

A Review on Milk Adulterants: Serious Impact on Human Health

Dr. Manju Meena

Assistant Professor Chemistry, R.R. Govt. College, Alwar

Email Id: meena.manju14@gmail.com

Abstract

Food adulteration has surged as a worldwide concern posing a serious threat to health hazards and fatal diseases round the globe. It has been increasing at a very rapid pace due to poor enforcement of laws, ineffective existing policies and monitoring system. Adulteration of milk has not only reduced its nutritional values but also led to a wide array of allergies and in tolerance to certain proteins and several other diseases. Milk has been an indispensable part of our diet because of its rich content of vital nutrients. The demand and supply gap in milk production along with its perishable nature have resulted in the increased menace of milk adulteration. Various adulterants such as detergents, urea, ammonium salts, sodium chloride, nitrates, sulphates, salicylic acid, benzoic hydrogen peroxide, formaldehyde, boric acid, neutralisers and melamine present in the milk give rise to serious health problems such as nausea, gastroenteritis, hepatitis, renal failure, heart problems, asthma pneumonia, cancer and allergic reactions. This paper describes the adverse health effects of consuming adulterated milk.

Keywords: Adulterants, detergents, food adulteration, formalin, hydrogen peroxide, melamine milk, neutralisers, urea

INTRODUCTION

Food adulteration may be a global problem, and due to a lack of surveillance and policies, developing countries are at higher risk related to it. This is also one of the most prevalent phenomena in many countries, which has been ignored. Food adulteration is an act of purposely degrading the quality of food offered for purchase, either by combining or replacing inferior substances or by eliminating some important ingredients. Milk is a complete food and an important source of almost all nutrients needed for the proper growth and maintenance of the body. Milk possesses its own importance in human life, but the high demand and supply gap, its perishable nature, inadequate quality checks, lack of proper law enforcement and high price of its byproducts make it the most vulnerable product for adulteration.^[1] After the major incidence of melamine adulteration infant formula milk in China. it became a global concern, otherwise, considered a problem of underdeveloped countries only.^[2] Milk adulteration can pose serious health hazards.^[3]

The purity of milk is commonly checked by a lactometer for some common parameters such as percentage of fat, solid-not-fat (SNF) percentage, freezing point and its protein contents. Adulteration is done to manipulate these parameters.^[4]

Milk adulterants that are less harmful include water, sugar, starch, vegetable oil, vegetable proteins (soya, wheat and pea) and milk from different species.

Water is added to increase the quantity of milk, but depending on its source (ponds and wells near agricultural sites) in villages, there are chances of water being contaminated with pathogens, heavy metals and agricultural chemicals such as fertilisers, insecticides and pesticides. Consumption of such water could cause infectious hepatitis, cholera, bacillus dysentery, typhoid, paratyphoid, salmonellosis, colibacillosis, giardiasis, cryptosporidiosis and amoebiasis.^[5] The presence of pesticides and heavy metals poses serious health risks for consumers, including dermatological, gastrointestinal, neurological, carcinogenic, respiratory, reproductive and endocrine effects.^[6]

Now adding to it, this diluted milk could further be adulterated with reconstituted milk powder, cane sugar, formalin, hydrogen peroxide, boric acid, caustic soda, benzoic acid, salicylic acid, ammonium sulphate, urea, detergents and melamine. These hazardous substances have the potential to cause serious health related problems.^[7]

Adulterants have been added to the milk to achieve specific goals.^[8]

SNF percentage of milk is falsely improved by the addition of cane sugar, starch, sulphate salts, urea and sodium chloride.

Quantitative protein tests performed by regulatory agencies detect the total nitrogen as an indicator of protein content. Therefore, melamine and urea, due their nitrogen rich nature, have been illegally added to milk to mask the low protein content of diluted milk.

To increase the shelf life of milk, preservatives such as formalin, salicylic acid, benzoic acid and hydrogen peroxide are added.

Ammonium sulphate increases the density of milk: therefore, it is commonly used to mask the dilution of milk with water.

