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Review Article

Assessment of the Authenticity and Detection of Fraud in Turmeric Powder from Local Markets in Yaoundé and Douala, Cameroon

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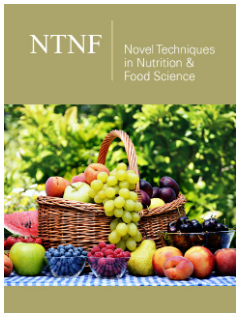
ISSN: 2640-9208



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Submission: June 06, 2025

Published: June 19, 2025

Volume 8 - Issue 3

How to cite this article: Taty Brandy Perkwang, Fokwen Kellybright Enih, Tene Hippolyte Mouafo, Dama Benjamin and Wilfred Angie Abia*. Assessment of the Authenticity and Detection of Fraud in Turmeric Powder from Local Markets in Yaoundé and Douala, Cameroon. Nov Tech Nutri Food Sci. 8(3). NTNF. 000688. 2025. DOI: 10.31031/NTNF.2025.08.000688

Abstract

Turmeric (*Curcuma longa*) is widely used as a spice globally, in part, vulnerable to fraud due to its culinary and medicinal popularity. This study assessed the authenticity and associated fraud in turmeric powder from local markets in Yaoundé and Douala, Cameroon. Information on turmeric as well as knowledge on turmeric authenticity and fraud was gathered amongst turmeric sellers (through face-to-face) and consumers (through online) using structured questionnaires. Turmeric powder samples (N=103) were purchased from sellers (N=79) across local markets in Yaoundé and Douala. Authenticity assessment and fraud detection were performed using a microscopic and physicochemical techniques. Altogether, 79 sellers and 119 consumers responded to the questionnaires. The findings revealed that turmeric powder is mainly produced in the North West (55.7%), West (26.7%), Centre (24.05%), Littoral (1.26%) and South West (1.26%) regions in Cameroon. Most of the studied turmeric powder were "orange-yellow" to "golden-yellow" color (92%), while a few were dark brown (5.8%) or "whitish-yellow" (1.9%) color. Turmeric powder consumers (74.6%) and sellers (69.6%) suspected that turmeric powder sold in Yaoundé and Douala are potentially adulterated. Microscopic examination of turmeric powder starch granules revealed 93.2% (96/103 samples) compliance and 6.8% (7/103) non-compliance. One (1.03%, 1/103) turmeric powder sample was suspected to be adulterated with chalk powder and another one sample suspected for adulteration with meta nil yellow. Lead chromate and aniline dye were not detected in any sample. Although majority of the studied turmeric powder from local markets in Yaoundé and Douala were authentic, the 6.8% turmeric powder samples suspected as non-compliant and the 1.03% samples that contained illegally added chalk powder or met anil yellow may require further verification using sophisticated analytical techniques.

Keywords: Authenticity; Fraud detection; Adulteration; Turmeric powder; Sellers; Consumers; Yaounde; Douala

Introduction

Turmeric (*Curcuma longa*) is a well-known spice for its culinary and medicinal values. The global market value for turmeric is on the rise, for example, from 2000 to 2021 and projected to increase geometrically until 2030 [1]. Global turmeric production is dominated by India, which accounts for 80% of the total supply, followed by China (8%) and Myanmar (4%) [2]. Turmeric is widely valued for its deep yellow-orange color, earthy aroma and warm, slightly bitter taste [3]. Its health benefits range from anti-inflammatory and antioxidant properties to disease prevention [4,5]. However, due to its growing popularity and economic value, turmeric has become vulnerable to fraud.

The authenticity of turmeric powder refers to its purity and adherence to the quality. But its authenticity is frequently undermined by fraudulent activities, where chemical dyes such as met anil dye, aniline dye and lead chromate and bulking agents including corn flour and chalk powder are used [6] to enhance colour and weight respectively [7] and for economic gains [8,9]. Such adulteration, driven by economic gains not only diminish the quality of turmeric but also pose significant health risks to consumers [10]. For example, lead chromate, a neurotoxin, can accumulate in the body and induce neurological impairments and developmental disorders, particularly in children and pregnant women [11,12], while banned dyes like met anil yellow are linked to liver toxicity and potential carcinogenicity [10].

Data on turmeric powder authentication and detection of associated fraud from Africa is still inadequate at the time when the continent is speculated as an emerging turmeric production arena with Ethiopia leading the continent [9]. Furthermore, ascertaining the authenticity and any associated fraud in turmeric powder from African nations is crucial. Additionally, considering adulterants are potentially toxic to the body, data on authenticity and fraud may inform consumers, enabling them to make the right decisions when purchasing turmeric powder and by extension playing active role in ensuring their health and safety [10]. In response to this challenge, for the first time in Cameroon, this study provides data on authenticity and associated fraud in turmeric powder sourced from local markets in Yaoundé and Douala.

