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# An Evaluation of Adulteration of Selected Foods Available in Shops in Peliyagoda Urban Council Area

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## ABSTRACT

**Background:** Food adulteration is the intentional adding of non-food ingredients to a food product to enhance its quality and quality before being sold. The presence of food adulterants in the body can trigger asthma, cancer, and various other health issues. **Method:** An analytical cross-sectional investigation was conducted into sugar, chili powders and turmeric powder samples. There were chemical and physical experiments conducted here. Physical tests consisted of clarity and grittiness tests. Chemical tests included the HCl test, Nessler reagent test, iodine test and H<sub>2</sub>SO<sub>4</sub> test. **Results:** When white particles were tested physically for contamination in water, 61 out of 70 samples (87.14%) had contaminated white sugar; all samples of brown sugar were uncontaminated. 60/70 (85.71%) of the white sugar samples contained ammonia, at the same time 3/9 (33.33%) of the brown sugar samples tested positive for ammonia during the Nessler reagent test. There are no traces of yellow color contamination in either the brown or white sugar samples. In physical testing of chili powder samples, among branded samples, 79.66% presented with grittiness. At the same time 33.89% presented white particles in chili powder. Among non-branded chili powder samples, most products showed grittiness and white particles. Nevertheless, all branded samples were free of calcium salt and starch contamination during chemical testing. Starch was found in 95% samples of non-branded chili powder, but not calcium salt. Physical testing revealed contaminated turmeric powders in all the samples. There were samples containing artificial colors in 49/54 (90.74%) of the non-branded samples, whereas 19/25 (76%) of the branded samples included artificial colors. **Conclusion:** All samples, branded and non-branded, contained starch and were free of chalk powder contamination.

**Keywords:** Food adulteration, Public Health Risk, Turmeric Powder Adulteration, Chili Powder Adulteration, Sugar Adulteration

## 1. INTRODUCTION

Foods are essential for all living things to live daily (Anagaw et al., 2024). Food includes any item that people produce, sell, or present for human consumption (Kolamunna and Dissanayake, 2023). It is a basic need of all living people. Food contains carbohydrates, water, fat, and protein. All the food in the world is either plants or animals. Nearly 2000 species of plants are grown for food (Ayza and Belete, 2015).

Food is the most important thing for all living things, so the decrease in its quality leads to various diseases and death, such as cardiovascular disease, type II diabetes, and cancers (Banti, 2020). One of the main ways to reduce the quality of food is to adulterate it. Adulteration can be defined in several ways. According to Banti, (2020) Adulteration involves either removing certain beneficial ingredients from a food product or substituting inferior ingredients with superior ones. Adulteration can involve the purposeful or inadvertent insertion of non-food items to improve the quality of food items in their raw or prepared forms, preserve them, or enhance their appearance. According to Sasikumar (1970) Adulteration is the mixing or replacement of the original material with hazardous compounds or synthetic chemicals that do not meet regulatory standards or with other fictitious, inferior, faulty, spoiled, and useless components of the same or different plant.

20-30 % of people do not know that these foods are adulterated (Banti, 2020). People adulterate food in two main ways. They are direct adulteration and indirect adulteration. To generate revenue, direct adulteration involves replacing parts entirely or partially with inert or chemical materials, or inferior materials due to their morphological likeness. Indirect adulteration is inadequate assessment procedures and administrative mistakes that are the primary causes of adulteration (Sasikumar, 1970). Then it can be divided into four ways. There are Intentional adulterations, Unintentional adulterations, Metallic contaminations, and Microbial contaminations.

Intentional adulteration includes substances with properties like those of food. In unintentional adulteration, producers add unwanted substances due to carelessness or a lack of proper facilities. Metals or different metal complexes are the source of metallic contamination. In microbial contamination, microorganisms from various sources spoil the food. It could be during harvest, storage, processing, distribution, handling, and preparation (Bansal et al., 2017). Some intentional adulterants are sand, marbles, chips, stones, and chalk. Some incidental adulterations are pesticides and residues. Examples of metallic contaminations are arsenic from pesticides and lead from water (Mayuri and Supriya, 2022).

