



Essential Macro-Minerals, Crude Protein And Total Antioxidant Activity Of Powdered Ginger  
And Turmeric At Varied Drying Methods

Gina B. Barbosa<sup>1</sup>, Cresilda V. Alinapon<sup>1</sup> and Myrna G. Pabiona<sup>2</sup>

<sup>1</sup> Department of Chemistry, College of Arts and Sciences, Central Mindanao University, University Town, Musuan, Bukidnon, Philippines

<sup>2</sup> Department of Soil Science, College of Arts and Sciences, Central Mindanao University, University Town, Musuan, Bukidnon, Philippines

---

ABSTRACT

Drying is widely used and one of the most effective methods for food preservation. This study reports the macro-mineral, crude protein, and antioxidant activity of locally produced powdered ginger and turmeric using the air-, oven- and sun drying methods. Kjeldahl method, atomic absorption spectroscopy, and phosphomolybdenum method were used to determine the crude protein, macrominerals (K, Ca, and Mg), and total antioxidant activity (TAA), respectively. Highest TAA was observed in sun-dried turmeric ( $7.82 \pm 4.97$  mg AAE/g dried sample) while the lowest TAA was observed in sun-dried ginger powder ( $2.14 \pm 0.31$  mg AAE/mg dried sample). The measured crude protein of turmeric ranged from  $8.34 \pm 0.93$  -  $8.54 \pm 0.14\%$  while  $6.25 \pm 0.42$  -  $7.41 \pm 1.05\%$  for ginger. Essential macro-minerals in turmeric and ginger at varied drying methods ranged from 0.07 to 2.21 % for K, 0.04 to 0.12 % for Mg, and 0.79 to 1.15 % for Ca. ANOVA revealed that the effects of drying methods only significantly affected Mg for turmeric and K and TAA for ginger. Crude protein and Ca content were not significantly affected by the drying methods in both turmeric and ginger powder. Results of this study provide significant insights that prepared turmeric and ginger powder are good sources of crude protein, macro-minerals (Ca, Mg, K), and possess antioxidant properties. All drying methods studied are efficient in retaining the crude protein and calcium content of the ginger and turmeric powder, and the TAA of the turmeric powder.

*Keywords:* Essential mac-mineral, crude protein, total antioxidant activity

---

INTRODUCTION

Agricultural products are mostly perishable, and its abundance depends on the season. To ensure the availability of seasonal food or agricultural products throughout the year, food preservation became an important activity in households and communities (Hassan et al., 2007).

Drying is a common way of preserving food. It is an ancient process used to remove water in food through vaporization, and thereby reducing its water activity which results in longer shelf life (Guiné, 2018). Drying also helps to minimize the use of refrigeration systems for transport and storage which are known to be expensive. And most importantly, drying improves the digestibility of foods, increases concentration of nutrients, and can make some nutrients more readily available (Zaharaddeen and Oviosa, 2019).

Ginger (*Zingiber officinale* Roscoe) also known as "luya" in Filipino is widely cultivated in the Philippines and a native to tropical Asia. According to Mao et al (2019) Ginger have been identified to contain phenolic compounds including gingerols, shogaols, and paradols, which account for its antioxidant, anticancer, antimicrobial, and anti-inflammatory properties. Dried ginger reported to have vitamin C (9.33g/100g), protein (5.08g/100 g), fat (3.72 g/100 g) and minerals like iron, calcium, phosphorous, zinc, copper, chromium and manganese (Shirin Adel P.R.

and Prakash, 2010). In Filipino cuisine, ginger is a common in ingredients in tinola, goto, arroz caldo, paksiw, batchoy and pinakbet. The famous Filipino salabat is also made out of fresh or powdered ginger.

Turmeric (*Curcuma longa*) also known as "luyang dilaw" in Filipino is widely cultivated in India, Middle East and South East Asia. Turmeric roots are reported to contain volatile oils which includes turmerone, and coloring agents called curcuminoids. Curcuminoids consist of curcumin demethoxycurcumin, 5'-methoxycurcumin, and dihydrocurcumin, which are found to be natural antioxidants (Prasad and Aggarwal, 2011). According to Ahameula et al (2014) and Restrepo-Osorio et al (2019) dried turmeric contains a significant amount of proteins, fibers, fats, and minerals such as iron, calcium, phosphorous, zinc, potassium and magnesium. In addition, turmeric has been used as a food coloring, ingredients in cosmetics or topical ointments, and supplements. It is also responsible for curry's distinctive yellow color and flavor.

