

Smart Milk Adulteration Detection

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Abstract- Adulteration is extremely basic today and the most normally adulterated nourishment item is milk. The most widely recognized explanation behind adulteration is the utilization by producers of undeclared materials that are less expensive than the right and pronounced ones. Adulteration brings down the nature of nourishment and now and then, harmful synthetic substances are likewise added which can be dangerous to health. Adulteration of products either in liquid or solid form can harm or pose serious health risk issues to the consumer. The present investigation was arranged with the primary goal of recognizing purchasing practices of homemakers and their degree of awareness identified with chosen food items. Being considerate of the health & betterment of the society we have planned a project which will allow the customer to know about the level of purity of product which they are buying and being aware of it in future.

I. INTRODUCTION

Liquid adulteration is one of the most common issues with the quality of food. Apart from being a moral violation it also affects health in a big way. Some of them are renal and skin disease, eye, and heart problems and may also lead to cancer. Reliable testing of food items is required for assessing the value and to preventing the customers of being defrauded both economically and in terms of health. So, in our project, we have focused on milk adulteration detection. In most cases adulteration is being done intentionally so as to increase profits while in some cases it might be due to the non-availability of proper technology to detect adulterants and unawareness of adulterants in case of industrial workers.[1]

Sometimes milk items are adulterated with cheap liquids like water and whey and are referred to as “economic adulteration”. Diluted food item contains reduced nutritional values and the water that may have been used for adulteration might have been contaminated which poses dangerous health issues. Addition of water results in the change of specific gravity which also results in discoloration of milk. Based on the above principle lactometer which works on the principle of changes in specific gravity is used for detecting adulteration in milk. But to compensate for the changes in specific gravity sugar is added. And to compensate for the changes in colour a small amount of food is also added. Maltodextrin is used in dairy foods to add flavor and reduce the cost of the products. One more commonly used adulterant is the addition of milk whey (the by-product obtained after making cottage cheese from the milk).[2]

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Whey is also created by chemicals which further affect health. Now, this artificially created whey also causes many medical issues. Cold press oils are adulterated by refined oils. During the refining process, fatty acids are created which causes further harm. Trans fatty acids are not required by the body and affect one's health.

Hydrogenated oils are much more harmful than refined oils which causes trouble if used. Milk and natural product juices have principal significance in the human diet. Increasing demand of these milk foods has made them vulnerable to economic adulteration during processing and in the supply chain. Removal of the cream or selling of skimmed or partially skimmed milk as whole milk is additionally one type of milk adulteration. Compound adulterants are utilized for various purposes. The most commonly used adulterants are formalin, chlorine, ammonium sulphate, starch, sodium carbonate, formalin, and hydrated lime.

To meet the deficit of milk, the synthetic milk is prepared by mixing urea, caustic soda, refined oil and common detergents which has a poisonous effect. Widespread use of chemical preservatives to preserve milk in warm weather is a great concern in the food industry. Worries about food safety and guideline have guaranteed the improvement of different procedures like physical, biochemical/immunological and molecular systems, for adulterant detection in food. Molecular strategies are progressively ideal with regards to detection of natural adulterants in food, albeit physical and biochemical procedures are best for the detection of different adulterants in nourishment. Potential advantages and disadvantages of different systems, for example, physicochemical techniques, chromatography, immunoassays, sub-atomic, electrical, spectroscopy with chemometrics, electronic nose, and biosensors have been found. For detection of chemical adulterants sophisticated instrument is required. With the progression of innovation, more up to date procedures have been designed to recognize various types of fluid adulterants, however in a similar pace, the mind-boggling strategies for milk adulteration have been developed.

II. LITERATURE SURVEY

Various Past electrical methods to detect milk adulterants are as follows -

Potentiometric Sensors- Potentiometric allows the determination of a wide spectrum of ions and inexpensive, portable equipment that can be developed. Trivedi et al. have reported a potentiometric biosensor³ to detect urea adulteration in milk. It uses an NH₄⁺ ion-sensitive electrode as the transducer.[3]



Conductance Measurement- The conductance measurement between two electrodes is a well-known technique to detect adulteration. Most of the times the electrical equivalent model of the electrodes immersed in the sample is evaluated to identify the adulterated milk.[4]