Methodology

Study site

The study was conducted in major markets in two cosmopolitan cities in Cameroon (Yaoundé and Douala): The administrative capital city, Yaoundé (Central Market, Essos market, Makolo market, Nsam Market, Odza market, Mendong market, Mvog-beti market, Mvog-Mbi Market, Acacia Market, Soa market, Mfoundi market) and the economic capital city, Douala (Central market, Nkouloulou Market, Bonamoussadi Market, Logpom Market, Sandaga Market, Cite sic market, Deido Market, Carrefour Market, PK 14 Market), in Cameroon. These cities were selected partly because they are cosmopolitan and may constitute the major markets for turmeric powder in Cameroon. In addition, an online survey was done in Cameroon

Target population

This study involved two types of participants. One category were adults who were turmeric business operators (sellers) selling turmeric powder and/or turmeric rhizome (dry/fresh). These participants were approached directly in their market places where they voluntarily agreed to participate in the study. The second category of participants were consumers of turmeric powder who were invited to participate online.

Survey

Structured questionnaires were used to carry out the surveys. For the turmeric powder sellers, they were approached in their market places and after warm greetings and encouraging words as if were from the regular customers, the investigators introduced themselves and made a brief oral presentation of the study to the seller in his/her language of choice (English and/or French) and provided responses to questions. When a seller agreed to participate, a structured questionnaire was administered to he/she at his/her market place to provide his/her frank responses. Filling the questionnaires were in some cases done by the seller him/herself and in most cases where they either could not write or were busy with their business, the investigators read out each question and the seller provided his/her response and in turn, the investigator filled in the form for them. About 4- 5 sellers were selected randomly in each local market in Yaoundé and Douala, Cameroon. For the consumers of turmeric powder, an online structured questionnaire was distributed through individuals and group WhatsApp platforms. Once the google form link containing the questionnaire was shared on the group WhatsApp, members of the group who consumed turmeric took a voluntary interest to fill in the questionnaire and in some cases aided in distributing the questionnaire to others they know consume turmeric too. All consumers who could voluntarily provide frank responses to the online questionnaires (through google form link) were involved in the study.

Sampling and processing of control sample

In the markets studied, spices sellers are generally located in a specific location, while a few of them are mobile. For each targeted market, the spices selling zone was divided into 6 or 10 segments depending on the size of the zone. From the 6-segment zone, sub-zones 1, 3 and 5 were randomly considered for the sampling process. For the 10-segment zone, sub-zones 2, 4, 6, 8 and 10 were randomly considered for the sampling process. A maximum of two samples were purchased per included sub-zone. A total of 103 samples were purchased and distributed as follows: 62 from sellers in Yaoundé; and 41 from vendors in Douala. 79 of the 103 samples were purchased from sellers who provided responses to the questionnaires while 24 samples were purchased from sellers who did not provide responses to the questionnaires, one sample per seller. Each sample (50-100g) was purchased, labeled and stored in airtight containers at the Institute of Medical Research and Medicinal Plant Studies (IMPM) laboratory where they were stored at ambient conditions until analysis.

To obtain a self-made control turmeric sample, fresh turmeric rhizomes were purchased from one of the studied markets i.e., Mvog-Beti market in Yaoundé. The rhizomes were thoroughly washed using tap water, sliced with a kitchen knife and dried in a hot air oven (Heraeus U60/60) at 40 °C for two days as described by Lim et al. [13]. Thereafter, the dried rhizome slices were then milled using a powder grinder (SHAZI powder grinder machine). 115g of the turmeric powder was obtained, stored in an airtight container and kept away from light and humidity as a control sample.

Laboratory analysis

Authenticity testing

Visual inspection of turmeric powder: Visual inspection of each turmeric sample was done as described by Pantola & Pooja

[14] and TOI (2024). Briefly, 1g of each turmeric sample and 1 g of the control were placed on a white A4 paper next to each other allowing for relative comparisons using the physical eyes. During visualization, inconsistencies in colour and uniformity were reported. The colour of each experimental turmeric powder sample was compared to that of the control sample and where it was not the same colourarion, the colour was then described relative to the colour of the control sample.

Microscopic examination of starch granules: Microscopic examination for the presence of non-turmeric starch in each turmeric powder sample was investigated according to the standard protocol of the FSSAI (2017) and further described by Osman et al. [15] The physical characteristics, such as particle shape/structures and colour of each of the turmeric powder sample was examined under a light microscope. In brief, a very small quantity of turmeric was placed on a slide and mixed with 3 drops of distilled water (added with the aid of a dropper) using a spatula. Thereafter, the slide was placed under a light microscope (Leica, 2000) at a magnification power of 40x.