Ginger and turmeric are commonly preserved through drying. However, the need for well-established data and the scarcity of scientific studies on the locally produced turmeric and ginger powders in terms of mineral content (Calcium, Ca; Magnesium, Mg; and Potassium, K),

---

**Corresponding author:**

Gina B. Barbosa

Email Address: ginavbatoy@yahoo.com

Received Aug 4, 2021; Accepted Oct 12, 2021

---



Figure 1. Photograph of representative rhizomes of ginger (A) plant and (B) turmeric.

crude protein, and total antioxidant activity (TAA) after drying is of great importance. Moreover, solving nutritional problems or mineral deficiency as addressed by Angeles-Agdeppa et al (2019) that nutrient intakes of Filipino schoolchildren and adolescents were highly inadequate, particularly among the poor and those living in rural areas. Hence, this study investigates the level of mineral content (Ca, Mg, and K), crude protein, and TAA in both ginger and turmeric after air-, sun- and oven-drying.

## METHODOLOGY

### Location of the study

Preparation of turmeric and ginger powders, metal, and crude protein analyses were conducted at the Soil and Plant Analysis Laboratory (SPAL), Department of Soil Science, College of Agriculture, Central Mindanao University (CMU), University Town, Musuan, Bukidnon, Philippines. Antioxidant activity determination was done at the Natural Science Research Center (NSRC), CMU.

### Sample Collection

Turmeric rhizomes were collected in Northern Mindanao Agricultural Crops and Livestock Research Complex (NMACLR), Dalwangan, Bukidnon, Philippines (8°12'01.26"N, 125°02'35.73"E) while ginger rhizomes were collected in San Martin, Malaybalay City, Bukidnon, Philippines (7°59'55.3"N, 125°11'42.3"E). The collected samples were placed in a sack and were transported to SPAL. Rhizomes were immediately subjected to sample preparation upon arrival in SPAL. Representative photographs of the rhizome samples are shown in Figure 1.

### Sample Preparation

Rhizomes were washed thoroughly with tap water to remove the soil debris and finally rinsed with distilled water. Rhizome samples free of wet were weighed then divided into three (3) parts and transferred to the assigned tray. The rhizomes were peeled using a knife. The peeled samples were then washed with tap water then finally rinsed with distilled water. Samples were chopped thinly

using a knife, divided into three parts with 3000 g allocated for each of the three (3) drying methods.

### Air Drying

Clean ginger and turmeric rhizomes placed in a clean tray were air-dried for nine (9) days at ambient temperature which is between 27°C – 31°C .

### Oven Drying

Clean ginger and turmeric rhizomes were transferred into an aluminum foil and oven-dried at 65°C for 78 hours. (on what basis the duration of drying (78hrs) was decided)

### Sun Drying

The third portion of the clean turmeric and ginger rhizomes were boiled separately for 40 minutes, transferred into a clean tray to drain water, then transferred into a plastic wire mesh for sun-drying for six (6) sunny days. Samples were considered dry after air-, sun- and oven-drying when samples were tried to break into smaller pieces, it would snap and crack crisply and not bend or be malleable at all.

The loss on drying was calculated using equation 1 below:

$$\text{Loss on drying} = \frac{\text{Initial weight of sample} - \text{Weight of sample after drying}}{\text{Initial weight of sample}} \times 100 \quad \text{Equation 1}$$

### Total Antioxidant Activity (TAA) determination

The TAA of the extracts was determined by adapting the method previously described by Prieto, Pineda, and Aguilar (1999) with several modifications such as the use of Eppendorf tubes as the reaction vessel and centrifugation after the reaction. In an Eppendorf tube containing 400 µL of the test solution and 1200 µL of a reagent solution (prepared by mixing an equal amount of 0.6 M sulfuric acid, 28 mM sodium phosphate, and 4 mM ammonium molybdate) were added. The Eppendorf tubes were then covered tightly with aluminum foil and

incubated at 95 °C in an oven for 90 min. After incubation, the mixture was allowed to cool to room temperature. The mixture was centrifuged at 5000 rpm for 3 min. A 200 µL of the supernatant liquid was transferred into a well of a 96-well plate. The absorbance of the mixture was measured at 695 nm. The same procedure was done on the working ascorbic acid standards for the calibration curve and blank (ethanol). The TAA, expressed in milligram ascorbic acid equivalents per gram sample (mg AAE/g sample).

