Detection of Urea and Detergent Adulteration in Milk through Conductivity and pH Analysis

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Abstract

Milk adulteration is an increasingly prevalent issue, often driven by the intent to maximize profits. In general, food adulteration tends to rise when demand surpasses supply, and milk is no exception. While the addition of water is a common form of adulteration, other harmful substances such as urea, detergents, foreign fats, neutralizers, and flour are also frequently used. This study focuses on detecting milk adulteration specifically caused by the addition of urea and detergent, using a combination of percentage fat of milk, pH value and electrical conductivity as indicators.

Keywords: Milk Adulteration, Conductivity, pH, MLR.

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Introduction:

Food adulteration has seen a significant rise across the globe. There are three primary reasons contributing to this issue. First is the gap between food demand and supply. Due to the limited availability of natural resources, certain food items are frequently in short supply. Second, there is a lack of simple and accessible household methods to detect adulteration, making it difficult for consumers to identify impure food. Third, the motivation to earn additional profit leads many to engage in adulteration, making it a common practice in many of the foods we consume daily.

To help address this concern, the Food Safety and Standards Authority of India (FSSAI) published a book in 2012 titled “Quick Test for Some Adulterants in Food” (1), which outlines various methods for detecting adulteration. Among the most commonly adulterated items is milk, which is a vital part of our daily diet. One of the oldest and simplest ways to adulterate milk is by adding water to increase its volume. Although this increases quantity, it compromises quality. To detect such adulteration, the GERBER method (2) is in used, which calculates the percentage of fat. The other method to detect the water adulteration is the use of a lactometer to measure the specific gravity of milk. Urea is also a common milk adulterant added to extend shelf life. It is also used in the preparation of synthetic milk and to artificially increase the SNF (Solids-Not-Fat) value. Additionally, urea content in milk may rise due to the unbalanced feeding of cows (3). The associated risks to health due to consumption of urea include acidity, indigestion, ulcers, and certain types of cancer. Urea poses significant harm to the heart, liver, and kidneys (3), particularly affecting the kidneys, as they are required to exert additional effort to eliminate excess urea from the body (4). Detergents are considered among the most commonly used adulterants in milk (5). The primary motivation behind this fraudulent practice is the financial gain obtained through the partial or complete substitution of milk with cheaper and easily available substances (6). Consuming detergent adulterated milk poses significant health risks, including allergic reactions, infections, and metabolic disorders (6). This highlights the necessity of detecting urea and detergent in milk. The standard method for detecting urea in milk utilizes the DMAB reagent, which produces a distinct yellow coloration in the presence of urea (1). Similarly, the detection of detergent is performed using the Bromocresol Purple reagent, which causes the milk sample to turn violet if detergent is present (1). However, these methods are predominantly chemical-based and require specific technical skills, as well as access to laboratory-grade reagents and instruments operated by trained personnel. Consequently, such procedures are not feasible for use by the average consumer or layperson. Moreover, these tests primarily indicate the presence or absence of adulterants but do not provide quantitative information about their concentration in the sample.

