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Food Adulteration Practices and Awareness among Urban consumers – A case study of Hyderabad city, Telangana, India

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Abstract

Food adulteration has become a global problem nowadays. Almost all food items are prone to adulteration intentionally or non-intentionally for various reasons like financial gain, increasing quantity, etc. In this study, we asked consumers about their understanding of food adulteration and authenticity, the types of adulterants they use, and their methods for detecting them at the household level. In Hyderabad, Telangana, India, a diverse group of respondents was asked to answer a self-designed questionnaire distributed online and offline. This study comprised 418 respondents. Findings reveal that while a significant portion of respondents 324, 77.5%) are aware of the issues, many lack knowledge about common adulterants and their specific health risks. 292 (69.9%) respondents reported that economic gain is the primary motivation for adulterating food. Among all food items, milk, turmeric, spices, oils, pulses, fruits, and vegetables are frequently adulterated. This study highlights the need for improved consumer education, stricter regulations, and effective enforcement to combat food adulteration and protect public health.

Keywords: *Food Adulteration, Consumer awareness, Adulterants, Health risks, Traditional detection methods.*

1. Introduction

Food, the cornerstone of human well-being, is unfortunately vulnerable to a deceptive practice known as food adulteration. The meaning of adulteration of food from the Oxford Dictionary is the addition of any substance to food items, which leads to a reduction in the quality of food items. An adulterant is a substance that is added to food in order to lower its quality while increasing its quantity. This act of adding an adulterant to food items is known as food adulteration [1]. Food is a vital aspect of life, defined as any substance consisting of carbohydrates, water, fats, and proteins that humans and animals can consume for nutrition [2]. Consuming quality foods is a basic requirement for obtaining vital nutrients and is essential for human growth and maintenance. Quality foods play a critical role in providing the necessary nutrients for maintaining good health and for the full growth and development of the body [4]. According to the World Health Organisation [3]. Food adulteration refers to intentionally adding prohibited substances to partially or completely replace healthy ingredients or falsely producing fresh products. The Food and Agriculture Organisation (FAO) of the United Nations defines adulteration as the addition of any foreign material or ingredient to food or the substitution of another material for a product's original ingredient in order to increase a product's mass or weight, lower its quality, or boost its value (FAO, 2019). According to the US Food and Drug Administration (FDA), Food can be harmful if it contains poisonous substances or is spoiled, rotten, or prepared in unsanitary conditions, if a crucial ingredient is absent or substituted, or if the label is deceptive. It may also be hazardous [5]. Food adulteration is defined as "the intentional or unintentional contamination of food or food materials by the addition of any substance which adversely affects the nature, substance, and quality of food" by the Food Safety and Standards Authority of India [6].

The first studies of food adulteration were conducted around 1830 by Frederick Accum, a German scientist. He discovered numerous toxic metals in food and drink items [7-8]. An adulterant is a chemical substance that should not be present in other substances (e.g., food, beverages, and fuels) for legal or safety reasons. The act of adding adulterants is known as adulteration [9]. Various food items are susceptible to food adulteration, including dairy products, grains, seafood, oils, alcoholic drinks, honey, fruits, and vegetables, and can be adulterated in numerous ways[10-12]. According to the most recent data available, about half of the food consumed daily is contaminated [13]. It is estimated that about 5 and 7% of worldwide trade is obtained through fraudulent products, with a yearly cost of up to $40 billion [14]. According to another report, approximately 22% of food products are found to be adulterated each year [15-16]. This act involves the intentional addition of inferior or harmful substances to food products, often for economic gain [17]. The consequences of food adulteration range from reduced nutritional value to serious health risks, posing a significant public health concern [18]. Approximately 57% of people develop health issues from consuming adulterated and contaminated products [19-21]. Food adulteration can also have a negative financial impact since it lowers consumer confidence in food safety

and quality, which lowers demand and sales. This can damage the reputation and profitability of food businesses, leading to job losses and reduced economic growth [22-25]. Food can be intentionally or unintentionally adulterated. Intentional adulteration is usually for financial gain, while accidental adulteration is caused by ignorance, negligence, or lack of [26-27]. This practice can occur at any stage of the food preparation supply chain, either for commercial gain or due to negligence and lack of proper hygienic conditions during processing, storage, transportation, and marketing [28]. Varghese and Ramamoorthy pointed out a correlation between the rise in packaged food consumption, especially in emerging nations like India, and the usage of organic and inorganic colourants [29]. Common examples of food adulteration in supply and value chains include the use of rotten ingredients and the addition of toxic substances (e.g., illegal dyes, harmful preservatives), misbranding and changing the manufacturing and expiration dates, as well as changing the list or mislabelling ingredients with similar ones [30]. Additionally, adulteration can involve the addition of low-quality, inexpensive, or unhealthy ingredients, often inorganic materials (such as sand, dust, clay, mud, and pebbles) to increase product weight. These ingredients can pose health and safety issues for consumers. The primary obstacles associated with food adulteration are declining customer confidence, low originality leading to low market awareness, and public health concerns [31]. Despite its prevalence, consumer knowledge about food adulteration remains a topic of debate. While some studies suggest a growing awareness, others highlight significant gaps in understanding. This lack of knowledge can leave consumers vulnerable to unknowingly purchasing and consuming adulterated food products. To address this issue, this study delves into consumer knowledge of food adulteration through a self-designed questionnaire distributed via Google Forms. By gathering data from a diverse audience, the study aims to provide valuable insights into:

- **Consumer awareness levels:** How familiar are consumers with the concept of food adulteration and its associated health risks?
- **Identification methods:** What strategies do consumers currently employ to identify adulterated food products?
- **Common adulterants:** Which types of adulteration are consumers most concerned about in specific food items?

2. METHODOLOGY

The following sections of this paper will present the collected data on consumer knowledge about food adulteration, analyse the findings, and discuss their implications for promoting safer food practices. The questionnaire, designed to capture various aspects of consumer understanding, included sections on:

- **Sociodemographic characteristics:** This section provides a context for interpreting the data by capturing basic demographic information about the respondents.
- **Knowledge and authenticity:** This section assesses consumer awareness of food adulteration and their habits regarding food safety practices.
- **Common adulterants in specific food items:** This section explores consumer knowledge of specific adulterants found in various food products.
- **Traditional methods of detecting adulteration:** This section examines the methods consumers currently use to identify adulterated food products.