Fraud detection methods

Lugol's test for starch: The presence of starch in turmeric powder was assessed following the protocol outlined by FSSAI [16]. Each sample of 0.25g of turmeric powder was weighed and transferred into a beaker. The powder was then mixed with 2mL of hot distilled water and heated to 100 °C to create a suspension. Thereafter, 3 drops of Lugol's iodine solution (amber-orange colour) were added to the suspension. The intensity of the color change was immediately observed, with a shift from yellow to blue-black indicating the presence of starch. The intensity of the blue-black coloration was graded according to a scale of 1 (low starch)-5 (excess starch) for all the samples, i.e. +1: Very light blue-black coloration, +2: Light blue-black coloration, +3: Moderate blue-black coloration, +4: Dark blue-black coloration, +5: Very dark blue-black. Assessment of presence of extra starch as adulterant was done by first comparing the intensity of the blue-black colouration of the control to that of samples and secondly assuming all samples with +3 and +5 were potentially adulterated with starch.

Test for aniline dye: Following the protocol of FSSAI [16] and Mukta [17], Aniline dye in turmeric powder samples was determined. A sample of 0.25g of turmeric powder was placed in a test tube and 2mL of distilled water was added to create a suspension. Subsequently, 1mL of rectified spirit was added to the suspension. The immediate separation or disappearance of the yellow color in the rectified spirit layer indicates the presence of Aniline dye.

Test for the presence of lead salt: To evaluate the presence of yellow oxides of lead in turmeric powder, the procedure recommended by FSSAI [16] was utilized. Initially, 0.25g of turmeric powder was introduced into a test tube. Distilled water, measuring 0.5mL, was then added to form a homogeneous suspension. Following this, 0.25mL of concentrated hydrochloric acid was carefully introduced into the suspension. The mixture was observed for any immediate color changes. The development of a magenta hue signifies the presence of yellow oxides of lead within the turmeric powder.

Test of met anil yellow dye: The presence of met anil yellow in turmeric powder was assessed using the method described by FSSAI [16], further elaborated by Mukta [17] and Verma et al. [18]. A sample of 0.25 grams of turmeric powder was placed in a test tube and 1.25mL of distilled water was added to create a suspension. Thereafter, 5 drops of concentrated hydrochloric acid were added to the suspension. The color change was immediately observed. The appearance of a pink/violet color that disappears upon dilution with water indicates the presence of unadulterated turmeric. A persistent color indicates the presence of met anil yellow.

Test of the presence of chalk in turmeric powder: To determine the presence of chalk powder in turmeric powder samples, the method outlined by FSSAI [16] was employed. A sample of 0.25 grams of turmeric powder was introduced into a test tube that contained 1.25mL of distilled water, forming a suspension. Thereafter, 15 drops of concentrated hydrochloric acid were added to the mixture. The appearance of effervescence, characterized by the release of bubbles, indicates the presence of chalk powder (calcium carbonate) in the turmeric powder.

Statistical analysis

The data from investigations were recorded in MS Excel, cleaned and exported to Statistical Package for Social Science 20.0.0 (SPSS Inc., IBM Corporation, Chicago, United States) for analysis. They were submitted to descriptive statistics and summarized as frequencies and percentages. For experiments carried out in the laboratory, all tests were performed with at least three repetitions.

Results

Survey outcomes

Knowledge, attitude and practices of turmeric powder sellers and consumers: According to the market survey, 79 vendors (50 from Yaounde and 29 from Douala) out of the 103 sellers which samples were purchased from, were willing and provided responses to the questionnaire. From the responses gotten, vendors revealed of buying fresh rhizomes from turmeric framers or suppliers from the North-West and West region of Cameroon and processed them into turmeric powder. Others bought pre-processed turmeric powder from bulk sellers. This suggests that the North -West and West regions of Cameroon were the main turmeric-producing areas in Cameroon, although turmeric is cultivated in smaller quantities across the country as shown in Figure 1. Additional turmeric-producing regions identified were the Center, Littoral, West and South West. Thirty participants (38%) out of 79 indicated that they process the fresh turmeric rhizomes into the turmeric powder through a series of steps (Figure 2). Fourty-nine participants (62%) revealed that they purchase already dried slices of turmeric rhizomes and grind the slices themselves when a client comes prior to selling the turmeric powder to a client. The steps include washing of turmeric roots, slicing the roots into small sizes for easy and drying using sunlight and grinding the dried rhizomes into powder prior to selling.