#### Crude Protein (Kjeldahl method)

##### Digestion

A 0.2 g of air-dried, oven-dried, and sundried plant samples were separately weighed, wrap in a piece of quantitative filter paper, and drop as package into the digestion tube. One (1) g of catalyst (100g potassium sulfate, 10 g copper sulfate, one gram selenium) was added, and five (5) mL of concentrated sulfuric acid carefully poured to into the mixture. While digesting the sample using digestion heater, the heater was regulated so that the H<sub>2</sub>SO<sub>4</sub> condenses about 1/3 of the way up to the neck of the tube. The tube was rotated at intervals to facilitate the digestion of the sample. When the sample no longer contains carbonaceous material as shown in the appearance of blackish color or a when clear digests was obtained, the digestion stops. After cooling, 30 mL distilled water was added and cautiously mixed. The contents were transferred to 500mL Kjeldahl flask for distillation.

##### Distillation

Twenty mL of the 4% H<sub>3</sub>BO<sub>3</sub> in a 125 mL Erlenmeyer flask was used as receiving solution. It was placed under the condenser of the distillation set-up so that the end of the condenser is below H<sub>3</sub>BO<sub>3</sub> solution. A 25 mL of 10 N NaOH was added to the flask by holding the flask at 45° angle so that the alkali reached the bottom of the flask without mixing with the digest. As soon as the alkali mixed with the sample, the flask was attached as quickly as possible to the distillation set-up. The contents were mixed by swirling, and distillation started immediately.

The heating was regulated to prevent suck-back of H<sub>3</sub>BO<sub>3</sub> and to minimize frothing or bumping during distillation. The flow of the cold water through the condenser was monitored to keep the temperature of the distillate at about 35°C. When the distillate was about 100mL, the receiver flask was lowered so that the end of the condenser was above the surface of the distillate. After rinsing the end of the condenser with distilled water, the flask was removed and the distillation terminated.

##### Titration

Determination of the NH<sub>4</sub>-N was followed by titrating the distillate with 0.05 N standard acid. The color change at the endpoint is from green to purple. The blank solution was run simultaneously with the sample and carries the titration to the same end point. Equation 1 was used to calculate crude protein. Kjeldahl method does not measure the protein content directly. A known conversion factor of 6.25 was used to convert the measured nitrogen

concentration to a protein concentration (Equation 2).

$$\%Nitrogen = \frac{(T-B) \times N \times 0.014}{S} \times 100 \quad \text{Equation 2}$$

where:

- T = sample titration, mL of standard acid
- B = blank titration, mL of standard acid
- N = normality of the standard acid
- S = oven-dry weight of the sample in g

#### **Digestion of turmeric and ginger powder for metal analysis**

Digestion of the rhizome powder was done following the method of AOAC (2005). One gram air-dried, oven-dried and sundried plant samples of turmeric and ginger were weighed and placed in 30 mL porcelain crucibles. Porcelain crucibles were placed into a cool muffle furnace, and increase temperature gradually to 550°C. The ashing continued for five (5) hours after attaining 550°C. The furnace was shut –off after five (5) hours and was allowed to cool by opening the door cautiously for rapid cooling. When cooled, the porcelain crucibles then taken out carefully. The cooled ash was added with minute amount of distilled water from a jet of wash bottle at the side of the crucible. A 5-mL of 6 N HCl was added to allow soaking of ash, and the solution was allowed to stand for at least 30 minutes, and mixed with a glass rod. After 30 minutes, the solution was filtered using Whatman filter paper, diluted to 50-mL using deionized water, thoroughly mixed, and properly labelled.