2.1. Study area

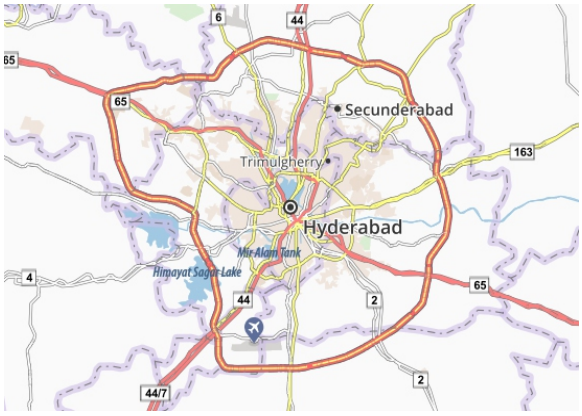

Figure 1: Radius of Hyderabad City Map; Source: [32].

This study investigated consumer knowledge of food adulteration in Hyderabad City, Telangana, India. Hyderabad is located at a latitude of 17°36′N and a longitude of 78°47′E. At an average height of 542 meters (1,778 feet), it occupies an area of about 650 square kilometers (250 square miles) (Fig.1). Hyderabad, the capital of Telangana, is India's 7th most populous city. Along with being a hub for IT, finance, and pharmaceuticals, it also has a fascinating past and is home to historical sites like the Charminar and Golconda Fort. Hyderabad is an ideal location for studying knowledge about food adulteration because of the following reasons:

- **Diverse Population:** With a population of over 35 million people, Hyderabad offers a wide range of demographics, including various income levels, educational backgrounds, and cultural influences, making it possible to collect data from a diverse sample that strengthens the generalizability of your findings.
- **Foodie Culture:** Hyderabad is renowned for its diverse food scene, featuring a mix of street vendors, upscale restaurants, and traditional Hyderabadi cuisine. This environment exposes residents to various food sources, potentially increasing their awareness of food adulteration concerns.
- **Media Exposure:** Hyderabad is a major media centre with local and national news outlets that frequently cover stories about food safety issues. This extensive media coverage can raise public awareness about adulteration practices.

2.2. Data collection and procedure

A self-designed questionnaire was employed to collect data from 418 respondents. Participants were recruited through online surveys and random in-person interviews at grocery stores and farmers' markets. The questionnaire utilised a mix of multiple-choice and open-ended questions to assess consumer awareness of food adulteration practices, their ability to identify adulterated products, and their preferred sources of information on food safety.

This study employed a hybrid data collection approach to gather comprehensive insights into consumer knowledge of food adulteration. This strategy aimed to reach a diverse population and maximise participation.

2.2.1 Offline Data Collection

- **Targeted Recruitment:** Researchers visited locations frequented by the target population (e.g., grocery stores, farmers' markets) to identify potential participants.
- ·**Informed Consent:** Researchers explained the study's purpose and obtained informed consent before administering the questionnaire.
- **Direct Interview:** Researchers directly asked participants the questionnaire questions, ensuring comprehension and clarification if needed.
- **Paper-Based Questionnaire:** A physical copy of the questionnaire was used, allowing participants to directly mark their answers.

2.2.2 Online Data Collection

- **Google Forms Questionnaire:** A user-friendly questionnaire was designed using Google Forms.
- **Accessibility:** The questionnaire was accessible through various online platforms, including social media (mention specific platforms used) and relevant websites.
- **Social Media Distribution:** Targeted social media groups (e.g., cooking groups, health groups) were used to distribute the questionnaire link.
- **Informed Consent Statement:** The online questionnaire included a clear and concise informed consent statement outlining the study's purpose and data anonymisation.

2.3 Statistical Analysis

The collected data was tabulated and analysed with the help of the statistical technique of percentage coefficient. To calculate the percentage, the frequency of a certain cell is multiplied by 100 and divided by the total responses in that particular category to determine the percentage.
The formula: Percentage = (Number of respondents in a category / Total number of respondents) x 100.

3. RESULTS

3.1 Sociodemographic characteristics:

Table 1: Sociodemographic characteristics of respondents

Characteristics	PARAMETERS	FREQUENCY	PERCENTAGE
Age	16-25	170	40.6
	26-35	108	25.8
	36-45	73	17.4
	45-55	56	13.3
	56-65	11	2.6
Sex	Male	186	44.4
	Female	231	55.2
Religion	Christianity	64	15.3
	Muslim	76	18.1
	Hindu	274	65.5
Marital status	Married	233	55.7
	Unmarried	185	44.2
Educational Background	Illiterate	96	22.9
	Primary	10	2.3
	Secondary	89	21.2
	Graduation	148	35.4
	Above graduation	75	17.9

Figure 2: Pie charts showing the Sociodemographic Characteristics of respondents and their percentages

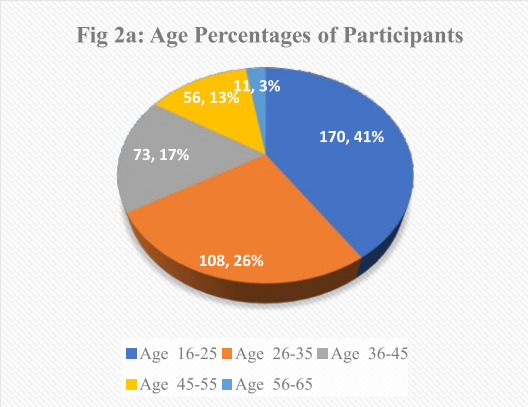

Figure 2a: Pie chart showing Age gap analysis and frequency of respondents.