Existing Non-Chemical methods of Milk Adulteration Detection

To date, several non-chemical and instrumental methods have been developed for the detection of milk adulteration. Near-Infrared (NIR) Spectroscopy has been employed to identify water adulteration by observing the decrease in light reflectance at wavelengths of 1200 nm and 1450 nm as water concentration increases in the milk sample, a principle that is also applicable for detecting whey adulteration (7) (8). Fourier Transform Infrared (FTIR) Spectroscopy has proven effective in detecting multiple adulterants, including cornstarch, sodium bicarbonate, sodium citrate, formaldehyde, and saccharose, as well as varying levels of added water or whey (9). Time Domain Nuclear Magnetic Resonance (TD-NMR) Spectroscopy has been utilized to identify adulterants such as whey, urea, hydrogen peroxide, and synthetic milk (10). Ultrasonic techniques have also been investigated, where adulteration is detected by analyzing changes in propagation delay and signal attenuation. An increase in milk fat percentage leads to a higher propagation delay, while attenuation varies with both fat and skimmed milk content (11). Similarly, an increase in vegetable oil adulteration results in decreased ultrasonic velocity, and water adulteration can be detected through variations in output voltage (12) (13). Electronic nose (E-nose) systems, incorporating an array of eight distinct sensors, have been employed to detect skimmed milk adulteration (14). Furthermore, optical detection using a 900 nm LED source and optical sensors has shown effectiveness in identifying skimmed milk based on changes in reflection angle (15). Additionally, freezing point osmometry is used to detect water adulteration, as the freezing point of milk decreases proportionally with the amount of water added in milk (16). A potentiometric biosensor was developed to detect urea adulteration in milk with high sensitivity (2.5×10^{-5} mol/L) and strong correlation accuracy (3). The phase angle of milk was found to increase with starch adulteration and decrease with urea adulteration (17). A combined use of the Kjeldahl method with either the Bradford or Markwell method was found effective for detecting melamine, urea, and ammonium sulphate adulteration in UHT milk (18). It was also found that the phase angle of milk sample increased with water and whey adulteration but decreased with urea adulteration in milk samples (19). Detergent adulteration in milk was detected using gold nanoparticles, showing an Indic blue color when detergent exceeded 1 µg/ml (20). An increase in milk capacitance was observed with higher concentrations of water, urea, starch, and detergent adulterants (21). Conductance was also used to detect the presence of detergent, hand wash and shampoo, the value of conductance increases as any of the adulterant value increased in the milk sample (6). Measuring the dielectric properties of milk offers a simpler alternative. These methods do not require elaborate sample preparation or expensive equipment. The key dielectric properties studied so far include conductance (22), capacitance (23), and impedance phase angle (24). Among these, conductivity stands out as an easy-to-measure parameter. By monitoring the conductivity of milk, adulteration can be effectively detected. Moreover, in the present market, several companies offer affordable handheld devices capable of measuring conductivity at higher frequencies, making this approach both practical and accessible. Previous studies have often overlooked the influence of milk fat percentage during adulteration detection. In the present investigation, this critical parameter was systematically considered by varying the fat content of milk samples. Although a similar approach was earlier employed for detecting water adulteration in milk, pH was not included as a parameter in those studies (25). Measuring the pH of the milk provides insight of milk purity as the milk pH should be between from 6.6 to 6.8 (26). Since pH serves as a reliable indicator of milk purity and varies with factors such as water content and solids-not-fat concentration, its inclusion in the present study provides a more comprehensive evaluation. Consequently, this work systematically examines the combined effects of milk fat percentage, conductivity and pH on the detection of urea and detergent adulteration, offering a more controlled and holistic analysis compared to earlier research.

Experimental Setup

In this experimental study, total four parameters were measured for each milk sample that are percentage of milk fat, conductivity, pH and temperature. Out of these four the three parameter were measured using, two handheld devices: temperature, electrical conductivity and pH. For conductivity measurements, the COM-100 device (HM Digital®) was used, providing readings in millisiemens (mS). The pH was measured using another handheld device from HM Digital®, model pH-80 (HM Digital®). Both this devices have inbuilt temperature sensor, to measure the temperature. Along with this the percentage value of milk fat is measured using the Gerber method.

Sample Preparation and Measurement

Raw milk from cows and buffaloes was collected at the milk collection center in Dingucha, Gujarat. The fat content of each sample was determined on-site using the Gerber method. To ensure representation across a broad range of fat concentrations, milk samples were selected with fat contents ranging from 3% to 8% in 1% increments, resulting in six distinct sample categories. This range was chosen because the fat content of cow and buffalo milk in India typically lies between 3% and 8%. Furthermore, milk pricing for farmers in India is determined based on fat percentage, in increments of 1%. Therefore, a 1% incremental variation was adopted to reflect the practical classification used in commercial and dairy procurement systems. Since the pH of milk is generally affected by storage conditions and duration, the samples were stored in separate glass bottles at room temperature for one to two hours at the collection center itself. The experiments were conducted on-site to avoid transportation and to maintain the quality and freshness of the milk.

