Kinematic viscosity: vegetable oil at different temperatures

Abstract

This paper presents the development of ATmega32 microcontroller based kinematic viscosity measurement setup to measure viscosity of edible oils at different temperatures using redwood viscometer. This instrument system permits to keep the temperature of the sample at any desired value and recording of time for the collection of 50 cc of sample to compute its viscosity and to send the data to personal computer to enable the computer processing of such data. A dedicated Atmega32 based microcontroller board is employed for the hardware. A three layer neural network is used to train the viscosity at different temperature using back propagation algorithm and the trained neural network is used to compute the viscosity of edible oils. The details of its interface to measure kinematic viscosity, to measure, control the temperature, and evaluate results are explained in this paper.

Keywords: Back Propagation Algorithm, Artificial Neural Network, Microcontroller, kinematic viscosity, redwood viscometer.

Introduction

Viscosity measurement and control has great importance in food industry and accurate knowledge of viscosity is necessary for various industrial processes [2]. Viscosity is a direct measurement of a fluid’s quality. A change in viscosity can indicate a fundamental change in the material under test [9]. Liquid viscosity, a basic physical property, directly influences unit operations such as pumping, filtration, filling, distillation, extraction, and evaporation, as well as heat and mass transfer [3]. Viscosity is a very important property of lubricating oil [10]. Kinematic viscosity is defined as the ratio of absolute viscosity to mass density and has the unit of m2/s. Properties, like temperature and pressure, influence the Kinematic viscosity. Frying is one of the most commonly used methods of food preparation in the home and in industry, and the prolonged use of oil for this purpose causes changes in its physical and/or chemical properties [5, 6]. It is, therefore, essential to determine viscosities of the edible oils at various temperatures.

Neural networks are being applied to an increasing large number of real world problems. Their primary advantage is that they can solve problems that are too complex for conventional technologies; problems that do not have an algorithmic solution or for which an algorithmic solution is too complex to be defined. In this study, Neural Network is used to determine the kinematic viscosity of edible oils at various temperatures using back propagation learning. A three-layered neural network having seven neurons in hidden layer and one neuron in the input layer and one neuron in the output layer is used. The number of hidden neurons is determined empirically. The neurons in the hidden and output layer have sigmoid functions [1]. The weights between output and the hidden layers are updated using the pseudo impedance control algorithm [4]. This paper explains the measurement of viscosity of edible oils using microcontroller-based instrument and the feasibility in computation of viscosity of edible oils at various temperatures using neural network.

Design scheme

The block diagram of the microcontroller based viscosity measurement system is shown in Figure 1. The system hardware consists of Redwood viscometer, LM35D temperature sensor, level detector, and signal conditioning circuit, solid-state power controller and Atmega32 microcontroller. The Block A consists of Redwood viscometer which is based on the principle on laminar flow through capillary tube. The viscometer consists of a copper cup furnished with a pointer, which ensures a constant head and orifice at the center of the base of inner cylinder. The orifice is closed with a ball, which is lifted to allow the flow of oil during the experiment. The cylinder is surrounded by a water bath, which can maintain temperature of the sample to be tested at required temperature by the solid-state relay and microcontroller. The ATmega32 Microcontroller from Atmel company, is a low power, high performance 8 bit AVR microcontroller with 32 K Bytes in System Programmable Flash, one 16-bit Timer/ Counter and two 8-bit Timer/ Counter, an eight Channel 10 bit ADC, 32 programmable I/O lines in four I/O ports (Port A, Port B, Port C and Port D) and 2k Bytes of SRAM [11]. LM35D temperature sensor in block C is used to measure the temperature of the sample. This sensor is from National semiconductor, whose output is calibrated directly to Celsius, does not require any external calibration or trimming, and rated to operate over a range from -55 to 150°C. An instrumentation amplifier kept in block E is designed to amplify (gain 250) the signal from the temperature sensor. The analog temperature in the form of voltage is given to analog input of Port A and it is digitized by the microcontroller. The solid-state power controller in block G is built with opto coupler (MOC3040), TRIAC (BT136) and other components are used to control the power of the electric heater in block H. The pulse width modulation (PWM) is used to control the temperature. The microcontroller will read the data for temperature of the sample and control the temperature of bath at the set temperature. The level detector in block B consists of IR emitter and detector, which are used to measure 50 cc of sample collection in the glass jar. The output from the IR detector is given to a signal conditioning circuit in block D that provides an input (Port C) to the micro controller. The micro controller uses the count value of the timer to compute the viscosity of liquids. Block I consists of keyboard and LCD display, which are interfaced with Port B and Port D of microcontroller. The keyboard is used to enter experimental parameters and measurement in sequences into the system. The LCD display will display the measured data and the results. The orifice is opened, the timer in the microcontroller is started, and the timer is stopped when the IR detector senses the level of sample. The data and the computed results are sent to the PC (Personal Computer) for the further processing through the RS-232 interface which is kept in the block J