Milk fat is very expensive, so it is removed for additional benefits and is compensated by the addition of non-milk fat

Table 1: Commonly detected adulterants in milk	
Group	Examples
Preservatives	Formaldehyde, salicylic acid, benzoic acid, boric acid and hydrogen peroxide
Density improver /thickeners	Urea melamine, ammonium sulphate, paints and starch
Neutralisers	Sodium carbonate, sodium bicarbonate, sodium hydroxide and calcium hydroxide
Insecticide and pesticides	Organochlorine, organophosphate, synthetic pyrethroid and triazine
Fats	
Emulsifier	Detergents
Others	Water and milk of other animal

like vegetable oil, and to dissolve this fat, detergent is used as an emulsifying agent.^[9]

HEALTH EFFECTS OF ADULTERANTS

Melamine

It is a nitrogen-rich chemical compound obtained from the decomposition of urea and is 66% nitrogen (by mass). Melamine increases the nitrogen level and apparent protein content of milk.

^[10]Its ingestion has been implicated in urinary system calculi and acute obstructive renal failure in infants.^[11-14]

In 2008, the Chinese Ministry of Health revealed an increased incidence of renal stones in infants 12,892 children were admitted to the hospital after consuming milk adulterated with melamine and 104 had serious symptoms^[10] It was found by subsequent analysis that melamine had been added to milk which was diluted with water, an attempt to increase the nitrogen content and hence evaded the government regulatory quality tests that only tested protein (nitrogen) content.

In the presence of its analogue and common co-contaminant, cyanuric acid, toxicity is much higher.^[13] Both are excreted through the kidneys without metabolism with half-lives

Table 2: Detection techniques		
Adulterants	Test	Observation
Sodium chloride (Common salt)	Take 5 ml of milk in a test tube and add 1 ml of 0.1 N silver nitrate solution. Mix and add 0.5 mL potassium chromate (10%) solution	Yellow colour indicates a positive test
Buffalo milk in cow milk	Take a drop of milk sample on a clean slide and add one drop of Hansa serum in it, mix with a glass rod	If milk clots within a minute, it is positive for buffalo milk
Milk neutralisers (hydrated lime, sodium hydroxide, sodium carbonates and bicarbonate)	Take 5 ml. of milk in a test tube. Add 5 mL alcohol and 4-5 drops of rosolic acid to it	Pinkish red colour indicates a positive test
Formalin	Take 10 ml. of milk test tube, add a few drops of fene chloride in it, then add 5 ml. of sulphuric acid by the side of the test tube	Violet/blue ring at the junction of two liquids indicates a positive test
Sugar	Take 10 ml. of milk in a test tube and add 0.1 g resorcinol, then add 5 ml. HCl, mix and put in the water bath for 5 min	Red/ orange colour indicates a positive test
Starch	Take 3 ml. of milk in a test tube and boil it. Cool to room temperature and add 2-3 drops of 1% iodine solution	Blue colour indicates a positive test
Gelatin	Take 10 mL of milk in a beaker. Add 10 ml. of acidic mercuric nitrate solution in it. Add 20 ml of water and mix well. Filter it. In filtrate. add picric acid solution	Opaque filtrate indicates a positive test. Yellow colour after the addition of picric acid in filtrate indicates a positive test
Urea	Take 5 ml. of milk in a test tube and add 0.2 ml. urease (or 2 g Arhar dal powder), shake well and add 0.1 mL bromothymol blue	Blue colour within 5-10 min indicates a positive test
Detergent	Take 5 ml, of milk in a test tube and add 0.1 mL of 0.5% BCP solution	Violet colour indicates a positive test (faint violet negative)
Hydrogen peroxide	Take 5 ml. of milk in a test tube and add an equal volume of raw milk and five drops of 2% solution of paraphenylenediamine	Blue colour indicates a positive test
Ammonium sulphate	Take 2 ml of milk in a test tube and add 0.5 ml. 2% NaOH solution and 0.5 ml. 5% phenol, heat in a boiling water bath for 20 s	Blue colour appears which converts into a deep blue
Benzoic and salicylic acid	Take 5 mL of milk in a test tube and add sulphuric acid to acidify it, then add 0.5% ferric chloride drop by drop	Benzoic acid shows a buff colour while salicylic acid shows a violet colour
Nitrate	Take 10 mL of milk in a beaker and add 10 ml. mercuric chloride solution, mix and filter.	Blue colour indicates a positive test