According to Mahendra Pal and Mahinder (2020), 22% of food is adulterated every year. Globally, nearly 57% of people develop health problems due to eating adulterated or contaminated foods. Among them, 32% are children and 25% are adults (Mahendra Pal and Mahinder, 2020). Commonly adulterated foods include milk, ice cream, milk powder, cheese, wheat flour, black pepper, chili powder, tea, coffee powder, sugar, mustard oil, turmeric powder, honey, and olive oil (Mahendra Pal and Mahinder, 2020).

Consumption of adulterated foods can lead to toxic effects and health issues, loss of essential nutrients needed to maintain proper health, and problems such as intoxication or allergies. Chemicals like formalin, which can cause asthma, skin conditions, and cancer, can be adulterated by fruit, fish, meat, and milk (Bansal et al., 2017). According to Mahendra Pal and Mahinder (2020), food adulteration can cause several diseases and health issues, including malaise, stomach disorders, heart problems, brain damage, paralysis, anemia, liver disorders, indigestion, nausea, vomiting, dizziness, diarrhea, dysentery, acidity, ulcers, autism, cancer, kidney malfunction, joint pain, metabolic dysfunction, food poisoning, vision problems and skin disorders.

The main objectives are to evaluate the adulteration techniques used on selected food materials (chili powder, turmeric powder and sugar) and to assess the prevalence of adulteration in chili powder, turmeric powder and sugar sold in shops within the Peliyagoda Urban Council area.

## 2. MATERIALS AND METHODS

The population has 79 retail and wholesale shops in Peliyagoda urban council area (Fig. 1). It has a low population size. Therefore, instead of using a sample size, we used the entire population for our study.



Figure 1. Peliyagoda Urban Council Area

## 2.1. Methodology of Chili Powder Contaminant Testing

### Materials:

Straight wire, glass rod, glass slide, measuring scale, spatula, 250 ml beaker with water, samples of chili powder, filter paper, a dropper, test tubes and a test tube rack to extract and observe the physical characteristics or chemical components of chili powder in a laboratory setting.

### Reagents:

Conc.HCl, Iodine solution, Dilute nitric acid, KI solution, Petroleum ether, 13N H<sub>2</sub>SO<sub>4</sub>, and Distilled water.

### Methods:

**Water Test:** Five grams of chili powder was weighed and dissolved in distilled water 250ml and allowed to stand for 20 minutes. After 20 minutes, the samples were examined. The water appeared clear when pure chili powder was used, whereas it appeared cloudy when adulterated chili powder was present.

**Grittiness Test:** 5g of chili powder was measured and added to the beaker of water. The chili powder sediment at the bottom was then rubbed using a glass rod. Any grittiness felt confirmed the presence of brick powder, sand, or other residues.

**HCl Test for Detection of Calcium Salts:** A small amount of chili powder sample was placed on a glass slide, and concentrated HCl was added to it. The distal end of a straight wire was dipped into the paste and held over the flame of a Bunsen burner. The appearance of a brick-red flame indicated the presence of calcium salts.

**Iodine Test for Detection of Starch:** Test tubes were labeled as control and respective sample numbers. Control chili powder was added to the control test tube and other samples were added to the sample test tubes. Two drops of iodine solution were then added to each test tube. The test tubes were allowed to stand for a few minutes and color changes were observed. The appearance of a blue-black color indicated the presence of starch.

**Potassium Iodide (KI) Test for Detection of Red Lead Salt:** Diluted nitric acid was added to the chili powder sample and allowed a few minutes. Then the sample was filtered using filter paper. Two drops of potassium iodide (KI) were added to the filtrate. The formation of a yellow-colored precipitate indicated the presence of red lead salts.

*Petroleum Ether and 13N Sulfuric Acid Test for Detection of Artificial Color:* The chili powder sample was extracted with petroleum ether, and 13N sulfuric acid was added to the extract, followed by distilled water. The persistence of a red color indicated the presence of artificial coloring agents.

*HCl and Ether test for Detection of Oil-soluble colors:* 2g of chili powder sample was added to a test tube. A few drops of ether were added, and the mixture was shaken well. Then, 2 mL of diluted HCl was added to the decanted ether layer and shaken. The color of the lower acid layer was then observed. A red color in the lower acid layer indicated the presence of oil-soluble color.

## 2.2. Methodology of Turmeric Powder Contaminant Testing

### *Materials:*

Turmeric powder samples, Test tubes, Test tube rack, Dropper, 250 ml beaker, Spatula.

### *Reagents:*

Concentrated HCl, Water, Petroleum Ether, 13N sulfuric acid, Distilled water, Diluted HCl, and Iodine solution.

