Unveiling Milk Safety in Chennai: A Comprehensive Evaluation of Adulteration Across Diverse Milk Sources

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KEYWORDS
Adulterant, cow milk, almond milk, vegan milk, breast milk

ABSTRACT
Introduction: Milk is a complex biological fluid made up mostly of water, carbohydrates, lipids, proteins, and many bioactive compounds. This extremely nutritious food contains vital components like energy-giving lactose, fat, bone-forming calcium, minerals, body-building proteins, and health-promoting vitamins necessary for all age groups. To increase the protein content, SNF, fat %, adulterants are added to milk, which unnaturally raising the milk's quality. Regretfully, there are adulterants that can have serious long-term health effects. Infants may experience renal failure and even die if they consume melamine at levels higher than what is considered safe.
Objectives: This study aims to systematically evaluate the extent and nature of all milk adulteration (breast, branded vegan, unbranded vegan milk, direct cow milk and packaged cow milk) in the Chennai city, Tamil Nadu, India.
Methods: The study was conducted for a period of 3 months from May 2024 to July 2024. The collected milk samples were analysed using Delstrips paper strips.
Results: The findings reveal a widespread presence of adulterants, with starch being the most prevalent across nearly all milk types. There were no statistically significant differences seen between government milk, private branded cow milk, and private direct milk in adulterant's sucrose and neutralizers. In contrast, almond milk offers a viable alternative for those seeking a vegan or lactose-free option, particularly for adults and older children.
Conclusion: Milk Adulteration poses a significant threat to public health, economies and the diary industry worldwide. The prevalence of adulteration, particularly in developing countries, highlights the need for improved regulatory frameworks, enhanced testing methods, and vigilant monitoring. This study has demonstrated the severity of milk adulteration, its consequences, and the imperative for collective action. The current research demonstrates that both breast milk and almond milk, when used appropriately, are safe options within their respective contexts.

1. Introduction

Milk is a complex biological fluid made up mostly of water, carbohydrates, lipids, proteins, and many bioactive compounds.[1] Humans have consumed milk from pre historic times. This extremely nutritious food contains vital components like energy-giving lactose, fat, bone-forming calcium, minerals, body-building proteins, and health-promoting vitamins necessary for all age groups.[2] As per the Nutrition Advisory Committee of the Indian Council of Medical Research, 10 ounces of milk should be part of an adult's daily balanced diet.[3] While milk enjoys great cultural status in India, many countries in the Far East and South East Asia have had limited access to milk or milk products until recently. This may come as a surprise to some. However, milk is a favoured food and holds a specific position in traditional Indian diets.[4]

Mediator move milk from the point of production to consumers and processing facilities. As a result, they fail to maintain adequate hygienic conditions during this transportation, which raises the number of viable bacteria overall. Various preservatives like formalin and some antibiotics are also added in milk to increase its shelf life.

This addition decreases the nutritive value of milk.[5] Urea, formalin, detergents, ammonium sulphate, boric acid, caustic soda, benzoic acid, salicylic acid, hydrogen peroxide, sugars, and melamine are a few of the main adulterants in milk that have been found to have serious negative health effects. Formalin is a potentially dangerous or harmful chemical. It is an extremely potent carcinogen. [6]

To increase the protein content, SNF, fat %, adulterants are added to milk, which unnaturally raising the milk's quality. Regretfully, there are adulterants that can have serious long-term health effects. Infants may experience renal failure and even die if they consume melamine at levels higher than what is considered safe.[7] Adding excessive starch to milk might cause diarrhoea caused by undigested starch in the intestines. [8] The Food Safety and Standards Authority of India (FSSAI) conducted the National Survey on Milk Adulteration (2011) to determine the quality of milk across the nation. The survey results showed that 68.4% of the samples did not comply with the Food Safety and Standards Regulations, 2011. While there are still quality issues, milk in India is generally safe, according to the FSSAI's most recent report from October 2019 on the National Milk Safety and Quality Survey, which was carried out in 2018. According to the survey, contamination in less than 10% of the milk samples was primarily from feeds and inappropriate farming practices (FSSAI, 2019).[9][10]

Vegan milk, also known as plant milk, nut milk, and non-dairy milk, has been a popular beverage worldwide for many years.[11] Apart from cow milk vegan milk is also consumed due to cow milk allergy and lactose intolerance. Vegan milk includes cereal based, legume based, nut based, seed based and pseudo cereal based milk. [12] Demand for commercially available breast milk was also significantly increased which was also being adulterated putting infants at risk [13]. Given the increasing urbanization and population density in Chennai, there is a growing demand for milk, which can incentivize unethical practices by suppliers to maximize profits. This study aims to systematically evaluate the extent and nature of all milk adulteration (breast milk, branded vegan milk, unbranded vegan milk, direct cow milk and packaged cow milk) in the Chennai city. By doing so, it seeks to identify potential health risks, inform regulatory bodies, and guide public awareness campaigns to ensure that the milk available in Chennai is safe, pure, and nutritious. The findings of this study could have significant implications for food safety regulations and consumer protection in the region.

