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Analysis of Physico-chemical Properties of Turmeric Powder Commercially Available in Sri Lankan Market

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ABSTRACT

At present, functional foods or nutraceuticals of plant origin, have gained popularity and constitute a major share of the health-care market. Majority of the consumers have a misconception, that these products are inherently safe for consumption. However, agronomic practices and processing procedures play a vital role in the quality of the ultimate product. Considering turmeric, color, aroma and other chemical properties of processed turmeric powder directly depend on the processing procedure. This study was conducted to determine the physico-chemical properties of turmeric powder manufactured by different manufacturers which were commercially available and largely used in Sri Lanka. Three batches from twelve different brands of turmeric powder and a pure turmeric powder sample were analyzed. Results were statistically compared using analysis of variance (ANOVA). Highest curcumin content (6.74 ± 0.01 %) was reported in sample 8, which had no significant difference with the control (6.47 ± 0.01 %). Highest volatile oil (5.85 ± 0.05 %) and oleoresin (17.55 ± 0.05 %) percentages were reported in the control sample. Gas liquid chromatograms (GLC) of all volatile oil samples report ar-turmerone as the main active compound, which is the most abundant compound in *Curcuma longa*. According to the results, the moisture, ash, and acid-insoluble ash percentages of all the samples were non-compliant with Sri Lanka standard (SLS), but the curcumin percentage of four market samples were compliant with SLS. There were significant differences among the market samples and the control sample, but the variation among batches in same sample was not significant.

1. Introduction

Plants and their products have always played a substantial role in human welfare by satisfying various essential needs ranging from food to medicine [1]. The plant products might accumulate toxic substances and heavy metals at significant levels when the plants are grown in polluted soil[1] and their products are processed and packed in unhygienic conditions; reflecting the failure of Good Agricultural Practices (GAP), Good Manufacturing Practices (GMP) and Quality Assurance (QA). Consuming poor quality or contaminated products regularly could lead to the accumulation of toxic matter in human organs resulting serious health problems [1].

Turmeric (*Curcuma longa*), botanically belongs to the Zingibaraceae family [2] and is a plant which is recognized as an important spice widely used as a condiment especially in South and South East Asian countries, Africa and Americas [3]. Turmeric has been used as a traditional medicine for the diseases such as biliary disorders, cough, anorexia, hepatic disorders, diabetic wounds, rheumatism and sinusitis [2,4]. Turmeric is primarily used as a treatment for inflammatory conditions in Ayurveda medicine, and it is used as stimulant, aspirant, carminative, astringent, detergent, cordial, emmenagogue, diuretic and martinet in traditional Chinese medicine [5]. Turmeric possesses antibacterial properties against different bacteria, viruses, fungi, and parasites [6,7]. In Sri Lanka, turmeric is generally cultivated in almost every part of the island except in areas of very high elevations. However, due to the high demand in the country, turmeric is imported; mostly from India, China, Myanmar, and Bangladesh. But since December 2019, new regulations have been imposed by the Sri Lankan government to limit the importation of turmeric [8].

Turmeric powder which is produced from turmeric rhizome is widely used in Sri Lankan food

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not only as a colouring agent but also to enhance the flavour and organoleptic properties which uplift the acceptability of food [4]. Curcumin is the main active compound of turmeric and curcumin is one of the best natural colorants in the food industry. Curcumin comprise of three compounds; Curcumin I, Curcumin II (Demethoxycurcumin) and Curcumin III (Bisdemethoxycurcumin), which are also called curcuminoids. Figure 1 illustrates the chemical structures of the curcuminoids [4]. Natural curcumin from the turmeric rhizome consists 77% of Curcumin I, 17% of Curcumin II and 3% of Curcumin III [4].

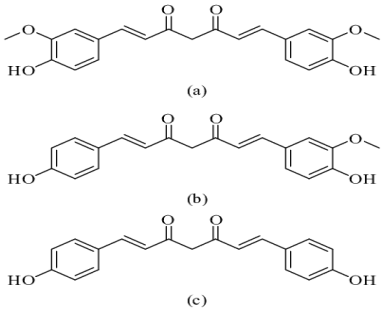

Figure 1: Chemical structure of (a) Curcumin I, (b) Curcumin II (Demethoxycurcumin), (c) Curcumin III (Bisdemethoxycurcumin)

Different methods and equipment are used to process turmeric. However turmeric processing consists of four basic steps which are washing, curing, drying and polishing [9]. Color, aroma and other chemical properties of processed turmeric directly depend on the processing procedure [9,10]. The volatile oil of turmeric contains ar-turmerone, curlone and ar-curcumene as the main compounds (Figure 2). Turmeric is considered more or less as an essential ingredient in daily meals of the national population. As such there is high consumption in the country and therefore lawful standards have to be set to ensure its quality. Thus Sri Lanka Institute of Standards has stipulated standards to ensure the quality of spices which includes turmeric in order to assure the required quality and also to prevent any adverse effects on human health.

