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## ASSESS PREVALANCE AND IMPACT OF WATER ADULTERATION ON MILK COMPOSITION AND STANDARDS

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**ABSTRACT:** *Milk quality is critical for ensuring public health, consumer confidence, and the production of safe dairy products. However, the adulteration of raw milk with water remains a common form of food fraud that compromises its nutritional composition and quality. This study assessed the prevalence and impact of water adulteration in raw milk and evaluated variations in milk composition across dairy farmer groups in Bhutan to provide baseline information for developing milk quality standards and implementing a quality-based milk pricing system. A total of 6,665 raw milk samples were collected from 52 Gewogs across 17 Dzongkhags between July 2022 and June 2024 and analyzed for major compositional parameters. The results revealed that 25.33% of the milk samples were adulterated with water. Water adulteration significantly reduced milk fat, protein, lactose, solids-not-fat (SNF), ash content, and freezing point values, thereby lowering the nutritional quality of milk. Considerable variation in milk composition was observed among Dzongkhags. Wangdue, Trongsa, and Lhuntse Dzongkhags exhibited comparatively higher milk quality, characterized by elevated fat, SNF, protein, lactose, and ash contents, whereas Thimphu and Tsirang Dzongkhags recorded lower compositional values and a higher prevalence of water adulteration. The findings highlight the widespread occurrence of water adulteration and its adverse effects on milk quality. Strengthening routine quality monitoring, establishing rapid adulteration testing facilities at milk collection and processing centers, and implementing quality-based milk payment systems are recommended to improve milk quality, protect consumers, and support the sustainable development of the dairy sector.*

**Keywords:** Adulteration; Dairy; Milk composition; Quality.

### 1. INTRODUCTION

Milk is one of the oldest foods known to mankind and is the normal, clean, and fresh secretion, extracted from the udder of a healthy cow, and free from colostrum. Dairy milk contains many nutrients necessary for human health. It is an excellent source of carbohydrates, fat, protein, vitamins, and minerals vital for body growth, health maintenance, and disease prevention German and Dillard (2006). Fresh milk is considered a complete diet because it

supplies the essential nutrients in a balanced form than other foods. On average, cow milk is made up of 87% water, and 13 % milk solid. The milk solid is further broken down comprising 3.7% fat, 8.9% milk solid not fat. The milk solid not fat comprises 3.4% protein, 4.8% lactose, and 0.7% minerals (Aurand et al. 1987).

Several studies have been conducted to evaluate differences in milk composition. Some of these factors include genetic factors

(Wangpom et al. 2017), seasonal variation, temperature–humidity index (Bertochi et al. 2014), feeding system and feed management practices (O’Callaghan et al. 2017), lactation stage, animal health and herd management (Paparwee et al. 2023). The composition of milk directly affects its quality, texture, taste, and nutritional value. The primary components of milk include water, fats, proteins (mainly casein and whey proteins), lactose (milk sugar), minerals (like calcium and phosphorus), and vitamins (like A and D). Understanding the specific milk composition requirements for various dairy products is vital for ensuring product quality and its benefits for human health. For example, cheese production relies heavily on milk protein (mainly casein), while butter production depends on milk fat content.

The composition of milk significantly affects the production of dairy products such as butter, cheese, paneer, and yogurt and these products dominate the Bhutanese market. Ruminant milk protein is the best for cheese making as it contains 78% casein, which is crucial to precipitating at a specific pH, enhancing curd formation, and cheese making (Jenkins and Mc Guire 2006). A higher percentage of fat is ideal for the possibility of processing the dairy products that require rich fat percent. Proteins in milk provide essential amino acids and contribute to texture and nutritional values, lactose supplies energy, and minerals are important for coagulation and taste, (Wedholm et al. 2006). However, the composition of milk is affected by various types of adulterations. The adulteration of milk poses a social and global challenge in developing countries like Bhutan due to insufficient policies and monitoring measures. Farmers adulterate milk to keep it temporarily fresh and to prevent financial losses. For instance, water is added to increase the volume of milk which is the cheapest and the easiest method

(Barham et al. 2014). Adding higher concentrations of hard water to milk increases acidity, which lowers its quality and shortens shelf life.