### *Methods:*

*Water Test for Detection of Clarity:* A beaker of water was mixed with 5g of turmeric powder. The sample was allowed to stand for 20 minutes without being stirred or mixed. Twenty minutes later, the samples were examined. If the water appeared clear, it indicated pure turmeric, while a cloudy appearance indicated adulterated turmeric powder.

*HCl test for Detection of Chalk powder test:* 5g of turmeric powder and water were added to the test tube and thoroughly mixed. Then, concentrated HCl was added to the test tube. The formation of bubbles indicated the presence of chalk powder.

*Petroleum Ether and 13N Sulfuric Solution Test for Detection of Artificial Color:* A turmeric powder sample was extracted using petroleum ether, allowing for the isolation of fat-soluble components such as dyes. After extraction, 13N sulfuric acid was added to the extract to react with any substances present. Distilled water was then added to dilute the mixture and facilitate observation. This procedure is typically used to detect the presence of artificial colorants, particularly oil-soluble ones, in turmeric powder. The persistence of a red color after these steps is taken as an indication of adulteration with artificial color.

*Ether and HCl test for detection of oil-soluble colors:* Two grams of turmeric powder were added to the test tubes. A few drops of ether were added, and the mixture was shaken well. Two milliliters of diluted HCl were then added to the decanted ether layer and shaken. The color of the lower acid layer was observed. A red color in the lower acid layer indicated the presence of an oil-soluble color.

*Iodine Test for detection of starch:* The test tubes were labeled as 'control' and with the respective sample numbers. Turmeric powder was added to the control tube, while the other samples were added to the corresponding sample tubes. Two drops of iodine solution were then added to each test tube. After a few minutes, color changes were observed. A green-blue color indicated the presence of starch.

*HCl test for detection of Meta nil Yellow Test:* Five grams of turmeric powder were added to a test tube, followed by a few drops of concentrated hydrochloric acid. A pink color appeared. Then, distilled water was added. If the pink color disappeared, it indicated pure turmeric. If the pink color remained, it indicated the presence of meta-nil yellow.

## 2.3. Methodology of Sugar Contaminant Testing

### *Materials:*

The materials used in this experiment included a 250 mL beaker, sugar samples, a spatula, test tubes, and a test tube rack.

### *Reagents:*

The reagents used in this experiment were distilled water, concentrated hydrochloric acid, and Nessler's reagent.

### *Methods:*

*Clarity test for detection of Chalk Powder:* Ten grams of sugar were dissolved in a beaker of water and left to stand for a few minutes. White particles were observed precipitating at the bottom. The presence of these particles indicated the addition of chalk powder.

*HCl test for detection of yellow color:* Five milliliters of the above solution were taken and added to a test tube. A few drops of concentrated hydrochloric acid were then added. The lower acid layer turned pink, indicating the presence of a non-permitted yellow color.

*Nessler's reagent test for detection of Urea:* Nessler's reagent was prepared using potassium iodide (KI), distilled water, mercury (II) chloride (HgCl<sub>2</sub>), and potassium hydroxide (KOH). Test tubes were labeled according to sample numbers, and 2 grams of sugar were added to each tube. Nessler's reagent was then added to each test tube and allowed to react for a few minutes. An orange color developed, indicating a positive result.

### 3. RESULT

Three food items were tested. Each sample was analyzed using different methods to obtain accurate results.

#### 3.1. Chili powder

A total of 79 chili powder samples were analyzed (Fig. 2). Among these, 59 were branded chili powder samples, and 20 were non-branded.

##### *Branded Chili Powder Samples:*

Of the 59 branded samples, three physical tests were conducted. In the physical tests, 47 out of 59 samples (79.66%) showed grittiness, and 20 out of 59 samples (33.89%) contained white particles. All branded samples tested positive in the water test. In the chemical analysis, no samples contained calcium, and all tested negative for iodine. Additionally, none of the branded samples contained red lead salts, oil-soluble colors, or artificial colors.

##### *Non-Branded Chili Powder Samples:*

All 20 non-branded samples showed both grittiness and the presence of white particles in physical testing. All samples also tested positive in the water test. In chemical testing, 19 out of 20 samples (95%) contained starch, and 5 out of 20 samples (25%) contained artificial colors. None of the non-branded samples contained calcium, red lead salts, or oil-soluble colors.

