USING OF ELECTRICAL CONDUCTIVITY ON FOOD CONTROL AND FOOD PROCESS

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ABSTRACT

The electrical conductivity measurement is applied for determination of various characteristics of agricultural materials and food control. When a change occurs in the structure of many food, the electrical conductivity of them also varies. These properties are also useful in the detection of processing conditions or the quality of foods. The electrical conductivity of foods has been found to increase linearly with temperature, and water/ionic content. Electrical conductivity measurements have been used extensively in the food industry to detect contaminants in water and to monitor microbial activity. Electrical conductivity measurement may also used as a simple and direct measurement method.

Keywords: Electrical conductivity, food production, food industry, food quality, food control

INTRODUCTION

Electricity conductivity of food material is a function of product characteristics (composition, sugar and salt content, pH etc.) and electricity conductivity is influenced by the heating process itself, notably, by the temperature (Lamsal and Jindal,2014).

Electrical properties are important in processing foods with pulsed electric fields, ohmic heating, induction heating, radio frequency, and microwave heating. These properties are also useful in the detection of processing conditions or the quality of foods (Barbosa-Canovas et al. 2006). Food can also contain desirable or undesirable compounds excreted by microorganisms, such as bacteria or fungi (Oćon et al., 2013; D'Ostuni et al.,2016; Ferre,2016). During the preparation for sale stage of food production, artificial preservatives can be added to foods to extend their storage time and other chemical additives can be introduced in order to improve their taste or

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texture. Quality assesment in food industry in mainly based on sensory panel control, because a vast amount of food quality indicators is subjective and impossible to capture by measurable physical parameters. Moreover, even if the particular product property is quantifiable through a physical variable, sensors appropriate for food control are rarely available (Ortega-Rivas, 2010).There are several paths in analytical treatment of foods. Electrical conductivity measurements have been used extensively in the food industry (Carcia-Golding et al.1995; Curda and Plockova 1995; Paquet et al.2000). Electrical conductivity measurement was also used as a simple and direct measurement method to determine whey demineralization throughout conventional electrodialysis processes with monopolar membranes (Hiraoka et al.1979; Higgins and Short,1980).

USING OF ELECTRICAL CONDUCTIVITY IN DAIRY INDUSTRY

Electrical conductivity has been used widely in dairy industry. It is one of the testing methods used to determine quantities such as soluble salts (Crow, 1994), protein content in whey powder (Zhuang, et al., 1997), and casein content during renneting (Dejmek, 1989). It can also be used as a diagnostic of intramammary infection (Woolford, Williamson, & Henderson, 1998). Electrical conductivity measurement has long been used during CIP as a quality-control indicator. For instance, detection of mastitis for quality control of milk, to analyze fermentation processes for production of cheese starters (Paquet, et al., 2000), to monitor the start-up and preheating phases of milk pasteurization process (Henningsson, et al., 2005). Conductivity is considered a valid method for evaluating the growth and acidity of LAB in milk (Baynes et al.,1983; Lanzonavo et al.,1993; Paquet et al.,2000; Schwann, 1985). The microorganisms that caused greater increases of EC were Staphylococcus aureus and a gram-negative bacterium (Roukbi et al., 2015).

Since traditional methods for evaluating milk quality are lengthy, labor-intensive, and expensive (Harding, 1995), several analytical and electrical methodologies have been developed to detect milk adulteration.EC, which increases during the infection of dairy cows, is also one of the diagnostic methods for detection of subclinical mastitis. EC is determined by the concentration of anions and cations. According to Kitchen (1981), mastitis increased the EC of milk because of changes in ionic concentrations. As a result of damage to the udder tissue, concentrations of lactose and K^+ decreases, and concentrations of Na^+ and Cl^- increases. The contents and nutritional values of milk, which are important for human nutrition, may be changed with a systemic or mammary gland infection of host animals.

USING OF ELECTRICAL CONDUCTIVITY IN MEAT INDUSTRY

Electrical conductivity (EC) was widely used in meat research to check the quality of meat. Perre et. al.,(2011) used EC as a data to measure the meat quality of six different trials distributed over

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winter and summer. Banach and Zywica(2010) tried to use EC to examine the beef meat types. Litwińczuk et al.,(2008) compared the chemical composition and physicochemical quality(contain EC) of the meat of mature slaughter horses and reported that the longissimus dorsi muscle was characterized by significantly lower values of specific electrical conductance. Damez et al.,(2007) explain tissues conductivity changes in preferential directions during beef meat ageing. However, researches on establishment of kinetic model based on electrical conductivity are scarce.