#### **Metal Analyses**

Aliquots were prepared for the determination of the concentration of K, Ca, and Mg by Atomic Absorption Spectroscopy (AAS), Agilent-280FS. For Ca and Mg, 1:49 dilutions, one (1) mL of rhizome digest solutions were added into 50 mL centrifuge tubes Nalgene type using one mL pipette. Five (5) mL of 20,000 ppm SrCl<sub>2</sub> solution were added and brought to volume with distilled water. For K, 1:49 dilutions were done by adding one (1) mL of rhizome digest solutions into 50 mL centrifuge tubes Nalgene type using one (1) mL pipette and diluted with 49 mL of distilled water.

## **RESULTS AND DISCUSSIONS**

The results of this study are summarized in Table 1. Drying is widely use and one of the most effective methods for food preservation (Singh et al., 2010). It is a process where moisture in fresh material is removed to reduce water activity which leads to the inhibition of microbial growth and minimization of deteriorative biochemical reactions. The percent loss on drying in varying drying methods ranges from 86.47-90.99% for ginger, while for turmeric ranges from 86.39-89.30%. According to Zaharaddeen and Oviosa (2019), removal of moisture using heat generally improves the digestibility of foods, increases concentration of nutrients, and can make some nutrients more available.

Furthermore, drying can also reduce the weight and size of plant material, thereby minimizing the extraction cost, and solvents can easily penetrate the sample, which

Table 1. Moisture, macro-minerals, crude protein and TAA after at varied drying methods

Sample	Drying method	Loss on drying, %	*Macro-minerals			*Crude Protein, %	*TAA, mg AAE/g dried sample
			Total Ca, %	Total Mg, %	Total K, %		
Ginger	Air	86.88	1.21±0.06 <sup>a</sup>	0.12±0.02 <sup>a</sup>	2.21±0.08 <sup>a</sup>	7.04 ± 0.60 <sup>a</sup>	2.80 ± 0.46 <sup>a</sup>
	Oven	86.47	1.21±0.11 <sup>a</sup>	0.12±0.02 <sup>a</sup>	1.91±0.04 <sup>b</sup>	6.25 ± 0.42 <sup>a</sup>	3.22 ± 0.16 <sup>a</sup>
	Sun	90.99	1.35±0.19 <sup>a</sup>	0.11±0.04 <sup>a</sup>	1.48±0.06 <sup>c</sup>	7.41 ± 1.05 <sup>a</sup>	2.14 ± 0.31 <sup>b</sup>
Turmeric	Air	86.39	1.13±0.16 <sup>a</sup>	0.11±0.01 <sup>a</sup>	1.73±0.06 <sup>a</sup>	7.67 ± 0.29 <sup>a</sup>	6.73 ± 0.41 <sup>a</sup>
	Oven	87.98	1.08±0.07 <sup>a</sup>	0.07±0.03 <sup>b</sup>	2.18±0.13 <sup>a</sup>	8.54 ± 0.14 <sup>a</sup>	4.48 ± 0.41 <sup>a</sup>
	Sun	89.30	1.15±0.09 <sup>a</sup>	0.08±0.01 <sup>c</sup>	1.83±0.41 <sup>a</sup>	8.34 ± 0.93 <sup>a</sup>	7.82 ± 4.97 <sup>a</sup>

\*values are in mean±SD (n=5) in five replicates

<sup>a,b,c</sup> significant difference of mean (Turkey's <0.05)

Digits with the same superscripts means no significant difference

results in more phytochemicals in the extract (Saifullah et al., 2019).

In this study, curing process which involved boiling fresh and clean rhizome, was done prior sun drying since it was previously reported by Gounder and Lingamallu (2012) that the cured rhizomes of *C. longa* have higher yield of volatile oils than those of the fresh and dried. This was further confirmed in the study of Barbosa and Minguillan (2021) which revealed that ethanolic extracts of the cured rhizomes of *E. philippinensis* and *C. longa* exhibited higher total antioxidant activity, total phenolic content, and curcumin content than the fresh one.

For measured antioxidant activity, the highest TAA was observed in sun-dried turmeric (7.82 ± 4.97mg AAE/g dried sample), followed by air-dried turmeric (6.73 ± 0.41 mg AAE/g dried sample), and oven-dried turmeric (4.48 ± 0.41mg AAE/g dried sample). Regardless of the drying method, the lowest TAA was observed in ginger. A 2.14±0.31, 2.80 ± 0.46, and 3.22 ± 0.16 mg AAE/g dried sample of TAA were measured in ginger after being subjected to the sun, air and oven drying, respectively. The effects of drying methods with respect to TAA were significantly observed in ginger but not in turmeric.

