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Estimation of Fat Contents in Milk: A Review

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Abstract: India is the largest producer of milk producing more than 100 million tons of milk per annum. The quality of milk depends on the fat content as that of protein and lactose in milk. A number of fat detection techniques, measures the fat content in milk keeping aside the effect of temperature. The paper discusses the relative study of various milk fat detecting methods and effect of change in sample temperature under test. This sample temperature can be controlled with the recent techniques known as FLC and ANFIS. It is proven that FLC and ANFIS are better suited for temperature control applications. Hence the benefits of these controlling techniques can be made to control the milk sample temperature to be tested.

1. INTRODUCTION

Dairy production is an important sector of the national economy countries in the world. India is the largest producer of milk producing almost 121.8 million tons of milk per annum [4]. Also milk production is a livestock enterprise in which small-scale farmers can successfully engage in order to improve their livelihoods. Regular milk sales also allow them to move from subsistence to a market based income.

Milk contains protein, fat, lactose, a variety of vitamins, minerals and other nutritional elements, so it is looked at as one of the main food. The quality of milk is directly related to the health of consumers. To ensure the quality of milk and dairy products, dairy industry in several key areas such as cows scientific farming, the acquisition of raw milk, milk and dairy processing quality control, milk products qualified inspection, etc. need to repeatedly test the quality of milk. There are many indicators that value the quality of milk, but the most commonly used is the main nutrients in milk – fat, protein and lactose content. Lactose content relatively changes smaller, while fat and protein changes dramatically. So the standards require that the fat and protein content in milk quality testing mandatory monitoring indicators. As for these two components in the detection, the traditional method is chemical based, (which are complicated and requires chemical reagents to test a long time) such as the fat in milk is usually measured by Babcock method, Geber method, Rose-Gottlieb method and the protein content measure used Kjeldahl method [3, 8].

2. FAT DETECTION TECHNIQUES

In recent years, milk composition analysis in the field of faster development is the ultrasonic testing method. Pasteurization and sterilization of milk can be carried out by ultrasound and also the duration of scoring necessary to achieve pasteurization and sterilization effects is reduced at the increase of the power of ultrasonic influence [14]. Ultrasonic characteristic parameters, velocity and attenuation coefficient changes with the quality of milk. The temperature of test sample has a great effect on accuracy measure of ultrasonic parameters [1]. Also the ultrasonic parameters find good stability within 35ºC to 45ºC temperature range and it is relatively appalling when the temperature is lower than 35ºC or higher than 45ºC. Thus milk ultrasonic parameters measure with dynamic temperature diminished the impact of temperature and makes detecting relatively accurate for measurement of fat and protein content in milk. Using Surface Acoustic Wave devices different liquid samples can be analyzed keeping the sample temperature under controlled conditions of 23ºC [6].

The Near Infrared (NIR) spectral technique for component concentration measurement in milk with hybrid algorithm tries to reduce the interference of temperature variation [2]. The water, fat and protein are the key factors causing the absorption and scattering of photon. If the temperature changes, the optical properties of milk will change, indicating that the corresponding optical parameters will change. When the temperature of milk increases, the viscosity decreases and the fat globules distribute more uniformly. As a result, the effect of scattering caused by fat composition becomes weaker and the reduced coefficient decreases. On the other hand, the relationship between temperature and absorption coefficient is ambiguous. Hence the temperature of sample is one of the most important factors for the prediction precision, and is also the important parameter which can provide the information of particle structure variation. The wavelet packet transform can be employed to split the spectra into different frequency components, which can be refold to the corresponding 3D sub-matrices. The 3D orthogonal signal correction algorithm is applied to remove the interference information irrelevant to analyze in each 3D sub-matrix. The hybrid algorithm named as WPNOSC-NPLS tries to remove the interference of temperature variation in NIR spectra of milk. In this algorithm, the 3D spectra are decomposed to several frequency components through the unfolding method and the WPT algorithm. After removing the irrelevant information by NOSC algorithm, the new 3D spectra matrix is formed by the summation of all the filtered components. Then, the NPLS algorithm is applied to develop the calibration model based on the WPNOSC-filtered spectra. The WPNOSC-NPLS algorithm is applied successfully to analyze the spectra of milk for fat concentration measurement.

Near Infrared spectrometry can also be employed with Partial Least Squares to estimate milk composition and milk powder [5, 30]. The Visible and Near-InfraRed (VIS-NIR) spectrometry equipment consists of an excitation light source able to produce a continuous spectrum for all wavelengths and a photo-detection system for measuring the received light in the same light spectrum. It can be used for un-homogenized fresh raw milk without any kind of previous treatment, homogenization or dilution, and could be implemented with low-cost devices such as LEDs and photodiode-array in visible and near-infrared wavelengths (<1100 nm). Experimental results have demonstrated the capability of method to predict fat and lactose content of milk with high explanation of variance [5]. The infrared spectrometers used by large dairy companies in the world are very expensive. Hence the dairy industry is in need of cost effective & highly reliable measurement system to monitor the quality of dairy products. An electromagnetic sensor has the potential to offer a good solution leading to a robust instrument with high accuracy at a low capital cost. The technique uses center around planar electromagnetic sensors operating with radio frequency excitation [28].

