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Detection of adulteration in daily food items : Insights into laboratory procedures

Monika Koul[1]*, Romila Rawat Bisht[1] and Arjun Adit[2]

Abstract

Food adulteration is a widespread global problem. Consumption of adulterated food has both short and long- term health implications. Presence of adulterants in immunity booster foods, plant beverages, spices and condiments are a growing cause of concern as these are taken almost daily and can pose high health risks. Most incidents of the food adulteration go unnoticed as small doses of adulteration do not show immediate effects. Deaths of infants and children due to intake of adulterated food, especially infant milk and powder milk has pushed the regulatory agencies to impose strict penalties on individuals and industries involved in such acts. Detection of adulterants require huge investments and often regulatory agencies, or small food testing labs do not get adequate support to setup of sophisticated equipment for detection of adulterants. Therefore, microscopic techniques and micro-chemical tests that do not need extensive paraphernalia and that can be carried out in any basic science laboratory can be reliable and alternative methods to detect adulteration in common food samples. These techniques are scientific, qualitative standard techniques that are authenticated and accepted worldwide. Lately, techniques like DNA analysis and ELISA based techniques are also being used for detection of food adulterants. Sensors with enzyme-based probes are also being used and these are used by many industries. However, the methods come with their own pros and cons. Further improvements in the techniques that are portable and simple will help in containing and detecting the problem of adulteration. The methods are cost-effective and approved by the food regulatory agencies and certified protocols are available. The methods are mostly qualitative and are reliable and dependable.

Key words: Adulteration, Health risk, Laws, Regulations, Laboratory methods

1. Introduction

Food is an important resource that is required to lead a healthy life. Food contains carbohydrates, proteins, fats, vitamins, and minerals that provide nutrition to the body, helps in the growth of the body and build a strong defence system to fight diseases (Das et al., 2017; Uauy 2005). It is not only the quantity of food but the quality of food that is important to lead the healthy life (Chen 2011). The quality of food is compromised on account of various reasons such as improper storage, contamination on field or during transport or due to adulteration (Grunert 2005). Most of the food that is derived from natural resources in unprocessed form is generally unadulterated. Adulteration of food can occur unintentionally at various stages of supply chain or is carried out with a proper intent (Khan 1992). Around fifty seven percent of people across the globe have developed health problems due to ingestion of adulterated and contaminated foods. It is estimated that around 22% of foods are adulterated every year. According to Singh and Dwiedi (1995) the incidents of food adulteration all over the world and in India increased substantially due to spurt in small and medium scale food processing units. Food adulteration has been termed as an emergency as ingestion of adulterated

* Corresponding Author
1. Department of Botany, Hansraj College, Delhi-110007
2. Department of Botany, University of Delhi, Delhi-110007

food items is causing adverse health effects. Incidents of adulteration of basic food items such as cereals, pulses, oilseeds, spices, and food products derived from these have been reported in many countries including India (Srivastava 2015; Verdu 2016). Debasing the quality of food intentionally by either adding or replacing the food substances with undeclared alternative components has become a regular practice of some traders. Food industry has also noticed that some traders indulge in removal of some valuable components from the food which is also considered as a fraudulent practice by the industry. It has also come to the notice of Food Corporation of India (FCI) that many food commodities from India that were exported were confiscated and rejected on the grounds of adulteration. Practices such as addition of some flavours and substances to improve shelf life of processed food items randomly can also result in food adulteration. According to a study carried out on the meat products by Montowska and Fornal (2019) fraudulent adulteration of food products with undeclared components might also have allergenicity potential. Food adulteration practice by unscrupulous traders is usually done to lower the cost of the food items so that sales can be improved. Small vendors add cheap adulterants to increase the bulk of a given food product for economic gains. In a review on adulteration of food at global level, Ayeza and Billet (2015) have pointed out that food adulteration is a global problem and the industry and market of adulterated food constitutes a billion-dollar industry.

