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Electronic Measurement of Milk Adulteration using Microwave Frequencies

Dr S. P. Venu Madhava Rao
Department of Electronics & Communication Engineering
Kommuri Pratap Reddy Institute of Technology (KPRIT)
Ghatkesar, Hyderabad
principal@kpritech.ac.in;spvenu@yahoo.com

***Abstract*—** Food adulteration is an act for debasing the quality of food with an admixture or through the substitution of inferior substances or by removing some invaluable ingredients from the food product. Milk could be adulterated by adding water or by removing the cream or by adding artificial coloring agents like Annatto, caramel, coal tar, preservatives like formaldehyde, boric and other acids. There are several ways of identifying whether the milk has been adulterated or not and most of these techniques use chemicals. In this paper a method is proposed which is based on the change in the dielectric constant of the milk when it is adulterated. This change in the dielectric constant or the attenuation constant is frequency dependent and can be measured at microwave frequencies. In this paper an experimental set up has been proposed using a microwave frequency source and Arduino board is used.

Keywords- *Milk, Adulteration, chemicals, Microwave frequencies, power law, dielectric constant, attenuation, measurement.*

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I. INTRODUCTION

Food adulteration is an act of intentionally changing the quality of food offered for sale by adding or replacing by inferior substances or by removing some valuable ingredients [1]. The term food adulteration takes into account one the intentional addition of substances which adversely affect nature and quality of foods. Second the incidental contamination during the period of growth, harvesting, storage and transportation. Food adulterants are substances which are added to food items for economic and technical benefits. Such substances reduce the value of nutrients and also cause the food to be contaminated and not fit for consumption. Milk could be found adulterated by adding water or by removing the cream or by adding artificial coloring agents like Annatto, ceramal, coal tar colors and preservatives like formaldehyde, boric & other acids etc[2].

A food is said to be adulterated:

a) When a substance is added that depreciates its quality and injuriously affects it.
b) Cheaper or inferior substances are substituted wholly or in part.
c) Any valuable or necessary constituent has been wholly or in part abstracted
d) It is an imitation
a) It is colored or otherwise treated, to improve its appearance or if it contains any added substance injurious to health.
b) For whatever reason its quality is below the standard.

Milk and dairy product adulteration came into global concern after breakthrough of melamine contamination in Chinese infant milk products in 2008. However, history of milk adulteration is very old. Swill milk scandal has been reported in 1850 which killed 8000 infants in New York alone. Milk is considered to be the 'ideal food' because of its abundant nutrients required by both infants and adults. It is one of the best sources for protein, fat, carbohydrate, vitamin and minerals. Unfortunately milk is being very easily adulterated throughout the world. Possible reasons behind it may include-demand and supply gap, perishable nature of milk, low purchasing capability of customer and lack of suitable detection tests [3]. The motivation for food fraud is economic, but the impact is a real public health concern. The situation is significantly worse in developing and underdeveloped countries due to the absence of adequate monitoring and lack of proper law enforcement. Qualitative detection of adulterants in milk can be easily performed with chemical reactions while quantitative detections are complex and diverse. Type of quantitative detection techniques depend on the nature of adulterants in milk. For example, LC (Liquid Chromatography) and ELISA (Enzyme Linked Immunosorbent Assay) are the most common techniques used to detect foreign protein; PCR (Polymerase Chain Reaction) and PAGE (Polyacrylamide Gel Electrophoresis) are usually used to detect milk from different species as adulterants in milk of a particular species. Milk adulteration detection techniques [4] need to be very specific and rapid, because defrauders have escaped condemnation claiming less effectiveness of the conventional detection techniques [5].

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II. TYPE OF ADULTRANTS IN MILK

Milk powder is the second most likely food item being in the risk of adulteration after olive oil. Adulterants in milk mainly include addition of vegetable protein, milk from different species, addition of whey and watering which are known as economically motivated adulteration. These adulterations do not pose any severe health risk, however some adulterants are too harmful to be overlooked. Some of the major adulterants in milk having serious adverse health effect are urea, formalin, detergents, Ammonium Sulphate, boric acid, caustic soda, benzoic acid, salicylic acid, hydrogen peroxide, sugars and melamine.

Common parameters that are checked to evaluate milk quality are- fat percentage, SNF (Solid-not-Fat) percentage, protein content and freezing point[6]. Adulterants are added in milk to increase these parameters, thereby increasing the milk quality in dishonest way. For example, cane sugar, starch, sulfate salts, urea and common salts are added to increase solid-not-fat (SNF). Urea, being a natural constituent of raw milk, has a maximum limit imposed by FSSAI (Food Safety and Standards Authority of India) Act 2006 and PFA (Prevention of Food Adulteration) Rules 1955 which is to be 70 mg/100 ml. Commercial urea is added to milk to increase non-protein nitrogen content . Similarly, melamine is added to increase protein content falsely [7]. Ammonium sulphate is added to increase the lactometer reading by maintaining the density of diluted milk. Formalin, Salicylic acid, Benzoic acid and Hydrogen peroxide act as preservatives and increase the shelf life of the milk. Since milk fat is very expensive, some manufacturers of milk and dairy products remove milk fat for additional financial gain and compensate it by adding non-milk fat such as vegetable oil [8]. Detergents are added to emulsify and dissolve the oil in water giving a frothy solution, which are the desired characteristics of milk.

Unfortunately, some of the adulterants have severe health impact, sometimes in the long run. The ingestion of melamine at levels above the safety limit can induce renal failure and death in infants. Both peroxides and detergents in milk can cause gastro-intestinal complications, which can lead to gastritis and inflammation of the intestine [9]. Excessive starch in the milk can cause diarrhea [10,11] due to the effects of undigested starch in colon, however, accumulated starch in the body may prove very fatal for diabetic patients. Urea in milk overburdens the kidneys as they have to filter out more urea content from the body [12]. In addition, carbonate and bicarbonates might cause disruption in hormone signaling that regulate development and reproduction.