##### *The Chi-square test for Chili powder samples*

*Observed numbers*

**Table 1.** Observed numbers of chi-square test for chili powder

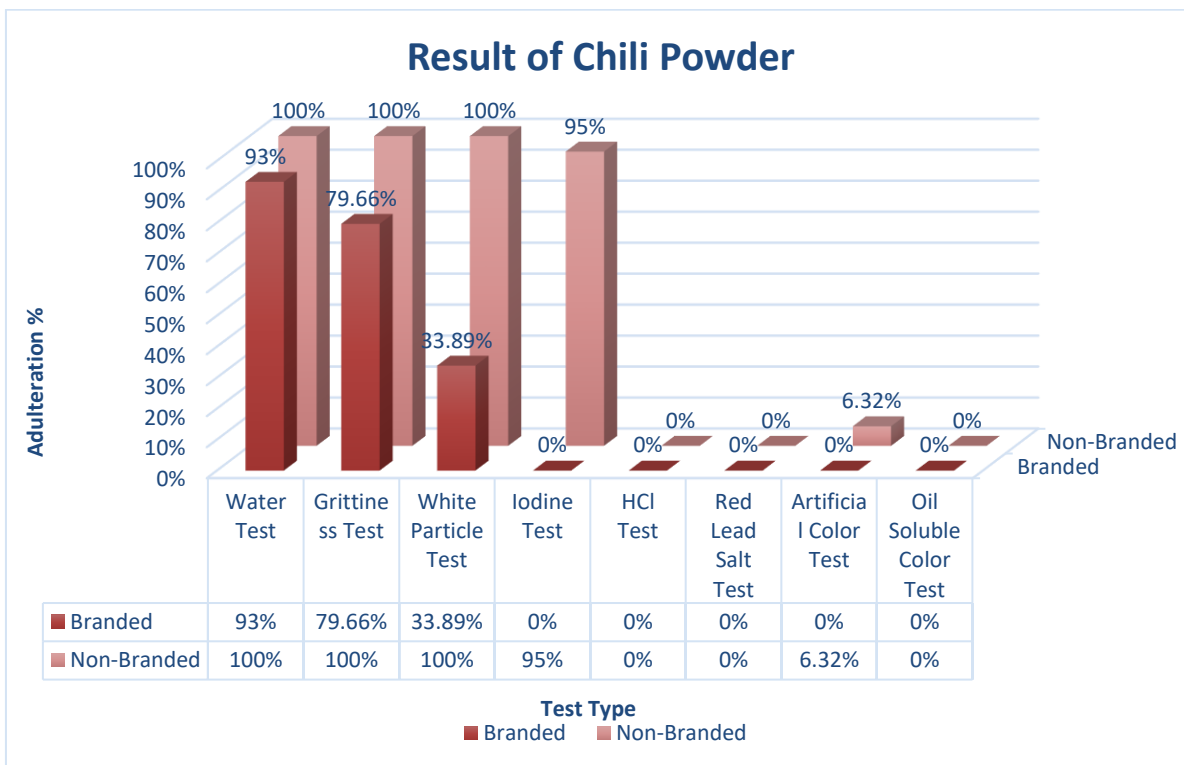
Test Type	Contaminate		Total (n)	Proportion in group A
	Brand	Non-B		P=a/n
Water Test	55	20	75	0.73
Grittiness	47	20	67	0.70
White particles	20	20	40	0.50
Iodine	0	19	19	0.00
HCL	0	0	0	0.00
Red lead salt	0	0	0	0.00
Artificial color	0	5	5	0.00
Oil soluble color	0	0	0	0.00
Total	122	84	206	

Expected numbers

**Table 2.** Expected numbers of chi-square test for chili powder

Test Type	Expected numbers		O – E		(O-E) <sup>2</sup> /E	
	B	Non-B	B	Non-B	B	Non-B
Water Test	44.42	30.58	10.58	-10.58	2.52	3.66
Grittiness	39.68	27.32	7.32	-7.32	1.35	1.96
White particles	23.69	16.31	-3.69	3.69	0.57	0.83
Iodine	11.25	7.75	-11.25	11.25	11.25	16.33
HCL	0.00	0.00	0.00	0.00	0.00	0.00
Red lead salt	0.00	0.00	0.00	0.00	0.00	0.00
Artificial color	2.96	2.04	-2.96	2.96	2.96	4.29
Oil soluble color	0.00	0.00	0.00	0.00	0.00	0.00
Total	122.0	84.0	0.00	0.00	18.65	27.07

Chi square point = (Observed - Expected)<sup>2</sup>/Expected      X<sup>2</sup>=45.72      df=14.07



**Figure 2.** Results of chili powder

According to Tables 1 and 2, the calculated value exceeds the critical table value for the appropriate degrees of freedom. Therefore, it can be concluded that the presence of adulteration in chili powder is statistically significant (Figure 2).