Food adulteration besides having health implications also has economic implications on a country like India. India is an exporter of spices, beverages, and many other plant-based foods. Jaffee (2005) in an exhaustive economic evaluation study on adulteration of spices pointed out that many consignments of red chilli were recalled by European Union as these were found to be adulterated with Sudan III. Common food commodities like milk, milk products, pulses, spices, packaged juices and meat and poultry products collected from various places in separate studies by CSE (Centre for Science and Environment) and Food Safety and Standards Authority of India (FSSAI) laboratories have found some amount of adulteration in all India survey of food items by random sampling. Scientists working in food industry and research institutes have studied the impact of adulterants in food on nutritional quality and other parameters. It is important to forecast risks involved in food adulteration as it can protect the consumers. People who are at more risk, especially people with comorbidities, children infants and adults should be protected, and adequate care should be taken about their diet. However, it is only after the comprehensive food policy that adulteration of food was noticed as an issue requiring concern. It was clearly mentioned that Food Testing and Analysis is an essential part of the food safety ecosystem of the country. FSSAI recognizes and notifies NABL accredited food laboratories under Section 43 of FSS Act, 2006 and these laboratories have been licensed to test the food items for their health and nutritional quality and to detect the fraudulent adulteration. Government of India has also clearly specified the punishment and penalties to be imposed on people or an industry who are found guilty of any adulteration in the food. The consumer protection bill presented in the parliament on 5th January 2018 called for strict punishment for person who indulges in fraudulent practice of adulteration.

2. Food Safety Regulations, Government of India (2011)

Food Safety and Standards, Government of India, Ministry of Health and Family Welfare has put forward various regulations regarding the food safety issues. These regulations are important from the consumer perspective as these are guiding principles from food processors, manufacturers, small traders, and other organizations that are involved in packaging, storage and procuring of food. Main guidelines that are included in 2011 document include: Licensing and Registration of Food Businesses by both small and medium enterprises; Packaging and Labelling of food; Laboratory and Sampling Analysis of processed and unprocessed food and Food Product Standards and Food Additive Regulation.

Besides, the laws and legislations that meet the consumer needs are important. It is also important that consumers are made aware about the undesirable components in food, health implications.

Punishment for Adulteration

1. Minimum imprisonment of six months and a minimum fine of Rs 1,000 is penalty for the person who is convicted for import, manufacture, storage, sale, or distribution of adulterated food.

2. Penalty is minimum imprisonment of six months that may extend up to 3 years and minimum fine of Rs 1,000 is the punishment sanctioned for import, manufacture, storage, sale, or distribution of food that causes adverse health impacts.
3. Imprisonment of six months that may extend up to 3 years and minimum fine of Rs 1, 000 if problems are created while audit and collection of food samples by food inspectors.
4. Minimum imprisonment of six months that may be extended up to 3 years and minimum fine of Rs 1, 000 can be put on person who gives false warranty for the quality of food.
5. Minimum imprisonment of one year that may extend up to six years and minimum fine of Rs 2, 000 for safe and distribution of adulterated food.
6. Minimum imprisonment of three years that may extend up to life and minimum fine of 5, 000 rupees for sale or distribution of food products that are likely to cause death or serious harm to the body.

