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Analysing the Composition of Commercial Turmeric Powder: Assessing Contaminants and Its Impacts Curcumin and Water-soluble Vitamins Levels

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Authors' contributions

This work was carried out in collaboration among all authors. Authors SA and CL designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors MT, KNAA and GA managed the literature searches and evaluated the first draft. All authors read and approved the final manuscript.

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ABSTRACT

Aims: Turmeric, with its active component *curcumin*, has garnered global attention for its medicinal benefits, including anti-inflammatory and antioxidant properties. This study aimed to analyse turmeric powder obtained from the Greater Accra Metropolis for nutrients and contaminants.
Study Design: Experimental.

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Place and Duration of Study: Entrance Pharmaceuticals, Accra for 6 months.
Methodology: 22 samples from 10 different processing sites and open markets were tested using physical and chemical methods. HPLC identified *curcumin*, ascorbic acid, riboflavin, thiamine, and pyridoxine levels. An independent t-test was done to compare concentrations of these nutrients in the powdered turmeric samples from the two sources.
Results: Assessment showed no yellow lead salts but 9.1% were adulterated with chalk, and 91% contained metanil yellow. *Curcumin* (2014.95 vs. 567.79), riboflavin (21.60 vs. 1.75), thiamine (14.75 vs. 0.65 mg/mL), pyridoxine (9.35 vs. 0.65 mg/mL), and ascorbic acid (0.00 vs. 101.60 mg/mL) were significantly higher ($p<0.05$) in processed samples than open market ones. Samples without adulterants had higher *curcumin* and micronutrient levels.
Conclusion: Strengthening monitoring programs is crucial to tackling food adulteration concerns.

Keywords: Curcumin; turmeric; vitamin B complex; vitamin C; adulterants.

1. INTRODUCTION

Turmeric, which is derived from the rhizomes of *Curcuma longa* (family-*Zingiberaceae*) is a perennial plant with a short stem and large oblong leaves, bearing oblong rhizomes, which are usually branched and brownish-yellow in colour. Turmeric has gained attention in the West and the rest of the globe, particularly because of its broad range of medicinal benefits [1]. The significance of turmeric dates back almost 4000 years to the Vedic culture in India. It is extensively used in Ayurveda, Unani, and Siddha medicine as home remedies for various diseases [2]. Turmeric is largely and commonly used as a spice, food preservative, and colouring material in India, China and Southeast Asia [3]. It is also beneficial in traditional medicine and serves as a household remedy for various diseased conditions, including biliary disorders, anorexia, cough, diabetic wounds, hepatic disorders, rheumatism, autoimmune diseases and sinusitis [4,5].

Curcumin, the major active component of turmeric has been demonstrated to possess a broad range of biological actions including anti-inflammatory, antioxidant, anticarcinogenic, antimutagenic, anticoagulant, antifertility, antidiabetic, antibacterial, antifungal, antiprotozoal, antiviral, antifibrotic, antivenom, antiulcer, hypotensive, and hypocholesterolemic activities and improves skin tone [6,7,8]. The *curcumin* content in turmeric varies; ranging from 0.3% to 8.6% [9].

Although fresh turmeric is usually free of contaminants, turmeric powder can be adulterated with certain chemical compounds or substances used as substitutes for *curcumin* [10]. Recent studies have reported the mixing of *Curcuma zedoaria*, a wild relative of turmeric, into turmeric powder due to its close resemblance with turmeric. Similarly, metanil yellow, a toxic azo dye has also been added to turmeric powder to mimic the appearance of *curcumin* when the actual *curcumin* content is low [9].

Food adulteration is gradually becoming an epidemic, affecting the health of individuals across the globe. The use of colours, chemicals, pesticides, and additives has become of great concern in our food industry and is often practised for financial gain without taking into consideration its long-term and harmful repercussions on the health and fate of the country [11,12]. Food adulteration is no longer limited to local produce and subsequently has gradually found its way into packaged commodities as well. Adulteration seeks to degenerate the quality of a food product, making it substandard for human consumption and seriously risking the health of the consumer.