	In 1 ml. filtrate add 4 ml. of diphenylamine sulphate or diphenylbenzidine reagent	
Borax and boric acid	Take 5 ml. of milk in a tube and add 1 mL of concentrated HCl in 4, then dip a turmeric paper and dry 100°C	If the turmeric paper turns red, it indicates a positive test
Vanaspatti	Take 3 ml. of milk in a test tube and add 10 drops of hydrochloric acid, mix one tablespoon of sugar	Red colour within 5 min indicates a positive test

estimated to be a few hours. Each may form crystals in urine. When both are present in urine, they can combine as melamine cyanurate complexes. This results in highly insoluble, larger and more numerous calculi than either of the two chemicals alone.^[14] These calculi irritate the urinary tract lining and may lead to obstruction, abdominal pain and uraemia.

Urea

The addition of water to milk results in a reduction in whiteness and density, and to maintain these properties, urea is generally used as an adulterant.^[15] Urea increases the shelf life and nonprotein nitrogen content and maintains the SNF amount.^[16]

Ingestion of urea causes irritation to the gastrointestinal tract. Symptoms may include nausea, vomiting, diarrhoea, headache, confusion and electrolyte depletion.^[17]

Formaldehyde

To extend the shelf life of milk, formalin is used illegally as a preservative in minute quantities. According to the World Health Organization, the estimated daily take of formaldehyde in adults should be in the range of 1.5-14 mg/day.^[18] However, if consumed in excess, formaldehyde adversely affects the gastrointestinal tract, kidney, liver and lungs and may lead to cancer.^[19-21] Formaldehyde ingestion irritates the mucous membranes and causes inflammatory changes in the liver and kidneys.

In addition, there is evidence linking formaldehyde with nasopharyngeal cancer. The International Agency for Research on Cancer has classified formaldehyde (as well as formalin) as a Group 1 carcinogen.

When ingested, formaldehyde may cause severe pain with inflammation, ulceration and necrosis of the mucous membranes lining almost every internal organ, nausea, vomiting blood, diarrhoea with bloody stool, blood from urine, gastrointestinal lesions, acidosis, vertigo and circulation failure. Systemic effects include metabolic acidosis, central nervous system depression and coma, respiratory distress, renal failure, liver failure, cancer and tumour development and irreversible neurotoxicity.

Neutralisers

On standing, bacterial overgrowth produces lactic acid from lactose which curdles the milk.^[22] In spite of the food legislation, neutralisers such as sodium bicarbonate, sodium carbonate, sodium hydroxide and calcium hydroxide are commonly misused to mask the pH and acidity values of spoiled milk. Carbonates and bicarbonates can cause disruptions in hormone signalling that regulates development and reproduction.^[23] Carbonates in milk produce

gastrointestinal problems, including gastric ulcers, diarrhoea, colon ulcers and electrolyte disturbances.

Sodium hydroxide increases sodium ingestion which is harmful to hypertensive patients. It prevents the body from utilising lysine, essential amino acid in milk, which is required by growing babies.

Benzoic acid

Commonly used as a preservative in beverages. It causes metabolic acidosis, asthma, urticaria, hyperpnoea and convulsions. Many countries have prohibited its use in dairy products.^[24] To make a greater profit, many dairy suppliers are still using it to extend the shelf life of milk.