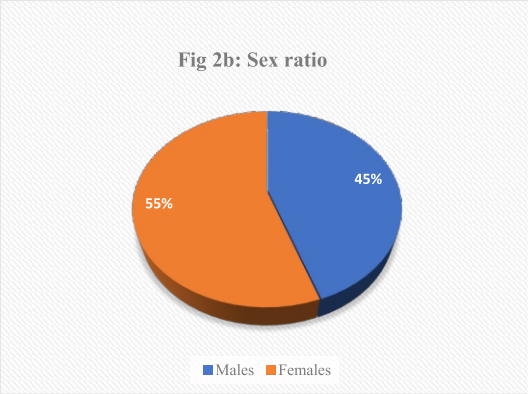

Figure 2b: Pie chart showing Sex ratio percentage of participants

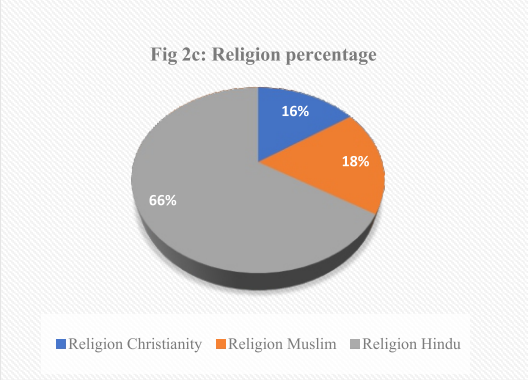

Figure 2c: Pie chart showing Religion percentage among participants

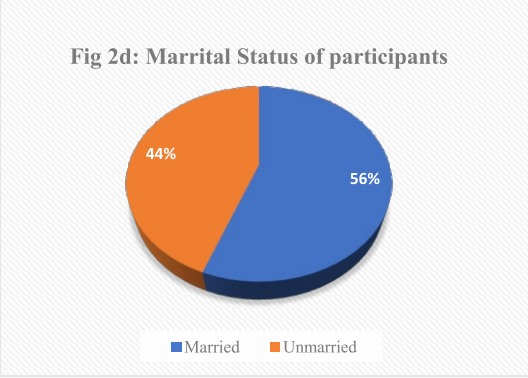

Figure 2d: Pie chart showing Marital Status of participants

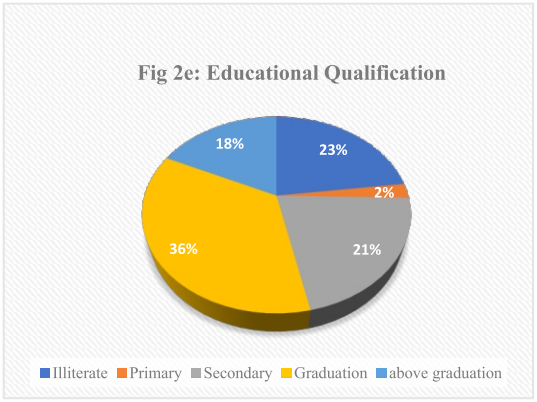

Figure 2e: Pie chart showing Educational Qualification of participants

The study recruited a total of 418 participants (Table 1). Age distribution (Fig. 2.a) revealed a concentration in the younger demographic, with 170 respondents (40.7%) falling between 16-25 years old. The remaining participants were distributed across age groups: 26-35 years (n=108, 25.8%), 36-45 years (n=73, 17.5%), 46-55 years (n=56, 13.4%), and above 55 years (n=10, 2.4%). The sample comprised 55.26% females (n=231) and 44.74% males (n=187) (see Fig. 2.b). In terms of religion (Fig. 2.c), Hinduism was the predominant faith among respondents (n=274, 65.8%). Islam (n=79, 18.9%) and Christianity (n=65, 15.3%) were also represented. The marital status (fig 2.d) breakdown showed a slight majority of married participants (n=233, 55.7%) compared to unmarried individuals (n=185, 44.3%). Educational backgrounds varied (Fig. 2.e), with 96 respondents (23%) identified as illiterate. Primary education was completed by 10 participants (2.4%), while 89 (21.3%) had finished secondary education. Graduation or higher education was attained by 223 individuals (53.3%), with 75 (17.9%) exceeding a graduate degree.

3.2. Knowledge about food adulteration and authenticity.

Table 2: Respondents' knowledge about food adulteration and authenticity.

		Frequency	%
1. Are you aware of food adulteration?	Yes	324	77.5
	No	94	22.5
2. Do you check the expiry dates before purchasing packaged food products?	Yes	227	54.3
	No	110	26.3
	Sometimes	81	19.4
3. How often do you read the ingredients list on packaged food?	Mostly	128	30.6
	Rarely	290	69.4
4. Have you ever experienced any health issues due to consuming adulteration?	Yes	216	51.7
	No	202	48.3
5. What is the most common health effect you observed after consuming adulterated food?	No	117	27.9
	Yes	301	72
	Yes, specify		
	Stomach pain	60	14.3
	Fever	36	8.6
	Vomiting	87	20.8
	Diarrhea	35	8.3
	Nausea	8	1.9
	Allergic reactions	9	2.1
	Food poison	19	4.5
	Gastric	17	4
	Diabetic	5	1.1
	Digestion problem	8	1.9
	Constipation	1	0.2
	Illness	4	3.3
	Stomach upset	4	3.3
	Stomach infection	1	0.2
	Respiratory problems	1	0.2
	Headache	1	0.2
	Liver problems	1	0.2
	Obesity	2	0.4
	Cancer	2	0.4
6. Do you buy adulterated food after knowing it is adulterated?	Yes	90	21.5
	No	328	78.5
7. What is the reason for buying adulterated food?	Easily available	118	28.2
	Less costs	154	36.8
	Lack of knowledge	114	27.3
	Long shelf life	32	7.7
8. Where do you usually buy your groceries?	Local market	265	63.4
	Supermarket	153	36.6
9. Do you trust the quality of food sold in your local market?	Yes	261	62.4
	No	157	37.6
10. Do you think local market food products will have a higher chance of adulterations than supermarket package foods?	May be	263	62.9
	May not be	121	28.9
	Yes, definitely	34	8.1
11. In your opinion why is food adulterated?	For-profits	292	69.9
	For supplying in large quantity	126	30.1
12. Are you willing to pay a premium for food products guaranteed to be adulterated?	Yes	159	38
	No	259	62
13. What do you do after knowing that food is adulterated will you consume?	Yes, will consume	82	19.6
	No, will not consume	336	80.4
14. What measures should be taken to reduce food adulteration?	Public awareness	237	56.7
	Strict laws and regulations	134	32.1
	Educational workshops	47	11.2
15. How do we know that food is adulterated?	Colour	88	21.1
	Smell	162	38.8
	Quality	168	40.2
16. How do you know about food adulteration?	Through social media	256	61.2
	Through studies	162	38.8

The survey revealed a concerning awareness of food adulteration among participants (ref. Table 2). A significant majority (77.45%) acknowledged the practice, indicating a widespread concern about food safety. While many were aware of adulteration, in-depth knowledge about specific practices seemed limited. Only slightly more than half the respondents (54.43%) reported checking expiry dates before purchasing packaged foods, suggesting a potential gap in understanding how to identify adulteration. An even smaller proportion (30.69%) said they regularly read ingredient lists, which could be another indicator of limited knowledge about potential adulterants. Interestingly, despite the high awareness of adulteration, nearly half the respondents (48.44%) hadn't personally experienced any health issues from consuming adulterated food. This could be due to under-reporting of symptoms or a lack of awareness of the connection between food adulteration and specific health problems. The survey also explored the factors influencing consumer choices when faced with potentially adulterated food. While a large majority (78.41%) said they would avoid adulterated food if they knew about it, a significant minority (21.58%) indicated they might still purchase it. This highlights the complex decision-making process around food choices, where factors like cost or limited access to safe alternatives might influence behaviour. Perceptions about the reasons behind food adulteration were also explored. The most common belief (69.78%) was that adulteration is done to increase supplier profits, reflecting concern about the economic motivations behind the practice. Finally, the survey investigated how consumers learn about food adulteration. Social media emerged as the primary source of information (61.15%), followed by quality checks by authorities (40.28%) and studies/research (38.84%). This suggests a reliance on informal channels alongside some awareness of official efforts to ensure food safety. While awareness is high, in-depth knowledge about practices and identification methods seems limited. Personal experiences with health issues might be under-reported, and economic factors influence purchasing decisions. The dominance of social media as a source of information highlights the need for reliable and accessible educational resources.