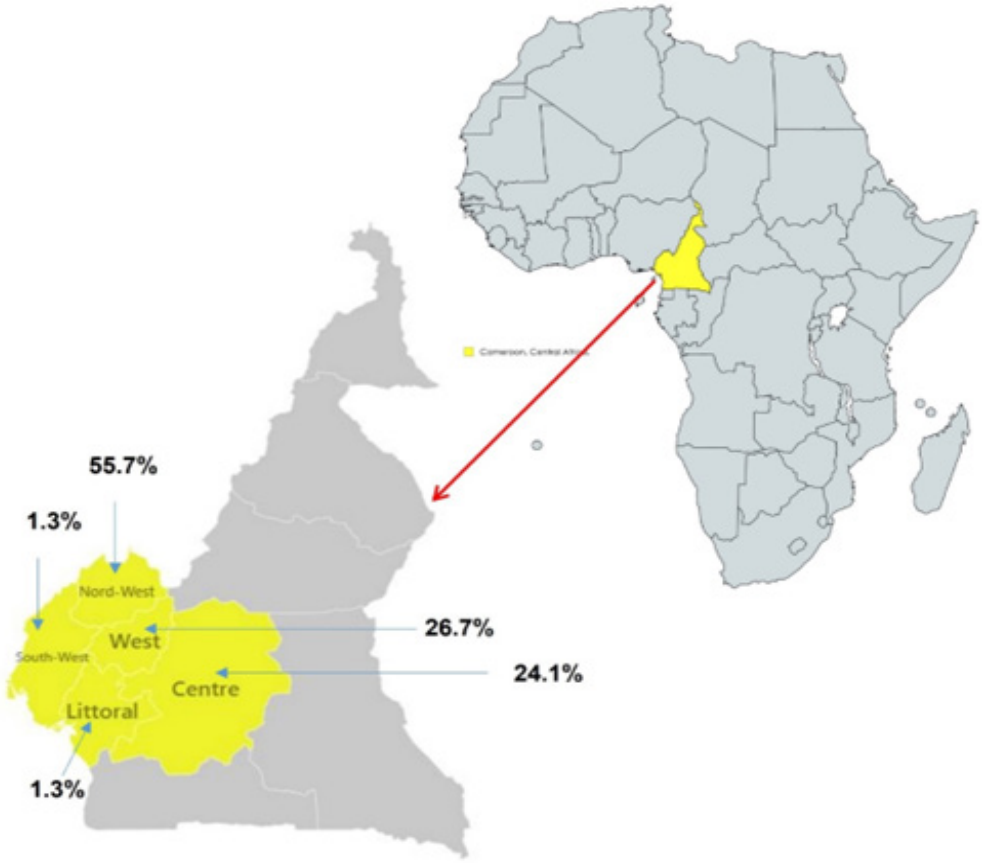

Figure 1: Percentage of turmeric rhizome production in Cameroon by Region.

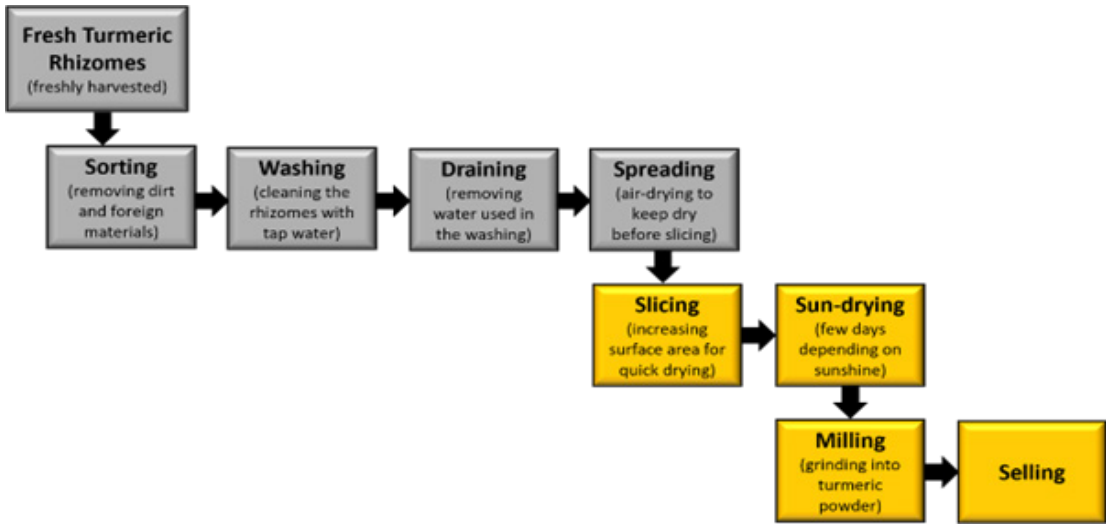

Figure 2: Steps involved in Processing Turmeric powder in Cameroon by sellers.

Opinions on speculation, authenticity and adulteration of turmeric powder: The high demand for turmeric, driven by its medicinal and culinary benefits stated by the sellers (69.6%) and consumers (74.6%) has created room for sellers wanting more gains and hence employing malpractices. As shown in Table 1, 74.6 % of consumers and 69.6 % of the sellers acknowledged that turmeric powder sold is being adulterated by unknown sellers for economic gains. Table 1 below gives the reasons why turmeric powder is being adulterated with the main reason being to increase profit as stated by 77.2% of the sellers and 80.7% of the consumers. Other reasons given were to attract customers and increase quantity and quality. Some common authenticity methods that can be used to identify genuine turmeric powder are also shown in Table 1 with the most common method being visual inspection as 60.8% and 63.9% of sellers and consumers respectively stated. Despite consumers emphasizing quality checks criteria (Table 1). when purchasing turmeric powder, many may fail to verify the authenticity of their product.