Ultrasonic Detectors- Chemicals like sodium bicarbonate, sodium carbonate, formalin, are added to milk to preserve it for a longer time or as a neutralizer to prevent curdling. Mohanan et al. has reported the study of thermoacoustic analysis to identify the chemicals. In this method, the density and ultrasonic velocity are determined for different samples while the temperature is kept fixed for a particular measurement. Ultrasonic velocities were measured by a single crystal ultrasonic interferometer at a frequency of 2 MHz [5]

Piezoelectric Sensor- Jiali et al. have reported the determination of bacteria counts in fresh milk in real-time using piezoelectric transducer. The detection system consists of a cell for detection, oscillator, frequency counter and computer in which self-developed software is installed to capture the transducer response with the change of culture media during bacteria growth. The transducer could acquire sufficient data rapidly and enabled real-time monitoring of bacteria growth.[6]

Impedance Probe- Milk containing bacteria convert lactose into lactic acid over time. This, in turn, changes the electrical parameter of the milk. Conductivity is an easy parameter to detect bacteria but it is strongly influenced by the fat content of the milk and primarily used for the detection of mastitis. Fourie et al. have presented a stainless-steel rod-based impedance probe for bacterial content measurement of milk. It has been described that the probe must be thoroughly cleaned after testing and the measurement is dominated by the impedance of the electrode-electrolyte interface. The stainless-steel rod has the advantage of cleaning over copper and brass probes. The sensor has been integrated with a microcontroller circuit for automatic measurement and data storage.

III. PURPOSE OF THE PROJECT

First stage of our project involves the detection of various adulterants that are present in milk. Different types of adulterants that are mainly found in milk are as follows:

Water- Water is the most common adulterant in milk. Though a major percentage of natural milk contains water but milk with added water is a serious concern to the milk consuming community. On one hand it decreases the nutritious value; on the other hand, chemicals are added to compensate the density and colour after dilution with water. Since the addition of water is the easiest way of adulteration of milk, so a variety of techniques are also available for its detection.

Chlorine- Chlorine is added to compensate for the density of the diluted milk after addition of water. Mastitis in cow also raises the chlorine level in the milk. Chlorinated milk can cause clogging in arteries and develop heart problems.[7]

Antibiotics- Antibiotics are used mainly to treat a variety of diseases and 80% of dairy herds use antibiotics for treatment of mastitis disease. These antibiotics in the form of antimicrobial residues are found in abundance in milk. Sometimes these reagents are also added to increase the shelf life of milk.[8]

Non- Milk Products- Milk, milk powder and other dairy products are often adulterated by low priced non-milk proteins such as soy, pea and soluble wheat proteins (SWP). Bovine rennet whey powder (a waste product from cheese production) is sometimes mixed in milk powder. Sometimes milk fat is replaced by fat from other sources which may also pose a risk to human health.[9]

Low-Valued Milk- Milk is adulterated by mixing lower-valued milk with higher valued milk. For example, often goat milk is adulterated with cow milk for greater profit. It has been found that health hazards related to this practice are not well defined (some may have allergy in cow's milk) but from the commercial and ethical point of view, this is a great concern in the food industry.

Low priced cow milk is often added in the milk of ewes, goats, buffalos and in sheep's milk.

Milk Powder- Sometimes milk powder as an adulterant is added in fresh milk, this is done for economic advantage when a country has milk powder in excess or subsidy is provided for dried powder milk.

Colour- Many food colourants are also added to improve the appearance and have a hazardous effect on health.

Soap- Soap is added to milk to increase the foaming of milk and thus to have thick milk.

The addition of such chemicals will cause health problems especially related to stomach and kidneys. So here the lactometer fails to find fat content as it works on the principle of density and ph. meter is required to detect this change of adulteration in milk.

IV. PROBLEM AND PROPOSED SOLUTION

Problem-

The main problem associated with adulteration is the variety of adulterants now available in the market. Each adulterant has a different way of detection and involves a variety of methods. Our problem statement is going to focus on base/main consumable as milk. Now, it has been a common observation and extensive reports that have come out stating that detergent and caustic soda are now largely used as an adulterant. Now, these adulterants help milk generate foam and help in imitating adulterated as a real one. Also, these do so without bringing noticeable change in the density of milk. As, a result of which the conventional method involving using Lactometer fails as it works on the principle of change in density of the milk.