### 3.2. Turmeric Powder

A total of 79 turmeric powder samples were tested, including 54 non-branded samples and 25 branded samples (Fig. 3).

#### Non-Branded Turmeric Powder Samples:

Out of the 54 non-branded samples, 49 (90.74%) contained artificial colors, and all were found to be contaminated. Every sample also contained starch, while 8 samples (14.81%) tested positive for oil-soluble colors. None of the non-branded samples contained chalk powder or metanil yellow.

#### Branded Turmeric Powder Samples:

Among the 25 branded samples, 19 (76%) contained artificial colors, and all samples tested positive in the water test. All branded samples were contaminated and contained starch. However, none of them contained chalk powder, oil-soluble colors, or metanil yellow as adulterants.

#### The Chi-square test for Turmeric Powder Samples

Observed numbers

**Table 3.** Observed numbers of chi-square test for turmeric powder

Test Type	Contaminate		Total (n)	Proportion in group A
	Brand	Non-B		P=a/n
Water test	25	54	79	0.68
Chalk powder	0	0	0	0.00
Artificial color	19	49	68	0.72
Oil soluble color	0	8	8	1.00
Iodine test	25	54	79	0.68
Metanil yellow	0	0	0	0.00
Total	69	165	234	

Expected numbers

**Table 4.** Expected numbers of chi-square test for turmeric powder

Test Type	Expected numbers		O – E		(O-E) <sup>2</sup> /E	
	B	Non-B	B	Non-B	B	Non-B
Water test	23.29	55.71	1.71	-1.71	0.13	0.05
Chalk powder	0.00	0.00	0.00	0.00	0.00	0.00
Artificial color	20.05	47.95	-1.05	1.05	0.05	0.02
Oil soluble color	2.36	5.64	-2.36	2.36	2.36	0.99
Iodine test	23.29	55.71	1.71	-1.71	0.13	0.05
Metanil yellow	0.00	0.00	0.00	0.00	0.00	0.00
Total	68.99	165.01	0.00	0.00	2.67	1.11

Chi square point = (Observed - Expected)<sup>2</sup>/Expected      X<sup>2</sup> = 3.8      df = 11.07

According to Tables 3 and 4, the calculated value is smaller than the critical table value for the appropriate degrees of freedom. Therefore, some types of adulteration evaluated in this study were not present, and their incidence is not as high as initially expected.

