71.21 a	55.76	<0.0001
Total antioxidant capacity	198.79 b	99.71 a	22.41	0.000
DPPH	60.81 a	47.89 a	4.16	0.126

Means in rows followed by the same letter are not significantly different at the 5% level of probability ($p < 0.05$)

Since elemental species like ferrous iron can trigger the generation of reactive oxygen species within animal and human systems, the capacity of substances to chelate iron proves to be a valuable antioxidant attribute. In the present study, curcumin registered a significantly higher ($p < 0.05$) iron chelation ability compared with turmeric, while turmeric powder had the highest ($p < 0.05$) concentrations for ABTS, DPPH, and total antioxidant capacity.

Liposoluble antioxidants

The content of vitamin E expressed as tocopherol isomers concentrations in turmeric and curcumin extract, is presented in Figure 2. The analytical results showed that curcumin extract had a significantly higher ($p < 0.05$) concentration of α-tocopherol and γ-tocopherol, compared to the turmeric powder. In contrast, curcumin powder did not contain δ-tocopherol, which was present in a significant amount of turmeric powder.

Plant-derived products and foods serve as primary sources of tocopherols and phytosterols essential for the human body, as these compounds are not naturally produced within the human system. Additionally, the conversion of tocopherol forms via methylation and demethylation does not occur endogenously [26]. Tocopherols are known for their antioxidant properties and their role in mitigating cardiovascular and neurodegenerative ailments. Among them, α-tocopherol exhibits superior biological activity due to its heightened retention in human plasma and tissue compared to other tocopherols.

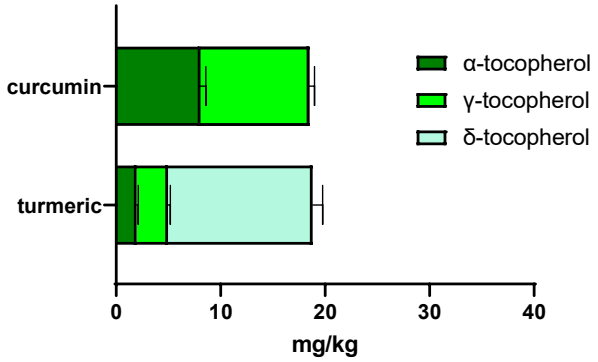

Figure 2. Vitamin E concentrations expressed as tocopherol isomers in turmeric and curcumin samples

Alpha-tocopherol's potent antioxidant capabilities stem from its additional electron-donating methyl groups in the chromanol group, which shield against lipid peroxidation and various oxidative stressors. However, despite its robust antioxidant capacity, α-tocopherol cannot effectively neutralize reactive nitrogen species, a function better fulfilled by γ-tocopherol, thanks to its unsubstituted C-5 position [27].

The HPLC analysis of carotenoids in turmeric and curcumin samples (Figure 3) showed that zeaxanthin was the predominant carotenoid in both types of samples, with a significantly higher ($p < 0.05$) concentration in the curcumin extract. Lutein also registered a significantly higher ($p < 0.05$) concentration in curcumin extract compared with turmeric powder, while astaxanthin was found only in turmeric powder. Canthaxanthin has not been found in any of the analyzed samples.

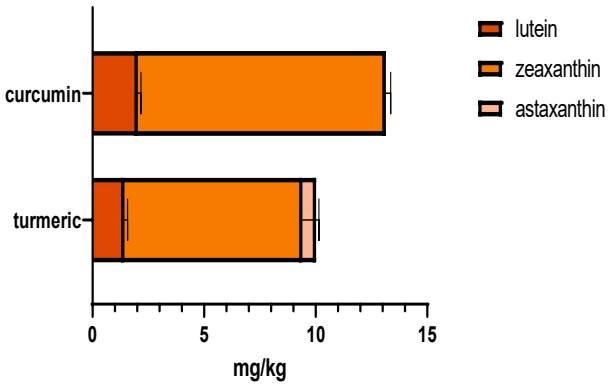

Figure 3. Carotenoid concentrations expressed as lutein, zeaxanthin, and astaxanthin in turmeric and curcumin samples

Carotenoids, being highly lipophilic molecules, are recognized for their ability to efficiently scavenge reactive oxygen species at the cellular level, thereby reducing the risk of overall oxidation. Zeaxanthin and lutein, prominent constituents of the yellow spot (fovea centralis) in the retina, contribute to the vision, and their deficiency may lead to complete blindness [28]. Carotenoids, along with various plant-derived compounds, have demonstrated remarkable therapeutic and health-promoting potential in enhancing the production performance of poultry [29]. Achieving the desirable skin coloration in poultry is often facilitated through feed supplementation with synthetic or natural carotenoids. A high-carotenoid diet administered to broilers enhanced pigmentation and conferred protective immunity against infectious bursal disease [30]. Numerous studies have shown that carotenoids sourced from natural origins can boost the productivity of poultry and alleviate oxidative stress. Feeding trials conducted in poultry have highlighted benefits in terms of both productive and reproductive performance, as well as improvements in the oxidative stability of poultry products such as eggs and meat.

4. Conclusions

The results of this study showed the comprehensive antioxidant activity of turmeric and curcumin extract, based on complex antioxidant profile (liposoluble and watersoluble antioxidants), free radicals' scavenging (ABTS and DPPH), metal-chelating activity and antioxidant capacity.

The outcomes of this study can serve as a foundation for developing innovative food products by using poultry nutrition and harnessing the potential benefits of this ancient spice.

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