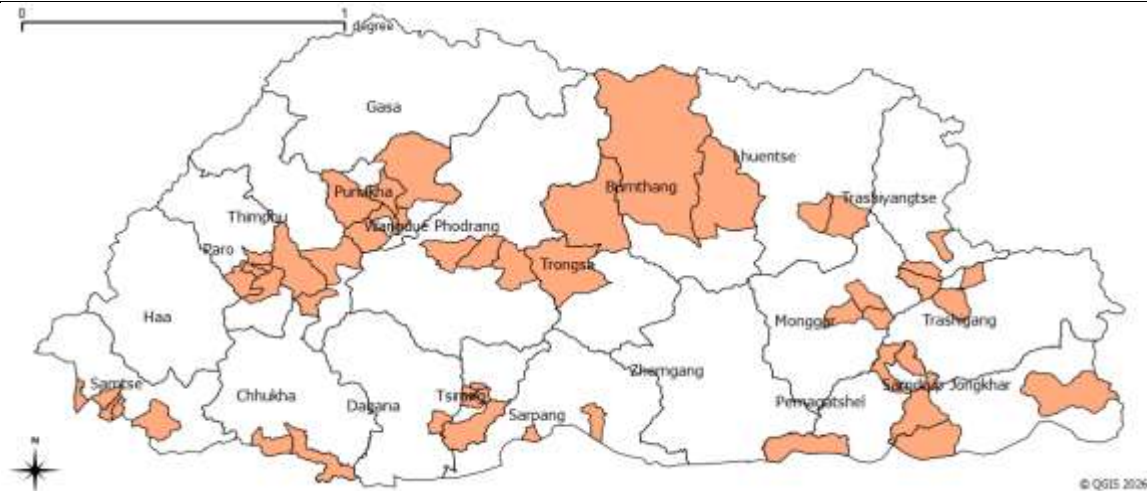
Farmers diluting raw milk with water can cause significant contamination. This water may contain feces, manure, industrial waste, and household effluents, which increases the risk of microbial and chemical contamination in milk (Kedjia 2018).

The milk composition particularly protein and solid-not-fat-based milk pricing schemes are adopted for payment in most developed countries. A quality-based milk grading system is required to improve milk quality and increase consumers' food safety as the current payment system is volume based. The lack of regulation in the marketing system and the failure to adopt clean milk production practices result in poor milk quality. It is therefore crucial to evaluate the milk compositions among different dairy farmer groups across various dzongkhags to establish standards for milk grading. The present study aims to assess the prevalence and impact of water adulteration in raw milk and evaluated variations in milk composition across dairy farmer groups in Bhutan, to provide baseline information for developing milk quality standards and implementing a quality-based milk pricing.

## 2. MATERIALS AND METHODS

### 2.1 Study areas

A total of fifty two Gewog(s) from seventeen Dzongkhags based on the numbers of farmers in the dairy farmers groups and the volume of the milk supplied for sampling were purposely selected. The selected Gewog are shown in Figure 1:



**Figure 1:** Map showing study area covering different Gewog from different Dzongkhags.

## 2.2 Study period, animals' selection and milk samples collection

A cross-sectional study was conducted between July 2022 to June 2024. The milk sample were collected from Jersey cross cattle, with breed percent ranging from 50% to 87.5%. Milk samples of approximately 50 ml was aseptically collected in the plastic vials from each household using a sterile ladle and stored immediately in temperature-controlled equipment to bring the milk sample temperature to 7°C for compositional analysis. All dairy farmer group members supplying milk to the milk collection centre were selected for the compositional milk study. Out of 6,665 total samples collected, 91.40% (n = 5,933) were collected at milk collection centre from individual farmers, 6.81% (n = 442) were collected from bulk milk containers intended for transport to the MPU, and remaining 1.76% (n = 114) from MPU bulk containers.