Adulterated products can have many adverse effects on our health. Spices like turmeric powder, chilli powder, and other powdered spices that have a high percentage of residual contaminants in them are known to be adulterated, as they can be easily combined with food colouring, added starch etc., for consumers [10]. Some of these adulterants include metanil yellow, yellow lead salts, chalk, lead chromate etc.

Food adulteration and the presence of contaminants affect the quality of a food product and contribute significantly to many diseased conditions ranging from skin diseases to life-threatening conditions including several disorders of the stomach. The human body is highly sensitive to food adulteration with accompanying side effects including diarrhoea, dysentery and vomiting [13]. The complications of the long-term adverse effects of adulterated

foods are associated with diseased conditions which may include cancer of the liver, cardiovascular disorders, peptic ulcers, kidney failures etc.

Several studies have been done for qualitative and quantitative analysis of *curcumin* from turmeric powder as well as its therapeutic and medicinal purposes such as anti-inflammatory, anti-cancer, anti-protozoal, anti-viral and anti-bacterial [14]. Studies have also found it to be effective for the treatment of Alzheimer's, depression, leprosy, fever, menstrual problems, water retention, kidney problems etc. [8]. However, fewer studies have been done concerning how adulterants or contaminants in turmeric powder affect its *curcumin* and micronutrient composition. This study therefore sought to investigate *curcumin* and micronutrient components of turmeric powder obtained from different local markets in Accra Metropolis of Ghana and to investigate the presence or absence of contaminant due to adulteration.

2. MATERIALS AND METHODS

2.1 Collection of Samples

Turmeric powder samples were obtained from 10 different local markets in the Greater Accra Metropolis of Ghana. Two samples each were obtained from these markets. Two fresh turmeric powder samples were also obtained directly from accredited processing sites before distribution to the various suppliers in the various markets. All samples obtained were stored at room temperature, and protected from light and moisture before analyses. The samples obtained from the 10 (ten) different markets were labelled 1 – 10. In each of these markets, two samples labelled A and B were sampled bringing the total number of samples to twenty (20). Moreover, the fresh turmeric powdered samples obtained directly from two different processing sites before distribution to the various suppliers in the various markets were also labelled 11A and 11B.

2.2 Detection of Food Adulterants in Powdered Samples

2.2.1 Test for yellow lead salts

About one gram of each sample was placed in test tubes. A 10 mL concentrated HCl was added, slightly shaken and allowed to stand for a while. The colour of the samples was observed after a few minutes. A magenta colouration indicates the presence of yellow oxides of lead [10].

2.2.2 Test for chalk

About 1 g of the samples were placed in a test tube. A few drops of distilled water were added slowly to the sample followed by the addition of a few drops of 37% HCl with a. The sample was observed after about a minute. Effervescence indicated the presence of chalk contaminant [10].

2.2.3 Test for metanil yellow

About 0.1 g of the powdered sample was placed in a test tube; 2 mL of 1-propyl alcohol was added to dissolve the sample. This was followed by the gradual addition of 7 drops of concentrated HCl. The colour of the sample was observed after a few minutes. The disappearance of the red colour with the addition of distilled water indicates the presence of metanil yellow [10].

2.2.4 Test for aniline dyes

To about 0.5 g of the powdered turmeric sample, a few drops of distilled water were added followed by the addition of 10 mL of absolute ethanol. The colour of the sample was observed within a minute. The immediate disappearance of the yellow colour indicates the presence of aniline dye [10].

2.3 Qualitative and Quantitative Analysis of *curcumin* Using HPLC

The qualitative and quantitative determination of *curcumin* were carried out on Agilent 1260 Infinity II High Performance Liquid Chromatography equipped with auto vial sampler, quaternary pump, multicolumn thermostat (MCT) and viable wavelength detector (VWD). The United States Pharmacopeia National Formulary (USP 41, NF 36, V3) protocol was used for the analyses [15].

