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Design of Simple Instrumentation System for the Quality Analysis of Milk (Casein Analysis)

V. G. Sangam,[*] M. Sandesh., S. Krishna., S. Mahadevanna
[*]Department of Instrumentation, BVB College of Engineering and Technology,
Hubli- 0091-580031, Karanataka, India
E-mail: sangamvg@yahoo.com

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Abstract: This paper describes the design of a simple instrumentation system for the analysis of casein concentration in the milk. Casein is one of the major constituent of milk and its concentration describes the quality of the milk. Normally casein is analyzed by conventional analytical methods or by using Spectrophotometric methods. Here an attempt has been made to develop a simple portable system using optical instrumentation technique. The objective of the developed system is the real time analysis of the casein concentration of the milk at the field. The system involves UV light source, UV filter, cuvette, photo detector, display unit, data Acquisition Card (DAC) as peripheral with USB port. Appropriate program has been developed in visual studio 6 and turbo C. Repeated number of real time analysis was carried out for different samples of milk; the results obtained are in excellent agreement with the amount determined by standard conventional methods with an accuracy of ±1.5 %, and the response time is within 100 seconds. This system can be used in the field for the quality analysis of milk as an independent unit and can also be interfaced to PC with USB port. The system has good accuracy, less response time and low cost. *Copyright © 2010 IFSA.*

Keywords: Casein, Filter, DAQ, Accuracy, Response time.

1. Introduction

The casein is one of the major components of the milk. The concentration of protein in the milk varies with breeds, normally it is about 3.25 % (in which, ¾ is casein) [1]. In cow milk Casein is extracted from the proteins in the milk; it is structured in voluminous globules. These globules are mainly responsible for the white color of the milk. According to various species, the casein amount within the total proteins of the milk varies. Casein can be found in two main types: edible and technical. Edible casein is widely used in both medicine and food, both for nutritional value and as a binder. Technical casein is used in an enormous range of products, including paints, cosmetics, and many types of adhesives. A not-insubstantial number of people have a casein allergy and may find themselves experiencing negative reactions to casein-containing food products. The amount of casein in whole milk varies according to the breed and stage of lactation and also according to the quality of the female's nutrition. Normally milk is said to be good if the casein concentration is in the range 24-29 g /L [1-2], the casein content of milk represents about 80 % of milk proteins.

Casein consists of a fairly high number of proline peptides, which do not interact. There are also no disulfide bridges. As a result, it has relatively little secondary structure or tertiary structure. Because of this, it cannot denature. It is relatively hydrophobic, making it poorly soluble in water. It is found in milk as a suspension of particles called casein micelles which show some resemblance with surfactant-type micelle in a sense that the hydrophilic parts reside at the surface. The caseins in the micelles are held together by calcium ions and hydrophobic interactions [3]. There are several models that account for the special conformation of casein in the micelles. One of them proposes that the micellar nucleus is formed by several submicelles, the periphery consisting of microvellosities of κ-casein. Another model suggests that the nucleus is formed by casein-interlinked fibrils. Finally, the most recent model proposes a double link among the caseins for gelling to take place. All 3 models consider micelles as colloidal particles formed by casein aggregates wrapped up in soluble κ-casein molecules [3-4]. Various methods for the casein analysis already exist, such as precipitation method, separation method, in which casein is determined by, Kjeldahl analysis in addition to these HPLC is also used [5-8]. The Near-Infrared Reflectance Spectroscopy (NIRS) and NMR methods are also used for the analysis [9]. These methods are time consuming, needs sample preparation, and needs various reagents. Also, these methods are accurate but are expensive, needs skilled person for the analysis, needs sample preparation, and can not be carried to the field for the analysis. Reports have been also made to use better instrumentation system for the evaluation of casein content of the milk [10-11]. These systems are complex and are not feasible to use in the field, also stability is not suitable.

Here we have made an attempt to develop a stand alone system for the casein analysis of the milk, that involves the design and implementation of a simple instrumentation based system. The developed system is cost effective, accurate, and gives speedy response, does not require sample preparation, and system can be taken to the field (portable), and also can be interfaced to PC.

2. Method

The various steps involved in developing complete system are, Evaluation of spectral properties of casein, Instrumentation system design, Interfacing and Programming of DAQ circuit, Calibration and field test.