Table 1: The main reasons for adulteration and authenticity checks for turmeric powder as stated by the sellers and consumers.

Parameters	Sellers		Consumers	
	F	%	F	%
To increase profit	61	77.2	96	80.7
To attract Customers	23	29.1	32	26.9
To increase quality	1	1.3	20	16.8
To add yellow colour	-	-	18	15.1
To increase shelf-life	-	-	15	12.6
To increase quantity	-	-	1	0.8
Visual Inspection	48	60.8	76	63.9
Smell	19	24.1	52	43.7
Taste	0	0	39	32.8
Rely on supplier's quality	9	11.4	33	27.7

Additionally, Figure 3 below gives some adulterants used to fraud turmeric powder in Cameroon markets, with the main adulterant being corn flour with 62% and 36.1% of sellers and consumers respectively confirming its use. This adulterant is used to increase the quantity of the turmeric powder being sold. Furthermore, chemicals such as Aniline, met anil dye were speculated to be used by 8.9% of sellers and 26.9 % of consumers. various turmeric powder storage methods are shown in Table 2. The most common method of storage is storing in a cool dry place (51.3%) and airtight container (45.4%). A significant portion of consumers noticed quality deterioration, as 40.7% observed a colour change, 31.4% experienced mold and 33.1% noted a loss of aroma. Only a small percentage reported insect infestation or no noticeable changes.

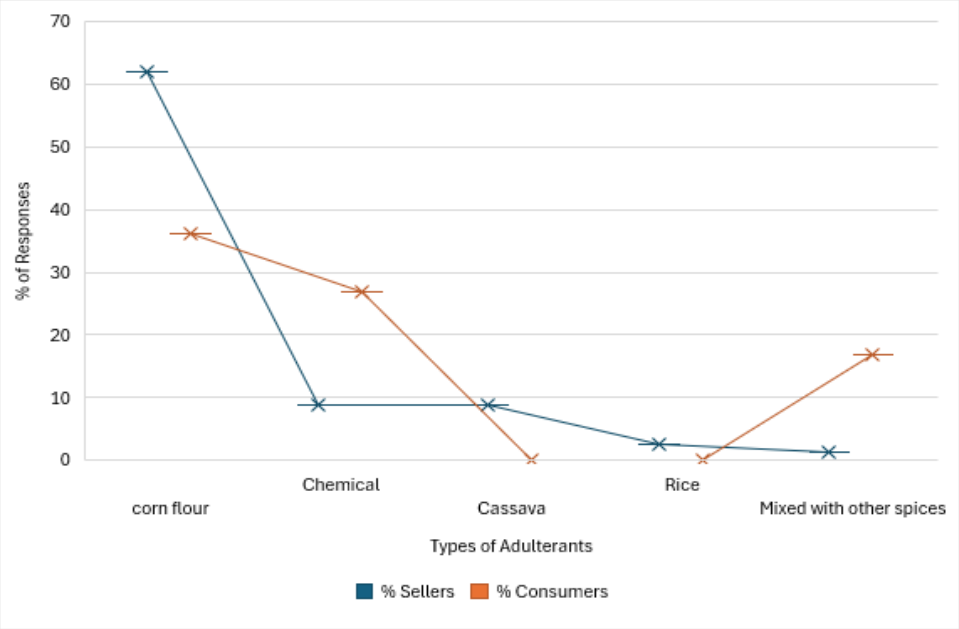

Figure 3: Adulterants and their level of usage in Turmeric powder.

Table 2: Ways in which turmeric powder is being stored and possibly physical deterioration.

Parameter	Frequency	Percentage
Ways of Storage		
Airtight container	54	45.4
Cool dry place	61	51.3
In refrigerator	10	8.4
Don't pay attention to storage	16	13.4

Changes observe in stored turmeric powder over time		
Colour change	48	40.7
Mold	37	31.4
Loss of aroma	39	33.1
Presence of insects	11	9.3

Authenticity of the studied turmeric samples

Physical observation with naked eyes

The characteristic colour of the turmeric samples ranges from whitish yellow to dark brown. When compared to the colour of the control for turmeric powder in this study shown in Figure 4 to be golden yellow. 1.9% (2 Samples) of the 103 samples were whitish yellow, 92.3% (95 samples) had an orange yellow to golden orange yellow and 5.8% (6 samples) had a dark brown colour.