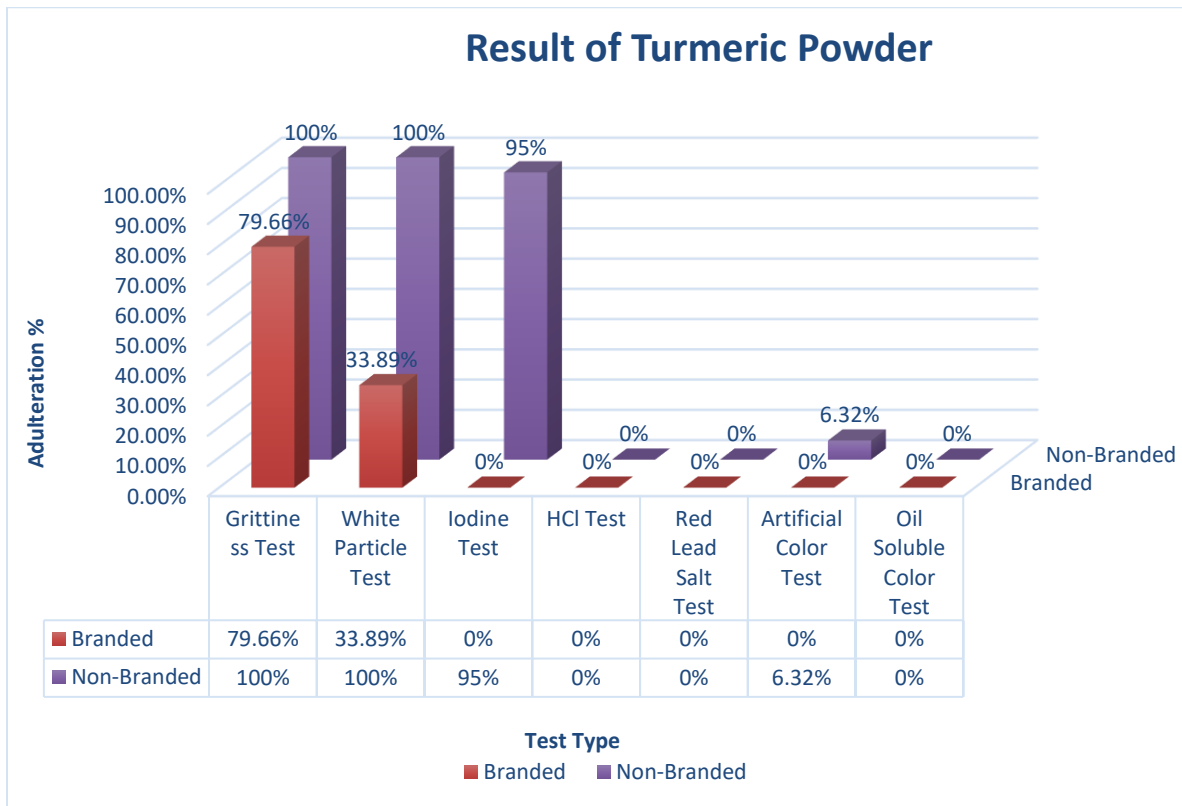


Figure 3. Results of turmeric powder

### 3.3. Sugar

A total of 79 sugar samples were tested, including 70 white sugar samples and 9 brown sugar samples (Fig. 4).

#### White Sugar Samples:

Among the 70 white sugar samples, 61 (87.14%) showed the presence of white particles. Ammonia was detected in 60 samples (85.71%) using Nessler’s reagent. All white sugar samples were free from yellow color contamination.

#### Brown Sugar Samples:

None of the nine brown sugar samples were contaminated with white particles, and all were free from yellow color contamination. However, 3 out of 9 samples (33.33%) tested positive for ammonia during the Nessler’s reagent test.

*The Chi-square test for Sugar Samples**Observed numbers***Table 5.** Observed numbers of chi-square test for sugar