Several reports were published about the effect of different drying methods on the antioxidant capacity of plants (López-Vidaña et al., 2016). For instance, Lee and Lee of (2009) reported that increasing the drying duration at 100°C had increased the percentage drop of isoflavone content in soybeans. Thermal drying (microwave-, oven-, and sun-drying) of the leaves of ginger species such as *Alpinia zerumbet*, *Curcuma longa*, *Etlingera elatior*, and *Kaemferia galanga* resulted in a drastic decline in total phenolic content and antioxidant activity (Chan et al. 2009). According to Lim & Murtijaya (2007), the reduction in antioxidant properties during oven drying is caused by the degradation of phytochemicals, degradative enzymes, and heat decomposition due to slow heat transfer. This maybe the reason why the measured antioxidant activity of turmeric after oven drying is lower, compared to the other two drying methods.

In addition, it is interesting to note that the levels of antioxidant in turmeric is higher compared to ginger

regardless of varying drying method. A similar trend was reported by Mushtaq et al (2019) that the free radical scavenging activity and DPPH of turmeric powder extract was higher than ginger powder extract. According to Zagoosh et al. (2019), the production of active ingredients in medicinal plants is guided by genetic processes which means that antioxidant level of one plant to another varies. Furthermore, other than species, the quantity and quality of active ingredients in medicinal plants are strongly influenced by several factors such as water, air, soil, elevation, extraction methods, and antioxidant measurements. This might be the contributing factors why the measured TAA in ginger are lowered compared to turmeric.

-(contradictory to the results shown) – Cresilda -addressed

In Results part the measured TAA is reported to be highest in sun-dried turmeric (7.82 ± 4.97mg AAE/g dried sample) whereas sun-drying has been mentioned as the contributing factor for reduced TAA after sun drying compared to other drying method. –Cresilda- addressed.

This is contradictory, so may be clarified Plant-based proteins have been the subject of growing interest from researchers and consumers because of their potential health benefits, particularly in weight management and mineral bone enhancement. The world health organization (WHO) even recommended a daily intake of 0.83g/Kg per day of plant-based protein (Ahnen et. al., 2019). The crude protein content in turmeric and ginger powder after different drying methods are presented in (Table 1). The measured percent crude protein of turmeric ranges from 8.34 ± 0.93 -8.54 ± 0.14%, while 6.25 ± 0.42-7.41 ± 1.05% for ginger. A dried turmeric powder reported by Mushtaq et al (2019) contained 8.72 ± 0.41% crude protein which is a little bit higher but likely similar compared to our reported range. However, in case of ginger powder, the crude protein reported by Mushtaq et al (2019), Shirin Adel P. R. and Prakash (2010), Osabor et al (2015), and Sangwan et al (2014) were lower compared to our obtained range. This varying data in ginger might also be affected by the factors mentioned by Zagoosh et al. (2019). Nevertheless, results of this study indicate retention of crude protein even at varied drying methods., Suggesting that both ginger and turmeric might be a good source of plant-based protein

aside from peas and legumes.

(Retention of crude protein after drying as observed in this study should be corroborated with supporting references.) – Cresilda (addressed)

Minerals are essential to human life. According to Karppanen et al.(2005), increased intakes of K, Ca, and Mg and low consumption of sodium have an excellent blood pressure- lowering effect. The mean levels of the studied essential elements in turmeric and ginger at varied drying methods (Table 1) ranges from 0.07 to 2.21 % of K, 0.04 to 0.12 % of Mg, and 0.79 to 1.15 % of Ca. The highest levels of K, Ca, and Mg in turmeric are found in oven-dried turmeric (2.18%), sun-dried turmeric (1.15%), and air-dried turmeric (0.11%), respectively. In the case of ginger, highest values of K, Ca and Mg were observed in air-dried ginger (2.21 %), sun-dried ginger (1.35 %) and oven-dried ginger (0.12 %), respectively. Similar results were also reported by Ahameula et al (2014) and Restrepo-Osorio et al (2019), and Mushtaq et al (2019) in dried turmeric and ginger, respectively. This indicates that minerals such as K, Mg, and Ca are still present despite different drying methods used, suggesting, dried powdered ginger and turmeric are good sources of macro-minerals. (This observation should also be corroborated with supporting references.) – Myrna/