In the laser light scattering theory, the ratio of the scattered light intensity to the transmitted light intensity, which is called as scattered–transmitted-ratio method, can be adopted as the optical parameter representing the milk fat content and the protein content [8]. The influence of the fluctuation of the power of the light source is eliminated and the accuracy of determination is improved accordingly. The system uses a real-time approach that satisfies the challenging requirements of dairy farming. The test is carried out by dual-angle laser light scattering method. In detail, the ratio of the scattered light (at 90 ± 0.05^{o} scattering angles, relative to the incident beam direction) intensity to the transmitted light intensity, is adopted as the optical parameter representing the milk fat content and the protein content. Different samples of fresh milk came from either different cows or the same cows in different periods are collected and fat & protein contents where measured. Prior to the test, the samples were homogenized and diluted first, and then through the constant temperature equipment (40ºC in a water bath) they were brought into the sample box by the electric pump. The accuracy of this measuring method is verified using reference, the Rose-Gottlieb method for fat content and the Kjeldahl determination of N method for protein content in milk. Results of this study indicate the feasibility of using this technology for fresh milk fat and protein analysis.

3. IMPACT OF TEMPERATURE

The above discussed methods have to be calibrated, hence many laboratories, therefore, are using a method developed by the Swiss chemist and dairy-owner Niklaus Gerber, patented in 1891 under the name "Acid-Butyrometrie"[29]. The determination of fat content according to Gerber involves running off the fat into a special measuring vessel, the butyrometer, and determining its volume as a percentage by mass. The fat is present in milk in the form of small globules of various diameters, from 0.1 to 10 micrometers [3]. Milk fat is lighter than water and creams if it is left standing. A fat-rich layer accumulates on the surface. Stirring and careful shaking restore the original distribution. If the layer of cream cannot be evenly distributed in this way, the milk should be slowly heated to 30ºC – 40ºC and gently swirled around until a homogenous fat distribution is achieved. The milk is cooled to 20ºC for further process of test. The volumeters for Gerber test are calibrated at 20ºC. Any variation in temperature will influence the volume. Air pocket reduces the density and hence the mass of milk measured.

In the testing process after centrifuge, the butyrometers are placed for 5 minutes in a water bath heated to 65ºC. It is important to maintain an exact temperature so as to obtain accurate results. Only a read-off at 65ºC will ensure an exact result. If the temperature is too low, the volume of the column is reduced and a fat content reading that is too low will be indicated. As the temperature decreases, the fat become solid particles from the liquid small ball in milk, then mutual assembles into fat regiment with different shape and size which is uneven in the milk as, the Figure 1 shows. When the temperature increases, the milk of protein gradually become denatured from the uniform distribution of granular and its distribution is irregular.

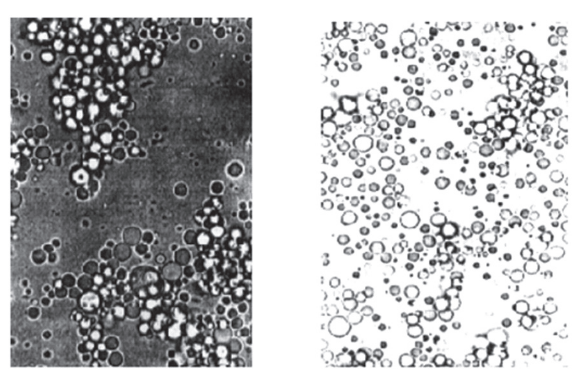

Figure 1: Microscope Picture of the Milk of Fat in Different Temperature [1]

Thus for determination of fat content in milk, the desired milk sample temperature has to be maintained. It can also be said that for different technique of fat detection different temperature levels are used, which should be precisely controlled.

4. FUZZY AND NEURO FUZZY SYSTEM

Since past several years, fuzzy control has emerged as one of the most active and fruitful areas for research in the application of fuzzy set theory [15]. Various authors have described their pioneering research based on fuzzy logic system. The application such as water bath temperature control [7, 17, 26], temperature control of polymerization reaction [21], solar air-conditioning system [24], estimate heat tolerance of plants by chlorophyll fluorescence measurement [18], implementation of fuzzy logic system based on FPGA using VHDL [19, 20], educational light tracking system [22], petroleum separation process [23], fluid level control system using SCADA [25], refrigeration plant [27] and many more are found to be giving valuable results for Fuzzy Logic Controllers (FLC) as compared to conventional controllers that tested. Fuzzy logic is the logic on which fuzzy control is based, is much closer in spirit to human thinking and natural language than the traditional logical systems. The FLC provides an algorithm which can convert the linguistic control strategy based on expert knowledge into an automatic control strategy.