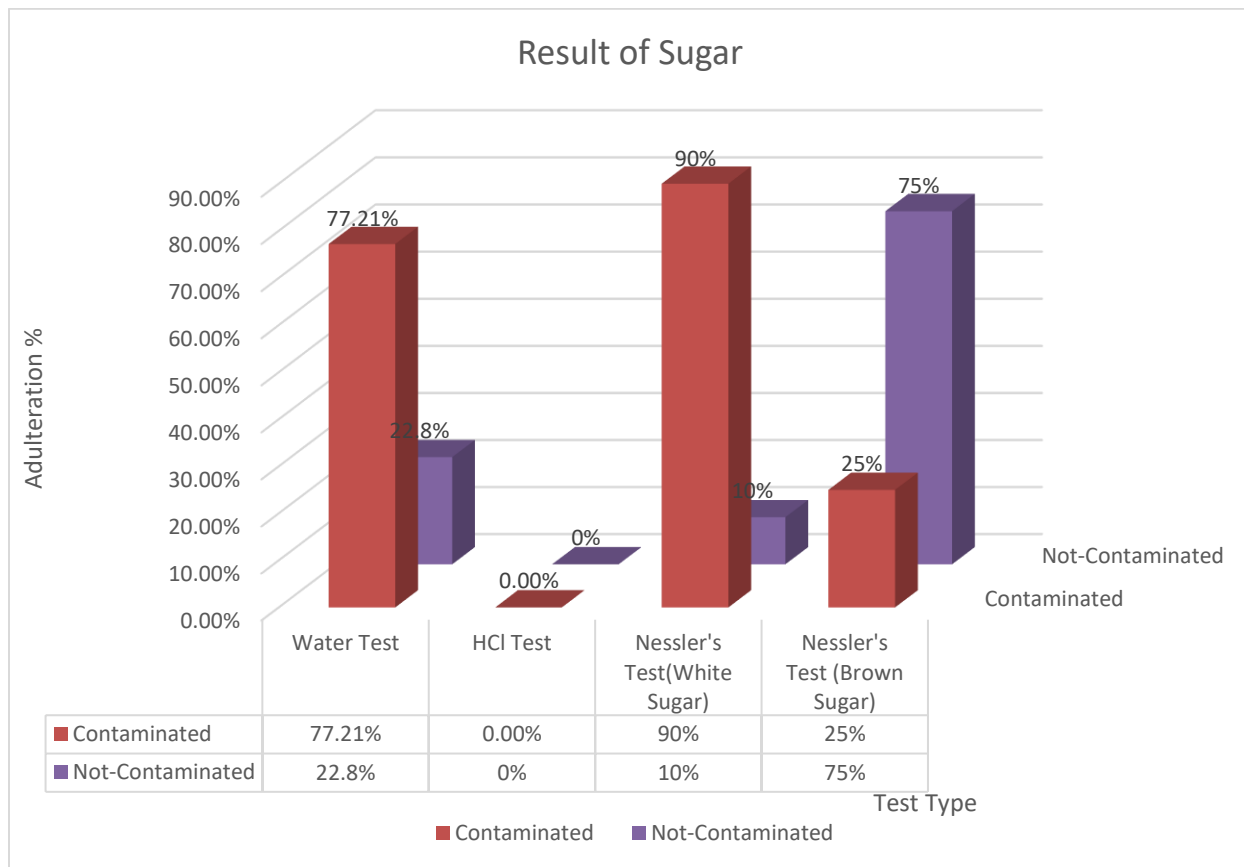
Test Type	Contaminate		Total (n)	Proportion in group A
	Yes (A)	No (B)		
Water test	61	18	79	0.77
HCl test	0	0	0	0.00
Nessler's test (White sugar)	60	7	67	0.90
Nessler's test (Brown sugar)	3	9	12	0.25
Total	124	34	158	

*Expected numbers***Table 6.** Expected numbers of chi-square test for sugar

Test Type	Expected numbers		O - E		(O-E) <sup>2</sup> /E	
	Yes	No	Yes	No	Yes	No
Water test	62	17	-1	1	0.02	0.06
HCl test	0	0	0	0	0	0
Nessler's test (White sugar)	52.58	14.42	7.42	-7.42	1.05	3.82
Nessler's test (Brown sugar)	9.42	2.58	-6.42	6.42	4.38	15.98
Total	124	34	0	0	5.45	19.86

Chi square point =  $(\text{Observed} - \text{Expected})^2 / \text{Expected}$   $X^2 = 25.31$   $df = 7.81$

According to Tables 5 and 6, the calculated value is greater than the critical table value for the appropriate degrees of freedom. Therefore, the results confirm a significant prevalence of adulteration in the sugar samples tested.



**Figure 1.** Results of sugar

#### 4. DISCUSSION

Many qualitative and quantitative methods are available to detect the presence of adulterants in food. While some of these methods are expensive, others are more affordable (Sciuto et al., 2017). Rapid and inexpensive techniques are available for detecting adulteration in common food items such as chili powder, turmeric powder, and sugar. Qualitative methods are typically used to identify the presence of adulterants, whereas quantitative methods help determine the extent of adulteration (Tewksbury, 2009).

A significant number of food adulteration cases have been reported worldwide (Osburn et al., 2009). Various types of adulterants can be found in chili powder, including oil, rice flour, bran, fruit residues, plant husk, rice powder, sawdust, talc powder, brick powder, artificial color, oil-soluble color, red lead salts, and salt powder (Momtaz et al., 2023). Previous studies have employed a variety of techniques to detect such adulteration, beyond those used in this research. For example, Sudan dye, a toxic substance often added to chili powder, tomato sauce, and palm oil can be detected using UV-visible spectroscopy, infrared spectroscopy, and Raman spectroscopy (Sciuto et al., 2017).

Intentional adulteration includes the addition of brick powder to chili powder and chalk powder to sugar. Various techniques are available for detecting such adulteration, including physical, chemical, biochemical, and molecular methods. Of these, biochemical and molecular techniques are among the most advanced (Choudhary, 2023). For instance, thin-layer chromatography (TLC) and high-performance liquid chromatography (HPLC) are advanced methods used to detect turmeric powder adulteration. Additionally, Random Amplified Polymorphic DNA (RAPD) techniques can be used to identify turmeric adulteration at a molecular level (Sasikumar et al., 2024). FT-Raman and FT-IR spectroscopy are advanced methods used to detect harmful substances like meta nil yellow in turmeric powder. These techniques have proven effective in identifying carcinogenic chemical contaminants in food powders (Dhakal et al., 2016).