For each milk type, a 100 ml sample was used for experimentation. The electrical conductivity was measured using the COM-100 device, followed by pH measurement using the pH-80 device. To assess the impact of adulteration, urea was gradually added to the milk samples. After each incremental addition, conductivity and pH were re-measured, continuing this process until 10 grams of urea had been introduced into each 100 ml milk sample. However, during all measurements, the temperature of the milk samples was maintained at 25°C using a general-purpose water bath. Both the COM-100 and pH-80 devices included built-in temperature sensors, allowing simultaneous monitoring of temperature alongside conductivity and pH measurements. This feature ensured consistent thermal conditions throughout the experiment. Readings were recorded only when the milk sample had stabilized at exactly 25°C. After each incremental addition of the adulterant, the milk sample was thoroughly stirred and allowed sufficient time to settle and equilibrate to the target temperature before taking further measurements.

This stepwise procedure enabled a detailed examination of how milk properties are altered by urea adulteration. Conductivity results are illustrated in Figure 1, and corresponding pH values are shown in Figure 2.

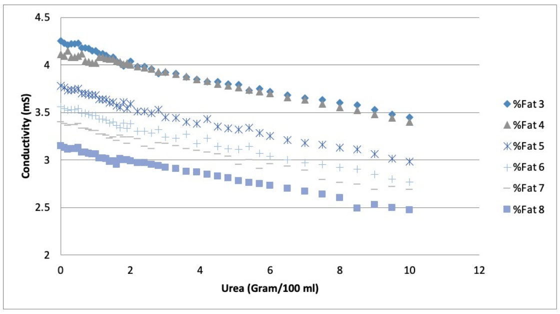

Figure-1. Representation of conductivity vs amount of urea with, classification by percentage of milk fat

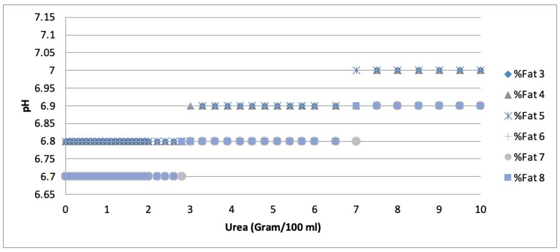

Figure-2. Representation of pH vs amount of urea with, classification by percentage of milk fat

The same procedure was applied using detergent instead of urea as the adulterant across all six milk types. However, the amount of detergent added was limited to a maximum of 1 gram, as both pH and conductivity readings reached to saturation, making further additions unnecessary. Normally to yield more profit the low cost detergents are been used. Those low cost detergent carries major amount of Sodium Bi-carbonate (Na_2CO_3). In this experiment same type of low cost detergent was used. A total of 300 milk samples were analyzed for urea adulteration. In the case of detergent adulteration, the addition of higher concentrations caused the conductivity values to exceed the measurable range. Therefore, the analysis was limited to samples containing detergent concentrations up to 1 gram per 100 mL, resulting in a total of 66 samples being used for detergent analysis. Figure 3 and Figure 4 present the experimental results for conductivity and pH measurements, respectively. Both figures illustrate the variation in these parameters with respect to different concentrations of detergent used as an adulterant in milk.

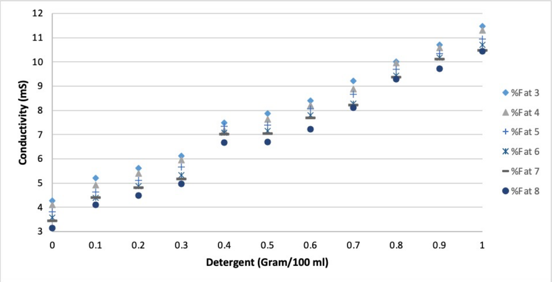

Figure-3. Representation of conductivity vs amount of detergent with, classification by percentage of milk fat