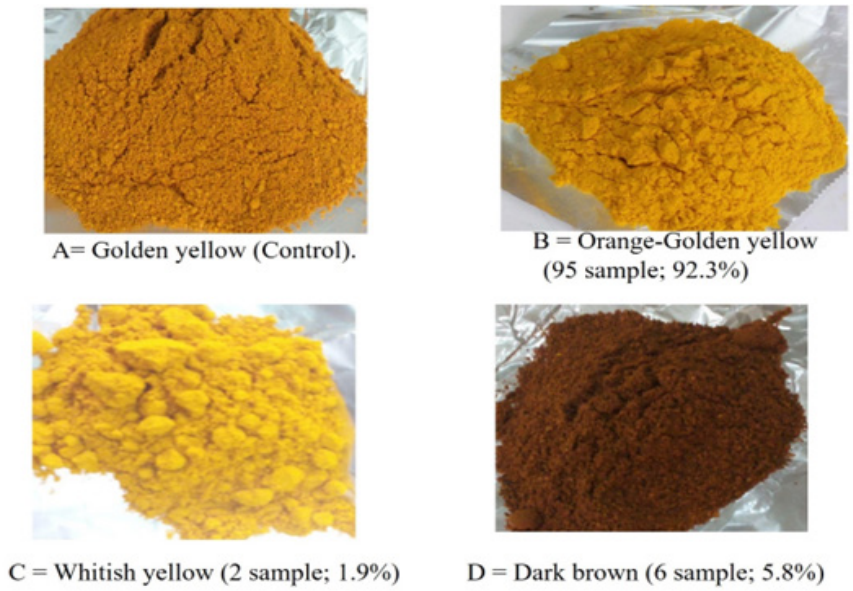

Figure : Authentic (A) and Inauthentic (B) microscopic Visualization of Turmeric powder.

Microscopic analysis

104 samples (including the self-prepared control) were observed microscopically and 96 (93.2%) samples had no evidence of adulteration with corn flour addition, while 7(6.79%) samples showed structures characteristic of corn flour, as shown below. Additionally, the microscopic test revealed the presence of corn flour structures in 4 samples from Yaoundé and 3 from Douala. The test revealed key differences between inauthentic and authentic turmeric powder, particularly in the shape and size of starch granules. Authentic turmeric starch granules appeared elongated, cone shape and larger, whereas inauthentic samples containing corn flour exhibited irregular, oval to spherical granules and smaller in size, which are distinctive features of corn starch. Additionally, authentic turmeric samples showed a uniform granular distribution with well-defined birefringence under polarized light, while inauthentic samples demonstrated mixed starch populations, disrupting the typical microscopic profile of turmeric. Figure 5 shows authentic turmeric powder (Picture of the control sample) when observed under the microscope, while Figure 5B illustrates inauthentic turmeric powder with visible corn flour structures.

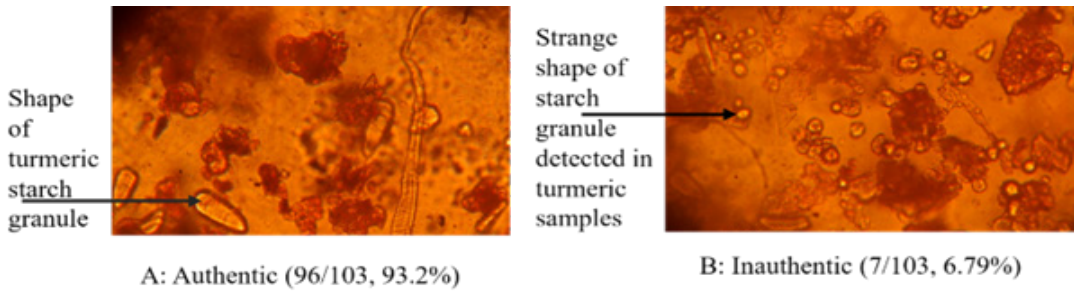

Figure 5: Authentic (A) and Inauthentic (B) microscopic Visualization of Turmeric powder.

Table 3: Frequency of adulterants in studied turmeric samples.

Source	Number (percentage) suspicious for adulteration				
	Starch	Aniline dye	Lead Chromate	Metanil dye	Chalk
Control samples					
Yaounde (n=1)	-	-	-	-	-
Test samples					
Yaounde (n=61)	13 (21.3)	0	0	1 (1.6)	1 (1.6)
Douala (n=42)	9 (21.4)	0	0	0	0
Total samples (N=103)	22 (21.4)	0	0	1 (0.97)	1 (0.97)

Adulteration of the studied turmeric samples

Table 3 below presents the physiochemical laboratory results of various tests conducted to detect fraud in turmeric samples collected from Yaoundé and Douala. The Lugol test, used to detect the presence of added starch, revealed that 22 samples (13 from Yaoundé and 9 from Douala), had a +3-intensity coloration and above suggesting possible adulteration with non-turmeric starch sources. The aniline test, which detects synthetic dyes such as aniline yellow, yielded negative results across all tested samples, indicating no presence of this harmful colorant. Similarly, the lead oxide test, used to identify the presence of lead-based adulteration, returned negative results for all samples. However, the met anil dye test detected one positive sample from Yaoundé, signifying potential contamination with this synthetic dye. Additionally, the chalk adulteration test identified one positive sample from Yaoundé, indicating the use of calcium-based fillers.