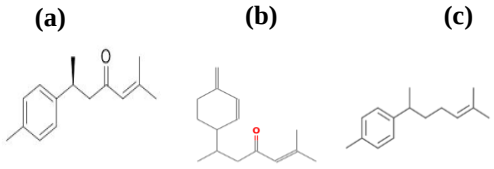

Figure 2: Chemical structure of (a) ar-turmerone, (b) Curlone, (c) ar-curcumene

This study was conducted to comparatively analyze the levels of specific physical and chemical properties such as moisture content, curcumin content, composition of volatile oil, percentage of volatile oil, oleoresin, ash, and acid-insoluble ash in turmeric powder available in the local market, to determine the level of deviation of the chemical compounds from the locally grown turmeric rhizome and also to compare the results with the requirements of the current Sri Lankan Standards.

2. Material and Methods

2.1 Materials

Toluene, absolute ethanol and hydrochloric acid (HCl) of analytical grade were purchased from Sigma-Aldrich.

2.2 Sample selection

Twelve samples were obtained from twelve different brands of turmeric powder which were locally produced and available commercially in Sri Lanka. The samples were purchased randomly from the Sri Lankan market between January to April in 2020. These samples were labeled 1 to 12 and were analyzed this study. Locally cultivated turmeric rhizomes; following the proper agricultural practices as per the instructions of the Department of Export Agriculture, were obtained from a farmer field in Namaloya area in Ampara district. The turmeric rhizomes were processed at the Central Research Station, Department of Export Agriculture, Matale. The rhizomes were cleaned, the fingers and the mother rhizomes were separated and were blanched in a closed pot filled with 3/4 of water, for 30 min and 45 min, respectively. The rhizomes were dried under sunlight until the moisture percentage was reduced to 10%. Then the removal of the skin in the rhizomes was done by the turmeric polisher machine and it was ground using the grinder (IKA Laboratechnik 6000 min-1, France) to obtain turmeric powder. The Namaloya turmeric was selected as the control.The experiment was arranged in a Complete Randomized Design (CRD) with the total of thirteen treatments, with three replicates for each treatment.

2.3 Determination of moisture content

Quantitative determination of moisture was conducted using the distillation method (AOAC Official method 986.21, 1988). Forty (40.000) g of the turmeric powder sample was placed in a round bottom flask with 150.0 mL toluene to cover the test sample completely and boiling chips (pumic stone granular) were added into it. The round bottom flask was attached to the condenser through a Clevenger arm and the mixture was heated by the moisture distillation unit for 4 h. Then the receiver was cooled to the room temperature and the volume of water which was collected in the graduated tube was read from the tube to calculate the percentage of moisture content (Equation 1).

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A correction blank for toluene was conducted by adding 1.0 ml of distilled water to 150.0 ml of toluene in the distillation flask. Refluxing was done at a rate of 0.1 mL s^{-1} until consecutive readings at 5 min intervals showed no difference (Equation 2).

$$\text{Moisture content (\%)} = \frac{\text{Volume of water (ml)}}{\text{Correction factor}} \times \frac{100}{\text{Dry weight of the sample (g)}} \quad \text{(Equation 1)}$$

$$\text{Correction factor} = \frac{\text{Distilled water volume trapped (ml)}}{\text{Distilled water volume added (ml)}} \quad \text{(Equation 2)}$$

2.4 Determination of curcumin content

ASTA method 18.0 was used to determine the curcumin content [11]. An exact 0.100 g of turmeric powder was weighed and was placed inside a round bottomed flask which was covered with an aluminum foil. Then 30.0 ml of absolute ethanol was added and the round bottom flask was connected with a refluxing condenser. The refluxing was continued for 2.5 h and the setup was let to cool down to the room temperature. Then it was filtered into a 100 ml volumetric flask and was washed with absolute ethanol up to the mark. Then, 2.0 ml was pipetted out into a 25 ml volumetric flask and it was volume up with absolute ethanol up to the mark. The absorbance was measured at 425 nm with absolute ethanol as the blank using the UV-visible spectrophotometry (Agilent Cary 60, Australia) and curcumin percentage was calculated (Equation 3).

$$\text{Curcumin content (\%)} = \frac{\text{Absorbance of the extract} \times 125}{\text{Cell length (cm)} \times \text{Dry weight of the sample}} \quad \text{(Equation 3)}$$

2.5 Determination of volatile oil content by Hydro distillation

Determination of volatile oil content was conducted according to the Modified Clevenger Method using Clevenger's apparatus as per the AOAC Official method 962.17, 1996. Fifty grams of the sample was placed in a 1000 mL round bottom flask with 300.0 mL water. The apparatus was assembled and the Clevenger trap was filled with water until water began to flow into the flask. An efficient water-cooling condenser was placed on top of the trap and the flask was heated maintaining the temperature of the heating mantle at 70 ^{0}C for 4 h, until there was no change in the oil level in the trap. The oil volume was measured after the set up was cooled to the room temperature and oil percentage was calculated according to the dry basis (Equation 4).