2.1. Determination of Spectral behavior of Casein

Casein absorbs ultra violet light of wavelength in the range 270-290 nm (peak absorption at 280 nm).The characteristic absorbing wavelength of milk is determined by scanning milk sample using Spectrophotometer; the same is repeated by taking the casein sample. The response of the spectrophotometer is shown in Fig. 1. Here we have used Edible Casein, which is a low fat milk protein, contains 5-10 % percent of the carbohydrates, and has a good flavor profile and excellent nutritional properties making it ideal for medical, nutritional application and for use in pharmaceutical industries. In both the cases the maximum absorbance wavelength obtained was at 280 nm. The optical filter for the wavelength of 280 nm has been used for the system.

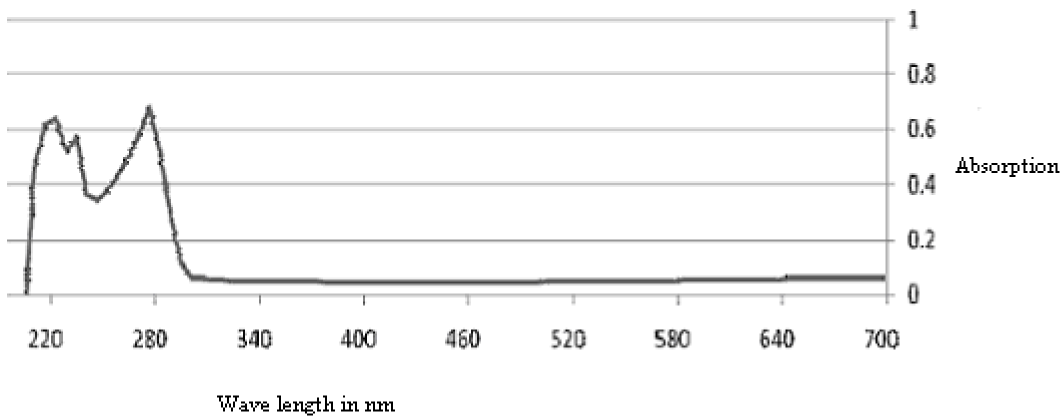

Fig. 1. Response of Spectrophotometer.

2.2. Instrumentation System Design

The main components of instrumentation system used for the system are, signal conditioning circuit, microcontroller based and PC based data acquisition system.

The signal conditioning circuit (SCC) involves LDR sensing circuit and amplifier circuits. The output of LDR is converted into voltage and amplified using two stage amplification [12] and their gains are G_1 and G_2 respectively. The output of the second stage amplifier is in the range of 0 to 5 V. The Output of SCC should be maximum, if there is full illumination of light on LDR (i.e. for 0 gm/ltr of casein is present in given sample of milk), and the output of SCC should be minimum, if no illumination of light on LDR (i.e. for 26 gm/ltr of casein is present in given sample of milk). The 280 nm UV light is completely absorbed by milk sample.

The output of the LDR is given as input to the first stage amplifier. The amplifier configured in inverting mode. The gain of an inverting amplifier given as,

$$G_1=R_{f1}$$

The output of the first stage amplifier (V_{01}) is given as input to the second stage amplifier.

$$G_2=R_{f2}.$$

The total gain is given by $G= G_1*G_2$

The gain G is designed so that Output of SCC should be 5V, if full illumination of light takes place on LDR and Output of SCC should be 0V, if no illumination of light takes place on LDR.

As shown in the schematic diagram, Fig. 2, Ultraviolet light source is first passed through the optical filter to surpass all the radiations other then 280nm radiation, later passed through the milk sample under test. According to Beer Lambert's law, the absorption of the characteristic wavelength of a particle is directly proportional to concentration of that particle and the path length traversed by the light in the sample. Maximum absorbance was observed at 280nm, for pure milk concentration ranging between 26-29 gms/ltr. As concentration of casein goes on reducing the absorbance also decreases. More the voltage less is the concentration of the Casein. The voltage from the LDR is fed to the signal conditioning circuit, later followed by ADC. Eight bit serial ADC 0831 (National Semiconductor) is used. It operates on +5 V power supply. The conversion time of ADC is 32 microsecond. The clock frequency needed for ADC (250 kHz) was generated using 555 timer circuit operating in a-stable mode with 50 % duty cycle. Microcontroller AT89C51 is used for computation to calculate unknown concentration of casein. Microcontroller is interfaced to 16 X 2 liquid crystal display to display the value. The ports are configured as; Port A [RA0 bit] as input for analog input channel, Port B [RB0 to RB2 bit] as output for RS, R/W, E pins, Port C as output for data lines.