3.3: Common adulterants in food items

Table 3: Common adulterants in food items reported by the respondents

Food item	Adulterant	Frequency	%
Groundnut paste	Flour	35	8.3
	Corn flour	17	4
	Water	15	3.5
	Vegetable oil	40	9.5
	Colour	14	3.3
	Flour and oil	7	1.6
	Don't know	116	27.7
Powdered pepper	Food colour	28	6.6
	Pear seed flour	7	1.6
	Spices	47	11.2
	Flour	20	4.7
	Sawdust	14	3.3
	Cola nut	3	0.7
	Brick powder	2	0.4
	Papaya seeds	25	5.9
	Don't know	97	23.26
Tomato paste	Starch	29	6.9
	Colour	94	22.4
	Bissao leaves	13	3.1
	Don't know	108	25.8
Honey	Burnt sugar	113	27
	Water	11	2.6
	Burnt foam	7	1.6
	Starch	8	1.9
	Don't know	112	26.7
Tomato powder	Food colour (metanil yellow)	54	12.9
	Wheat flour	10	2.3
	Colour+ unknown substance	67	16
	Don't know	116	27.7
Wheat flour	Cornflour	47	11.2
	Chalk powder	33	7.8
	Gluten	38	9
	Don't know	127	30.3
Bread	Citrine	28	6.6
	Alum	89	21.2
	Don't know	122	29.1
Powdered spices	Sawdust	28	6.6
	Spoiled spices	56	13.3
	Industrial chemicals	37	8.8
	Don't know	117	27.9
Coconut oil	Shea butter (melted)	31	7.4
	Adulterated with cheaper oils like palm oil	95	22.7
	Don't know	119	28.4
Milk powder	Bread flour	17	4
	Non-dairy creamer	92	22
	Detergents	25	5.9
	Starch	12	2.8
	Don't know	106	25.3
Ginger powder	Yellow soapstone powder	79	18.94
	Do not know	160	38.36
Ice cream	Colour	46	11
	Flour	31	7.4
	Vegetable oil	32	7.6
	Starch	20	4.7
	Don't know	113	27
Beef	Colour	12	2.8
	Cheaper meat	99	23.6
	Don't know	124	29.6
Turmeric	Colour	40	9.5
	Sawdust	13	3.1
	Yellow dye (metanil yellow)	92	22
	Chalk powder	13	3.1
	Don't know	86	20.5
Milk	Water	142	33.9
	Flour	6	1.4
	Starch powder	50	11.9
	Chalk powder	17	4
	Urea	30	7.1
	Detergent	13	3.1
Olive oil	Tea tree oil	26	6.2
	Other vegetable oil	93	22.2
	Don't know	114	27.2
Sugar	Chalk powder	42	10
	Flour	32	7.6
	Washing powder	18	4.3
	Don't know	148	35.4
Black Pepper	Papaya seed	124	29.6
	Don't know	115	27.5
Coffee seed powder	Tamarind seed powder	67	16
	Burnt sugar	42	10
	Don't know	127	30.3
Kebab powder	Pear seed Powder	40	9.5
	Artificial colour	72	17.2
	Don't know	122	29.1
Tea leaves	Coloured leaves	71	16.9
	Artificial colouring agents	102	24.4
Common salt	Kadamire brick powder	39	9.3
	Flour	24	5.7
	Chalk powder	35	8.3
	Talk powder	23	5.5
	Gypsum	35	8.3
Pulses	Dyes	57	13.6
	Sand	89	21.2
	Stones	89	21.2
Fruits and vegetables	Cobalt	28	6.6
	Malachite green (preservative)	62	14.8
	Artificial ripening agents	87	20.8

Participants were asked to identify common adulterants frequently found in commonly used food products such as groundnut paste, powdered pepper, honey, wheat flour, and bread. The findings were tabulated in Table 3. According to the respondents, the food items most vulnerable to adulteration are milk, pulses, fruits, and vegetables. Following closely are turmeric, common salt, milk powder, honey, and tomato paste.

Findings on milk, the most frequent adulterant reported by respondents was water, with 33.9% and starch was the second most frequently reported adulterant, with 26.04%. The data shows that dyes, sand, and stones were frequently reported as adulterants. Among the respondents, 57 (13.6%) indicated finding dyes, while a significant number, 89 each (21.2%), reported encountering sand and stones in pulses. This suggests that a substantial portion of respondents have come across adulterated pulses, highlighting a potential food safety issue. The data on fruits and vegetables raises some concerns. Cobalt, malachite green (a preservative), and artificial ripening agents were reported as frequent adulterants. Among the respondents, 28 (6.7%) mentioned cobalt, 62 (14.8%) reported malachite green, and a concerningly high number, 87 (20.8%), indicated the presence of artificial ripening agents. The data also revealed that a considerable number of respondents were uncertain about the potential adulteration in various food categories, including ginger powder, sugar, coffee seed powder, kebab powder, and bread. This highlights a potential knowledge gap regarding food adulteration. Some respondents reported not consuming products like kebab powder, olive oil, beef, bread, and honey. Olive oil, in particular, was cited as a less preferred option due to its non-indigenous nature and higher cost. Additionally, the established use of sunflower and peanut oils within local diets influenced the consumption choices of respondents. Similarly, many respondents prepared their own powdered spices, pepper, groundnut paste, and ginger paste at home, explaining their lower consumption of these products. Regarding beef, only 79 respondents identified as Muslim consumers, with the remaining participants abstaining due to religious reasons. Lastly, a smaller group expressed unfamiliarity or a lack of habit in consuming kebab powder, bread, and honey.