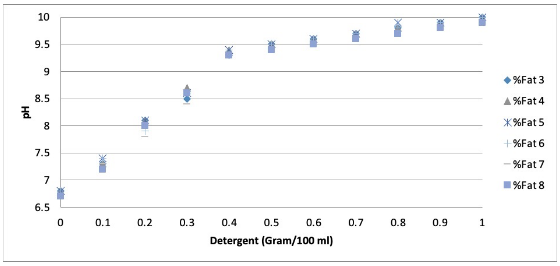

Figure-4. Representation of pH vs amount of detergent with, classification by percentage of milk fat

Experimental results

Several important observations were obtained from the analysis. First most important is that conductivity has dependency on the percentage fat of milk sample. It is observed as the amount of fat percentage increases the conductivity decreases. In the case of urea adulteration, an inverse relationship was identified between fat content and electrical conductivity. Specifically, milk samples with higher fat content exhibited lower electrical conductivity values. As urea concentration increased, conductivity decreased further. However, relying solely on conductivity to detect urea proved inadequate. For instance, a low-fat adulterated sample exhibited conductivity levels similar to those of high-fat pure milk. In contrast, pH values exhibited a consistent upward trend with increasing concentrations of urea. However, the rate of change was relatively gradual. The results for urea adulteration detection indicate the necessity of measuring all three parameters to accurately validate the presence of the adulterant. However, pH measurement alone proves to be more effective when the concentration of urea adulteration is relatively high.

For detergent adulteration, a sharp rise in electrical conductivity was evident, even with minimal adulteration of detergent. pH values increased rapidly between 0.1 and 0.4 grams of detergent. Beyond this point, although pH continued to rise, the rate of change diminished, indicating a saturation effect at higher detergent concentrations.

From Figures 1 to 4, it can be observed that all three parameters, pH, conductivity, and fat percentage, exhibit measurable relationships with milk adulteration. To quantify these relationships, a multiple linear regression model was developed using the “scikit-learn” (sklearn) library in the Python environment. Separate models were constructed for each adulterant, and the corresponding regression coefficients and intercepts are presented in Table 1. These mathematical models were applied to predict the concentration values in newly tested milk samples, in which the adulterant levels were already known. This process was conducted to evaluate the accuracy and reliability of the developed predictive models.

Table 1: Mathematical Model

Adulterant (mg / 100ml)	Coefficient of each parameter			
	%fat of milk	pH	Conductivity(mS)	Constant
Urea	2084.96	6531.16	10490	6261.70
Detergent	28.11	13.22	132.72	−742.60

Figures 5 and 6 present the relationships between the actual and predicted concentrations of urea and detergent in milk samples, respectively, demonstrating the effectiveness of the developed models in detecting and quantifying milk adulteration. For urea adulteration, the multiple linear regression model achieved a coefficient of determination (R^2) of 0.93, indicating a strong correlation between predicted and actual values. The mean deviation in estimating urea concentration was 709 mg per 100 ml within the measurement range of 0 to 10,000 mg per 100 mL, corresponding to an overall deviation of approximately 7.09% relative to the total range. Similarly, for detergent adulteration, the model achieved an R^2 value of 0.94, reflecting a high degree of accuracy between predicted and observed concentrations. The average deviation in estimating detergent concentration was 7.63 mg per 100 ml over the range of 0 to 1000 mg per 100 mL, which corresponds to an approximate deviation of 7.63% of the total range. In case of urea out of 100 test milk samples, only 7 samples failed to be detected that is having less values then 50 mg. The developed mathematical model effectively confirms the presence of urea adulteration, with urea concentration predicted within an average deviation of approximately 7%. In the case of the specific detergent type considered, the model demonstrated complete detection accuracy, successfully identifying even 100 mg of detergent in a 100 ml milk sample. These findings suggest that both regression models are suitable for reliable identification of adulterated milk samples.