Additional facility has also been made to interface the system to PC. The DAQ card is used for the same [13]. Program is written in visual studio C++, program is written according to values obtained from calibration with standard concentrations.

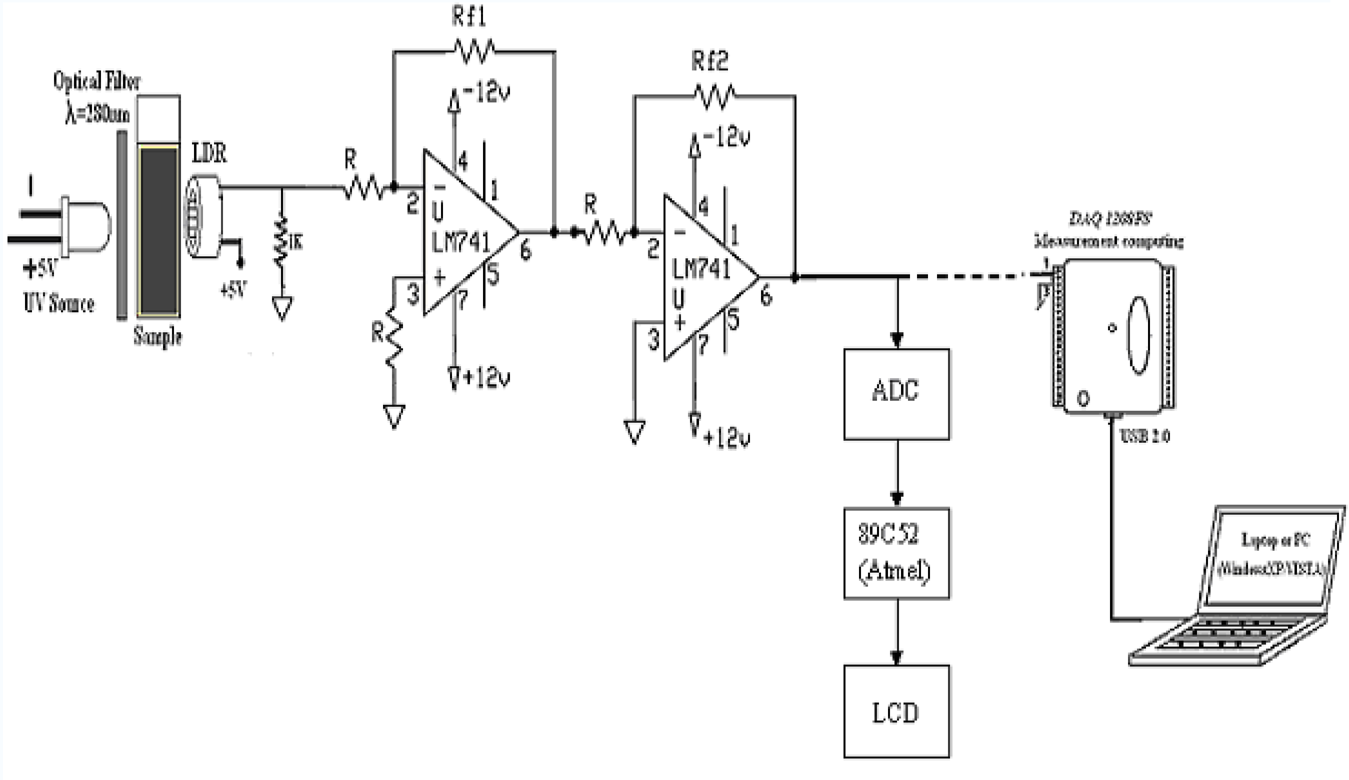

Fig. 2. Schematic diagram with data acquisition system.