3.4: Food products and their means of detection

Table 4: Traditional methods of detection of food adulterants by respondents

Food products	Means of detection	Frequency	%
Groundnut Paste	Not smooth or presence of particles	33	7.8
	Thickening of soup	18	4.3
	Whitish appearance	31	7.4
	Lighter appearance with oil	34	8.1
	The gel-like consistency of soup	17	4
Powdered Pepper	Looks very red	25	5.9
	Pure black pepper sinks in water, while adulterated powder might float	38	9
	Different odour other than that of pepper	33	7.8
	Taste sweet	16	3.8
	Smells differently	14	3.3
	Mostly moist because of the adulterants	9	2.1
Tomato Paste	Flour addition makes it very thick	60	14.3
	Looks pale than the usual red colour	72	17.2
Honey	The presence of sugar attracts ants	39	9.3
	Watery when diluted with water and spreads easily	19	4.5
	Flammable when pure	16	3.8
	Stomach upset after consumption	13	3.1
	Rubbing in the palm to check for the presence of particles	5	1.1
	A cotton wick dipped in pure honey will burn, but a cracking sound will be heard if there is water in the	6	1.4
	Put a spoon of honey in a cup of water; pure honey will settle at the bottom	11	2.6
	Pure honey will not freeze in a freezer	4	0.9
	Change in original taste and thickness	5	1.1
	Adulterated honey will break at intervals when pouring it out from a spoon or container	1	0.2
	Pure honey will settle when mixed with water, but adulterated one will mix quickly with water	16	3.8
	Pure honey leaves traces on a smooth surface	3	0.7
Tomato powder	Unknown particles settle when mixing with water in a container	55	13.1
	Looks very red	78	18.6
Wheat flour	Add wheat flour to a glass of water. If the flour is pure, it will settle at the bottom of the glass. If it is adulterated, it will float on the surface or form lumps.	60	14.3
	Add wheat flour to water and make a dough, knead the dough under running water for a few minutes if the water turns milky white it indicates the presence of starch	69	16.5
Bread	The addition of citrine makes the bread very sweet	126	30.1
Powdered Spices	Mix with water and allow to settle. Adulterants will suspend	124	29.6
Coconut oil	Pure coconut oil is transparent and colourless when in liquid form. If it appears cloudy or has a yellowish tinge, it may be adulterated.	80	19.1
	Pure coconut oil has a distinct aroma of coconut. If the oil has a rancid or stale smell, it may have been mixed with other oils or gone bad.	57	13.6
Milk Powder	Mix with water, and adulterants will suspend	123	29.4
Ginger Powder	It will not smell and taste like the original ginger	124	29.6
Ice cream	Looks like porridge when flour is added	125	29.9

Meat (beef)	Soaking in water will get rid of the adulterants (colour)	124	29.6
Turmeric	Take a small amount of turmeric powder and add a few drops of water to it. If the water turns reddish-brown, it is a sign of the presence of metanil yellow dye	59	14.1
	Rub a piece of raw turmeric on a rough surface. If it is pure, it will leave a bright yellow colour, but if it is adulterated, the colour will be dull or pale.	55	13.1
	Check for the presence of chalk powder by adding turmeric powder to a glass of water. If the powder settles at the bottom of the glass, it is pure, but if it floats or leaves a white residue, it is adulterated.	19	4.5
Milk	Put a drop of milk on a vertical surface; if it flows slowly, then it is not adulterated	47	11.2
	Pure milk will leave traces when allowed to flow on a smooth surface	43	10.2
	Taste different	37	8.8
Olive oil	Taste different	42	10
	Staining on the tongue after consumption	21	5
	The colour changes to dark red upon heating indicating adulteration	35	8.3
	Iodine test for adulteration with starch	18	4.3
Sugar	Dissolve sugar in water; the presence of white precipitate indicates adulteration with chalk	128	30.6
Black pepper seed	Black pepper seed will sink in alcohol while papaya seed will float	122	29.1
Coffee	Add coffee powder to water; if the powder settles, it is adulterated	120	28.7
Kebab powder	Colour change with water (mix a small amount of kebab powder with water and observe the colour of the mixture. If the colour changes to red or pink, it may indicate the presence of artificial colouring agents).	119	28.4
Tea leaves	Observe for artificial colours in water (place a small number of tea leaves in a glass of water and observe if any artificial colours are being released).	62	14.8
	Burn a small number of tea leaves and observe the colour of the ash. If the ash is grey or white, it indicates that the tea leaves are pure. However, if the ash is yellow or any other colour, it may indicate the presence of adulterants	38	9
	Mix tea leaves with common salt and observe if any yellow colour is produced. If so, it may indicate the presence of metanil yellow, a harmful chemical that is often used as an adulterant in tea leaves	21	5
Common salt	Observation of texture and taste.	65	15.5
	Detection of impurities by visual inspection	63	15
Pulses	Soaking in water and observing for added colours	65	15.5
	Crushing and visual inspection for foreign matter like stones, sand	66	15.7
Fruits and vegetables	Observation of colour, texture, and smell.	46	11
	Detection of pesticide residues by washing and testing.	44	10.5
	If a fruit smells or tastes unusually sweet, it may indicate that sugar has been added to enhance its flavour.	42	10

The respondents chose different traditional methods for detecting food adulteration from the given questionnaire, as shown in Table 4. There are many simple visual, olfactory, and taste tests available to identify adulteration in different foods. For instance, spice or turmeric powders with a stronger colour may be visually indicative of adulteration. Similar visual cues can be used to identify papaya seeds in black pepper and stones in pulses. Adulterants can be distinguished from coconut oil by its unique scent; if the oil smells different, it might be tainted. Certain foods can also be confirmed at home with easy testing. For example, a straightforward water test can be used to check for adulteration in honey. While contaminated honey may dissolve or create a murky solution in water, pure honey will not. These simple tests can be useful resources for customers to ensure. A majority of 59 respondents suggested a simple water test for detecting adulteration in turmeric powder. Adding a few drops of water to turmeric powder and observing a reddish-brown colour could indicate the presence of harmful metanil yellow dye. Another method, mentioned by 55 respondents, involves rubbing raw turmeric on a rough surface. Pure turmeric leaves a bright yellow stain, whereas a dull or pale colour might suggest adulteration. To detect adulteration in coconut oil, rely on your senses. Eighty respondents reported that pure coconut oil is transparent and colourless when liquid. Cloudiness or a yellowish tinge could indicate adulteration, as noted by some respondents. Furthermore, 57 respondents noted that the aroma of pure coconut oil is distinctively coconut-like. If the oil smells rancid or stale, it may be combined with other oils or has gone bad. There have been reports of several conventional techniques for identifying adulteration in pulses. Soaking in water (65 respondents) helps identify added colours that may leach into the water. Crushing and visually inspecting for stones, sand, and other foreign matter was mentioned by 66 respondents. Finally, 46 respondents suggested observing the colour, texture, and smell of pulses for any abnormalities.

A significant number of respondents (128) reported a simple water test for identifying adulteration in sugar. Dissolving sugar in water and observing a white precipitate indicates the presence of chalk powder, a common adulterant. A clever test using alcohol was mentioned by 122 respondents. Pure black peppercorns sink in alcohol, while adulterants like papaya seeds float.