$$\text{Oil content} = \frac{\text{Oil volume (ml)}}{\text{Dry weight of the sample (g)}} \times 100 \quad \text{(Equation 4)}$$

2.6 Determination of oleoresin percentage by Soxhlet extraction

An exact ten (10.000) g of the sample was inserted into a paper thimble and covered with a cotton plug. The thimble was inserted into the Soxhlet arm and was fixed to a weighed 250 ml round bottom flask. Absolute ethanol was added into the flask and the apparatus were assembled. The heater was switched on and the distillation was carried out for 18 h. The ethanol was thereafter evaporated until the oleoresin remained in the flask. The flask was cooled to the ambient temperature, and the weight of the flask with oleoresin was measured to calculate the weight of oleoresin (Equation 5).

$$\text{Oleoresin content (\%)} = \frac{\text{Weight of oleoresin (g)}}{\text{Dry weight of the sample (g)}} \times 100 \quad \text{(Equation 5)}$$

2.7 Determination of the chemical composition in volatile oil by GC Analysis

The GC analysis of turmeric oil was carried out using a 6890 series Shimadzu GC 8A chromatograph (Agilent Technologies, Palo Alto, CA, USA) equipped with Flame Ionization Detector (FID) and carbowax column (Internal diameter: 50 m x 0.25 mm, film thickness: 0.25 µm). The temperature was programmed from 50^{0}C – 230 ^{0}C at 4 ^{0}C min^{-1}. The temperature of both injector and detector were kept at 230 ^{0}C. Initial temperature was set at 50 ^{0}C. Hydrogen was used as the carrier gas at a flow rate of 45 mL min^{-1}. Peak areas were computerized by a Shimadzu C-R6A chromatopac data processor.

2.8 Determination of total ash content

An exact weight of 0.500 g of the sample was placed inside a crucible. 2.0 ml of ethanol was poured on to it and ignited to burn off ethanol. The sample was ignited in a muffle furnace at 550 ± 25 ^{0}C for 6 h to obtain carbon free white ash. The ash was cooled in a desiccator and the weight was recorded. The process was repeated at 30 min time intervals until the difference between two successive readings did not exceed 1 mg.

2.9 Determination of acid-insoluble ash content

AOAC 2000 gravimetric method was used to determine the acid insoluble ash content. The total ash of 0.500 g of the sample was dissolved in 25.0 mL of 5 M HCl, covered with a watch glass and boiled in a water bath for 5 min. It was filtered through an ash-less filter paper (Whatmann 42). The filtered sample was washed with hot water until the washings were acid free. The filter paper with the residue was placed in a crucible and ignited in the muffle furnace at 600 ^{0}C for 1 h. It was cooled in a desiccator and the weight was recorded. The

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process of heating, cooling and weighing was repeated at 30 min time intervals until the difference between two successive readings did not exceed 1 mg.

2.10 Statistical analysis

The results were obtained from three parallel areas following complete randomized design (CRD). Data analysis was done using SAS 9.0 statistical software with proc ANOVA. The means were compared with Dunnett's multiple range test using least significant difference at p = 0.05.

3. Results and Discussion

3.1 Moisture content

Figure 3 illustrates the moisture content of the commercial turmeric powder samples and the control sample. The highest moisture content is observed in sample 11 (12.00 ± 0.00%) and the lowest moisture content is recorded in sample 3 (6.72 ± 0.03 %). The maximum acceptable amount of moisture content given by the Sri Lanka standards institute is 12.00 % in mass and all the samples were in agreement with SLS. The moisture content of turmeric powder depends on the soil, climatic condition, temperature, humidity, geography, seasonal changes and the growing condition of the turmeric rhizomes which were used as the raw materials [4,5]. More importantly the processing technique is a major contributing factor for the variations of the moisture content [9]. The packaging material used, the storage conditions provided, also play an important role in maintaining the moisture content of the sample.

3.2 Curcumin content

Curcumin, the main active component in turmeric, possesses the important medicinal properties that help to prevent and control many disease conditions related to respiratory, neurological, and cardiovascular systems addition to metabolic and inflammatory diseases [4,12]. Curcumin has a characteristic orange-yellow colour and it is the colouring agent of turmeric [12]. Curcumin percentage determines the colour intensity of turmeric powder; higher the curcumin content more orange the colour of turmeric would be. Curcumin is the compound responsible for all the antibacterial, anti-inflammatory, anticancer, antioxidant and antimutagen activity of turmeric, thus it serves as a measure of the quality of turmeric [13,14].