Boric acid

Due to effectiveness towards yeast, moulds, bacteria and other microbes, it preserves milk for a long duration. It is not carcinogenic but it can cause nausea, vomiting, stomach ache, diarrhoea and rashes.^[25]

Salicylic acid

It is a preservative. In low concentrations, the adverse health effects might be mild, but prolonged abuse results in inflammation in the sinus and nasal passage, vomiting, hyperpnoea, lethargy, cerebral and pulmonary oedema, seizures and multiple organ failure.^[26]

Ammonium sulphate

It is intentionally added to manipulate the lactometer reading. Its presence falsely increases the density of milk. Even in low amounts, it can irritate the gastrointestinal tract with symptoms of nausea, vomiting and diarrhoea. Being a neurotoxin, it can cause confusion and behavioural changes.^[27]

Chlorate

It is goiterogenic and is associated with inhibition of iodine uptake. The entry point of chlorine in milk is through the addition of chlorinated water or by chlorine-based disinfectant used for cleaning purposes in the dairy industry.^[28]

It is also responsible for the production of methemoglobin, especially in neonates and in G6PD deficient persons.

Pesticides

The most common pesticides detected are organochlorine, organophosphate, synthetic pyrethroid and triazine. Fodder and water consumed by cattle are the main entry point of these harmful chemicals in milk.^[29] They are carcinogenic and severely affect the immune system, nervous system and reproductive system. They increase the risk of Parkinson's disease, birth defects and endocrine malfunctioning.^[30]

Detergent

It causes severe health problems, including cancer. The main purpose of adding detergent is to hide the adulteration of foreign fats in the milk. After removing the expensive milk fat, Vanaspati oil or other low-quality fats are added to adjust the fat concentration, and for their emulsification, detergents are added. Dioxane present in detergent causes cancer, and its other components cause nausea, skin irritation, gastrointestinal complication, neurotoxicity, endocrine malfunctioning and heart problems.^[31]

Starch

Its adulteration in milk causes diarrhoea and irritation of the colon. It is very harmful for diabetic patients. Water is added to milk to increase the volume, but diluted milk is not preferred economically, hence, starch is added to maintain density and solid constituents. Undigested starch irritates the gut and causes diarrhoea.

Hydrogen peroxide

H₂O₂, being a bactericidal agent, is used as a milk preservative worldwide, but it can irritate the mucosa of the gut and cause gastritis. It can cause tachycardia, cardiac arrhythmia and gastric disorders. It is a potent free radical causing damage at the cellular level and causes ageing.^[32]

Vegetable oil

It is added to increase the fat content of milk. As talk fat is of high economic value, it is removed and sold separately to gain more profit. Low-quality oils having higher trans-fatty acids are associated with an increased risk of cardiovascular disease. It also causes obesity, colon cancer, breast cancer, pre-eclampsia, vision impairment and diabetes.^[33]

Paint/colour

Paints are loaded with heavy metals like lead causing nausea vomiting, gastritis, headache, dizziness and confusion. Paint is added to increase the thickness of watered milk. It can cause depression and unconsciousness after prolonged consumption.^[34]

Some adulterants along with their detection techniques are shown in Tables 1 and 2

Alternatives to milk

Now a days, consumers are choosing plant-based non-dairy milk alternatives and shifting to vegan diets. Various alternative drinks/foods are available in the market to replace milk, such soya milk, vegan yoghurt, rice milk, oat milk, almond milk, hazelnut milk, coconut milk, quinoa milk and potato milk.^[35] These cereal/legume/oil seeds/nuts-based vegan drinks are rich in vitamins, minerals and antioxidants. They provide a low calorie diet which does not contain cholesterol and lactose giving a good reason to use them in place of milk.

However, in legume-based alternatives of dairy products. low protein and calcium availability along with sensory acceptability is a major limiting factor.

CONCLUSION

The addition adulterants for gaining more profit increases the quantity of milk, concomitantly leading to the loss of nutrients. Consumption of such synthetic and adulterated milk gives rise to several health problems.

Strict policies, public awareness and organised dairy industry are required to control milk adulteration in our country.

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