## CONCLUSION AND RECOMMENDATION

Air-dried and oven-dried ginger powder have higher TAA than sun-dried ginger powder. TAA of oven-dried of turmeric is lower compared to the sun and air-dried. All essential macro-minerals were detected in all samples, and the levels were in the order of  $K > Ca > Mg$  in both prepared turmeric and ginger. Significant difference on the different drying methods were only observed in K and TAA for ginger and Mg for turmeric. The crude protein of all samples was retained even after drying. All in all, regardless of drying methods used, ginger and turmeric retain its crude protein and Ca while TAA was retained in turmeric. Hence, both ginger and turmeric are good sources of proteins, antioxidants and macro-minerals that can be used or consumed by people with mineral deficiency. Furthermore, it is recommended that further investigation must be done on other types of drying methods and determine the micro-mineral content such as iron, zinc and copper.

Acknowledgment

We are grateful to Lovely Ann Lumiano for the assistance in the conduct of the entire research study; CMU through the University Research Office for the funding (R-0218) and all support; NSRC and SPAL for hosting the laboratory analyses; Department of Agriculture - Northern Mindanao Agricultural Crops and Livestock Research Complex (NMACLRC) through Ms. Arlyn Timario and Shellane Daluz for kindly providing us the samples.

## REFERENCES

Ahamefula I, Onwuka, G. I. & Nwankwo, Chibuzo. (2014). Nutritional Composition of Tumeric (*Curcuma longa*) and its Antimicrobial Properties. *International Journal of Scientific & Engineering Research*, (5)10, 1085 –

1089.

Ahnen, R.T., Jonnalagadda, S.S., &Slavin, J.L.(2019). Role of plant protein in nutrition, wellness, and health, *Nutrition Reviews*, 77(11), 735–747, <https://doi.org/10.1093/nutrit/nuz028>

Angeles-Agdeppa, I., Denney, L., Toledo, M. B., Obligar, V. A., Jacquier, E. F., Carriquiry, A. L., & Capanzana, M. V. (2019). Inadequate nutrient intakes in Filipino schoolchildren and adolescents are common among those from rural areas and poor families. *Food & Nutrition Research*, 63. <https://doi.org/10.29219/fnr.v63.3435>

Barbosa, G. B., & Minguillan, J. M. O. (2021). Antioxidant activity and total phenolic content of fresh and cured rhizomes of *Curcuma longa* and *Etlingera philippinensis*. *International Food Research Journal*, 28(4), 839-847.

Chan, E. W. C., Lim, Y. Y., Wong, S. K., Lim, K., Tan, S., Lianto, F., & Yong, M. (2009). Effects of different drying methods on the antioxidant properties of leaves and tea of ginger species. *Food Chemistry*, 113(1), 166-172.

Darvishi, H., Asl, A.R., Asghari, A., Azadbakht, M., Najafi, G., & Khodaei, J. (2013). Study of the drying kinetics of pepper. *Journal of the Saudi Society of Agricultural Sciences*. <http://dx.doi.org/10.1016/j.jssas.2013.03.002>

Ding, S., An, K., Zhao, C., Li, Y., Guo, Y. H., & Wang, Z. (2012). Effect of drying methods on volatiles of Chinese ginger (*Zingiber officinale* Roscoe). *Food and Bioprocess Technology*, 90(3), 515-524.