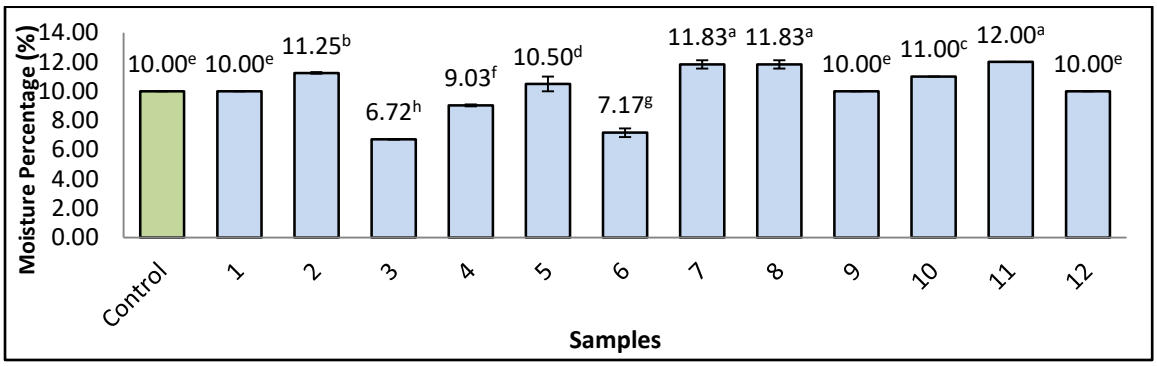

Figure 3: Moisture percentage of the turmeric powder samples (means represented by the same letter are not significantly different at p = 0.05)

Figure 4 shows the results obtained for the curcumin percentage of the commercial samples available in the Sri Lankan market and the control sample. The highest curcumin percentage (6.74 ± 0.01 %) is obtained in sample 9 and it has no significant difference with the control sample (6.47 ± 0.01 %).The lowest curcumin percentage (1.98 ± 0.02 %) is obtained in sample 6. According to ISO/IEC 17025:2005 standard, the accepted average range for curcumin is from 2.00% – 10.00%. But according to FAO/WHO Codex Alimentarius and SLS Standard the acceptable curcumin percentage should be higher than 3.00% [15]. According to the Department of Export Agriculture, the standard quality specification the average curcumin percentage of local turmeric is between 3.00% - 6.00%. In the current research work four of the market samples did not comply with the Codex standard and SLS.

Curcumin is a highly light sensitive chemical compound [16]. Curcumin can be degraded upon exposure to UV light. Therefore, if suitable packing and storage facilities are not provided, the curcumin content in turmeric powder can be reduced. Agronomic practices, type of soil and climatic conditions also may affect the curcumin percentage [17]. Curcumin percentage is inversely proportional to the boiling time and drying time [18] thus, the processing technique is a major contributing factor to the curcumin percentage of turmeric powder.

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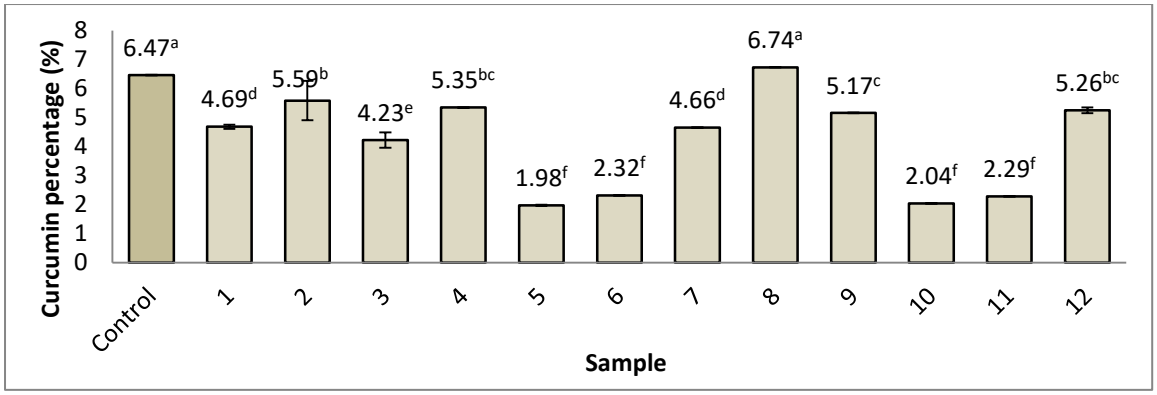

Figure 4: Curcumin content of turmeric powder samples (means represented by the same letter are not significantly different at p = 0.05)

3.3 Volatile oil and oleoresin content

Figure 5 represents the volatile oil and oleoresin content of the turmeric powder samples. The highest oil (5.85 ± 0.05 %) and oleoresin percentages (17.55 ± 0.05 %) were obtained from the control sample. Turmeric oil contains volatile compounds which are not harmful or irritable to the skin [19, 20], while turmeric oleoresin contains turmeric oil, curcumin and other resinous material [20]. Apisariyakul et al. have reported that fifteen isolates of dermatophytes and four isolates of pathogenic fungi were inhibited by turmeric oil when neither of them was inhibited by curcumin. Their tests have also proven that turmeric oil and curcumin have no effect on isolates of yeast [19]. Studies have shown that lesions caused by dermatophytes can be treated by dermal application of turmeric oil such that it can be used to replace the imported expensive drugs [19]. Hastak et al. have studied the effect of turmeric oil and turmeric oleoresin on cytogenetic damage in patients suffering from oral submucous fibrosis and have proven that both are excellent scavengers of free radicals. Both have reduced the number of micronuclei in circulating lymphocytes, while oleoresin has been more effective in reducing the number of micronuclei in oral mucosal cells [20].