2.3.1 Standard preparation

A USP chemical reference standard *curcumin* was used as the primary standard in the preparation of the standard solution.

2.3.2 Standard solution

About 50 mg of USP primary standard *curcumin* was weighed into a 50 mL volumetric flask. A 30 mL of analytical grade acetone was added to the standard and sonicated for about 15 minutes. A 1 mL, 0.8 mL, 0.6 mL, 0.4 mL and 0.2 mL of the standard was pipetted into five separate 25 mL volumetric flasks and subsequently diluted to volume with mobile phase to produce a

percentage weight by volume (%w/v) concentrations of 0.004%, 0.0032%, 0.0024%, 0.0016% and 0.0008%. The different standard concentrations were vialed and placed into the HPLC for injection.

2.3.3 Sample stock solution

About 0.5 g each of the powdered turmeric samples was weighed and transferred to a 50 mL volumetric flask. A 30 mL of acetone was added and sonicated with the help of a sonicator for about 30 minutes. The samples were allowed to cool to room temperature and filtered through a filter paper of 0.45-□m pore size into conical flask, the initial 15mL of the filtrate discarded.

2.3.4 Sample solution

A 1 mL each of the filtered samples was pipetted into a 25 mL volumetric flask and diluted to volume with the mobile phase. The samples were vialed and placed into the HPLC for injection.

2.4 Qualitative and Quantitative Analysis of Micronutrients Using HPLC

The micronutrients analysed include ascorbic acid (vitamin C), thiamine hydrochloride (vitamin B1), pyridoxine hydrochloride (vitamin B6), and riboflavin (vitamin B2). The analyses were carried out on Agilent 1260 Infinity II High Performance Liquid Chromatography using the United States Pharmacopeia National Formulary (USP 41, NF 36), volume 3 or 4 protocol as appropriate [16].

2.4.1 Ascorbic acid (vitamin C)

2.4.1.1 Standard Preparation

A 500 mg of USP Ascorbic acid reference standard was weighed into a 100 mL volumetric flask. A 30 mL diluent was added and sonicated for about 15 minutes. It was diluted to volume with the diluent. A 1 mL, 0.8 mL, 0.6 mL, 0.4 mL and 0.2 mL of the standard stock solution were pipetted into five separate 50 mL volumetric flasks and diluted to volume with diluent to produce a percentage weight by volume (%w/v) concentrations of 0.01%, 0.008%, 0.006%, 0.004% and 0.002%. The different standard concentrations were vialed and placed into the HPLC for injection.

2.4.1.2 Diluent preparation

A 0.56 g of edetate disodium dihydrate and 2.04 g of monobasic potassium phosphate was weighed and transferred into a 1000 mL volumetric flask. A 200 mL of distilled water was added and sonicated until reagents are completely dissolved. It was diluted to 1000 mL with distilled water.

2.4.1.3 Sample preparation

About 0.5 g each of the powdered turmeric samples was weighed and transferred to a 100 mL volumetric flask. A 30 mL of diluent was added and shaken mechanically for about 20 minutes. It was then diluted to volume and sonicated for an additional 10 minutes. The samples were allowed to cool to room temperature, and passed through a membrane filter of 0.45-□m pore size, discarding the first 5 mL. 1 mL of the samples were pipetted into separate 50 mL volumetric flask and diluted to volume with diluent.

2.4.2 Thiamine, pyridoxine and riboflavin

2.4.2.1 Standard preparation

About 0.5 g each of USP primary reference standard riboflavin, pyridoxine hydrochloride and thiamine hydrochloride were weighed into a 50 mL volumetric flask. A 30 mL of diluent was added to the reference standards and sonicated for about 15 minutes. A 1 mL, 0.8 mL, 0.6 mL, 0.4 mL and 0.2 mL of the standard solution were pipetted into five separate 25 mL volumetric flasks and subsequently diluted to volume with the diluent to produce a percentage weight by volume (% w/v) concentrations of 0.04%, 0.032%, 0.024%, 0.016%. The different standard concentrations were vialed and placed into the HPLC for injection.