Discussion

This study provides a detailed assessment of the authenticity and fraud detection of turmeric powder sold in Yaoundé and Douala. These cities were selected due to their large populations, which include an influx of people from conflict-affected regions and refugees. This economic pressure may drive some individuals to engage into food fraud, including turmeric adulteration. Additionally, as the population grows, disease prevalence may increase, potentially leading to higher turmeric consumption for instance during the period of Covid-19, the consumption rate of turmeric increased in order to increase immunity [19,20].

Knowledge, attitude and practices of turmeric powder sellers and consumers

The study found a high perception of adulteration among turmeric sellers and consumers in Yaoundé and Douala. About 69.9% of sellers and 74.6% of consumers acknowledged the likelihood of turmeric adulteration. However, turmeric is often adulterated to enhance appearance and weight for economic gain [21,22]. Furthermore, 8.9% of sellers and 26.9% of consumers could identify specific adulterants like aniline dye or lead chromate, indicating limited awareness of chemical adulterants beyond common fillers like corn flour. This highlights the need for educational outreach programs to raise awareness of the health risks associated with turmeric adulteration. The preliminary surveys suggest that sellers primarily purchase rhizomes from farmers and process them into powder for direct sale. Therefore, sellers may play a key role in potential turmeric fraud, which might facilitate traceability by identifying a single point of intervention for quality control. Consumers, based on their experiences with color, taste and efficacy, also provided valuable insights into variations in turmeric quality and potential adulteration for instance 36.1% confirmed turmeric is being adulterated with corn flour. Additional, due to difference in processing and handling of turmeric by sellers can lead to different in the quality of turmeric powder obtained as shown in Figure 2 [23].

Authenticity assessment

Physical observations revealed noticeable inconsistencies in color and texture, with some samples showing colour ranging from whitish yellow/light yellow, to dark brown [3]. These variations may be due to differences in the processing, prolonged storage under suboptimal conditions, or deliberate adulteration. For instance, lighter hues may indicate dilution with fillers like flour or cornstarch, while darker shades could suggest contamination with synthetic dyes or poor-quality raw materials. Additionally, some samples exhibited grittiness or uneven particle size, further raising concerns about potential adulteration or improper grinding techniques. Additionally, some samples exhibited grittiness or uneven particle size, further raising concerns about potential adulteration or improper grinding techniques. Notwithstanding, it is not strange to have turmeric powder with varied colours in the order of yellow coloration (e.g. light yellow, brownish yellow, etc) considering possibilities of different species and soil conditions which may potentially influence the level of curcumin responsible for the yellor colour of turmeric. This suggests a need for studies on soil suitability for turmeric of high curcumin levels [24] and analysis of curcumin levels in various turmeric powder from Cameroon. Microscopic analysis provided a closer look at these inconsistencies, revealing cornstarch granules in a subset of samples, supporting the idea that cornstarch is used locally to bulk up turmeric powder in Cameroon market. This finding aligns with the findings from Van Raamsdonk [25] and Kar et al. [26], which identified cornstarch as a common and cost-effective bulking adulterant used to increase product volume at a lower cost. The detection of such adulterants not only diminishes turmeric's medicinal potency but also poses risks to consumers with starch-related dietary restrictions, such as diabetics (Ngao et al., 2021). Furthermore, the presence of foreign particles suggests a lack of regulatory enforcement in the supply chain, emphasizing the urgent need for advanced detection methods (e.g., FTIR spectroscopy, HPLC) and standardized quality assurance protocols to combat fraud in Cameroon's turmeric powder trade.

Detection of adulterants

No evidence of adulteration with aniline dye, or lead oxide was found in the studied turmeric powder samples. This absence of toxic dyes and adulterants might be partly due to the strict regulatory measures and quality control practices implemented by local authorities in the region. Additionally, it could also be attributed to the sellers not being aware of or not using these specific adulterants, which might be less common in this region compared to others. This finding contrasts with reports from other regions like Europe and India, where adulteration with such substances has been documented [17,27]. The difference could be attributed to varying levels of regulatory enforcement and awareness among producers and consumers in these regions. Furthermore, the Lugol test, which is used to detect starch, showed a blue-black coloration in all samples, albeit with varying colour intensities. Specifically, 22 samples exhibited a color intensity ranging from +3 to +5, indicating a higher starch content. This includes the 7 samples that were identified as inauthentic through microscopic analysis. Although to date, the standard level or range of starch, either qualitatively or quantitatively, in turmeric powder from Cameroon is unknown, it can be speculated that the 7 samples validated as being non-compliant for starch granule test and for Lugol's starch test are potentially suspicious for starch adulteration. It is also suggestive that some samples might originally have a very high starch content while still being authentic. This finding is similar to studies in other regions where starch content has been identified as a common adulterant in turmeric powders [25,26]. However, the inclusion of authentic samples with high starch content highlights a potential challenge in using starch content alone as a definitive indicator of authenticity, except otherwise, the standard values for turmeric powder starch in Cameroon be determined. Therefore, additional methods, such as microscopic analysis of starch granules, may be necessary to accurately identify adulterated samples in resource scarce research infrastructures as in Cameroon. The varying starch content observed in this study might be due to difference in regional variations in agricultural practices or processing methods, which could influence the natural starch content of turmeric rhizomes [28]. Additionally, Lugol's test only tells us that starch is present, it does not inform us on the origin or source of the starch. Sophisticated spectroscopic tools such as the FTIR combined with chemometrics may distinguish the type of starch e.g. corn starch.