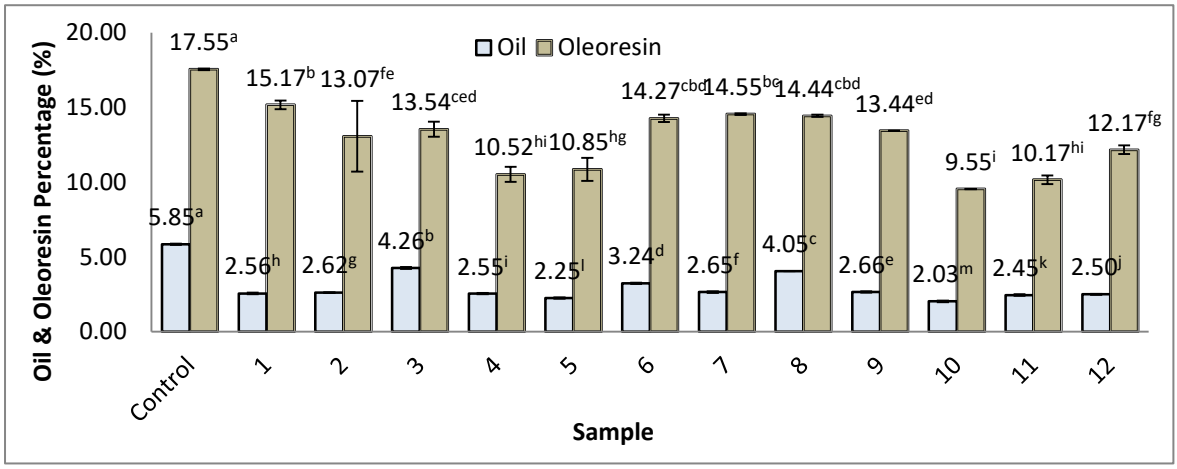

Figure 5: Oil and Oleoresin percentage of turmeric powder samples (means represented by the same letter are not significantly different at p = 0.05)

3.4 *Chemical composition in volatile oil*

The most abandon compound of the volatile oil can be used to differentiate the rhizomes of Curcuma species. Zwaving*et* et al. have characterized the essential oils of Curcuma species from India and Indonesia by the chemical composition in volatile oil. According to that study, volatile oil of *C. longa* L. reports 54.2% ar-turmerone, *C. aromatic* Salisb (wild turmeric) reports 25.5% β-curcumene and 18.6% ar-curcumene, *C. xanthorrhiza*Roxb. Reports 41.4% ar-curcumene, *C. aeruginosa* Roxb. reports 11.4% curcumanolides A/B, 9.9% curcumenol, and 8.5% isocurcumenol, *C. heyneana* Val. reports 14.2% 1,8-cineole/ lirnonene, 13.1% curcumanolides A/B, 7.4% isocurcumenol, 10.2% dehydrocurdione, 2.3% curcumenone as the most abandon compounds [19]. According to the results of the GLC analysis of the volatile oil samples in our study, ar-turmerone, curlone and ar-curcumene were identified as the most abandon

active compounds in all the samples. The most abandon active compound of the essential oil of turmeric (*Curcuma longa*) which is being used as a spice, is ar-turmerone [20]. ar-Turmerone is reported as the most abandon active compound in all the samples with the highest concentration (Figure 6). Thus, the presence of *Curcuma longa* in all the samples can be ensured. The highest ar-turmerone concentration is reported in sample 2 (65.17±0.01%) and it has no significant difference with sample 1 (64.32±0.01%). The control sample yields 55.20±0.01% of ar-turmerone which has no significant difference with samples 3 and 11.

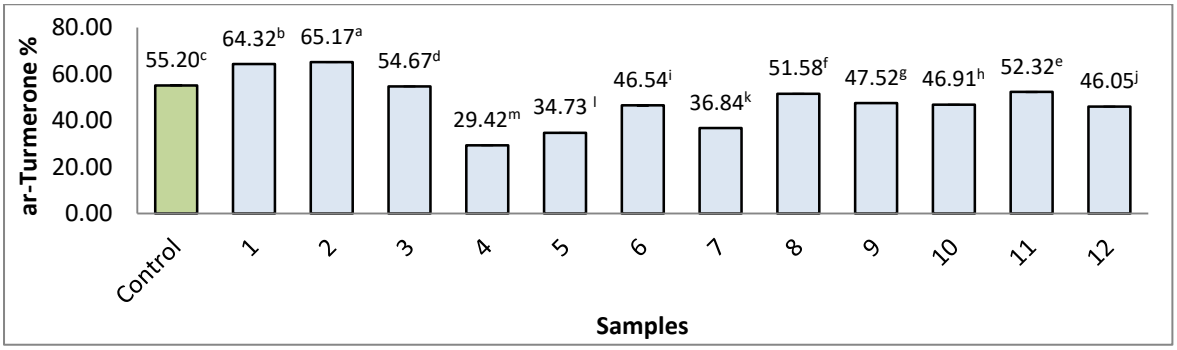

Figure 6: ar-Turmerone percentage of turmeric oil (means represented by the same letter are not significantly different at p = 0.05)

Curlone percentages of the samples are depicted in Figure 7. The highest Curlone percentage is recorded in sample 4 (32.26±0.01%), while the lowest percentage of Curlone is recorded in sample 2 (1.16±0.01%). The percentages of ar-curcumene of the samples are depicted in Figure 8. The highest ar-curcumene percentage is recorded in sample 11 (9.33±0.01%), while the lowest ar-curcumene percentage is recorded in sample 7 (2.92±0.01%).