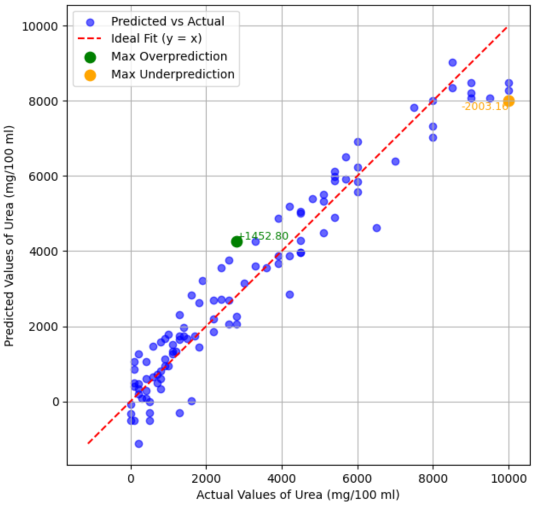

Figure 5: Predicted vs Actual Values of Urea with Maximum Deviations

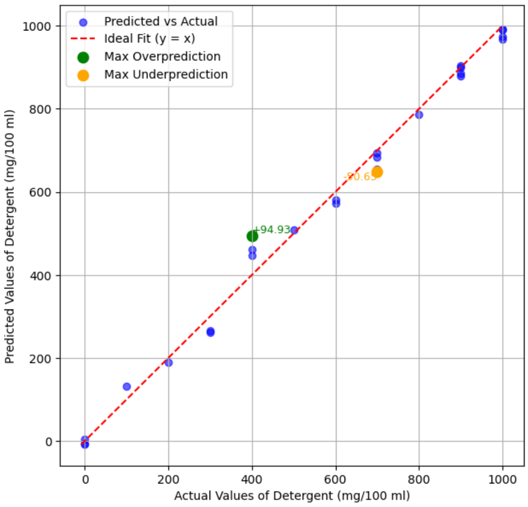

Figure 6: Predicted vs Actual Values of Urea with Maximum Deviations

Conclusion

In this study, two separate regression models were developed to estimate the quantity of adulterants, one of them is urea and other is detergent present in milk samples. The urea prediction model, constructed using a multiple linear regression approach, quantifies the adulterant in milligrams and demonstrates high accuracy, explaining over 93% of the variation in urea content ($R^2 = 0.93$). Standardized coefficients further enhance the interpretability of the model, making it well-suited for quality control applications that demand precise quantification. Similarly, the detergent detection model was also made using a multiple regression framework. It shows a slightly higher R^2 score of 0.94, indicating reliable prediction capability across a wide range of milk samples. It is capable of detecting even minor traces of detergent adulteration with significant consistency. The results also indicate that, in addition to pH and conductivity, the measurement of milk fat percentage plays a crucial role in accurately estimating adulteration levels. Variations in milk fat content significantly influence the conductivity of milk samples, thereby affecting the precision of adulterant quantification. The present model for detergent quantification is specifically optimized for a particular type of detergent, providing a solid foundation for future expansion to other detergent categories. Additionally, the milk samples utilized in this study were collected from a specific region of India, which ensures regional accuracy and reliability. With further validation using diverse milk sources and geographical regions, the proposed models hold strong potential for wider applicability across different animal types and global contexts.

References

1. **India, Food Safety and Standards Authority of.** *QUICK TEST FOR SOME ADULTERANTS IN FOOD.* s.l. : Food Safety and Standards Authority of India, 2012.

2. **Institution, Indian Standards.** *Determination of FAT by the GERBER Method.* New Delhi : FAD 19 dairy products and equipment, 1986. pp. 2-10.

3. *Potentiometric biosensor for urea determination in milk.* **Trivedi, U. B., et al.** 1, 6 2009, Sensors and Actuators, B: Chemical, Vol. 140, pp. 260-266. 09254005.

4. *A method for estimation of urea using ammonia electrode and its applicability to milk samples.* **Sharma, Rajan, et al.** 4, 11 2008, Journal of Dairy Research, Vol. 75, pp. 466-470. 00220299.

5. *Estimation of quality of raw milk(open & branded) by milk adulteration testing kit.* **Kandpal, SD, Srivastava, AK and Negi, KS.** 9 2012, Indian Journal of Community Health, Vol. 24, pp. 188-192.