Measurement

Sunflower oil and palm oil are purchased in local commerce. The principle of operation of redwood viscometer is based on measurement of time required to drain constant quantity of liquid through the narrow capillary tube. The cylinder of Redwood viscometer is filled up to a fixed height with sample of oil. The temperature of the sample to be maintained is given through the keyboard to keep the temperature of water bath at the particular temperature. When lifting the ball valve, the timer in the Microcontroller is started and when the level in the jar reaches 50 ml mark, the Infra Red (IR) detector senses the level and the timer in the Microcontroller is stopped by software. From the count value in the timer, time taken for the collection of 50cc is measured and the Kinematic viscosity is computed by the Microcontroller using the expression ?= (A*t) – (B/t) in 10-6 m2/s ……… (1)

Where A= 0. 26 and B= 172 (when t > 34) are constants of the viscometer which depends upon the diameter and height of cylinder, diameter of orifice and the length of orifice. ? = Kinematic viscosity of liquid and the t= time required to pass 50cc of liquid. The Experiment is repeated to measure Kinematic viscosity of sunflower oil for different temperature ranging from 30°c to 90°c.

Neural Network in Measurement Applications Learning and Testing

Artificial neural networks (ANNs) are the computer programs, which are biologically inspired to design to simulate human brain processes information. The neural networks gather their knowledge from input-output relationships in data and learn through experience, not from programming. The success of ANNs depends on the architecture, the learning algorithm and its parameters, the transfer function, the number of layers and processing elements (neurons). An artificial neuron is a simplistic representation that emulates the signal integration and threshold firing behaviour of biological neurons by means of mathematical equations. Stimuli are transmitted from one processing element to another via synapses or interconnections, which can be excitatory or inhibitory. The commonest type of artificial neural network consists of three layers, of units: a layer of “ input” units is connected to a layer of “ hidden” units, which is connected to a layer of “ output” units. Neural Network is used to determine the kinematic viscosity of edible oils at various temperatures using back propagation learning. A three-layered neural network (ANN) having seven neurons in hidden layer and one neuron in the input layer and one neuron in the output layer is used. The number of hidden neurons is determined empirically. The neurons in the hidden and output layer have sigmoid functions [7]. The weights between output and the hidden layers are updated using the pseudo impedance control algorithm [12]. It is found that for using this rule, convergence is relatively faster than the original generalized delta rule. A Neural Network is trained by temperature as input vector and Kinematic viscosity as output vector by using the back propagation algorithm method. The input and output vectors which are obtained from the experiments is used for learning. The objective of training is to adjust the weights so that application of a set of input produces the desired set of output. Under Supervised learning, both input and output data are given as data for the training. In this process, the weights are modified and the system is trained so as to get the desired output for a given input. In the training pattern the input vectors is temperature of the sample and the output vector is kinematic viscosity. The sigmoid function is implemented for both input and output to train the neural network. After training, the neural network is used to process the kinematics viscosity of sunflower oil and palm oil at various temperatures.