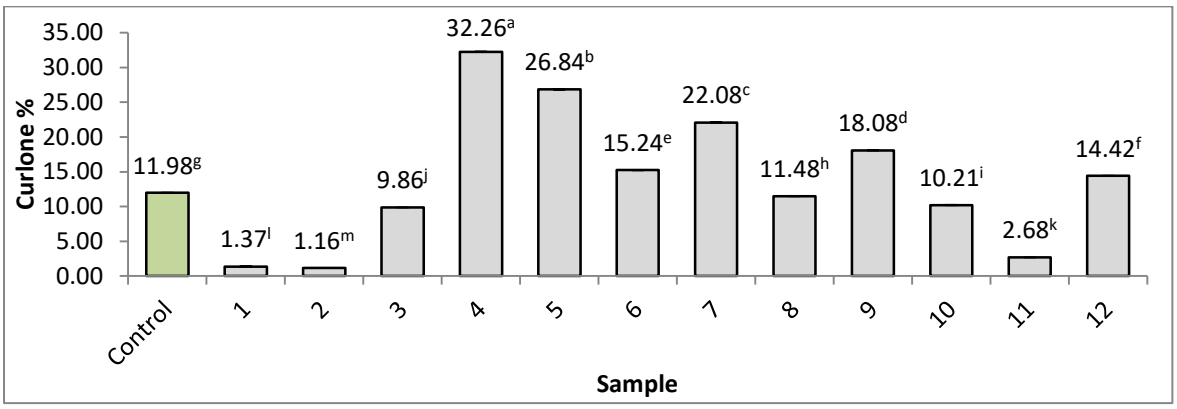

Figure 7: Curlone percentage of turmeric oil (means represented by the same letter are not significantly different at p = 0.05)

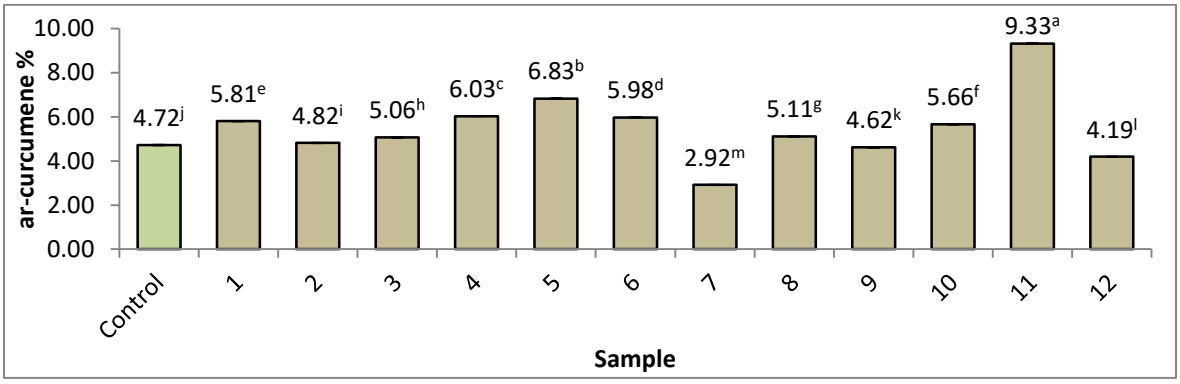

Figure 8: ar-curcumene percentage of turmeric oil (means represented by the same letter are not significantly different at p = 0.05)

3.5 Total ash and acid-insoluble ash content

Total ash and acid-insoluble ash contents are important parameters to illustrate the quality and the authenticity of the samples. Determination of the total ash content is an important index for nutritional evaluation. Ash is the organic residue remaining after complete ignition of organic matter, which can be used as a measure of the total amount of minerals present. Studies have indicated that constant feeding of turmeric powder could be important in sustaining strong bone, muscle contraction and relaxation, blood clothing, reduce blood pressure and help in hemoglobin formation due to the presence of minerals such as potassium and iron [20]. The ash content and acid-insoluble ash content are shown in Figure 9 and Figure 10 respectively. Highest ash content (8.00±0.02%) is recorded in the control sample, while the lowest ash content is recorded in sample 12 (3.00±0.01%). Nisar et al. have reported that there can be variations in ash content in turmeric powder due to the influence of environmental and geographical factors [14]. Environmental contaminations such as harvesting and processing techniques also affect the acid-insoluble ash content. **According to SLS the maximum amount of ash content is 8.00%.** As per the results all the samples complied with the current standard.