3. Adulteration of Common Food items of daily use

The recent data of food items shows that almost 50% of the foods that we eat everyday are adulterated. According to FSSAI report (2011), milk is one of the most adulterated food commodities. In a study carried out all over the country, in 1,791 milk samples, 68.4% of the samples departed from Food Safety Standards Authority of India. Kamal and Karuoi (2015) found that many milk food products and dairy products procured from the local vendors were adulterated with variety of substances ranging from less harmful to dangerous. Analysis of the common non-alcoholic beverages such as tea and coffee that are consumed for various health benefits almost daily are adulterated with various substances that affect the digestive and renal systems (Fang 1988). Tea leaves *Cammelia sinensis* are adulterated with artificial colour or with inferior quality tea. Top three leaves are used to make best quality tea, however inferior quality tea contains lower leaves that have low tannins and phenolics. Moreover, tea leaves are dyed with artificial colour to increase profit. Tea is also adulterated with dried consumed leaves to increase the bulk. Analysis have been carried out on samples collected from open markets, factories and fields by various people both from industry and academia to find out the adulteration source and quantum of adulteration. Interesting analysis (Bhatt 2003) and Pal and Das (2011) on tea samples independently to determine the presence of different adulterants showed high degree of adulteration and it varied with the cost of the packaged product. High cost tea sold in air-tight packs was less adulterated than low cost tea sold in open markets. Coffee, *Coffea arabica* beans and coffee powder were also found to be adulterated with coffee husks and stems, maize, barley, chicory, wheat, brown sugar, soybean (Toci et al., 2016). Honey, the other popular item of daily use is adulterated with various compounds both natural and synthetic. Honey adulteration is a topical issue as its importance in alternative medicine has increased widely. Besides, people are using sophisticated adulteration methods to earn profits. There are no quality indicators to detect honey adulteration. Fruit juices that are available in stores from various brands have also been implicated with adulteration. Colours, dyes, plant extracts of weeds are used to adulterate the juices. Authentic saffron is a trifid stigma that is collected from flowers of *Crocus sativus* and is an expensive spice and considered highly valuable in international market, but it is adulterated with ray and disc florets of Asteraceae flowers. Turmeric is adulterated with synthetic yellow dyes, both of organic and inorganic nature. Shuai et al. (2014) established that flax seeds that are a source of vegetable oil and are now-a-days used in baking and nutraceuticals is also adulterated with other vegetable seeds and detection possible only by chemometric methodology. The dropsy epidemic in Delhi in early 1990s brought into notice the adulteration of mustard seeds used to extract mustard oil, the most common cooking medium with Mexican yellow poppy seeds. The addition of papaya seeds to black pepper is also commonly done to make easy profit. Pulses are mixed with seeds of legumes with low protein value in many parts of India.

4. Detecting adulteration in Foods using Various Methods

Table 1. Low cost Laboratory Methods for Detecting Adulteration

Checking Adulteration in Tea

Detection of artificial colour	Spread tea leaves on the surface of clean glass containing water	Changes in the colour of water.
Detection Iron fillings	Spread tea leaves in a plate and hold a magnet near the leaves	Attachment to magnet confirming the presence
Detection of coal tar dye	Tea in water +5 ml of concentrated Hydrochloric acid	Pink or crimson colour indicated the presence
Detection of Catechu	Tea leaves + 5ml water +few drops of lead acetate solution. Addition offew drops of silver nitrate.	Appearance of greyish cloudiness
Test for Azo colour	Sample + strong alcohol and solution evaporated to dryness. Add water	Red or yellow or orange) indicated adulteration with azo dye.
Detection of Chicory	Tea + few drops of HCl+ 15 drops of potassium ferrocyanide solution. Boiledtill the appearance of dark green colour.	Brown and murky suspension

Detection of Adulteration in Common Foods

Food Product	Adulterant	Detection
Milk	Water	Pour milk on a polished slanting surface. Pure milk flows slowly, whereas milk adulterated water will flow fast.
Milk	Starch	Few drops of tincture iodine or iodine are added to milk and observation of blue colour indicates the presence of starch.
Milk	Urea	Mix the soybean flour or pigeon pea flour to milk and agitate the mixture with shaking. Colour change from red to blue indicates the presence of urea in the milk.
Milk	Detergent powder	Frothing of milk by continuous shaking and soapy tinge indicates adulteration.
Milk	Synthetic chemicals	Bitter taste and soapy touch after boiling indicate synthetic adulterants.
Spices	Excreta and other particles such as stones, vegetable waste, dust	Visual examination by looking at the mixture and sieving show the additions
Pepper corns	Papaya seeds	Papaya seeds can be separated out from pepper as they areshrunken, oval and greenish brown or brownish black in colour and have perisperm when section is cut.
Green chilli andleafy vegetables	Malachite Green	Cotton soaked in liquid paraffin and rubbed on the products. If the cotton turns, green shows presence of malachite green. Washing with water and detection of colour also shows use of malachite green.