Solution- In accordance with our previous discussion pH of pure milk 6.5pH. Adulterant which is used that is a soap solution in our case is alkali in nature and a fully saturated solution gives a maximum pH of 8.8 – 9. The output from the pH meter was in volts and which was received in the analog pin of Freeduino. So, here what we observed that the sensor was capable of covering the entire pH range of 0-14 in 0 – 3V scale. So, one of the methods was to first calibrate the pH levels with the voltage output given by the sensor and then using these pH levels and get a relation between the concentration of adulterant (soap solution) and pH of the solution.

But if this approach was chosen this will result in more errors because errors from both the calibration will get compiled and results in a larger error. So, we went for finding the relation between the pH of the solution and output voltage given by the pH meter.

First The first step involves calibrating pH meter output voltage to pH scale. Secondly, then we realized that there was no need to calibrate the pH scale. We directly found readings between the concentration of soap solution in milk and the pH voltage. This was done in order to reduce the magnitude of error which is inevitable whenever any calibration is done. Then, when we got the observations, we used statistical regression and curve detection to find a relation between the concentration of soap solution and pH

voltage. Then we implemented the equation found in code which was uploaded to Freeduino. Also, for taking observations we kept Mother Dairy cow milk as the pure milk standard and for soap solution, we dissolved 180mg detergent in 100 ml water. Then, after making all the connections and testing the project we got satisfactory readings. Also, while taking readings we went for a maximum of 40% adulteration which is also quite large and anything above that was not feasible in real-life scenarios. Block Diagram and Flowchart of our project are given below.

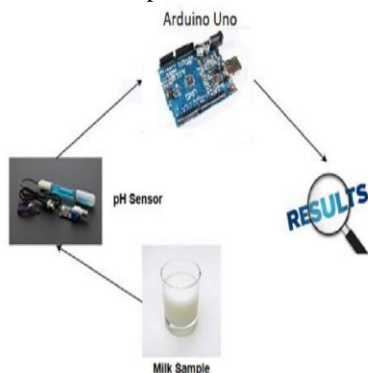


Figure 1 Block Diagram

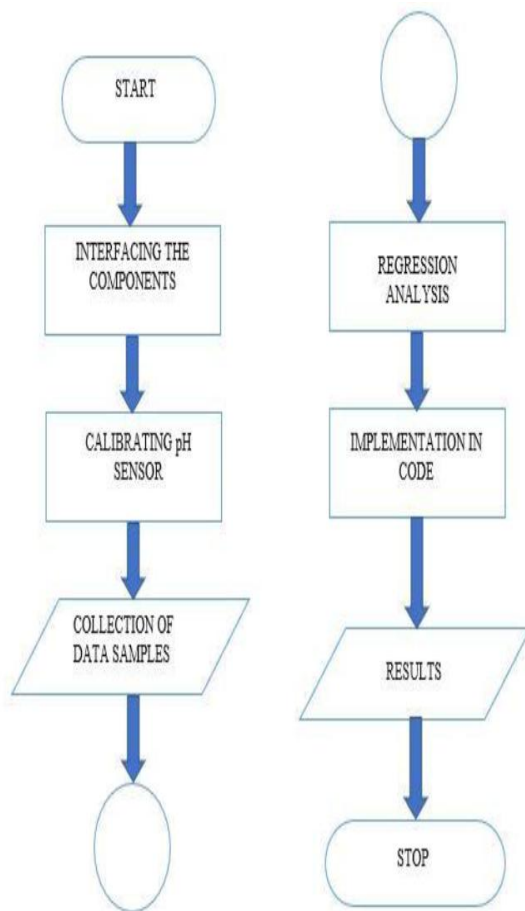


Figure 2 Flowchart

V. OBSERVATIONS

Table 1 contains observation of concentration of soap solution with milk and the observed voltage on ph. meter.

The concentration of Soap Solution (%)	pH Voltage (V)
0% (pure milk)	1.96V
5%	1.97V
9.52%	1.98V
14.9%	2.01V
19.7%	2.04V
25%	2.11V
30%	2.14V
35%	2.23V
40%	2.32V
100% (only soap solution)	2.9V