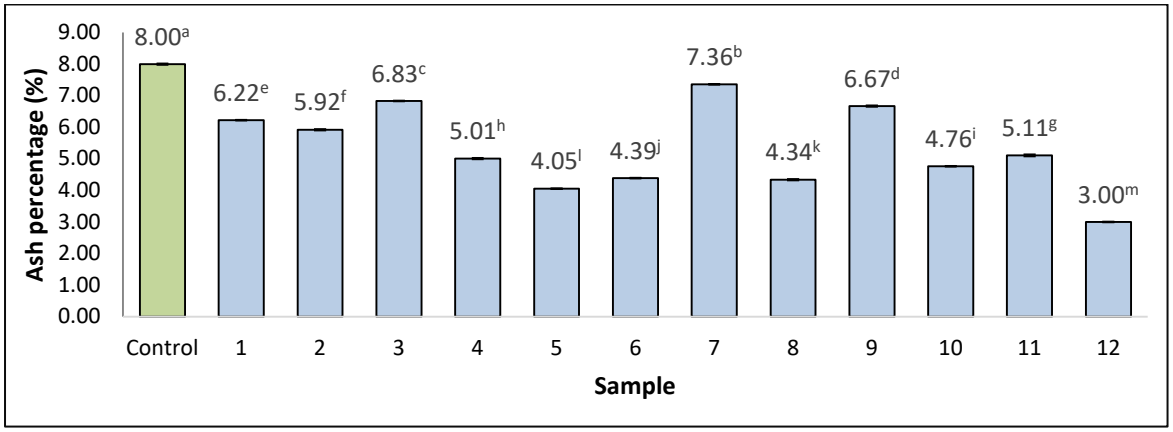

Figure 9: Ash percentage of turmeric powder samples (means represented by the same letter are not significantly different at p = 0.05)

Total ash content alone is not sufficient to assess the quality, since the plant materials often contain considerable levels of physiological ash which is derived from the plant tissue itself and non-physiological ash which is often from environmental contaminations such as sand and soil. Thus, the acid-insoluble ash content is important index to illustrate the purity of medicinal plants [20]. Since total ash content and the acid insoluble ash content are interconnected, failure in one parameter affects the accuracy of the other. The highest (0.98±0.01%) and the lowest (0.02 ±0.01%) acid-insoluble ash percentages are reported in samples 7 and 1, respectively. Himesh et al. state that high presence of silicates and silica increases the acid-insoluble ash content in *Curcuma longa* L. [20]. According to the SLS, maximum acid-insoluble ash percentage is 1.0%. All turmeric samples are below the maximum allowed limit for acid-insoluble ash content. Therefore, reasonable purity level is observed in all turmeric powder samples.

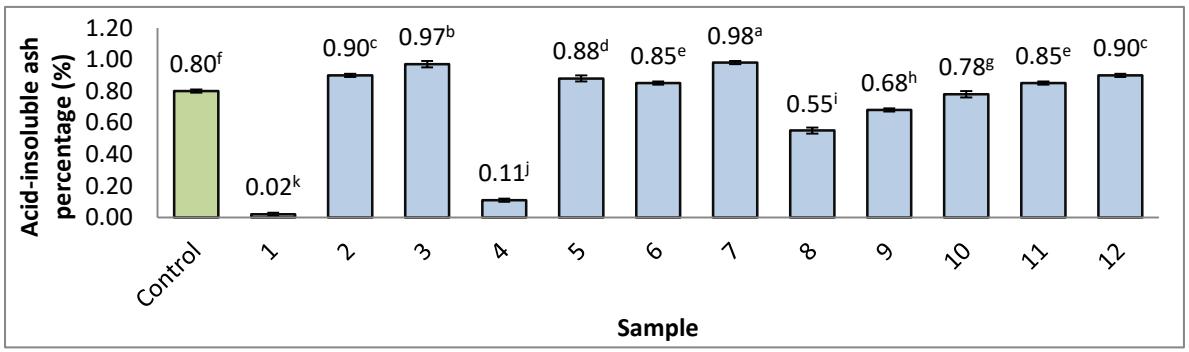

Figure 10: Acid-insoluble ash percentage of turmeric powder samples (means represented by the same letter are not significantly different at p = 0.05)

4. Conclusion

According to SLS the curcumin percentage should be more than 3.00%. The highest curcumin content (6.74±0.01%) was obtained from sample 8, and it had no significant difference compared to the control sample (6.47±0.01%). Among the market samples which were analyzed, four samples were compliant with SLS. Moisture percentage should be in an optimum level because it affects the shelf-life of the product. According to SLS the moisture percentage should not exceed 12.00%. The moisture percentages of the market samples vary from 6.72% to 12.00%, and all the samples are non-compliant with the standard. Maximum oil (5.85±0.05%) and oleoresin (17.55±0.05%) percentages were reported in the control sample. Oil content of the market samples varied from 2.03% to 4.26%, and the oleoresin content varied from 9.55% to 15.17%. Total ash and acid-insoluble ash contents are important parameters to measure the quality and the authenticity of the samples. Determination of the total ash content is an important index for the amount of minerals present. Acid-insoluble ash indicates the environmental contaminations such as sand and soil. According to SLS, maximum limit of ash and acid-insoluble ash contents are 8.00% and 1.00% respectively. Based on the results, ash and acid-insoluble ash content of all the samples are in compliance with SLS.