2.4.2.2 Diluent preparation

A 25 mg/mL solution of edetate disodium in distilled water water was prepared and used as diluent.

2.4.2.3 Sample preparation

About 0.5 g of turmeric powder sample was weighed and transferred into 50 mL. A 30 mL of diluent was added and sonicated for about 15 minutes. A 1 mL of the sample solution was pipetted into a 25 mL volumetric flask and diluted to volume. The sample was vialed and placed into the HPLC for injection.

2.5 Statistical Analyses

All numerical data were expressed as mean ± SD and assessed by students t-test. Values with $p < 0.05$ were considered significant.

3. RESULTS AND DISCUSSION

3.1 Qualitative Detection of Adulterants in Powdered Turmeric Samples

Results from Table 1 outline the presence or absence of various adulterants in the different turmeric powder samples obtained from 10 different markets in the Greater Accra metropolis of Ghana. From the results, all the powdered samples (100%) tested negative for yellow lead salts indicating that none of them was adulterated with the salt. However, two of the samples, specifically 7B and 10B (9.1%) were found to be adulterated with chalk.

The observed pink colouration indicates that the samples were adulterated with metanil yellow. Only samples 11A and 11B which were obtained directly from the processing sites prior to distribution tested negative for metanil yellow, providing a clear indication that the majority of the powdered turmeric samples sampled at random were adulterated with metanil yellow. None of the samples were found to contain aniline dyes. The percentages of the different adulterants varied significantly for each adulterant tested. The highest percentage was found in metanil yellow (90.9%), followed by chalk (9.1%) with both yellow lead salts and aniline dyes recording none.

Food providers and suppliers in their frantic efforts to maximize profits resort to the addition of adulterants to increase quantity hence reducing the quality of the food substance and endangering the lives of consumers (Atahar, 2013).

Table 1. Qualitative detection of adulterants in powdered turmeric samples

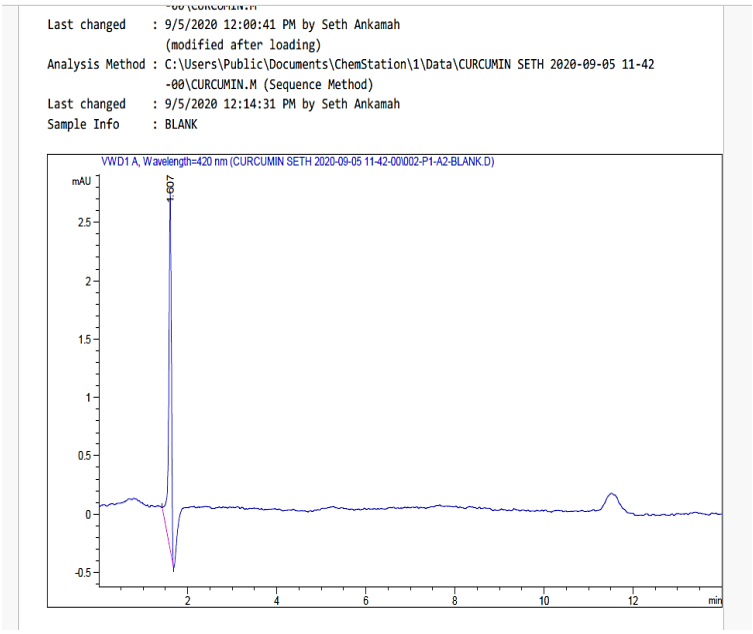
Adulterant	No. of positive samples	No. of negative samples
Yellow lead salts	NONE	22
Chalk	2 (7B, 10B)	20
Metanil yellow	20 (1A, 1B, 2A, 2B, 3A, 3B, 4A, 4B, 5A, 5B, 6A, 6B, 7A, 7B, 8A, 8B, 9A, 9B, 10A, 10B)	2 (11A, 11B)
Aniline dyes	NONE	22