## 2.3 Milk samples analysis

Samples analysis was carried out at the National Dairy Development Centre (NDDC) and respective milk processing units within a two-hour time period using

automatic ultrasonic milk analyser (Lactoscan FarmEco, Milkotronic Ltd, Bulgaria). All parameters were analyzed in triplicates. The parameters analyzed and recorded were fat, solid not fat, protein, density, lactose, ash, and water adulteration.

## 2.4 Data analysis

The data were entered in Microsoft Excel and subsequently exported to STATA version 18 for statistical analysis. Descriptive statistics, including mean, standard deviation, and minimum values, were used to summarize the variables. Differences in milk composition parameters between samples with added water and those without added water were evaluated using independent samples t-tests and chi-square tests, as appropriate.

## 3. RESULTS AND DISCUSSION

### 3.1 Milk sample collection and Dzongkhags covered

A total of 6665 milk samples were collected from fifty-two Gewogs under seventeen Dzongkhags (Figure 2). The highest milk sample (886 numbers) was collected from Thimphu Dzongkhag and the lowest from Lhuntse Dzongkhag (79 milk samples). The total number of milk samples collected differed due to the size and number of dairy farmer group members.

### 3.2 Milk composition

Table 1 presents the mean  $\pm$  standard deviation (SD) of various milk composition parameters across different study areas. The overall mean of the milk composition parameters recorded are  $4.77 \pm 1.31$  % fat,  $8.28 \pm 1.5$  % solid not fat,  $3.01 \pm 0.33$  % protein,  $4.56 \pm 0.51$  % lactose,  $0.67 \pm 0.07$  % ash,  $-0.54 \pm 0.06$  °C freezing point (FP) and  $3.38 \pm 6.84$  % water. The significant difference in milk compositional parameters for different locations could be due to different percent of cross-bred reared, different management practices like feeding, and environment. This result agrees with the findings by Wangdi et al. (2014) who observed that the difference in milk composition in different locations was reported to be due to management practices, breeding, lactations, and differences in environment and temperature. Overall, the average values indicate a fairly consistent composition across the Dzongkhags, with slight variations in fat, protein, and lactose concentrations, influencing the nutritional profiles of the dairy produced.

### 3.3 Fat content and Fat to Protein ratio

The study recorded the overall mean fat percent  $4.77 \pm 1.31$  (Table 1). Analysis of milk fat content across the studied Dzongkhags recorded notable variation. Samdrup Jongkhar recorded the highest mean fat percentage at 5.61%, followed by Wangdue (5.42%) and Trongsa (5.16%). In contrast, Paro Dzongkhag recorded the lowest mean fat percent at 4.20% followed by Thimphu Dzongkhag at (4.39%). The

higher fat percentage recorded in Samdrup Jongkhar may be due to improved feeding practices and a higher proportion of Jersey-cross breeds, which are known for higher milk fat content. This finding agrees with Barlowska et al. (2009) with an average fat content of cow's milk range around 3.7% and can vary widely between 2.8% – 8.1% depending on cattle breed, nutritional regime, and lactation stage. The standard value of fat content of cow's milk ranges from 3.5% to 5.0%, and the United States Government has established a whole milk standard at 3.25% (Anantakrishnan et al. 1993) and our current finding of 4.77% falls within the range and above the standardized value.

Table 2 shows the dzongkhag-wise mean fat-protein ratio. The overall mean of fat to protein ratio recorded was 1.58. The Dzongkhag wise fat to protein ratio was recorded highest in Samdrup Jongkhar with 1.93 and the lowest was recorded in Trashigang with 1.35. The significant difference in fat-to-protein ratio observed in milk can be attributed to an increase in milk fat and a decrease in milk protein, particularly arising from the feeding of animals with low protein diets. The fat-to-protein ratio (FPR) in milk is used to detect metabolic disorders and behavioral changes especially subclinical ketosis, in early lactating dairy cows (Arlauskaitė et al. 2025). Enemark (2008) reported that cows with a fat-to-protein ratio of above 1.5 are at greater risk for various complications like ketosis, ovarian cysts, mastitis, and lameness, which lead to production losses.