4. DISCUSSION

Adulteration of food is a major concern as it reduces the quality of food either by adding low-quality materials or by removing valuable components from the food. It is estimated that approximately 5 to 9% of the global food trade is adulterated [33]. This study revealed that 77.45% of the respondents were aware of food adulteration, but only 54% were checking expiry dates. The main reason for not checking expiry dates was that they were buying loose food products from local markets, thus they don't have expiry dates, such as flour, pulses, and oils. Surprisingly, only 30% of the respondents were reading the ingredients list, with reasons cited including lack of time, educational qualifications, and language being another problem, as this study is conducted in the Telangana region. Most people know Telugu, and some are not able to read English. The study also found that 96 illiterate participants were unaware of adulteration and unable to read the ingredients list, which is often in English.

Nearly 69.9% of the respondents believed that the reason behind food adulteration was for profit, which aligns with the concept of economically motivated adulteration (EMA). According to [34] Food adulteration is driven by financial gain, with food businesses adding cheaper and lower-quality ingredients to food products to increase their profit margin. Common forms of food adulteration include adding water to milk, mixing sawdust with ground spices, and incorporating synthetic colours into fruits and vegetables. Additionally, [35] that the lack of proper ingredient regulation and enforcement of food safety standards contributes to food adulteration. Weak food laws and understaffed or corrupt regulatory agencies in many countries create an environment where dishonest food businesses can engage in food adulteration without consequence. Further, some respondents mentioned that they would still consume adulterated food despite being aware of its adulteration, attributing this to financial issues and the perception that local market food products are cheap and highly prone to adulteration. Lack of knowledge about adulterated products and the availability of such products at low prices in markets were also cited as reasons for purchasing adulterated food products.

Most food items, ranging from milk to fruits and vegetables to grains, are adulterated to some extent. Adulterants can enter during agricultural processes when items are not thoroughly cleaned, and these can include visible adulterants such as stones, leaves, soil, and dust. While consumers can remove these adulterants through cleaning, other intentionally added adulterants are invisible or made to be invisible. These adulterants are generally harmful to health and can lead to serious problems such as cancer [36]. Colouring agents such as Sunset Yellow are sometimes added to turmeric and dal. Additionally, chalk powder can be used in sugar, papaya seeds in black pepper, and coloured leaves in tea [37].

4.1. Milk

Milk is adulterated with water [38-39], Flour, detergent, starch powder, chalk powder, and urea are other commonly used adulterants in milk [40-44]. Milk is mixed with water and commercial urea to raise its quantity and non-protein nitrogen content, respectively [45]. To increase their profits, producers of milk and dairy products remove the fat from the milk and replace it with non-dairy fat like vegetable oil. The oil is emulsified and dissolved in water with the addition of detergents, creating a frothy solution that is what is desired for milk [46]. Analysing 60 samples of milk in Faisalabad, a city in Pakistan, they found that milk is adulterated by water, urea, formalin, and hydrogen peroxide. In a study conducted by [47] it was found that NIR (Near Infrared spectroscopy) combined with multivariate methods can effectively and non-destructively detect and measure the presence of urea adulteration in various fresh milk samples. The study showed that the partial least-squares discriminant analysis (PLS-DA) model can accurately differentiate between milk samples adulterated with urea and fresh, unadulterated samples. Additionally, partial least-squares regressions (PLSR) models can be used to quantify the level of urea adulteration in milk samples. In this study, 142 respondents reported water as an adulterant in milk, followed by starch powder and urea, reported by 50 and 30 respondents, respectively. Adulterated milk causes digestive system disorders [48] and kidney damage with long-term consumption [49]. In 2012, a study conducted by the Food Safety Standards Authority of India (FSSAI) across 33 states found that milk in India is often adulterated with detergent, fat, and even urea, as well as diluted with water. Out of the 1791 random samples taken, only 31.5% (565) met the FSSAI standards, while the remaining 68.4% (1226) failed the test. This study is commonly referred to as the 2012 India milk adulterant scandal [50]. In a study conducted by [51-55] in Sudan, three hundred milk samples were collected from three distinct regions, and they were examined for the presence of starch adulteration, revealing that 35.5% of the samples were found to be adulterated with starch [53].

4.2. Turmeric

Turmeric is a popular herb that has anti-inflammatory properties. However, due to its widespread use, there have been concerns about adulteration, which has compromised the quality of the herb and may pose health risks. As a result, it is imperative to ensure that the public is protected by consuming high-quality, unadulterated turmeric [54]. Metanil yellow, sawdust, chalk powder, Sudan dye, and lead chromate are commonly used adulterants in turmeric [55-59]. [60] examined the presence of metanil yellow in turmeric powder using FT-Raman and Fourier transform infrared (FT-IR) Spectroscopy. The study detected a 5% concentration of metanil yellow in turmeric. Aniline dye-adulterated turmeric is carcinogenic [61-62]. In this study, nearly 92 participants reported the presence of metanil yellow in the turmeric. They also mentioned that the packaged turmeric has a brighter yellow colour than the pure turmeric that they make using dried turmeric roots. For the detection of adulterants few traditional methods were reported by respondents as mentioned in Table 3.4.

4.3. Coconut oil and Olive oil

There are two primary ways that edible oils and fats can be adulterated: 1) combining refined and cold-pressed oil, and 2) switching the pricey oils with cheaper ones [63]. Coconut and olive oils are adulterated with low-priced oils due to their greater market demand [64]. For example, olive oil is often mixed with vegetable oils like canola, rapeseed, and mustard to increase profits, which has become a significant issue [65-67] states that oil adulteration can lead to glaucoma, dropsy, glaucoma, blindness, paralysis, liver damage, and cardiac arrest. Over 600 people in Spain perished from "olive oil syndrome" as a result of the sale of inedible rapeseed oil as edible. According to a study by [68] it was found that olive oil may be adulterated with various substances, including sunflower oil, soybean oil, cottonseed oil, walnut oil, and animal fat. This indicates that there may be potential issues with the purity and authenticity of olive oil products in the market. Virgin coconut oil (VCO) might be adulterated with cheaper oils, like palm oil (PO). Thus, Fourier transform infrared (FTIR) spectroscopy was used to monitor the detection and quantification of VCO adulteration with PO [69]. In this study, 93 respondents stated that olive oil is adulterated with other vegetable oils, while in another study by [70] it was reported that at least 80% of extra virgin olive oil in Italy is adulterated with low-quality vegetable [71] .95 respondents believe that coconut oil is adulterated with cheaper oils like palm oil. Also, 119 and 114 respondents were unsure about the adulterants used in coconut oil and olive oil, respectively, and 80 respondents indicated that pure coconut oil is transparent and colourless when in liquid form. If it appears cloudy or has a yellowish tinge, it may be adulterated. 57 respondents mentioned that pure coconut oil has a distinct aroma of coconut.