6. *Detergent and Soaps Adulteration Detection in the Milk Using Artificial Embedded Sensors.* **Rajashekhar, B, S and Kusagur, Ashok.** 2, 2018, International Journal of Engineering & Technology, Vol. 7, pp. 1022-1024.

7. *Development of a hardware platform for detection of milk adulteration based on near-infrared diffuse reflection.* **De Souza Ribeiro, Lucas, et al.** 7, s.l. : Institute of Electrical and Electronics Engineers Inc., 7 2016, IEEE Transactions on Instrumentation and Measurement, Vol. 65, pp. 1698-1706. 00189456.

8. *Feasibility of Near-Infrared Spectroscopy to Detect and to.* **Sumaporn KASEMSUMRAN, Warunee THANAPASE and Artaya KIATSOONTHON.** 7 2007, ANALYTICAL SCIENCES, Vol. 23, pp. 907-910.

9. *Adulteration identification in raw milk using Fourier transform infrared spectroscopy.* **Coitinho, Tatiane Barbosa, et al.** 8, s.l. : Springer India, 7 2017, Journal of Food Science and Technology, Vol. 54, pp. 2394-2402. 09758402.

10. *Detection and quantification of milk adulteration using time domain nuclear magnetic resonance (TD-NMR).* **Santos, Poliana M., Pereira-Filho, Edenir R. and Colnago, Luiz A.** s.l. : Elsevier Inc., 1 2016, Microchemical Journal, Vol. 124, pp. 15-19. 0026265X.

11. *Ultrasonic Sensing System for detecting water adulteration in milk.* **Aditya Dave, et al.** 2016, IEEE Region 10 Conference (TENCON), pp. 2228-2231. 9781509025978.

12. *Ultrasonic detection of adulteration in fluid foods.* **Singh, V R and Dwivedi, S.** 1995, Proceedings of the First Regional Conference, IEEE Engineering in Medicine and Biology Society and 14th Conference of the Biomedical Engineering Society of India. An International Meet, pp. 1/73-1/74.

13. *Acoustic Attenuation Technique for the Detection of Adulteration in Milk.* **Anwar Sadat, Pallavi Gupta and M. J. R. Khan.** 12 2011, International Journal of Computer Applications.

14. **Yu, Huichun, Wang, Jun and Xu, Yadan.** *Identification of Adulterated Milk Using Electronic Nose.* 2007. pp. 275-285.

15. *Optical sensing system for detecting water adulteration in milk.* **Dave, Aditya, et al.** s.l. : Institute of Electrical and Electronics Engineers Inc., 2016, GHTC 2016 - IEEE Global Humanitarian Technology Conference: Technology for the Benefit of Humanity, Conference Proceedings, pp. 634-639. 9781509024322.

16. *Freezing point osmometry of milk to determine the additional water content - An issue in general quality control and German food regulation.* **Büttel, Britta, Fuchs, Markus and Holz, Birger.** 1, 2008, Chemistry Central Journal, Vol. 2. 1752153X.

17. *Electrical impedance Sensor for Real-Time Detection of Urea and Starch in Milk.* **Sude, Mohini and Ghodinde, Ketaki.** 2019, Third International Conference on Trends in Electronics and Informatics, pp. 431-434. 9781538694398.

18. *Is it possible to screen for milk or whey protein adulteration with melamine, urea and ammonium sulphate, combining Kjeldahl and classical spectrophotometric methods?* **De Lourdes Mendes Finete, Virgínia, et al.** 4,

s.l. : Elsevier Ltd, 2013, Food Chemistry, Vol. 141, pp. 3649-3655. 18737072.

19. *Milk Adulteration and Detection: A Review.* **Das, Siuli, Goswami, Bhaswati and Biswas, Karabi.** 1, s.l. : American Scientific Publishers, 1 2016, Sensor Letters, Vol. 14, pp. 4-18. 15461971.

20. *A simple method for detection of anionic detergents in milk using unmodified gold nanoparticles.* **Kumar, Pardeep, et al.** s.l. : Elsevier B.V., 10 2016, Sensors and Actuators, B: Chemical, Vol. 233, pp. 157-161. 09254005.