The FLC receives crisp data from the plants (application) data acquisition system and sending control or references to manipulated variables. The input or output variable, the decisions/control levels and the controller flow diagram relating are defined as the involved variables. The controller knowledge includes linguistic variables (LV), set of rules, reasoning period, way of the handling physical data, fuzzy logic operation and deffuzification method. Basically a fuzzy inference system is composed of five functional blocks [11, 31]:

- a rule base containing a number of fuzzy if-than rules
- a database which defines the membership function of the fuzzy sets used in the fuzzy rules
- a decision-making unit which transforms the crisp input into degrees of match with linguistic values
- a defuzzification interference which transform the fuzzy results of the inference into a crisp output.

ANFIS is the fuzzy based paradigm that grasps the learning abilities of ANN to enhance the intelligent systems performance using a priori knowledge. Using a given input-output data set, ANFIS constructs a fuzzy inference system (FIS) whose membership function parameters are tuned using either a backpropagation algorithm alone [32], or in combination with a least squares type of method. This helps fuzzy system to learn, adapt and optimize membership functions. This gives the best fit membership functions in fuzzy system.

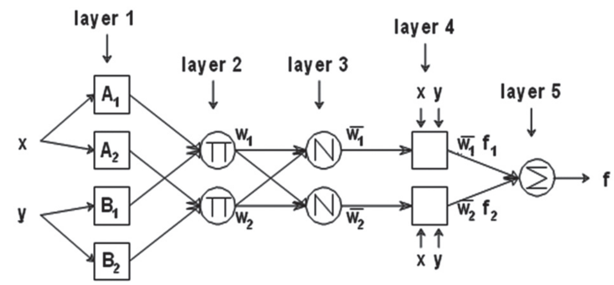

Figure 2: ANFIS Structure for Two Input Variables and Five Layers

5. NEURO-FUZZY TEMPERATURE CONTROLLER

Neural network can be used to solve highly nonlinear control problems. It can learn of its own accord to control a nonlinear dynamic system [7, 10]. The applications of neural networks to control system have become increasingly important. The massive parallel processing, nonlinear mapping, and self-learning abilities of neural networks have inspired new resources for possible implementation of better and more efficient intelligent control system [12]. Several learning architectures are proposed for training the neural controller to provide the appropriate inputs to the process so that a desired response is obtained [9]. A fuzzy inference system employing fuzzy if-then rule can model the qualitative aspects of human knowledge and reasoning processes without employing precise quantitative analyses. The Adaptive-Network-based Fuzzy Inference System (ANFIS) serve as a basis for constructing a set of fuzzy if-then rules with appropriate membership functions to generate the stipulated input-output pairs [11]. An example that describes a simple fact is:

If pressure is high, then volume is small

where *pressure* and *volume* are linguistic variables, *high* and *small* are linguistic values or labels that are characterized by membership functions. An adaptive network is a network structure consisting of nodes and directional links through which the nodes are connected. The part or all nodes are adaptive, which means their outputs depend on parameter pertaining to these nodes, and learning rule specifies how these parameters should be changed to minimize a prescribed error measure. A neural network controller has been implemented on a real-time temperature controller system without use of any conventional controller or knowledge regarding its dynamics [7, 12, 13].

The ref. [12] discusses in detail a neuro-fuzzy hybrid controller technique that theoretically compare with conventional controller. The system (temperature controller in this case) performance improves in setting time, rise time and overshoots. The fuzzy logic and neural networks can be combined to work with one another. If necessary the neural network can be altered for the needs of the user. This technique is robust in that only some rules in fuzzy knowledge required to be updated with change in input condition (set point), avoiding the need to retraining of the neural network. The neural network processes the data and knowledge representation in fuzzy logic is easy by combining these two technologies constructed inductively and independently found better result.

6. CONCLUSION

The various milk fat detecting techniques (Babcock method, Gerber method, Rose-Gottlieb method, Ultrasonic method, Near Infrared spectral, Laser light scattering) needs to maintain the temperature of milk sample under test. Fat globules content in milk largely depend on sample temperature. The fat globules can be evenly distributed with increase in temperature of sample. The Fuzzy Logic controller or Neuro-Fuzzy controller is applied to control temperature in different application and founds to be well suited. Hence to detect fat content in milk, the sample temperature may be controlled by Fuzzy Logic or Neuro-Fuzzy type controller technique.

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