4.4. Pulses

For pulses, the presence of sand and stone was reported by 89 respondents. Food grain adulteration involves mixing sand or gravel to increase the weight of the food grains. The cereal grains and pulses were mixed with plastic beads that resembled grains in colour and size [73]. Water is also sprayed on grains to increase their weight [72]. The most commonly adulterated type of lentils is Tur (arhar) dal, which is often mixed with a substance called metanil yellow. Metanil yellow is a type of food colouring that is not allowed to be used, but is still used frequently. Long-term consumption of metanil yellow can harm the developing and adult brain, causing neurotoxicity [74]. 65 respondents from this study observed added colours by soaking pulses. Sand, stone, marble chips, and filth are used as adulterants in food grains and pulses, which cause damage to the digestive tract [75]. Kesari dal is an adulterant that is cheap and looks similar to tur dal is found in pulses and besan, causing paralysis of the legs [70].

4.5 Fruits and Vegetables

Fruits and vegetables are crucial sources of essential vitamins and minerals. However, due to the indiscriminate use of pesticides and unhygienic practices in the supply chain, fresh produce often becomes contaminated [12]. Vegetables are often contaminated with malachite green, a chemical dye known to be carcinogenic.

Common adulterants in fruits and vegetables include oxytocin, saccharin, wax, calcium carbide, and copper sulfate [18] According to [22] vegetables are often adulterated with malachite green, a chemical dye that gives a bright glowing colour and is known to cause cancer. Calcium carbide is used to artificially ripen green fruits quickly, such as bananas, mangoes, guavas, papayas, tomatoes, and pineapple. Arsenic (Pesticide) is an adulterant that can be found in fruits like apples, which are often sprayed with lead arsenate. It can cause symptoms such as dizziness, chills, cramps, paralysis, and even death. Fluoride is found as an adulterant in drinking water, seafood, tea, etc., and excessive accumulation can lead to fluorosis, resulting in tooth discolouration and skeletal and neurological disorders. Pesticidal residue is an adulterant found in all types of food, causing both acute and chronic poisoning and damaging nerves and vital organs like the liver and kidneys. Oxalic acid is an adulterant found in spinach, amaranth, etc., and can cause renal calculi, cramps, and failure of blood to clot [19]. In this study, 87 respondents reported the use of artificial ripening agents in fruits and vegetables as adulterants. Sixty-two respondents mentioned the use of malachite green, and 28 respondents reported the use of cobalt as an adulterant.

4.6. Beef Meat

In a study by [54] It was discovered that beef meat products were adulterated. Through the use of drop polymerase chain reaction, 46 commercial samples were tested, revealing that the maximum mass ratio of beef was 19.6%. This indicates the presence of adulteration in the market. The addition of cheaper meats to more expensive varieties is a method for achieving significant economic gain in the current market. An investigation conducted in China on meat product adulteration revealed a disturbing trend. Beef and mutton, being more expensive cuts, were frequently substituted with cheaper meats like chicken, pork, or duck. Dishonest vendors capitalised on this practice to increase profits 43]. Additionally, 99 respondents to this survey stated that cheaper meat is used in place of beef.

4.7. Spices

Spices are economically important due to their various functions such as taste, colour, smell, preservatives, and medicinal properties. India is a major exporter of spices, accounting for around 12% of all spice exports worldwide, with a value of approximately $4 billion [24]. Since they are usually obtained in powdered form, adulteration is a possibility. Approximately 7% of spice lots were rejected due to accidental adulteration [21]. Black pepper, ginger powder, kebab powder, and black pepper powder are adulterated with papaya seeds, sawdust, brick powder, chalk powder, and artificial colours [65]. Spice adulteration happens in India due to several circumstances to maximise profits. Producers and merchants frequently adulterate spices to increase volume and reduce expenses [52]. These adulterants cause liver disorders [12] and cardiac arrest [56]. From this study, 72 respondents reported artificial colour in kebab powder, 124 reported papaya seeds in black pepper, and 42 members reported sawdust in powdered spices and powdered pepper together. Adulteration of black pepper with papaya seeds can be detected by observing flotation in water and examining physical characteristics under a magnifying glass [43]. In Kolhapur, Maharashtra, India, Sayali Harke conducted a study to find out how common it is to adulterate black pepper with papaya seeds. Papaya seeds were discovered in both of the black pepper samples analysed for the study by using the floating seeds in water method of detection, suggesting a high degree of impurity in the local market [43].

4.8. Tomato Powder

A report by the Food and Drug Authority (FDA) in Ghana stated that what is being sold on the Ghanaian market as tomato powder is annatto seed powder. Food vendors occasionally colour flour, such as cassava flour or wheat flour that has gone bad, and pass it off as tomato powder. There isn't any tomato powder available in Ghana right now 78 survey participants stated that they have observed tomato powder with a stronger red colour, which is an indication of adulteration.

4.9. Honey

Honey is one of the most commonly adulterated foods. This study found that 113 respondents indicated that burnt sugar is added to honey to increase quantity, along with burnt foam and starch. There are two ways that sugars can be employed as adulterants: direct adulteration and indirect adulteration. Indirect adulteration involves overfeeding bees with sugar syrups to boost honey yield in hives, whereas direct adulteration involves adding a specific ratio of sugar syrups to harvested honey to increase its sweet flavour [44]. Sayali Harke used a conventional cotton wick method to analyse the adulteration of honey with sugar and water. Analysis of two samples of honey revealed the presence of adulterants. When the cotton wick was lit, it made a characteristic cracking sound that indicated the honey sample had been mixed with water and sugar [23]. Honey adulteration can harm a consumer's health and nutrition in addition to affecting the product's chances on the domestic and international markets [20]. Honey adulterated with water causes small intestine problems and appendicitis. According to a study conducted by the Centre for Science and Environment, most honey brands being sold in the country contain varying amounts of antibiotics. Consumption of such honey over time could lead to antibiotic resistance, blood-related disorders, and injury to the liver.