3. Results and Discussion

The system is calibrated for different standard concentrations of Casein. Standard solution of different concentration is prepared by mixing the known amount of standard casein powder with distilled water. Initially, 26 gm/lt of standard casein sample was prepared and the corresponding output voltage is noted by placing the sample in the cuvette. The response was monitored until it reaches steady state. The time taken to reach steady state is 90 seconds. Similarly the process was repeated for different standard casein samples ranging between. 2 g/lt to 26 g/lt. The calibration achieved is linear in the range 5 g/lt to 26 g/lt, (casein lesser than 10 g/lt is considered to be very bad milk), calibration curve is shown in Fig. 3, it is also observed that calibration is reversible and repeatable. The zero setting is done by using distilled water. For the validation of the response various standard sample ranging between 15-20 g/lt have been prepared, Table 1 shows the results for the casein analysis for 18 g/lt, the results obtained are also compared with the Kjeldahl and spectrophotometer tests, The proposed system has shown very good repeatability compared to other two conventional tests.

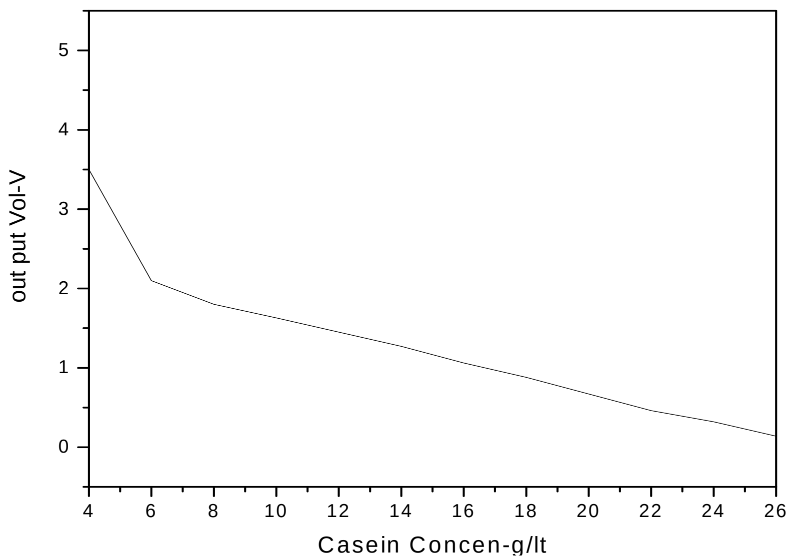

Fig. 3. Calibrative curve.

Table 1. Comparative analysis.

Casein: 18 g/lt No of analysis: 108			
	Kjeldahl	Spectrophotometer	Developed System
Mean	17.88	17.74	17.91
Repeatability	0.16	0.19	0.12

Analysis of variance indicated no statistically significant difference between the results from Kjeldahl, spectrophotometer and proposed system was observed. Repeatability of the all the three methods was found as the standard deviation, and was found that proposed system has good results.

Provision has been made to set zero for distilled water in the beginning. Once it is achieved then subsequent measurements can be made. The developed system has shown excellent experimental results. The results obtained for different concentrations have been compared with the results of conventional technique. The accuracy obtained is well within ± 1.5 %. The system showed stable response up to 110 analyses, without intermittent calibration, later there is decrease in accuracy of 10% was observed indicating the need of subsequent calibration after every 110 analysis. The stability response is shown in Fig. 4. The photograph of the developed system is showed in Fig. 5.

Conclusion

A Simple instrumentation system for casein analysis has been developed. The system has provision for interfacing with computer. The system proposed here is simple and precise and shows good sensitivity and can be used continuously for 110 analyses, later it needs calibration. In addition we have demonstrated the feasibility of the system through quantitative analysis. Various milk samples of the southern region of India have been analyzed. The results obtained are compared with the results of spectrophotometer and Kjeldahl tests and found that the results obtained are either the same or very close to the expected results with an accuracy of ± 1.5 %. The response time observed is well within 100 seconds. The system is interfaced with the laptop computer and field tests have been carried out, and there is no deviation in the results between laboratory and field tests. The proposed instrument can be used for speedy and accurate analysis of casein.