Blicharski et al., (1995) Lepetit and Hamel,(1998) and Pliquett et al., (2003) in their studies the application of measurements of electrical conductivity values for assessment of beef quality features have been carried out for many years. Methods based on electrical properties of muscular tissue, as an electric conductivity measurements are a supplement or even an alternative to pH measurement. Correlations between successive measurement of myofibrillar resistance of raw Longissimus dorsi muscle during ageing. Application of that type of methods is possible as a consequence of the specific muscle structure which shows conductivity features.

Sarang et al (2008) reported that conductivity measurements of meat cuts showed that lean is much more conductive than fat. The fat content of all lean muscle cuts was measured, and no strong relationship was observed between the electrical conductivity and the fat content of lean muscle. Fat distribution or marbling appears to be an important factor affecting the electrical conductivity of meat.

Yao et al. (2011), in their research compared between electrical conductivity and some usual freshness indicators. Tsironi et al., (2009) estimated quality indices (colour, microbial growth, TVB-N, sensory scoring) of gilthead sea bream fillets during refrigerated storage and kinetically modelled. Lepetit et al., (2002) also indicate the possibility of using electrical conductivity meat properties for control of the meat tenderness degree during its storage. Byrne et al., (2000) found that evaluated the quality of the heifers, electrical conductivity increased over the conditioning time.

USING OF ELECTRICAL CONDUCTIVITY IN DETERMINATION OF HONEY QUALITY

Electrical conductivity of honey is change depend on the mineral content, organic acids, proteins, some complex sugars, polyols and with botanical origin. (Terrab et al., 2003; Terrab et al., 2004). At present, electrical conductivity is the most useful quality parameter for the classification of unifloral honeys, which can be determined by relatively inexpensive instrumentation. This has been confirmed by the data, published in this issue (Persano Oddo and Piro, 2004). According to many authors the measurement of electrical conductivity instead of the

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time-consuming gravimetric method is an indirect technique to the determination of mineral content in some food (Acquerone et al., 2007). Accorti et al., (1986) and Accorti et al., (1987), analysed 297 samples of honey of different floral origins and showed that a highly significant linear correlation existed between ash determined according to the official method (Codex Alimentarius Commission, 1981/2001) and electrical conductivity determined by the standard method of the European Honey Commission (Bogdanov, Martin, & Lüllman, 1997). Electrical conductivity is a very important property of a honey because it is used to distinguish between floral and honeydew honeys (Kaškonienė et al., 2010).Floral honeys should have electrical conductivity values below 0.8 mS cm−1 and honeydew should have values above 0.8 mS cm−1 (Downey et al.,2005).

USING OF ELECTRICAL CONDUCTIVITY IN FRUIT AND FRUIT JUICES

The electrical conductivity (EC) of food systems is a key parameter of the ohmic heating process (Zhu et al,2010) Their study provided practical information on the EEC(effective electrical conductivity) behavior of particle–fluid systems, which is important for a better understanding of heating behavior in the ohmic heating process of particle–fluid food systems. Castro et al.(2004) found that the effects of field strength and multiple thermal treatments on electrical conductivity of strawberry products. Electrical conductivity increased with temperature for all the products and conditions tested following linear relations. Electrical conductivity was found to depend on the strawberry-based product. An increase of electrical conductivity with field strength was obvious for two strawberry pulps and strawberry filling but not for strawberry topping or strawberry-apple sauce. The variations in electrical conductivity of orange, pineapple and tomato juices had been evaluated during continuous ohmic heating process. Lamsal and Jindal, (2014) reported that electrical conductivity of fresh fruit juices was related, with sufficient accuracy to measurement temperature and total soluble solids; unit change in soluble solids had higher influence on electrical conductivity than unit change in temperature. Palanippan and Sastry (1991) reported that the electrical conductivity of the orange, carrot and tomato juices increased with temperature and decreased with solids content. The conductivity (EC) caused an increase of the total soluble solid components of the fruits (Krauss et al,2006). Icier et al (2008) similarly found that the electrical conductivity increased as the temperature increased ranging from 0.4 to 0.75S/m for fresh grap juice. Amiali et al. (2006) studied that the electrical conductivity (0.13 to 0.63S/m) increased linearly with increasing temperatures for fruit juices (apple, orange, and pineapple juices).Palaniappan and Sastri (1991) developed best-fit equations for electrical conductivity of tomato and orange juices as a function of total soluble solids and temperature at measurement. Qihua (1992), and Hung (1993) worked on modeling the electrical conductivity as a function of temperature and total soluble solids. Sastri and Salengke (1998) compared different mathematical models for ohmic heating of solid-liquid mixtures. Park et al.(2013) reported that