2. Objectives

This study aims to systematically evaluate the extent and nature of all milk adulteration (breast, branded vegan, unbranded vegan milk, direct cow milk and packaged cow milk) in the Chennai city, Tamil Nadu, India. . The sample included breast milk(5), vegan branded milk(3), vegan unbranded milk(3), government cow milk (9), private direct cow milk (4) and private branded cow milk (4). Vegan Branded milk is the packaged non-dairy milk which included soy milk, almond milk and coconut milk and vegan non branded milk is the homemade non-dairy milk obtained from coconut, cashew and almond. The collected milk samples were analyzed using Delstrips paper strips for milk adulteration testing.

3. Methods

Study Area

The observational study was conducted in the Chennai city, Tamil Nadu, India. The study was conducted for a period of 3 months from 2024 to 2024. Sample size was calculated using G power software. The power of the study is 95%, with a large effect size of 5 % a total of 28 sample was obtained. Simple random sampling method was used to collect the sample. The sample included breast milk, vegan branded milk, vegan unbranded milk, government cow milk, private direct cow milk and private branded cow milk Table 1.

Table 1: Sample collected for the study

Name of sample	No of sample
Breast milk	5
Vegan Branded milk	3
Vegan unbranded milk	3
Government cow milk	9
Private direct cow milk (directly from the cowman)	4
Private branded cow milk	4

The collected milk samples were analyzed using Delstrips paper strips for milk adulteration testing. The kit was obtained from the online website. The kit was used to find maltodextrin, neutralizers, hydrogen peroxide,

glucose, sucrose, urea, salt, starch and formalin. The kit was used for testing 27 samples each. By observing the colour changes the presence or absence of different adulterants were decided.

Table 1: Detection of Adulterants

S.NO	Adulterant	Presence of Adulterants	Absence of Adulterants
1.	Maltodextrin	Brown	Golden Yellow
2.	Neutralizers	Reddish pink	Light Orange
3.	Hydrogen Peroxide	Bluish grey	White to light grey
4.	Glucose	Bluish green	Light green
5.	Sucrose	Brick red	Pale yellow
6.	Urea	Yellow colour	Off white to slight yellow colour
7.	Salt	Yellow colour	Brick red colour
8.	Starch	Blue colour	Off white to cream colour
9.	Formalin	Purple/Violet colour	Brownish yellow coloured ring

Statistical analysis

Data were collected and entered in a spreadsheet. Statistics was done in SPSS software version 25. Descriptive statistics were used to find the frequency and percentage distribution of the adulterants present in the samples. Chi square test was done to compare the vegan branded and non-branded milk

4. Results

Table 2: Percentage of adulterants with the breast milk

	Adulterants	No of negative samples n(%)	No of positive samples n(%)
Breast milk	**Sucrose**	3(60%)	2(40%)
	Glucose	3(60%)	2(40%)
	Urea	2(40%)	3(60%)
	Salt	5(100%)	0(0)
Breast milk	**Neutralizers**	1(20%)	4(80%)
	H2O2	5(100%)	0(0)
	Maltodextrin	3(60%)	2(40%)
	Starch	1(20%)	4(80%)
	Formalin	5(100%)	0(0)

Table 2 represents the percentage of adulterants present in breast milk samples. No positive samples of formalin adulterant were present in breast milk. 60% of the breast milk sample contains urea 80% of the breast milk sample presents with neutralizers and starch. 40% of the breast milk contains sucrose, glucose and maltodextrin.

Table 3: Association of adulterants between the vegan branded and vegan unbranded milk

Adulterant	VEGAN MILK (BRANDED)		VEGAN MILK (UNBRANDED)		P value
	No of negative samples n(%)	No of positive samples n(%)	No of negative samples n(%)	No of positive samples n(%)	
Sucrose	3(100%)	0(0)	0(0)	3(100%)	**0.014***
Glucose	3(100%)	0(0)	3(100%)	0(0)	-
Urea	3(100%)	0(0)	3(100%)	0(0)	-
Salt	2(66.7%)	1(33.3%)	3(100%)	0(0)	0.273
Neutralizers	0(0)	3(100%)	3(100%)	0(0)	**0.014***
H2O2	3(100%)	0(0)	3(100%)	0(0)	-
Maltodextrin	3(100%)	0(0)	3(100%)	0(0)	-
Starch	2(66.7%)	1(33.3%)	2(66.7%)	1(33.3%)	1.000
Formalin	2(66.7%)	1(33.3%)	1(33.3%)	2(66.7%)	0.414

Table 3 represents the association of adulterants between the vegan branded and vegan unbranded milk. There was a statistically significant association between the branded vegan and unbranded vegan milk in the adulterant's sucrose and neutralizers. 33.3% of the vegan branded milk contains formalin. 66.7% of the vegan unbranded milk contains formalin. 100% of the branded vegan milk contains neutralizers. 33.3% of the vegan

branded and unbranded milk contains starch. 100% of the vegan unbranded milk contains sucrose. The 33.3% (n=1) of the sample negative in formalin adulterant is almond milk in both branded and unbranded vegan milk.