The Solvent-Free Solid Injector (SFSI) method has also been used to differentiate volatile organic compounds (VOCs) in chili powder. Trimethylamine and isosorbide serve as biomarkers for contamination and are detected using SFSI-GC (Gas chromatography) /MS (Mass Spectrometry) (Ko et al., 2014).

A more recent advancement is the use of hyperspectral imaging to detect color adulteration in red chili powder. This method has shown potential in identifying the presence of oil and Sudan dye (Hussain Khan et al., 2020). Moreover, chili powder is sometimes adulterated with black pepper or papaya seeds. DNA barcoding using the *psbA-trnH* primer pair has proven effective in detecting such adulteration. The modified CTAB method or QIAGEN DNeasy® Plant Mini Kit is used for DNA extraction, depending on the sample.

Adulteration is not limited to spices but affects a wide variety of foods, including honey, milk, green vegetables, ice cream, edible oils, butter, pulses, wheat flour, tea powder, coffee powder, and black pepper (Sudhirkumar and Sudhakar, 2022).

It's important to note that the presence of pathogens like bacteria, viruses, or protozoa does not necessarily indicate adulteration, but contamination. For example, Salmonella can contaminate ready-to-eat meat and fresh produce.

Market research in Bangladesh revealed that more than 70% of food products are adulterated with chemicals and artificial colors, especially fish, meat, and vegetables. Wet market products tend to be cheaper and fresher but are more susceptible to adulteration. Supermarket consumers are generally more aware of food safety and are less exposed to foodborne diseases such as cancer, diabetes, paralysis, and heart disease (Yeasmin et al., 2023).

Sudan dyes are highly toxic and carcinogenic, and their use in spices should be strictly monitored and banned. TLC and spectrophotometry have been developed as reliable methods to detect Sudan dye in chili powder (Gandhi and Mashru, 2019). Research in India has also identified Rhodamine B in chili powder, which is detectable using acetone. Dung powder and salt have been found in coriander powder, detectable through sensory methods and silver nitrate, respectively. Adulterants in turmeric, including yellow lead salt and aniline dyes, can be identified using concentrated HCl and spirit. Microscopic observation is used to detect the presence of starch, wheat, and rice, and microbial pathogens can be detected by culturing the samples (Sen et al., 2017). A novel technique using image processing, logistic regression, and noise removal has been introduced to detect chili powder adulteration (Desai and Patel, 2021).

Adulteration is often driven by profit, with fraudulent ingredients added to food to deceive consumers. Because many consumers lack awareness, most adulteration is deliberate and difficult to detect. Commonly adulterated items include groundnut paste, chili powder, honey, tomatoes, and palm oil. Sensory and textural tests, though not scientifically rigorous, serve as useful screening tools at the household level. Consumers are advised to purchase food from trusted sources and inspect products for signs of adulteration (Essuman et al., 2022).

## 5. CONCLUSION

Among the products tested, turmeric powder was found to be the most adulterated, primarily with starch. Both branded and non-branded samples contained starch. The highest percentage of artificial color contamination was observed in non-branded turmeric powder. No chalk powder contamination was detected in any of the turmeric powder samples. Chili powder ranked second in terms of adulteration, with the most common adulterants being gritty substances, particularly in non-branded samples. Starch contamination was also found exclusively in non-branded chili powder. Sugar was the least contaminated product among the three, with the most common adulterants being urea and, to a lesser extent, chalk powder.

### Informed consent

Not applicable.

### Funding

This study has received funding from KIU undergraduate research fund.

### Ethical approval

The study was approved by the Ethics Committee of KIU/ERC/L/23/017. In this research, an analytical cross-sectional investigation was conducted into sugar, chili powders and turmeric powder samples; meantime, ethically the "brand name" of the product not

mentioned in content and “brand image” not displayed as image in the article. The product ethical guidelines are followed in the study for observation, identification & experimentation.

### Conflict of Interest

The author declares that there are no conflicts of interests.

### Data and materials availability

All data associated with this study are present in the paper.

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