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electrical conductivity measurement was found to be a useful tool for understanding the pressure-induced textural changes of vegetable tissues.

USING OF ELECTRICAL CONDUCTIVITY IN OIL

Electrical conductivity measurements are currently not applied for the analysis of vegetable oils. Typical refined vegetable oils contain very low concentrations of charge carriers, and conductivity can be below the limit of detection (Abdelmalik et al., 2012). Only recently some data about electrical conductivity of vegetable oils were published (Kumar et al., 2013 and Pecovska-Gjorgjevich et al., 2012). Zhou, et al.,(2011) developed a method for measuring quality of oils by determining the electrical conductivity values of oils, and the results obtained using the other methods were highly consistent; moreover, the electrical conductivity method showed good repeatability. In addition, the results obtained using the the electrical conductivity method represented the total the electrical conductivity value, Yu et al. (2012) improved this method to determine the FFA content in edible oils based on the changes the electrical conductivity values of a potassium hydroxide solution layer during the reaction of potassium hydroxide with the FFA. These results indicated that the the electrical conductivity method could be applied to detect the quality of oils, and this method was simple and practicable. Yang et al.,(2014) reported that their study was to simplify the PV(peroxide value**)** analysis of edible oils by employing of the EC procedure. The obtained results had shown that the EC method was comparable to the EEC, AOCS, IUPAC, AOAC method in terms of accuracy. Moreover, the procedures of the EC method which can yield objective results were easier to perform than those of the EEC, AOCS, IUPAC, AOAC method. However, marginal amounts of organic solvents were used in these procedures, which may cause concern for environmental pollution. The range and accuracy of detection were determined by the changes in the EC values. The determination of the EC values was independent of the oil types.

Corach et al,(2012) reported that their work show that measurements of electrical properties, successfully applied to the characterization of FAME(Fatty Acid Methyl Esters) from soybean oil at the different stages of the production process as reported in previous works, can be also used in FAME from other vegetable oils.

RESULT

There are several paths in analytical treatment of foods. The most effective determination techniques are expected to be fast and non-destructive in order to reduce the need for expensive and time-consuming laboratory analyses. Electrical conductivity measurement may also used as a simple and direct measurement method. Experimental data on electrical conductivity measured

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for several food groups have been expressed in mathematical relationships. These models are useful in estimating the electrical conductivity of food materials.(Zhang, 2005).

Electrical properties are finding increasing application in agriculture and food processing industries (Jha et al, 2011).

1- Demineralization of whey and its fractions, leading to loss of ionic minerals, is monitored using a conductivity meter.

2- Lactic acid accumulates as a result of fermentation during the manufacture of yogurt and fermented dairy products, converting calcium and magnesium to ionic form and thereby increasing theconductivity reading. Thus, the progress of fermentation can be followed by increases in the conductivity of the yogurt base.

3- Conductivity of milk is the basis of the new ohmic process for sterilizing milk,

4- Detection of mastitis for quality control of milk, mastitis increased the EC of milk

5- Analyze fermentation processes for production of cheese starters

6- Electrical conductivity used as a data to measure the meat quality

7- Tissues conductivity changes in preferential directions during beef meat ageing

8- Electrical conductivity is the most useful quality parameter for the classification of unifloral honeys

9- Electrical conductivity of orange, pineapple and tomato juices had been evaluated during continuous ohmic heating process.

10- Electrical conductivity measurement was found to be a useful tool for understanding the pressure-induced textural changes of vegetable tissues.

11- FFA content in edible oils based on the changes the electrical conductivity

12- The electrical conductivity method could be applied to detect the quality of oils

13- Electrical conductivity measurements have been used detect contaminants in water and to monitor microbial activity.

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