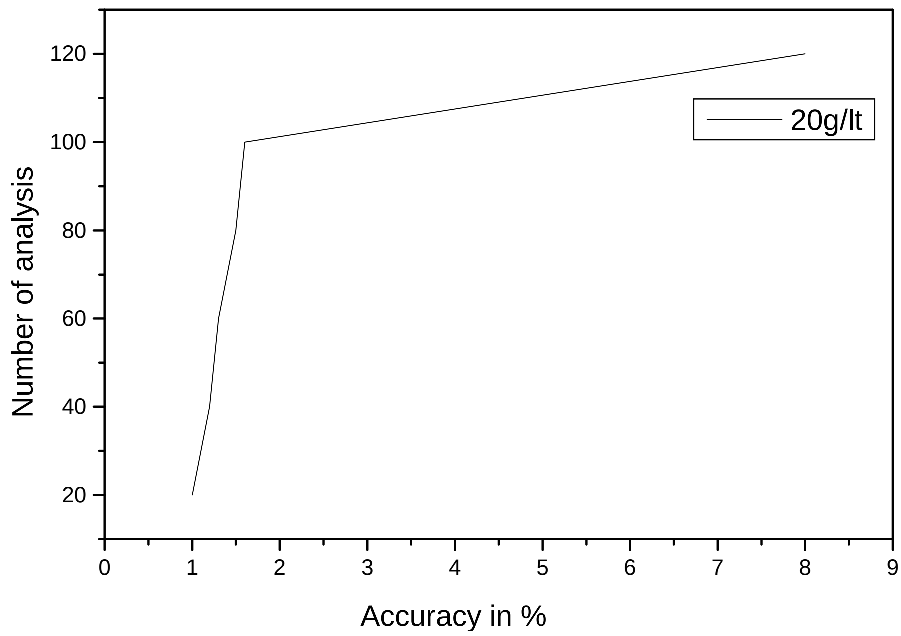

Fig. 4. Stability analysis.

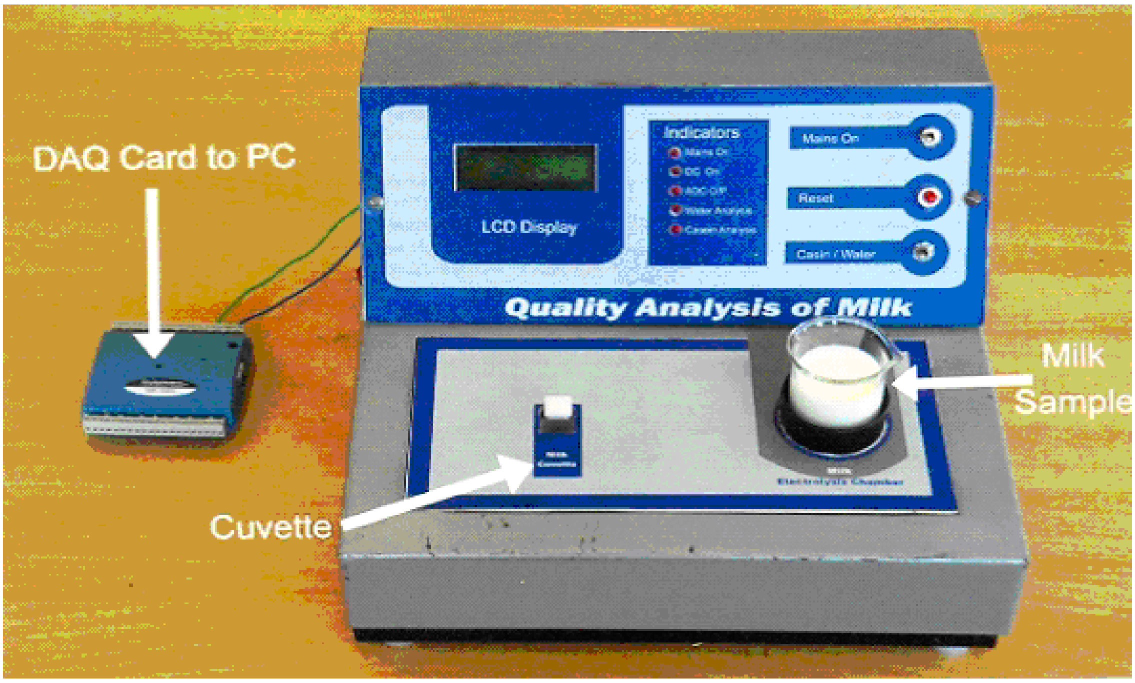

Fig. 5. Photograph of developed system.

Acknowledgement

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