Table 1

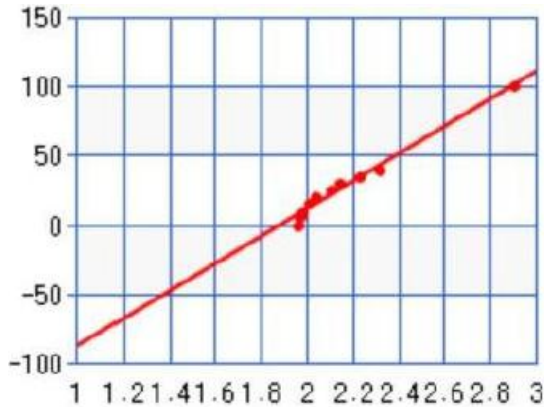


Figure 3

Linear regression performed with the values shown in table 1 Using these mathematical formulae

$$\bar{x} = \frac{\sum x_i}{n} \quad (1)$$

$$\bar{y} = \frac{\sum y_i}{n} \quad (2)$$

$$y = A + Bx \quad (3)$$

$$B = \frac{S_{xy}}{S_{xx}} \quad (4)$$

$$A = \bar{y} - B\bar{x} \quad (5)$$

$$S_{xx} = \frac{\sum (x_i - \bar{x})^2}{n} = \frac{\sum x_i^2}{n} - \bar{x}^2 \quad (6)$$

$$S_{yy} = \frac{\sum (y_i - \bar{y})^2}{n} = \frac{\sum y_i^2}{n} - \bar{y}^2 \quad (7)$$

$$S_{xy} = \frac{\sum ((x_i - \bar{x})(y_i - \bar{y}))}{n} = \frac{\sum x_i y_i}{n} - \bar{x}\bar{y} \quad (8)$$

$$r = \frac{S_{xy}}{\sqrt{S_{xx} S_{yy}}} \quad (9)$$

Correlation coefficient r = 0.9908

A=-187.0730
B=99.2544

Quadratic Regression is also performed using the formulae.

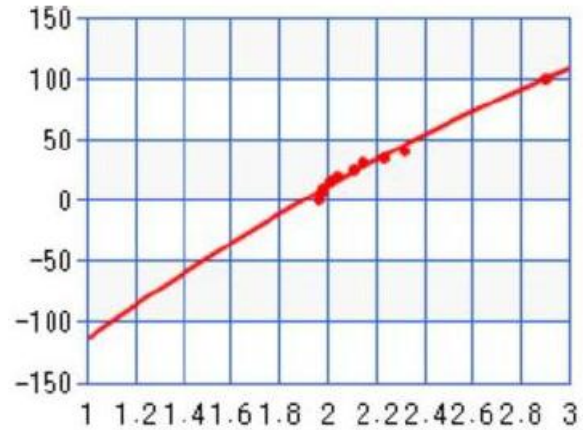


Figure 4

$$\bar{x^2} = \frac{\sum x_i^2}{n} \quad (10)$$

$$y = A + Bx + Cx^2 \quad (11)$$

$$B = \frac{S_{xy}S_{x^2x^2} - S_{x^2y}S_{x^1x^2}}{S_{xx}S_{x^2x^2} - (S_{x^1x^2})^2} \quad (12)$$

$$C = \frac{S_{xx}S_{x^2y} - S_{xy}S_{x^1x^2}}{S_{xx}S_{x^2x^2} - (S_{x^1x^2})^2} \quad (13)$$

$$A = \bar{y} - B\bar{x} - C\bar{x^2} \quad (14)$$

$$S_{x^1x^2} = \frac{\sum ((x_i - \bar{x})(x_i^2 - \bar{x}^2))}{n} = \frac{\sum x_i^3}{n} - \bar{x}\bar{x^2} \quad (15)$$

$$S_{x^2x^2} = \frac{\sum (x_i^2 - \bar{x}^2)^2}{n} = \frac{\sum x_i^4}{n} - \bar{x^2} \cdot \bar{x^2} \quad (16)$$

$$S_{x^2y} = \frac{\sum ((x_i^2 - \bar{x}^2)(y_i - \bar{y}))}{n} = \frac{\sum x_i^2 y_i}{n} - \bar{x^2}\bar{y} \quad (17)$$

$$r = \sqrt{1 - \frac{\sum (y_i - (A + Bx_i + Cx_i^2))^2}{\sum (y_i - \bar{y})^2}} \quad (18)$$

Correlation coefficient r = 0.9916
A=-270.7332
B=170.0219
C=-14.6137

Logarithmic regression is also performed using the formulae.

