Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/issn/15375110

Research Paper

Determining total solids and fat content of liquid whole egg products via measurement of electrical parameters based on the transformer properties

Yamei Jin [a], Na Yang [a], Xiang Duan [a], Fengfeng Wu [a], Qunyi Tong [a], Xueming Xu [a,b,*]

[a] School of Food Science and Technology, Jiangnan University, 1800 Lihu Road, Wuxi 214122, China
[b] State Key Laboratory of Food Science and Technology, Jiangnan University, 1800 Lihu Road, Wuxi 214122, China

ARTICLE INFO

Article history:
Received 8 June 2014
Received in revised form
22 September 2014
Accepted 29 September 2014
Published online 13 October 2014

Keywords:
Total solids content
Fat content
Liquid whole egg products
Transformer properties
Terminal voltage
λ value

A method for determining the total solids and fat content of liquid whole egg products based on the principle of transformer was developed. The electrical parameters (terminal voltage and λ value) in the secondary circuit, where the sample acted as the coil, were investigated under the action of alternating magnetic flux in the frequency range from 60 to 400 Hz. Findings indicated that subtle changes of quality indices could be detected by electrical parameters based on the transformer properties that relate to the amount of free ions in the samples. As the inductive voltage was fixed, terminal voltage was negatively correlated with quality indices of total solids and fat content. Therefore the decrement of impedance in the secondary circuit caused the increment of inductive current according to Ohm's law. Linear prediction models for the aforementioned quality indices based on these electrical parameters were also established. Judging from coefficients of determination (R^2) and the root mean square error of prediction (RMSEP) of these models, the λ value was found to be a better predictor for quality indices of liquid whole egg products than terminal voltage. It is believed that this method has the potential to evaluate the quality of liquid food materials over a wider frequency and temperature range.

© 2014 IAgrE. Published by Elsevier Ltd. All rights reserved.

1. Introduction

Eggs have long been recognised as an excellent source of nutrients as well as functional substances for their rich proteins, lipids, inhibitors, enzymes and biologically active ingredients. Liquid whole egg products make up a certain portion of the egg product market share (Mine, 2008) due to their processing convenience. The proportion of albumen and yolk greatly affects processing characteristics of liquid whole egg products and this proportion is mainly characterised by different moisture percentages, total solids content and fat content (Ragni, Berardinelli, Cevoli, & Sirri, 2011). For example, distinct total solids and fat content are due to different albumen-yolk

* *Corresponding author*. School of Food Science and Technology, Jiangnan University, 1800 Lihu Road, Wuxi 214122, China. Tel./fax: +86 510 85917100.
E-mail addresses: yameiking123@126.com, xmxu@jiangnan.edu.cn (X. Xu).
http://dx.doi.org/10.1016/j.biosystemseng.2014.09.017
1537-5110/© 2014 IAgrE. Published by Elsevier Ltd. All rights reserved.

Nomenclature

Symbols

λ value	the ratio of input voltage to terminal voltage
N_p	number of turns of primary coil
N_s	number of turns of secondary coil
a	significant level
P	p-value, probability
R^2	coefficient of determination

Abbreviations

ANOVA	one way analysis of variance
RMSEP	root mean square error of prediction
RMSEC	root mean square error of calibration

ratios influence foaming and gelling properties (Baldwin, 1986). Therefore, liquid whole eggs with specific albumen-yolk proportions are required for various food products such as pasta, mayonnaise and ice cream (Ragni et al., 2011).