**Table 1:** Dzongkhag wise mean and standard deviation of milk composition.

<b>Dzongkhag</b>	<b>N</b>	<b>Fat(%)</b>	<b>SNF(%)</b>	<b>Protein(%)</b>	<b>Lactose(%)</b>	<b>Ash(%)</b>	<b>Freezing Point (-)</b>	<b>Water Added(%)</b>
Thimphu	880	4.39 ± 0.96	7.69 ± 0.89	2.80 ± 0.33	4.24 ± 0.49	0.63 ± 0.07	0.49 ± 0.06	7.50 ± 9.76
Paro	565	4.20 ± 1.17	8.15 ± 0.72	2.96 ± 0.26	4.48 ± 0.42	0.67 ± 0.06	0.52 ± 0.05	3.80 ± 6.34
Chukha	720	4.87 ± 1.29	8.14 ± 0.65	2.96 ± 0.24	4.49 ± 0.42	0.65 ± 0.05	0.53 ± 0.05	2.70 ± 6.18
Samtse	327	4.69 ± 1.15	8.26 ± 0.66	3.00 ± 0.26	4.69 ± 0.42	0.69 ± 0.05	0.55 ± 0.05	1.42 ± 4.37
Punakha	342	5.14 ± 1.24	8.13 ± 0.77	2.95 ± 2.96	4.49 ± 0.40	0.67 ± 0.06	0.53 ± 0.05	2.20 ± 7.26
Wangdue	437	5.42 ± 1.02	8.74 ± 0.58	3.19 ± 0.22	4.82 ± 0.33	0.71 ± 0.04	0.57 ± 0.04	0.55 ± 3.11
Dagana	272	4.48 ± 0.92	8.41 ± 0.50	3.08 ± 0.14	4.66 ± 0.19	0.69 ± 0.03	0.55 ± 0.03	0.38 ± 1.48
Tsirang	528	4.68 ± 1.23	8.11 ± 0.95	2.95 ± 0.36	4.47 ± 0.51	0.66 ± 0.07	0.53 ± 0.07	4.55 ± 9.63
Bumthang	381	5.12 ± 1.37	8.43 ± 0.74	3.08 ± 0.25	4.65 ± 0.39	0.69 ± 0.05	0.55 ± 0.04	1.29 ± 4.95
Trongsa	263	5.16 ± 1.65	8.67 ± 0.71	3.14 ± 0.40	4.78 ± 0.39	0.71 ± 0.05	0.57 ± 0.05	0.70 ± 3.81
Sarpang	515	4.60 ± 1.06	8.46 ± 0.68	3.07 ± 0.25	4.64 ± 0.37	0.67 ± 0.04	0.55 ± 0.05	1.85 ± 4.68
Trashigang	217	4.40 ± 1.55	8.60 ± 0.90	3.13 ± 0.33	4.70 ± 0.48	0.67 ± 0.07	0.55 ± 0.06	2.09 ± 5.50
Mongar	193	4.68 ± 1.49	8.39 ± 1.63	3.08 ± 0.61	4.54 ± 0.86	0.66 ± 0.08	0.54 ± 0.08	3.46 ± 6.62
Lhuntse	78	5.11 ± 1.75	8.83 ± 1.68	3.20 ± 0.61	4.83 ± 0.93	0.69 ± 0.08	0.57 ± 0.09	2.71 ± 6.10
Trashhi Yangtse	93	4.49 ± 1.98	10.19 ± 9.12	3.33 ± 0.40	4.99 ± 0.66	0.70 ± 0.05	0.58 ± 0.04	0.23 ± 2.14
Pema Gatshel	412	4.81 ± 1.31	8.16 ± 0.95	2.98 ± 0.40	4.47 ± 0.60	0.65 ± 0.09	0.51 ± 0.07	1.64 ± 5.10
S/Jongkhar	253	5.61 ± 1.65	9.98 ± 1.12	2.90 ± 0.40	4.41 ± 0.60	0.66 ± 0.07	0.53 ± 0.07	4.17 ± 7.82
Overall (Mean ± SD)		4.81 ± 1.34	8.55 ± 1.37	3.05 ± 0.50	4.61 ± 0.50	0.67 ± 0.06	0.54 ± 0.06	2.43 ± 5.58