Table 5: Reasons behind adding adulterants and their health effects

Question	Adulterant	Reason for Addition	Health Effects	Reference
Groundnut Paste	Flour, Corn flour	increase weight and volume at a lower cost	Reduced protein and fat content, Nutritional Deficiency	[1]
Powdered pepper	Food colour	Enhance colour	Eye and skin irritation (certain colours	[2]
	Pear seed flour	Mimic black pepper at a lower cost	Potential digestive issues	[3]
	Sawdust	Increase volume at a very low cost	Respiratory problems, allergic reactions	
Tomato Paste	Starch	Thicken consistency	Reduced tomato content, digestive issues	[4]
	Colour	Enhance color	Potential allergic reactions to additives	[4]
Honey	Burnt sugar	Mimic the colour and taste of honey	Difficulty controlling blood sugar for diabetics-II, obesity abnormal weight	[5]
	Starch	Thicken consistency	Reduced honey content, digestive issues	[6]
Tomato powder	Food colour (metanil yellow)	Enhance color	Potential for carcinogenicity, neurological damage, kidney failure	[7]
	Colour plus unknown substance	Enhance colour and potentially mask spoilage	Difficulty assessing quality and potential health risks	
Wheat flour	Corn flour	Reduce cost	Reduced protein and gluten content	[8]
	Chalk powder	Whiten flour appearance	Reduced nutritional value, potential lead poisoning	
Bread	Alum (whitening agent)	Whiten bread crumb	Respiratory problems, stomach upset (high intake)	[9]
Powdered spices	Sawdust	Increase volume at a very low cost	Respiratory problems, allergic reaction	[10]
	Spoiled spices	Reduce waste	Potential for mold toxins and bacteria	
Coconut oil	Adulterated with cheaper oils like palm oil	Reduced cost	May affect the quality and nutritional profile, coronary heart disease	[11]
Milk powder	Non-dairy creamer	Reduce cost	Reduced protein and lactose content, Digestive disorders	[12]
	Starch	Increase volume	Reduced milk powder content	[13]
Ginger powder	Yellow soapstone powder	Mimic the color of ginger	Reduced ginger content, potential for lung problems with long-term exposure	[14]
Ice cream	Colour	Enhance colour	Eye and skin irritation (certain colours)	[15]
	Starch	Thicken texture	Increased sugar intake	[16]
Beef	Cheaper meat	Reduce cost	May affect quality and introduce contaminants from other animals	[17]
Turmeric	Yellow dye (metanil yellow)	Enhances colour	Toxic and potentially carcinogenic	[18]
	Chalk powder	Reduce cost	Reduced curcumin content (active ingredient), potential digestive issues	[19]
Milk	Water	Increase volume	Reduced milk fat and protein content	[20]
	Urea	Increase milk nitrogen content (mimics protein)	Kidney damage with long-term consumption	[21]
	detergent	To increase viscosity	Gastrointestinal complications, gastritis	[21]
	Starch	To keep its density	Diarrhoea	[22]
Olive oil	Other vegetable oil and rapeseed oil	Reduce cost	Nutritional deficiencies, kidney or liver disorders	[23]
Sugar	Chalk powder	Increase volume	Reduced sugar content, potential stomach infections	[24]
	Flour	Increase volume	Reduced sugar content, potential digestive issues	[25]
Black pepper	Papaya seed	Mimic black pepper at a lower cost	Papain content may cause uterine contractions and can lead to abortions	[26]
Coffee seed powder	Tamarind seed powder	Mimic coffee colour and texture	Potential digestive issues, diarrhoea	[27]
Kebab powder	Artificial colour	Enhance colour	Potential allergic reactions to additives	[28]
Tea leaves	Coloured leaves	Mimic the appearance of higher-quality tea	Liver Disorders	[29]
Common salt	Gypsum	Increase volume and weight	Reduced salt content, potential digestive issues due to sulfate content	[30]
Pulses	Dyes	Enhance color	neurotoxicity in the developing and adult brain	[31]
	Sand	Increase weight at a very low cost	Digestive problems, potential tooth damage	[32]
	Stones	Increase weight at a very low cost	Choking hazard, digestive problems	[33]
Fruits and vegetables	Malachite green (preservative)	Prolongs shelf life and gives a bright, glowing colour	Banned in many countries due to potential carcinogenicity	[34]
	Artificial ripening agents	Ripen fruits faster	May accelerate spoilage and reduce nutrient content	[34]

Table 5 provides detailed information about the various adulterants added to different food products, the reasons behind their addition, and their health effects. Food adulteration occurs for a variety of reasons, from cost-cutting and financial gain to prolonging shelf life and improving aesthetic appeal through unethical techniques like dilution, substitution, and contamination that raise health risks and undermine nutritional value and safety [3]. These adulteration practices pose a significant threat to consumer health. Adulterants such as flour, colourants, and cheaper substitutes are added to increase volume, enhance colour, or reduce costs. However, these practices lead to reduced nutritional value, potential digestive issues, allergic reactions, and even serious health risks such as carcinogenicity, Respiratory problems from sawdust, Kidney damage from long-term consumption of adulterated milk products, Severe stomach upset and organ damage from illegal adulterants like detergent. Adulteration is prevalent in a wide range of products, including groundnut paste, honey, tomato paste, spices, coconut oil, milk powder, turmeric, and even basic food items like salt and pulses. Additionally, harmful substances like detergent, urea, and malachite green are used, posing severe health risks.

5. CONCLUSION

The study's conclusions highlight the urgent need for increased consumer education and more stringent laws to address the widespread problem of food adulteration. Although customers show that they grasp the issue in general, they frequently don't know specifics regarding the kinds of adulterants and how common it is for items to be tainted. The deceptive tactics used by suppliers, such as false expiration dates, inadequate ingredient lists, and misleading labelling, are to blame for this lack of awareness. The widespread problem of food adulteration in the market has been brought to light by this study, along with its negative effects on consumer confidence and public health. The study found notable gaps in consumer practices and understanding related to food adulteration detection, despite increased awareness. The results point to the necessity of more consumer education and awareness initiatives to provide people with the power to make wise decisions and shield themselves from the dangers of contaminated food items. Numerous food commodities, including milk, turmeric, coconut oil, olive oil, legumes, fruits, vegetables, and spices, were shown to be susceptible to adulteration. Water, fake colouring, chemicals, and inferior replacements were common adulterants. These adulterants carry significant health hazards, which can include neurological disorders,

cancer, and digestive problems. The study also highlighted the economic motivations behind food adulteration, driven by the desire for profit maximisation. This practice not only compromises food quality but also undermines consumer trust and confidence in the food industry.

It takes a diverse approach to solve this problem. Enforcing strict laws and regulations that are in line with FSSAI standards can guarantee that food products are produced and distributed in compliance with predetermined protocols. Additional measures to protect consumer health include requiring the disclosure of all chemicals used and reducing the use of dangerous additives, preservatives, colours, and ripening agents. Furthermore, it is important to foster consumer awareness via focused educational initiatives. We can enable customers to make educated decisions and hold food suppliers to better standards by educating them on the frequency of food adulteration, the possible health hazards associated with tainted products, and easy detection techniques. In the end, this study highlights how crucial it is for government organisations, consumer advocacy groups, and food producers to work together to develop a more secure and open food chain. We can strive toward a future where customers may confidently enjoy a healthy and authentic food supply by tackling the underlying causes of food adulteration and raising consumer awareness.

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