III. PRESENT METHODS OF MEASUTING ADULTERATION IN MILK

Most of these methods are based on color based chemical reactions, where the output color after the addition of suitable chemicals is used to detect the type of adulteration. These tests can be done in any lab of level 1 safety and based on the availability of chemical reagents. The main drawback of these methods is that these are valid only for a limited range of concentrations and are not precise. The Table 1 shows the methods to identify different edible adulterants.

Table 1: Adulteration Identification Methods

S. No	Adulterant	Procedure	Observation
1	Sugar	HCL + Resorcinol Soln.	Red Color
2	Starch	1% Iodine Solution	Blue Color
3	Glucose	Barfoeds Reagent	Deep Blue
4	Common Salt	Silver Nitrate Soln.	Yellow Color
5	Buffalo Milk	Hansa Test Serum	Curdy Particles

However the qualitative detections are advantageous because these are simple, rapid and very easy to perform. Some of the adulterants are used to improve the taste of the milk, some hazardous chemicals are used to improve the physical appearance and shelf life and use of some of these can be fatal. In addition to these adulterants, mixed chemicals such as soap, detergents and coloring compounds are also added to improve the appearance of milk.

IV. PROPOSED METHOD

In this paper a method is proposed to test the adulteration in the Milk by making use of a test setup that uses micro wave frequencies. The microwave signal is generated from a typical microwave test bench set up in the laboratory. When this microwave signal passes through several media like milk it gets attenuated. The attenuation is dependent on the attenuation coefficient alpha (α) of the medium and the attenuation coefficient has a distinct value for different media. The value of α varies with the type of media, it also varies as temperature varies and is also dependent on frequency.

The attenuation coefficient at constant temperature is given by:

$$A=A_0e^{-ax} \quad \ldots\ldots\ldots (1)$$

Where

A is the amplitude of the signal after passing through the media

$\mathbf{A_0}$ is the amplitude of the microwave signal before passing through the medium

α is the attenuation coefficient and

x is the distance travelled by the microwave signal in the medium

The formula in (1) indicates that the attenuation of the signal depends on the distance travelled by the waves (x) but also on the attenuation coefficient α.

V. METHODOLOGY

The block diagram shown in Figure 1 gives the implementation of the system which calculates the adulteration

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level in the milk. As seen from the Figure (1) the set up includes a Reflex Klystron Power Supply, Wave Guide, Isolator, Direct Frequency Meter, Diode Detector, CRO, Arduino and a LCD display.

VI. RESULTS

The frequency of testing has been chosen as 9 GHz, the Beam voltage as 290 Volts and the Beam current is chosen at 20 mA. The various combinations of milk and water and the corresponding readings are chosen and it has been tabulated in Table 2 and Table 3.

Table 2 Readings of CRO

S. No	Milk(ml)	Water(ml)	Total (ml)	Output(CRO)
1	5	0	5	1 mW
2	4	1	5	2 mW
3	3	2	5	3 mW
4	2	3	5	4 mW
5	1	4	5	5 mW

The Table 2 shows the readings of the output after the analog signals are passed through the Arduino board and as observed on the LCD.

Table 3 Readings on Arduino

S. No	Milk(ml)	Water(ml)	Total (ml)	Output(LCD)
1	5	0	5	0.00488758553274682
2	4	1	5	0.00977517106549364
3	3	2	5	0.0146627565982405
4	2	3	5	0.0195503421309873
5	1	4	5	0.0244379276637341

As seen from the Table 2 and Table 3re, the output is changing according to the quantity of adulteration of the milk.

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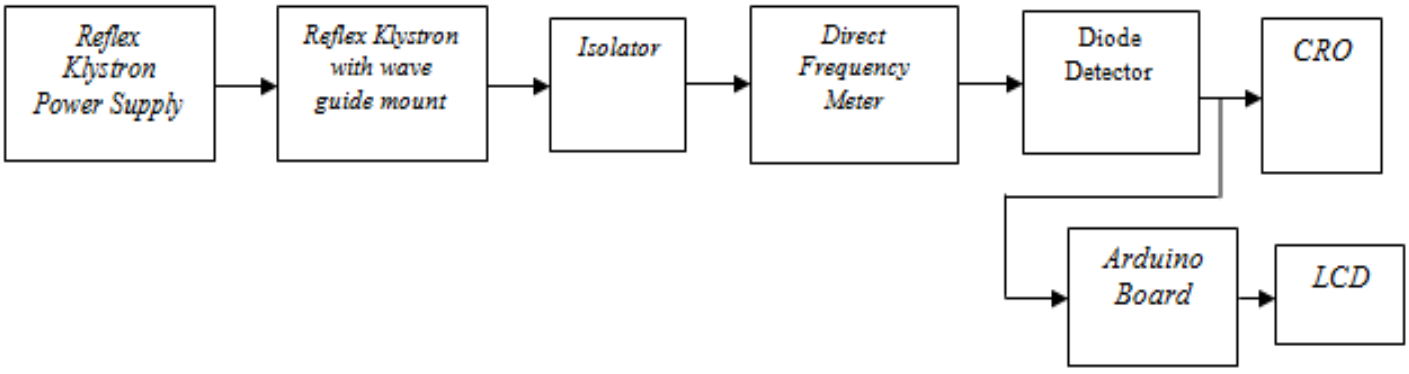

Figure 1: System level Set Up for Calculation of Milk Adulteration