Hassan, H.W., Umar, R.A. , Maishanu, H.M., Matazu, I.K., Faruk, U.Z., &Sani, A.A. (2007). The Effect of Drying Method on the Nutrients and Non-nutrients Composition of Leaves of *Gynandropsis gynandra* (Capparaceae). *Asian Journal of Biochemistry*, 2: 349-353. [10.3923/ajb.2007.349.353](https://doi.org/10.3923/ajb.2007.349.353)

Iwansyah, A.C., Manh, T.D., Andriana, Y., Aiman bin Hessian, M., Kormin, F., Cuong, D.X., Xuan Hoan, N., Thai Ha, H., Thi Yen, D., Thinh, P.V., The Hai, L., & Ngoc Minh, T. (2020). Effects of Various Drying Methods on Selected Physical and Antioxidant Properties of Extracts from *Moringa oliefera* Leaf Waste. *Sustainability*, 12. 8586. <https://doi.org/10.3390/su12208586>

Gounder, D. K., & Lingamallu, J. (2012). Comparison of chemical composition and antioxidant potential of volatile oil from fresh, dried and cured turmeric (*Curcuma longa*) rhizomes. *Industrial crops and products*, 38, 124-131.

Guiné, R. P. F. ( 2018). The Drying of Foods and Its Effect on the Physical-Chemical, Sensorial and Nutritional Properties, *International Journal of Food Engineering*, 4 (2), pp. 93-100, <https://doi.org/10.18178/ijfe.4.2.93-100>

Jimenez-Garcia, S.N., Vazquez-Cruz, M.A., Ramirez-Gomez, X.S., Beltran-Campos, V., Contreras-Medina, L.M., Garcia-Trejo, J.F., & Feregrino-Pérez, A.A. (2020).