21. *Detection of Adulteration in milk using capacitor sensor with especially focusing on Electrical properties of the milk. †.* **Worku, Dinku, et al.** s.l. : Available, 2020, MDPI Proceedings Journals, Vol. 15, pp. 1-10.

22. *Application of electrical admittance measurements to the quality control of milk.* **Mabrook, M F and Petty, M C.** 2, 2002, Sensors and Actuators B: Chemical, Vol. 84, pp. 136-141. 0925-4005.

23. *A novel technique for the detection of added water to full fat milk using single frequency admittance measurements.* **Mabrook, M. F. and Petty, M. C.** 1-2, 11 2003, Sensors and Actuators, B: Chemical, Vol. 96, pp. 215-218. 09254005.

24. *Development of two dielectric sensors coupled with computational techniques for detecting milk adulteration.* **Ghasemi-Varnamkhasti, Mahdi, et al.** s.l. : Elsevier B.V., 8 2017, Computers and Electronics in Agriculture, Vol. 140, pp. 266-278. 01681699.

27. *Detection of adulterated milk using two-dimensional correlation spectroscopy combined with multi-way partial least squares.* **Yang, Renjie, Liu, Rong and Xu, Kexin.** s.l. : Elsevier Ltd, 2013, Food Bioscience, Vol. 2, pp. 61-67. 22124292.

28. *A comprehensive approach for milk adulteration detection using inherent bio-physical properties as 'Universal Markers': Towards a miniaturized adulteration detection platform.* **Tripathy, Suryasnata, et al.** s.l. : Elsevier Ltd, 2 2017, Food Chemistry, Vol. 217, pp. 756-765. 18737072.

29. *Determining the adulteration of natural milk with synthetic milk using ac conductance measurement.* **Sadat, Anwar, Mustajab, Pervez and Khan, Iqbal A.** 3, 2006, Journal of Food Engineering, Vol. 77, pp. 472-477. 0260-8774.

30. *The conductivity of milk—the effect of the volume and degree of dispersion of the fat.* **Prentice, J H.** 2, s.l. : Cambridge University Press, 1962, Journal of Dairy Research, Vol. 29, pp. 131-139.

31. *Recent advances on determination of milk adulterants.* **Nascimento, Carina F., et al.** s.l. : Elsevier Ltd, 4 2017, Food Chemistry, Vol. 221, pp. 1232-1244. 18737072.

32. *Milk adulterant detection: Conventional and biosensor based approaches: A review.* **Nagraik, Rupak, et al.** s.l. : Elsevier B.V., 8 2021, Sensing and Bio-Sensing Research, Vol. 33. 22141804.

33. *Electrical Conductivity Changes in Milk Caused by Acidification: Determining Factors.* **Mucchetti, Germano, Gatti, Monica and Neviani, Erasmo.** 4, 1994, Journal of Dairy Science, Vol. 77, pp. 940-944. 0022-0302.

34. *Determining the fat content of milk and cream using AC conductivity measurements.* **Lawton, B A and Pethig, R.** 1, s.l. : IOP Publishing, 1 1993, Measurement Science and Technology, Vol. 4, pp. 38-41.

35. *A review of the analytical methods coupled with chemometric tools for the determination of the quality and identity of dairy products.* **Karoui, Romdhane and De Baerdemaeker, Josse.** 3 2007, Food Chemistry, Vol. 102, pp. 621-640.

36. *A Review on Conventional and Nonconventional Methods for Milk Adulteration Detection.* **Shah, Mehul and Dave, Jaimin.** 3 2017, International Journal for Research in Applied Science and Engineering Technology, Vol. V, pp. 1498-1501.

37. *On-line Estimation of Fresh Milk Composition by means of VIS-NIR Spectrometry and Partial Least Squares Method (PLS).* **Artime, Carlos Enrique Carleos, et al.** 2008, 2008 IEEE Instrumentation and Measurement Technology Conference, pp. 1471-1475.