Table 4: Percentage of adulterants in government milk

Adulterants	Government milk			
	North chennai		South chennai	
	No of negative samples n(%)	No of positive samples n(%)	No of negative samples n(%)	No of positive samples n(%)
Sucrose	7(100%)	0(0)	2(100%)	0(0)
Glucose	7(100%)	0(0)	2(100%)	0(0)
Urea	7(100%)	0(0)	2(100%)	0(0)
Salt	7(100%)	0(0)	2(100%)	0(0)
Neutralizers	6(85.7%)	1(14.3%)	2(100%)	0(0)
H2O2	7(100%)	0(0)	2(100%)	0(0)
Maltodextrin	7(100%)	0(0)	2(100%)	0(0)
Starch	5(71.4%)	2(28.6%)	0(0)	2(100%)
Formalin	2(28.6%)	5(71.4%)	1(50%)	1(50%)

Table 4 represents the percentage of adulterants in government milk. 71.4% of the sample collected in north Chennai contains formalin. In south Chennai 100% of the sample contains starch and 50% of the sample contains formalin. 14.3% of the sample collected in north Chennai has neutralizers, 28.6% of the sample collected in north Chennai has starch and 100% in south Chennai.

Table 5: Percentage of adulterants in private branded and direct cow milk

Adulterants	Private milk			
	Private Branded Cow Milk		Private Direct Cow Milk	
	No of negative samples n(%)	No of positive samples n(%)	No of negative samples n(%)	No of positive samples n(%)
Sucrose	4(100%)	0(0)	4(100%)	0(0)
Glucose	4(100%)	0(0)	4(100%)	0(0)
Urea	4(100%)	0(0)	4(100%)	0(0)
Salt	4(100%)	0(0)	4(100%)	0(0)
Neutralizers	4(100%)	0(0)	4(100%)	0(0)
H2O2	4(100%)	0(0)	4(100%)	0(0)
Maltodextrin	4(100%)	0(0)	4(100%)	0(0)
Starch	1(25%)	3(75%)	4(100%)	0(0)
Formalin	0(0)	4(100%)	0(0)	3(100%)

Table 5 represents the percentage of adulterants in private branded cow milk and private direct cow milk. 100% of the private branded and direct cow milk contains formalin. 75% of the private branded cow milk contains starch.

Table 6: Association of adulterants between the government and the private cow milk

	Government Cow Milk		Private Branded Cow Milk		Private Direct Cow Milk		P value
	No of negative samples n(%)	No of positive samples n(%)	No of negative samples n(%)	No of positive samples n(%)	No of negative samples n(%)	No of positive samples n(%)	
Sucrose	9(100%)	0(0)	4(100%)	0(0)	4(100%)	0(0)	-
Glucose	9(100%)	0(0)	4(100%)	0(0)	4(100%)	0(0)	-
Urea	9(100%)	0(0)	4(100%)	0(0)	4(100%)	0(0)	-
Salt	9(100%)	0(0)	4(100%)	0(0)	4(100%)	0(0)	-
Neutralizers	8(88.9%)	1(11.1%)	4(100%)	0(0)	4(100%)	0(0)	0.660
H2O2	9(100%)	0(0)	4(100%)	0(0)	4(100%)	0(0)	-
Maltodextrin	9(100%)	0(0)	4(100%)	0(0)	4(100%)	0(0)	-
Starch	5(55.6%)	4(44.4%)	1(25%)	3(75%)	4(100%)	0(0)	0.141

Formalin	3(33.3%)	6(66.7%)	0(0)	4(100%)	0(0)	3(100%)	0.238

Table 6 represents the association of adulterants between the government cow milk and the private cow milk. There were no statistically significant differences seen between government cow milk, private branded cow milk and private direct cow milk in adulterants. 66.7% of the government cow milk contains formalin. 100% of the private branded and direct cow milk contains formalin. 11.1% of the government cow milk contains neutralizers. 44.4% of the government cow milk sample contains starch and 75% of the private branded milk contains starch.