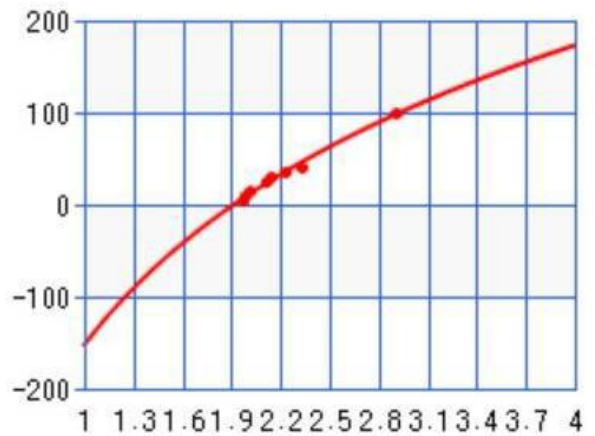


Figure 5

$$\bar{x} = \frac{\sum \ln x_i}{n} \quad (19)$$



$$y = A + B \ln x \quad (20)$$

$$S_{xx} = \frac{\sum (\ln x_i - \overline{\ln x})^2}{n} = \frac{\sum \ln x_i^2}{n} - \overline{\ln x}^2 \quad (21)$$

$$S_{xy} = \frac{\sum ((\ln x_i - \overline{\ln x})(y_i - \bar{y}))}{n} = \frac{\sum \ln x_i y_i}{n} - \overline{\ln x} \bar{y} \quad (22)$$

$$B = \frac{S_{xy}}{S_{xx}} \quad (23)$$

$$A = \bar{y} - B \bar{x} \quad (24)$$

Correlation coefficient $r = 0.9947$

$A = -151.3255$

$B = 234.2654$

VI. ERROR ANALYSIS

For the error analysis, we have taken a sample of some x concentration of soap solution in milk. And also, we have plotted the same for various observations in which we used our project to determine the concentration of soap with different forms of regression. It is found that minimum error is found in case of logarithmic then quadratic and then comes linear which is providing the least accuracy.

True Value 10% (10% soap and 90% milk)



Figure 6

So, as you can see from figure 6 red line signifies linear, blue is quadratic and purple is the logarithmically regressed curve.

True Value 15%



Figure 7

True Value 20%

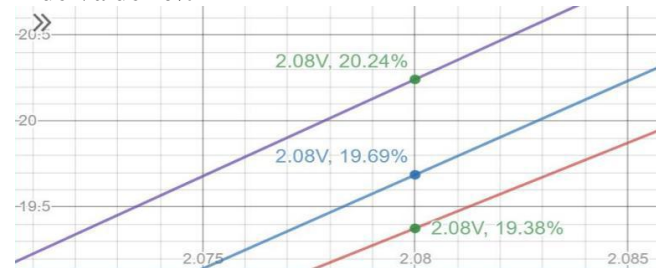


Figure 8

True Value 33.33%

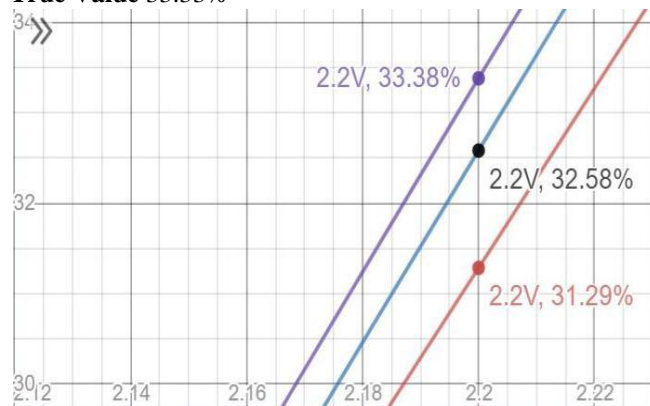


Figure 9

True Value 37.5%



Figure 10

True Value 42.86%



Figure 11

VII. CONCLUSION

In today's modern world adulteration is found in almost all of the substances. But it is more prominent in the food industry so we have designed a project which considers milk as pure item and soap solution as its adulterant. In the process of implementing our project, we used regression for finding the best curve possible for determining the concentration of soap solution in the given sample of milk. In our experiment, we found that the most accurate of the three (i.e. Linear, Quadratic, Logarithmic regression) Logarithmic regression was found to be the most accurate amongst them as it had minimum error from the true value. Quadratic regression was better than linear regression for 5 out of six cases so it was found to be the next best regression method after logarithmic one. Linear regression the most inaccurate in all of them. With this project, we would be able to determine the quality of milk that is found in our houses and in turn help the society be free of adulteration in milk.

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