Many studies have examined electrical properties to evaluate the quality of egg products. Ragni et al. (2011) measured the admittance of nine types of liquid whole egg products using a tetrapolar platinum cell in the 10–5000 Hz frequency range at 1, 1.5, 2 V alternating voltages. Results showed significant correlations between quality parameters (total solids and fat content) and admittance. Berardinelli, Ragni, Cevoli, and Guarnieri (2011) ran linear regression equations based on electrical conductivity measurements, with coefficients of determination (R^2) varying from 0.985 to 0.995. These regression models were used to predict total solids and fat content in liquid whole egg products. Ragni, Al-Shami, Mikhaylenko, and Tang (2007) investigated the dielectric properties of albumen and yolk during egg storage from 20 to 1800 MHz with an open-ended coaxial probe. They proposed that the age of the eggs can be calculated by permittivity at selected frequencies. In addition, a parallel plate capacitor, connected to a resonant radio frequency circuit, was used to detect the capacitance and voltage of eggs with different storage time and acceptable linear regression models were established to classify the eggs (Ragni, Gradari, Berardinelli, Giunchi, & Guarnieri, 2006). Thus, measurements of electrical properties have generally been conducted with open-ended coaxial probes or parallel plate capacitors and using these techniques, external electric or electromagnetic fields can be directly applied on the food materials, and their electrical properties were investigated over a specific frequency range.

In a transformer system, the primary and secondary coils are not electrically connected, but are magnetically linked (Fig. 1). They are bound to two sides of the magnetic core. An alternating input voltage is applied, which causes a primary voltage and a current flow in the primary coil. The flowing current generates a magnetic flux in the magnetic core that is proportional to the number of turns in the coil.

$$U_p = -N_p \frac{d\Phi}{dt} \quad (1)$$

Where U_p is primary voltage, N_p is number of turns of primary coil, Φ is magnetic flux, and t is time.

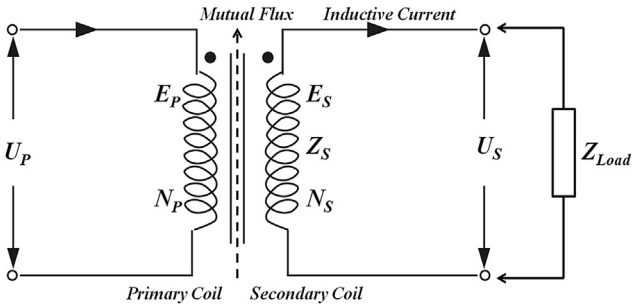

Fig. 1 – Schematic diagram of the detecting system based on transformer properties.

The flux in the o-core then induces a voltage in the secondary coil, the numerical relationship of which can be summarised by:

$$E_s = -N_s \frac{d\Phi}{dt} \quad (2)$$

Where E_s is inductive voltage and N_s is number of turns of secondary coil. The secondary coil has significant internal impedance; the inductive voltage will be divided between the internal impedance of the coil and the external impedance of the load resistor (Heathcote, 1998).

A simulated inductive detecting system was proposed by Pryor (2013) who found it to be effective for the rapid assessment of the conductivity of seawater based on the foundational of the transformer. The result of the study demonstrated that the liquids formed a closed loop under the action of alternating magnetic flux; their inductive current was generated and related to their electrical conductivity.

However, there are no practical analyses of electrical parameters based on the transformer properties used to evaluate the quality indices of liquid foods. Liquid foods could act as spiral conductors under alternating magnetic flux. Many free ions or polar molecules existed in complex biochemical systems, so liquid whole egg products might respond to the alternating magnetic flux. Therefore, our study investigated a detection system based on transformer properties to investigate the conductive characteristics in the secondary circuit, in which the whole liquid egg acted as a coil. This investigation was carried out in an extremely low frequency range from 60 to 400 Hz and input voltages ranging from 5 to 25 V. Specifically, the input voltage and primary voltage were measured to within a difference of 0.36 V. The difference in input voltage levels and frequencies were applied on the primary coil, and correlations were expressed with mathematical equations between electrical parameters and total solids or fat content. The frequencies selected include those within the range allocated for industrial, scientific and electricity applications at extremely low frequencies of 60, 120, 200 and 400 Hz (Caricchi, Crescimbini, Honorati, Bianco, & Santini, 1998; Ellenrieder, Andrade-Valenca, Dubeau, & Gotman, 2013; Falone et al., 2008; Kim et al., 2007).

Download English Version:

https://daneshyari.com/en/article/1711052

Download Persian Version:

https://daneshyari.com/article/1711052

Daneshyari.com