5. Discussion

The study's findings are expected to highlight the prevalence of adulteration practices in each milk category and their implications for public health. The comprehensive analysis aims to safeguard the health of Chennai's population by identifying critical areas for intervention and improvement in milk safety standards.

The most present adulterant is formalin. 33.3% of it is present in branded vegan milk and 66.7% is present in the unbranded vegan milk.71.4% of samples collected from North Chennai (government milk) presented with formalin and 50% of the samples collected from South Chennai (government milk) presented with formalin. In whole 66.7% of the government cow milk sample presented with formalin. The private branded and the private direct milk sample contains 100% of formalin. The current study finding was contrast to the study conducted by Ghulam Shabir Barham et al.2014 [14] (20% of samples with formalin) and Hemanth Singuluri and Sukumaran et al 2014 [15] (32% of samples with formalin). Formalin is a disinfectant commonly used to extend the storage life of liquid milk during shipping. It can cause gut corrosion, ulcers, and inflammatory diseases, perhaps leading to kidney failure.[16] There is evidence linking formaldehyde to nasopharyngeal cancer. The International Agency for Research on Cancer classifies formaldehyde and formalin as Group 1 carcinogens.

Ingesting formaldehyde can result in severe pain, inflammation, ulceration, and necrosis of mucous membranes lining internal organs, as well as nausea, vomiting, diarrhoea, gastrointestinal lesions, acidosis, vertigo, and circulation failure. Systemic consequences include metabolic acidosis, central nervous system depression and coma, respiratory distress, renal and hepatic failure, cancer and tumour development, and permanent neurotoxicity.[17] Early diagnosis of cancer has emerged as a priority to the public health objective whereby health professionals play leading role[18]

The next adulterant present in our study sample was neutralizers 100% of the breast milk samples contain neutralizers, 14.3% of the government milk sample collected from North contained with neutralizers and in total of government samples 11.1% of the samples presented with neutralizers. Neutralizers are used to balance the pH value to alkaline. The current study finding was contrast to the study finding with Ramya et al 2015 (6%) [19]. Similar study finding was Singuluri et al 2014[15] (26%) and Chanda et al 2012 (20%) [20]. Despite food regulations, neutralisers such sodium bicarbonate, sodium carbonate, sodium hydroxide, and calcium hydroxide are widely used to hide the pH and acidity of spoiled milk. Carbonates and bicarbonates can disrupt hormone signalling, impairing development and reproduction. Carbonates in milk can cause gastrointestinal issues such as stomach ulcers, diarrhoea, colon ulcers and electrolyte imbalance.[17]

The current study pioneered to evaluate not only cow milk but all forms of edible milk exposed to adulteration. Out of all adulterants starch is present in all forms of milk, breast milk (80%), 33.3% in both branded and unbranded vegan, 28.6% in government milk collected in north zone 100% in government milk collected in south zone, government cow milk 44.4%, 75% in private branded cow milk. Only the private cow milk obtained directly from cowman does not contained starch. Starch is added to milk to increase the SNF (Solid no fat) content when it is added in higher level the starch gets undigested leading to diarrhoea.[21] In the current study private cow milk was adulterated with 75% of the sample which was contrast to the study conducted in Varanasi (20% of the sample with starch) by Arun Kumar et al 2015[22]. The study conducted by Hemanth Singuluri and MK Sukumaran in 2014[15] reported that 0% of the samples presented with starch and also did not mention about the source of sample instead mentioned only the samples were obtained from the public and educational institutions. The current study highlighted the source of sample in the methodology for the clear understanding of the adulterants present in the sample. In vegan branded and unbranded milk, almond is free from formalin hence using both branded and unbranded almond milk is comparatively safer when compared to other vegan milk. Vegetable safeguards were designed to boost crop production in response to the world's rising demand.[23]

The findings reveal a widespread presence of adulterants, with starch being the most prevalent across nearly all milk types. By identifying critical adulteration practices and their sources, this study contributes valuable insights for public health authorities and consumers, aiming to protect the health and well-being of general population. However, the study's limitations include a potentially non-representative sample size and the inability to assess seasonal variations or regional differences in adulteration practices, which may affect the generalizability of the results. Further microbiological assessment of formalin adulterant and other vegan milk analysis study is needed in future.

In conclusion, our research demonstrates that both breast milk and almond milk, when used appropriately, are safe options within their respective contexts. Breast milk remains the gold standard for infant nutrition, providing essential nutrients and immune support critical for a child's early development. In contrast, almond milk offers a viable alternative for those seeking a vegan or lactose-free option, particularly for adults and older children. While it lacks the comprehensive nutritional profile of breast milk, it can be part of a balanced diet when complemented with other nutrient sources. Ultimately, each milk type serves different needs, and their safety and suitability depend on individual health requirements and life stages.

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