**Table 2:** Dzongkhag wise fat and fat to protein ratio.

Dzongkhag(s)	N	Fat percent	Protein percent	Fat to Protein Ratio
Thimphu	880	4.39	2.8	1.57
Paro	565	4.2	2.96	1.42
Chukha	720	4.87	2.96	1.65
Samtse	327	4.69	3	1.56
Punakha	342	5.14	2.95	1.74
Wangdue	437	5.42	3.19	1.7
Dagana	272	4.48	3.08	1.45
Tsirang	528	4.68	2.95	1.59
Bumthang	381	5.12	3.08	1.66
Trongsa	263	5.16	3.14	1.64
Sarpang	515	4.6	3.07	1.5
Trashigang	217	4.4	3.13	1.41
Mongar	193	4.68	3.08	1.52
Lhuntse	78	5.11	3.2	1.6
Trashhi Yangtse	93	4.49	3.33	1.35
Pema Gatshel	412	4.81	2.98	1.61
Samdrup Jongkhar	253	5.61	2.9	1.93

### 3.4 Solid Not Fat

The overall mean SNF recorded was  $8.28 \pm 1.5\%$  (Table 1). The SNF content varied markedly among Dzongkhags, with Trashhi Yangtse Dzongkhag recording the highest mean value of 10.19%, followed by Samdrup Jongkhar with 9.98% and Lhuntse with 8.83%. A significantly lower SNF levels were observed in Thimphu with 7.69%, Tsirang with 8.11%. The present findings of mean solid not fat of 8.28% is slightly lower than the recommended value ranging between 8.5 - 9.5% (Kebede 2018). Lower SNF in the present study could be due to higher water adulteration as it dilutes the solid not fat concentration, reducing its content in milk.

### 3.5 Lactose

The overall mean lactose observed was  $4.54 \pm 0.51\%$  (Table 1). Lactose content recorded a marked variation across the surveyed Dzongkhags. The highest mean lactose

percentage was recorded in Trashhi Yangtse at (4.99%), followed by Lhuntse at (4.83%) and Wangdue at (4.82%). A significantly lowest lactose concentrations were observed in Thimphu at (4.24%) and Samdrup Jongkhar at (4.41%), which may indicate the possible influence of water adulteration. A study by Wangdi et al. (2014) reported higher mean lactose content of 5.40%, exceeding the values observed in the present study. This discrepancy may be attributed to differences in the sampled dairy populations, as the earlier study included multiple dairy breeds available in the country, whereas the present study was confined to dairy farmer groups rearing Jersey crossbred cows and Brown Swiss crossbred cows. The comparatively low average lactose concentration (<4.70%) observed in the present study may be associated with

reduced milk production. Antanaitis et al. (2024) reported that milk lactose levels exceeding 4.70% were associated with a 16% increase in milk yield, suggesting that improving lactose percentage could contribute to enhanced milk production.