Table 2. Concentration of *curcumin* in powdered turmeric samples

Sample	Peak area 1	Peak area 2	***Curcumin* concentration (mean ± SD)**
1A	378.5	379.6	**379.05±0.78**
1B	458.3	457.5	**457.9±0.57**
2A	920.5	920.8	**920.65±0.21**
2B	715.8	714.6	**715.2±0.85**
3A	574.5	575.1	**574.8±0.42**
3B	600.2	601	**600.6±0.57**
4A	515.7	516.4	**516.05±0.49**
4B	793.7	793.9	**793.8±0.14**
5A	714.6	715.8	**715.2±0.85**
5B	475.6	476.7	**476.15±0.78**
6A	357.8	357	**357.4±0.57**
6B	300.2	299.4	**299±0.57**
7A	776.9	777.5	**777.2±0.42**
7B	689.7	690.5	**690.1±0.57**
8A	651	652.4	**651.7±0.99**
8B	571.2	572.5	**571.85±0.92**
9A	520.5	519.1	**519.8±0.99**
9B	592.6	593.3	**592.95±0.49**
10A	4165.8	417.6	**417.2±0.57**
10B	328.3	328.6	**328.45±0.21**
11	2015.2	2014.7	**2014.95±0.35**

Table 3. Mean comparison of *curcumin* concentration and water-soluble vitamins of turmeric powder from the market and processing sites

		N	Mean	SD	p-value
concentration of *curcumin*	Market	20	567.79	169.18	0.011
	Processing site	4	2014.95	0.29	
Riboflavin	Market	20	1.75	1.94	0.011
	Processing site	4	21.60	0.12	
Thiamine	Market	20	0.65	0.94	0.001
	Processing site	4	14.75	0.17	
Pyridoxime	Market	20	0.65	1.06	0.004
	Processing site	4	9.35	0.06	
Ascorbic acid	Market	20	0.00	0.00	-
	Processing site	4	101.60	0.12	



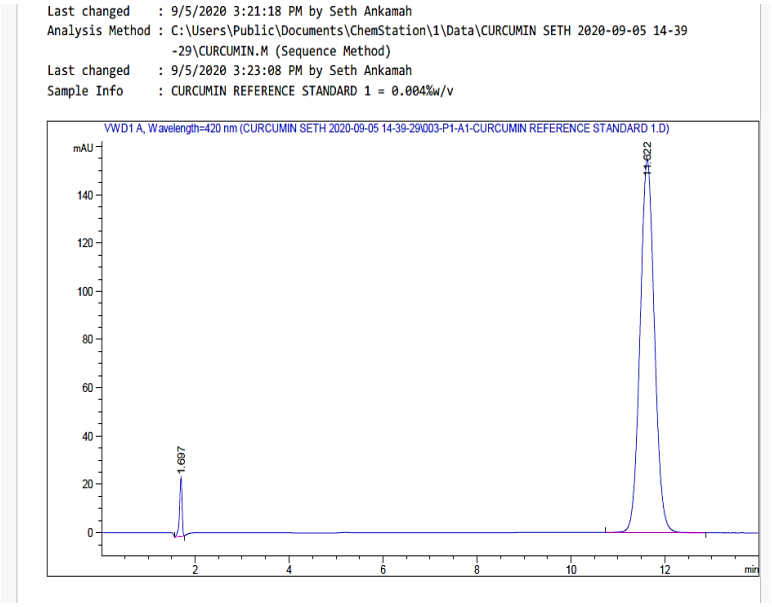


Fig. 1. A, The chromatographic peak for Blank, and. B. C*urcumin* reference standard at a concentration of 0.004 %w/v