Since turmeric is considered more or less as an essential ingredient in daily meals of the national population, more government intervention and monitoring should be brought in to this sector, in order to assure the required quality and to prevent any adverse effects on human health due to long term consumption of poor-quality products.

References

1. Bhat R, Kiran K, Arun AB, Karim A A. Determination of Mineral Composition and Heavy Metal Content of Some Nutraceutically Valued Plant Products. Food Anal. Methods 2010; 3:181–187. DOI:10.1007/s12161-009-9107-y
2. Asghari G, Mostajeran A, Shebli M. Curcuminoid and essential oil components of turmeric at different stages of growth cultivated in Iran. Research in Pharmaceutical Sciences 2009; 4(1):55-61.
3. Booker A, Johnston D, Heinrich M. The Welfare Effects of Trade in Phytomedicines: A Multi-Disciplinary Analysis of Turmeric Production. World Development 2016; 77:221–230.
4. Chattopadhyay I., Biswas K., Bandyopadhyay U, Banerjee BK. Turmeric and curcumin: Biological actions and medicinal applications (Review Article). Current Science 2004; 87(1): 44-53.
5. Li S, Yuan W, Deng G, Wang P, Yang P, Aggarwal BB, Chemical Composition and Product Quality Control of Turmeric (*Curcuma longa* L.). Pharm. Crop 2011; 5(1): 28–54.
6. Shakila RJ, Vasundhara TS, Rao DV. Inhibitory effect of spices on in vitro histamine production and histidine decarboxylase activity of *Morganella morganii* and on the biogenic amine formation in mackerel stored at 30 ^{0}C. Z LebensmUntersForsch. 1996; 203910: 71–6.
7. Gul P, Bakht J, Antimicrobial activity of turmeric extract and its potential uses in food industry. J. Food Sci Technol. 2015; 52(4): 2272-2279.DOI: 10.1007/s13197-013-1195-4
8. The Gazette of the Democratic Socialist Republic of Sri Lanka. 05.12.2019.
9. Food and Agriculture Organization of the United Nations (FAO), TUMERIC Post-harvest Operations Compendium, Post-harvest Compend. 2004; 21.
10. Prathapan A, Lukhman M, Arumughan C, Sundaresan A, Raghu KG. Effect of heat treatment on curcuminoid, colour value and total polyphenols of fresh turmeric rhizome. Int. J. Food Sci. Technol. 2009; 44(7): 1438–1444.
11. Analytical Methods | ASTA: The Voice of the U.S. Spice Industry in the Global Market. https://www.astaspice.org/foodsafety-technical-guidance/astas-analytical-methods/ (accessed Feb 3, 2021).
12. Anand P, Kunnumakkara AB, Newman RA, Aggarwal BB. Bioavailability of Curcumin: Problems and Promises. Molecular Pharmaceutics 2007; 4: 807-818.
13. Akamine H, Hossain A, Ishimine Y, Yogi K, Hokama K, et al. Effects of Application of N, P and K Alone or in Combination on Growth, Yield and Curcumin Content of Turmeric (Curcuma longa L.). Plant Production Science 2007; 10(1): 151-154. DOI: 10.1626/pps.10.151
14. Raza L, Ali MA, Yusof YA, Nasir A, Muneer S. Effect of different drying treatments on concentration of curcumin in raw Curcuma longa Food Research 2018; 2(6): 500-504. DOI: https://doi.org/10.26656/fr.2017. 2(6).109
15. Codex standard for turmeric. Codex Alimentarius Commission, Food and Agriculture

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Organization of the United Nations, World Health Organization 2021.

16. Apisariyakul A,Vanittanakom N, Buddhasukh D. Antifungal activity of turmeric oil extracted from Curcuma longa (Zingiberaceae). Journal of Ethnopharmacol. 1995; 49(3): 163-169.

17. Zwaving JH, Bos R. Analysis of the Essential oils of five Curcuma species. Flavour and Fragrance Journal 1992; 7: 19-22.

18. Hastak K, Lubri N, Jakhi SD, More C, John A, et al. Effect of turmeric oil and turmeric oleoresin on cytogenetic damage in patients suffering from oral submucous fibrosis. Cancer Letters 1997; 116(2): 265-269.

19. Mughal MH, Turmeric polyphenols: A comprehensive review. Integr. Food Nutr. and Metab.2019; 6: 1-6.

20. Rao Y, Xiang B. Determination of total ash and acid-insoluble ash of Chinese herbal medicine prunellae spica by near infrared spectroscopy. Yakugaku Zasshi 2009; 129(7): 881-886.

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