- Changes in the Content of Phenolic Compounds and Biological Activity in Traditional Mexican Herbal Infusions with Different Drying Methods. *Molecules*, 25(25)601. <https://doi.org/10.3390/molecules25071601>
- Kade, I. J., Ibukun, E. O., Nogueira, C. W., & da Rocha, J. B. T. (2008). Sun-drying diminishes the antioxidative potentials of leaves of *Eugenia uniflora* against formation of thiobarbituric acid reactive substances induced in homogenates of rat brain and liver. *Experimental and Toxicologic Pathology*, 60(4-5), 365-371.
- Karppanen, H., Karppanen, P., & Mervaala, E. (2005). Why and how to implement sodium, potassium, calcium, and magnesium changes in food items and diets? *Journal of human hypertension*, 19(3), S10-S19.
- Kong, L.-Y., Qin, M.-J., & Niwa, M. (2000). Diterpenoids from the rhizomes of *Alpinia calcarata*. *Journal of natural products*, 63(7), 939-942.
- Kuo, Y.-J., Hsiao, P.-C., Zhang, L.-J., Wu, M.-D., Liang, Y.-H., Ho, H.-O., & Kuo, Y.-H. (2009). Labdane diterpenoid glycosides from *Alpinia densespicata* and their nitric oxide inhibitory activities in macrophages. *Journal of natural products*, 72(6), 1097-1101.
- Lee, S., & Lee, J. (2009). Effects of oven-drying, roasting, and explosive puffing process on isoflavone distributions in soybeans. *Food Chemistry*, 112(2), 316-320.
- Lim, Y. Y., & Murtijaya, J. (2007). Antioxidant properties of *Phyllanthus amarus* extracts as affected by different drying methods. *LWT-Food Science and Technology*, 40(9), 1664-1669.
- López-Vidaña, E.C., Figueroa, I.P., Cortés, F.B., Rojano, B.A., & Ocaña, A.N. (2017) Effect of temperature on antioxidant capacity during drying process of mortiño (*Vaccinium meridionale* Swartz), *International Journal of Food Properties*, 20(2), 294-305. <https://doi.org/10.1080/10942912.2016.1155601>
- Maillard, M.-N., & Berset, C. (1995). Evolution of antioxidant activity during kilning: role of insoluble bound phenolic acids of barley and malt. *Journal of agricultural and food chemistry*, 43(7), 1789-1793.
- Mao, Q. Q., Xu, X. Y., Cao, S. Y., Gan, R. Y., Corke, H., Beta, T., & Li, H. B. (2019). Bioactive Compounds and Bioactivities of Ginger (*Zingiber officinale* Roscoe). *Foods (Basel, Switzerland)*, 8(6), 185. <https://doi.org/10.3390/foods8060185>
- Mushtaq, Z., Nadeem, M-T., Arshad, M-U., Saeed, F., Ahmed, M-H., Ain, B\_B., Javed, A., Anjum, F-A., & Hussain, S. (2019) Exploring the biochemical and antioxidant potential of ginger (*Adric*) and turmeric (*Haldi*), *International Journal of Food Properties*, 22:1, 1642-1651. <https://doi.org/10.1080/10942912.2019.1666138>
- Nicoli, M., Anese, M., & Parpinel, M. (1999). Influence of processing on the antioxidant properties of fruit and vegetables. *Trends in Food Science & Technology*, 10(3), 94-100.
- Osabor, V., Bassey, F., Umoh, U. (2015). Phytochemical Screening and Quantitative Evaluation of Nutritional Values of *Zingiber Officinale* (ginger). *American Chemical Science Journal*, 8(4), 1-6. <https://doi.org/10.9734/ACSJ/2015/16915>.
- Restrepo-Osorio, J., Nobile-Correa, D.P., Zuñiga, O., & Sánchez-Andica, R.A. (2020). Determination of nutritional value of turmeric flour and the antioxidant activity of *Curcuma longa* rhizome extracts from agroecological and conventional crops of Valle del Cauca-Colombia. *Revista Colombiana de Química*, 49(1), 26-32. <https://doi.org/10.15446/rev.colomb.quim.v1n49.79334>
- Prieto, P., Pineda, M., & Aguilar, M. (1999). Spectrophotometric quantitation of antioxidant capacity through the formation of a phosphomolybdenum complex: specific application to the determination of vitamin E. *Analytical biochemistry*, 269(2), 337-341.
- Roy, M. K., Takenaka, M., Isobe, S., & Tsushida, T. (2007). Antioxidant potential, anti-proliferative activities, and phenolic content in water-soluble fractions of some commonly consumed vegetables: Effects of thermal treatment. *Food Chemistry*, 103(1), 106-114.
- Saifullah, Md., McCullum, R., McCluskey, A. & Vuong, Q. (2019). Effects of different drying methods on extractable phenolic compounds and antioxidant properties from lemon myrtle dried leaves. *Heliyon*, (5)12. <https://doi.org/10.1016/j.heliyon.2019.e03044>
- Sangwan, A., Kawatra, A., & Sehgal, S. (2014). Nutritional composition of ginger powder prepared using various drying methods. *Journal of food science and technology*, 51(9), 2260-2262. <https://doi.org/10.1007/s13197-012-0703-2>
- Shirin Adel, P. R. & Prakash, J. (2010). Chemical composition and antioxidant properties of ginger root (*Zingiber officinale*). *Journal of Medicinal Plants Research*, 4(24), pp. 2674-2679. <https://doi.org/10.5897/JMPR09.464>
- Tomaino, A., Cimino, F., Zimbalatti, V., Venuti, V., Sulfaro, V., De Pasquale, A., & Saija, A. (2005). Influence of heating on antioxidant activity and the chemical composition of some spice essential oils. *Food Chemistry*, 89(4), 549-554.
- WHO. (2012). Guideline: Potassium intake for adults and children. Geneva, World Health Organization (WHO). SBN 978 92 4 150482 9
- Wohlmuth, H., Deseo, M. A., Brushett, D. J., Thompson, D. R., MacFarlane, G., Stevenson, L. M., & Leach, D. N. (2010). Diarylheptanoid from *Pleuranthodium racemigerum* with in vitro prostaglandin E2 inhibitory and cytotoxic activity. *Journal of natural products*, 73(4), 743-746.
- Zsila, F., Bikádi, Z., & Simonyi, M. (2003). Molecular basis of the cotton effects induced by the binding of curcumin

to human serum albumin. *Tetrahedron: Asymmetry*, 14(16), 2433-2444.

Zaharaddeen, N.G., &Oviosa, S. (2019). The effect of different drying methods on the elemental and nutritional composition of *Vernoniaamygdalina* (bitter leaf), *Journal of TaibahUniversity for Science*, 13:1, 396-401, DOI: 10.1080/16583655.2019.1582148

Zargoosh, Z., Ghavam, M., Bacchetta, G. et al. (2019). Effects of ecological factors on the antioxidant potential and total phenol content of *Scrophularia striata* Boiss. *Science Reports*, 9, 16021. <https://doi.org/10.1038/s41598-019-52605-8>