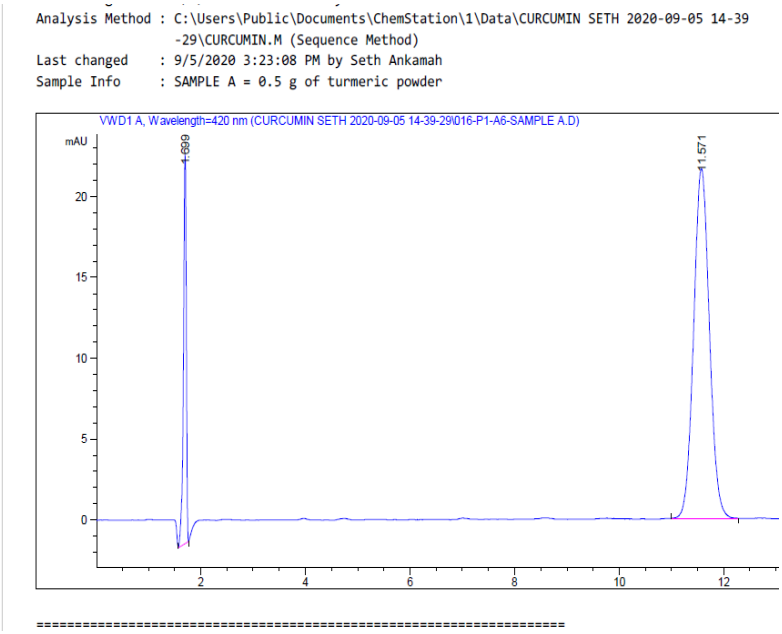


Fig. 2. The chromatographic peak for turmeric sample A

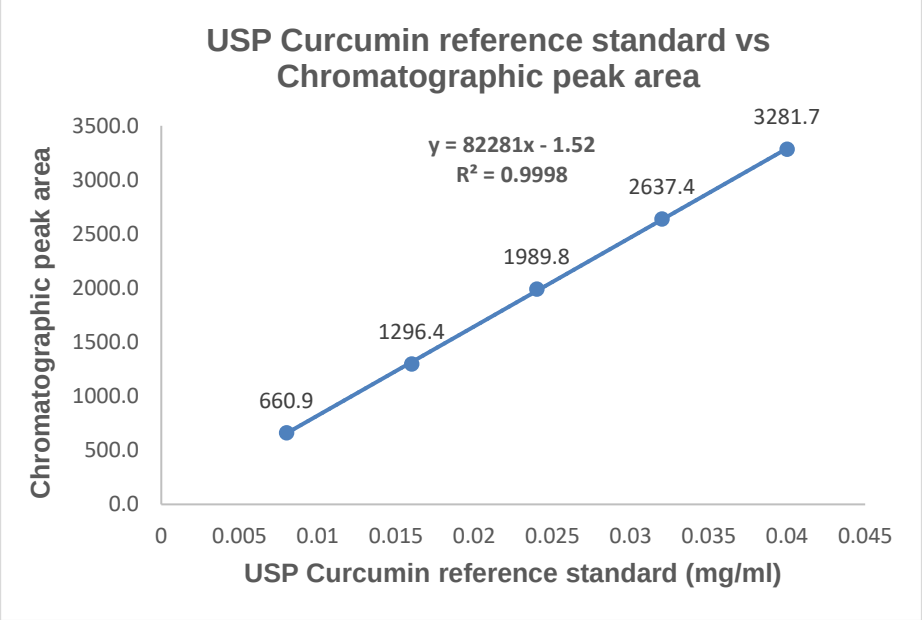


Fig. 3. A calibration curve for USP curcumin reference standard

Metanil yellow, a toxic azo dye has also been reported to have been added to turmeric powder to mimic the appearance of *curcumin* when the actual *curcumin* content is low. Similar to the findings in this study, Shweta et al., [17] found out that 10 out of 15 samples of turmeric powder were adulterated with metanil yellow, Sudan III and artificial colour. Similarly, Dhakal et al. [9] reported the mixing of Curcuma zedoaria, which is a wild relative of turmeric, into turmeric powder because of its close similarity to turmeric.