Cumin seeds	Coloured grass seeds and charcoal	Rubbing of green seeds with palms is done and if palms turn black adulteration is indicated.
Saffron	Dried tendrils of Maize cobs and vegetable stuff	Genuine saffron is a stigma of saffron flower. The adulterants break easily and if put in water loose colour immediately.The authentic saffron can be verified by microscopic examination and checking the colour change.

Source: FASSI Manual, 2011

It is becoming increasingly important to have methods that are reliable, reproducible, and dependable to detect the adulterants. Various methods that are being used to detect food adulteration. Paper Chromatography, Column Chromatography, Spectroscopy, Nuclear Magnetic Resonance, Stable Isotope analysis are some the sophisticated and advanced techniques that are being used (CABANero et al., 2006). The advanced instrumentation is highly priced but works with precision and even minute quantities of adulterants are detected. Metabolomics and proteomics and other throughput technologies are also used now-a-days in Food Industry (Cordella, 2002). These methods rely on expertise in handling the equipment, high quality analytical reagents and costly machines that need to be housed in laboratories that are facilitated with support system and uninterrupted power supply. Scanning Electron Microscopy can provide rapid information concerning the morphology of a solid sample, as well as identifying the chemical elements present. The method does not require prior sample preparation, as in optical microscopy, it entails a series of comparisons between samples and potential adulterants (Lopez, 1983). It has been found that DNA based techniques focused on the detection and determination of nucleic acid probes and their sequences, serve as a characteristic fingerprint to detect the adulterants, and determine the authenticity of a variety of food products. Contemporary techniques such as polymerase chain reaction (PCR) offer the potential for the identification of DNA. DNA molecular markers are employed to identify different species or varieties of plants and thus can identify if the product is from the authentic source. Molecular markers such as microsatellites have been used in the characterization of *Coffea* species, enabling discrimination between*C. robusta and C. arabica* and detection of the presence of adulterants. Martellossi et al. (2005) demonstrated that DNA can be obtained from roasted beans and even from instant coffee and then amplified by PCR and further used for finger printing. According to Lee et al., (2005) pH differential method has been used extensively by food technologists and horticulturists to assess the quality of fresh and processed fruits and vegetables. Pigments such as carotenoids and anthocyanins can also be used as makers. Determination of total monomeric anthocyanin content based on the structural change of the anthocyanin chromophores is frequently being used to determine the authenticity of beverages extracted and made from fruits. Quality control of anthocyanin-containing fruit juices, wines, natural colorants, and other beverages is determined by pigment estimation using spectrophotometers. Johanathan et al. (1980) suggested that honey has many components that are added to enhance the flavour of the end-product. Baroni et al. (2016) carried out studies on detection of adulterants in various honey samples by looking at pollen proteins. Besides this, SDS page and electrophoresis are used for detecting adulteration in honey (Won, 2008). Hand cut sections of pepper show distinct features such as wall structure and perisperm which is not present in papaya seeds. Hand cut sections of tea can also be identified as the leaves have characteristic anatomical features such as oil glands and tannin cells (Kochhar, 2016, Verma 2009). Most of these methods need both expertise, understanding and training. Also, some background knowledge of chemistry and biology is important.

Some low-cost practices and rapid qualitative tests are being used by many small-scale industries and food testing laboratories. These procedures require simple laboratory glassware, few reagents, and instruments. These procedures can be carried out by anyone with basic knowledge of science. Most of these methods are qualitative and portable.

Conclusions

Technological advancements are making it easy to detect fraudulent adulteration in food. Traders have also become alert and smart to use methods that can escape surveillance. Though there are many methods of finding adulteration in foods, no method is universal. Efforts need to be made to devise novel methods of detection of adulteration. Biosensors that are universally acceptable and can be adopted to many food commodities need to be made available. The entire supply chain needs to be warned and educated. A cross talk between producers, suppliers, marketers, risk assessment researchers will help in developing a safety assessment protocol. The local food vendors need to be educated about food safety by food safety inspectors, and experts from industry and academia. The affordable portable kits should be made available to the households so that the safety of common foods is ensured. Food safety has implications on society and thus more campaigns against adulteration need to be carried out. Educational institutions can play an important role in raising awareness and also in developing innovative safety kits as part of their social responsibility.

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