However, one sample from Yaoundé in this study tested positive for met anil yellow, a synthetic dye associated with adverse health effects and another sample still from Yaoundé exhibited chalk adulteration, a non-toxic yet deceptive additive that can lower the quality of the spice. The relatively low frequency of these adulterants in this study with less than 1% for both met anil yellow which have health implications and chalk, which can reduce the purity of turmeric powder, may suggest limited use of these chemical additives in Cameroon's turmeric powder market. Nevertheless, these findings indicate a need for comprehensive surveillance and regulatory measures to monitor and prevent potential toxic adulterants. Developing standardized testing procedures and strengthening enforcement can help protect consumers and uphold product integrity in Cameroon's turmeric market.

Combined discussion on field and laboratory (authenticity and fraud detection) findings

Turmeric authenticity and fraud may be compounded by several neglected factors during selling for which sellers may or may not be aware of. For example, some sell their turmeric powder in open mouthed containers on the same table containing different grinded spices powder, which allows for cross contamination and which may be falsely detected as adulterated turmeric powder, but correctly as inauthentic turmeric powder. Meanwhile, some sellers package their turmeric powder in closed mouthed containers and only open when a client is buying. Additionally, although a few sellers preserved their turmeric powders away from sunlight, some sellers allowed their turmeric powder, whether in open or closed mouthed containers, exposed to sun light without being conscious that the sun light has an effect on the colour of the turmeric -reducing its yellow colour as a result of reduction of its curcumin levels. It should be noted that wind or usage of common measuring cups across different powdered spices may be a risk factor for cross contamination. Also, allowing turmeric powder to open for too long also attract moisture which affects the authenticity of the turmeric powder. This is the first report on turmeric powder authentication and fraud investigation in Cameroon. The observed concerned awareness and education levels among turmeric powder sellers and consumers about the potential health risks associated with adulterated turmeric may require more attention by authorities, business turmeric operators and consumers. The suspicious non-compliant seven turmeric samples based on the combined microscopic test for starch granules and Lugol's test for presence of starch at different intensities provides a strong argument that starch is an adulterant in those studied turmeric samples. Starch from alternative sources such as corn is cheaply available in Cameroon and therefore potentially useful to fraudsters as bulking agents for economic gains. Another bulking agent, chalk powder, was only detected in a single sample, but should not be undermined considering the relatively cheaper cost of chalk. These bulking agents dilute the curcumin levels and jeopardize the intended culinary and/or medicinal values consumers paid for when purchasing the turmeric. Although presence of coloured dyes such as aniline and lead oxide dyes were not detected (except the one sample with detectable met anil yellow), there is need for investigation using sophisticated analytical systems such as the ICP-MS and NIR/FTIR coupled with machine learning. Considering they are toxic, adulteration of turmeric powder with such chemical dyes may result in health complications in consumers once they consume it. Based on the culinary and medicinal values of turmeric powder and taking into consideration the findings from this present study, there is need for the government to consider encouraging turmeric production and authentication as the case maybe elsewhere in Africa e.g., in Ethiopia [24] and Nigeria [29-34].

Limitations

This report on the authenticity and fraud in turmeric powder sold in markets in Yaoundé and Douala presents insights that can inform the development of a turmeric fraud mitigation strategy for the turmeric supply chain. However, there were complications and

reluctance of some sellers to participate in the survey portion of the study. Additionally, the absence of sophisticated equipment and total dependence on less sensitive methods might have caused a false positive result for the chemical test for chalk and met anil dye test. Finally, lack of standard values for the studied authenticity and/or fraud detection parameters such as starch levels in Cameroon made it difficult to draw definitive conclusions on some analysis.

Conclusion

For the first time in Cameroon, the authenticity and fraud status of turmeric powder from local markets have been determined. On the basis of the findings from this study and aforementioned discussion, it is speculated that majority of the studied turmeric powder from local markets in Yaoundé and Douala, Cameroon, were not authentic while some contained detectable levels of illegally added adulterants, mainly bulking agents (e.g. starch) adulterated for economic gains. This was not strange as consumers and sellers also speculated potential ongoing adulteration and indicated adulterants such as starch. There is a need to raise awareness and build capacities not only on the culinary and medicinal values of turmeric powder, but also on the need to protect its originality (keep it authentic) and restrain from any form of turmeric fraud, as well as basic techniques to detect fraud.

Acknowledgement

The authors would like to thank all the participants (both market survey and online) who took part in this study and provided candid responses. Their contributions have provided valuable insights into the prevalence of turmeric fraud in these two major cities in Cameroon and how stakeholders can effectively address the issue of turmeric inauthenticity and fraud.

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