3.2 Concentration of *curcumin* in Powdered Turmeric Samples

The concentration of *curcumin* and all the nutrients from the processing site and market centres are as shown in Tables 2 and 3. There was observed significant differences between Samples from processing site (11) ($p \leq 0.01$) compared to the market source.

The reduced *curcumin* concentration of the samples as shown in Table 3 is attributed to

several factors such as the presence of contaminants or adulterants in the samples. Research has shown that the *curcumin* content in turmeric varies due to certain factors include the presence of contaminants or adulterants. Dried, whole or fresh turmeric powder although is usually free of contaminants, the powdered turmeric can be adulterated with different chemical powders as substitutes for *curcumin* [18]. Dhakal et al., [9] in their study reported the mixing of *Curcuma zedoaria*, which is a wild relative of turmeric, into turmeric powder because of its close similarity to turmeric. Similarly, metanil yellow, an adulterant has also been reported to have been added to turmeric powder which sought to mimic the appearance of *curcumin* when the actual *curcumin* content of turmeric powder is low. It is noteworthy mentioning that the samples that tested positive for certain levels of adulterants shown in Table 1 recorded a significant reduction of *curcumin* content as compared to sample 11 (from the processing site) which tested negative for the adulterants under study. This study has shown that the significantly low concentration of *curcumin* content in the turmeric powders obtained from the different markets within the Greater Accra metropolis is as a result of the presence of contaminants, specifically metanil yellow in these samples.

Concerning individual micronutrients, the significant reduction of riboflavin may be as a result of the exposure of the samples to sunlight increasing the rate of degradation of the nutrient. Riboflavin is a water-soluble vitamin, and its degradation increases with exposure to both radiation and visible light with the rate of degradation increasing with an increase in temperature and pH [19,20]. Ghimeray et al. [21] studied the stability of riboflavin content in milk. The study revealed that about 85% of riboflavin content of milk in glass bottles was lost after about two hours of exposure to sunlight. Pyridoxine is relatively stable to heat and like riboflavin, it decomposes by oxidation and ultraviolet light as well as in alkaline solutions with the rate of decomposition increasing with an increase in exposure to sunlight. Thiamine hydrochloride in foods is relatively stable when food is subjected to a temperature of between 95^{o}C and 100^{o}C. However, research has established that thiamine is easily degraded by Ultraviolet (UV) irradiation [22]. Thiamine concentrations in food are affected by conditions such as pH, temperature and ultraviolet radiation similar to riboflavin and pyridoxine [23,24]. Conditions such as pH, temperature, and moisture content affect the thiamine content present in foods during processing and storage.

It is recommended that Law Enforcement Agencies in Ghana be more active in deterring producers and distributors from adulterating this and many other products on the open market of Ghana and further improving the safety of the general public.

4. CONCLUSION

This study revealed that none of the samples contained yellow lead salts. Two samples (9.1%) were found to be adulterated with chalk; twenty samples (90.9%) were adulterated with metanil yellow, with none of the samples containing aniline dyes. However, only two samples (9.1%) were found to be absent in all the adulterants. *Curcumin,* ascorbic acid, riboflavin, pyridoxine and thiamine contents were significantly lower in the samples obtained from local markets in Accra Metropolis compared to samples from the processing sites. *Curcumin* concentration was higher in samples that tested negative for adulterants and lower in samples that were found to contain adulterants. There is a need to strengthen monitoring programmes to screen food products in addressing the rapidly growing concerns over food adulteration. To achieve this, it is recommended that regular and periodic food surveillance, monitoring, inspection and random sampling of food products are carried out to reduce the public burden of the possible effect of the adulterants.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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