Using ‘ C’ language software is developed, to initialize LCD display, to start ADC, to read data from ADC, to measure and control the temperature of the sample, by giving commands to solid state controller, to read data from level sensor (IR sensor), to measure the time of the collections of 50cc of liquid with the help of the level detector, to give data for constants A and B, to compute the viscosity, to display the results in the LCD and to send the data to PC.

Results and Discussion

The developed Instrument has been used to measure the kinematic viscosity of unheated and heated (up to frying condition 250oC for 4 times) sample of sunflower and palm oil. The kinematic viscosity is measured at different temperature (from 30 °C to 90 ° C) for both unused (unheated) and used (heated) samples (sunflower oil and palm oil) and it is shown in Table 1. The variation of viscosity with temperature is shown in Figure 2 and 3. From the figures 2 and 3, it is observed that the measured kinematic viscosity of samples decrease with increase in temperature. This is due to higher thermal movement among the molecules, reducing intermolecular forces, making flow among them easier and reducing viscosity. It is observed that the divergence between the viscosity of unheated and heated oil is greater. At 90°C the digression between the curves is less in figure 2 than in figure 3. This quantifies the thermal degradation in the oils on heating and it is observed that thermal degradation in palm oil is greater than sunflower oil. The viscosity of heated oil is found to be greater than unheated oil, which shows their behaviour changes to non-Newtonian liquid. The determination of un-saturation in oils makes it possible to classify them and evaluate their oxidative deterioration which is directly related with the degradation of polyunsaturated fatty acids in the lipids and which are indispensable nutrients in human tissue. On repeated heating, the composition of oil saturates leads to increase the level of LDL cholesterol, affects digestion capability, increases blood pressure and spoils function of human heart.

In this study, ANN model is used to compute the kinematic viscosity of unused and used sunflower oil and palm oil at various temperatures. The data in the Table 1 is used as the training pattern for the neural network . After training of the neural network the weight of the neural network is saved. They can be reloaded at any time to determine the viscosity of sunflower and palm oil at unknown temperatures which is not used for training. The Table 2 gives the kinematic viscosity of sunflower and palm oil computed by the neural network. It is observed that the computed kinematic viscosity of sunflower oil and palm oil at unknown temperature is found to agree with experimental values.

Statistical analysis

Statistical analysis is made to check the accuracy of the measured values using software SPSS version 12. The data analysis of Figure 2 and 3 is done using non-linear regression method for the calculated viscosity (dependent) with rise in temperature (independent). Power law model is used to relate viscosity and temperature. Power law model: ? = k (T- Tref) n ………………. (2) Where k and n are constants. Tref is reference temperature (273 K) and T is the temperature measured. ? is the measured kinematic viscosity. The computed regression co-efficient of unheated and heated palm oil is found to be R2= 0. 990 and R2= 0. 989. The premeditated value of unheated and heated sunflower oil is R2= 0. 997 and R2= 0. 998 shows more exactness in measurement. The variance between the groups ranges between p < 0. 001 to p <0. 0001 indicating the best curve fit with minimum error. Therefore one can conclude that our regression model result is significantly better prediction of accuracy.

Conclusion

ATmega32 Microcontroller based instrument system has been developed to measure kinematic viscosity edible oils at different temperatures ranging from 30°C to 90°C. The variation of viscosity at different temperatures will indicate the non – degradation of the oils samples. The kinematic viscosity obtained by the designed instrument is compared with the rotational type viscometer to check the accuracy and reproducibility of the developed instrument and it is observed that the error in the measurement of kinematic viscosity of the oil is found to be less than 2%. The temperature measurement and control system is tested and the error in measurement of temperature is found to be within 1%. The error occurred in kinematic viscosity determination by the neural network concept is found to be less than 1%. The error can be minimized by increasing the number of training cycles and by changing the number of neurons in the hidden layer. It is observed that even in the absence of measured kinematic viscosity of oil it is possible to obtain reliable corresponding estimates by the Neural Network. The measurement system is configured to operate over the temperature range of 25°C to 100°C. The system is highly reliable, ease of handling, less expensive and portable.

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