### 3.6 Protein

The study recorded the overall mean protein percent of  $3.01 \pm 0.31$  (Table 2). Analysis of milk protein content across Dzongkhags revealed measurable spatial variation. The highest mean protein percentage was recorded in Trashhi Yangtse at (3.33%), followed by Lhuntse at 3.20% and at Wangdue (3.19%). These Dzongkhags exhibited protein levels above the national mean of 3.01%, indicating comparatively superior milk protein quality. Whereas, the lowest mean protein concentrations were observed in Thimphu at (2.80%) and Samdrup Jongkhar at (2.90%), both of which fell below the national average. The lower milk protein concentrations observed in these Dzongkhags may be attributed to poor feeding practices and possible unintentional water adulteration in milk

### 3.7 Water adulteration

The overall mean water adulteration recorded was  $3.38 \pm 7.72\%$ . The adulteration was recorded highest in Thimphu Dzongkhag ( $7.50 \pm 9.76\%$ ) and the lowest in Trashhi Yangtse ( $0.19 \pm 1.48\%$ ). Water adulteration findings for Thimphu dzongkhag falls within the range of 10 – 36 percent reported by Norbu et al. (2020).

A total of 6417 milk samples were collected of which 1626 (25.33%) samples were found positive for water adulteration ((Table 3). Samples collected from MPU bulk container has significantly higher level of water adulteration than individual and bulk

containers ( $p < 0.001$ ). Table 3 presents significant differences in the levels of water adulteration between individual milk collection and MPU samples collected ( $p < 0.001$ ). Specifically, 24.23% of samples from individual farmers, 30.16% of samples from bulk milk during transport to MPU, and a notably higher 60.81% of samples from MPU/sale counters were found to be adulterated, indicating a strong statistical significance. Most MPUs are situated in major towns like Thimphu and Tsirang, where water adulteration is higher. This issue is likely to be the result of rapid urbanization, logistical challenges, and a high human population demand for increased milk supply. This result agrees with the findings by Bhatt et al. (2008) who observed that adulteration practices are higher in urban areas than in rural areas.

**Table 3:** Water adulteration by collection point.

Collection point	Total	Percent	p value*
Individual farmer	5867	24.23	<0.001
Bulk container	431	30.16	
MPU	119	60.81	
Total	6417		

\*Chi sq test

Based on the above findings, water addition dilutes milk, leading to a reduction in caloric value and nutrient concentration, thereby minimizing its nutritional quality for human consumption. The rise in milk adulteration can be attributed to inadequate testing facilities at collection points, collection from different suppliers, and a lack of awareness regarding clean milk production practices. Additionally, some suppliers may adulterate milk with water to increase profit margins. Handford et al. (2016) justified that water

adulteration in dairy milk is a widespread and most common adulteration in developing countries

### 3.8 Ash content

The overall content recorded was  $0.67 \pm 0.09\%$ . The ash content of milk exhibited modest variation across the studied Dzongkhags. The highest mean ash percentage was recorded in Wangdue at (0.71%), closely followed by Trongsa at (0.71%) and Trashigang at (0.70%). These values were above the national mean ash content of 0.67%, indicating comparatively higher mineral concentrations present in milk from these Dzongkhags. Whereas, the lowest mean ash content was observed in Thimphu (0.63%), followed by Chukha (0.65%), both of which were below the national average. The reduced mineral content in these Dzongkhags may be influenced by factors such as feeding regimes, breed composition and stage of lactation, or possible dilution effects associated with water adulteration.

## 4. CONCLUSION

This study assessed the prevalence and impact of water adulteration on milk composition and quality. The findings revealed that 25.33% of the milk samples were adulterated with water. Water adulteration significantly reduced key milk constituents, including fat, protein, lactose, solids-not-fat (SNF), and freezing point values, thereby lowering the overall nutritional quality of milk. Evidence of adulteration was detected across several Dzongkhags, with relatively higher prevalence in urban and peri-urban areas where demand for raw milk is greater.

To safeguard milk quality and public health, regular awareness and training programs should be conducted for milk producers, collectors, and processing personnel. In addition, rapid milk-testing facilities should

be established at milk collection and processing centers to enable real-time detection of adulteration. Furthermore, sustained institutional commitment and strengthened regulatory mechanisms are essential to ensure effective monitoring, enforcement, and long-term improvement of milk quality standards to enable transitioning from volume-based to quality-based milk payment. Such a shift is expected to encourage the production and marketing of higher-quality milk and discourage adulteration practices.

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