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Analysis of heat and mass transfer during frying process of potato strips

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Introduction: Frying phenomena occur during the immersion of the product in oil at a temperature of 150–200 ºC, where a simultaneous heat and mass transfer take place. This is the most popular thermal processes of potato cooking. This fast drying is critical to improve the mechanical and structural properties of the final product. These conditions lead to high heat transfer rates, rapid cooking, browning, texture and flavor development. The fried potato is easier to transport and provides better texture. Researchers have assumed the existence of two regions for fried product, separated by an interface: the core (unfried) and crust (fried) regions. In general, frying process is very complex for two main reasons: i) due to the simultaneous heat and mass transfer between food material and frying oil, ii) due to the progressive deterioration of the oil and structural changes in foods (crust and core regions). The moving boundary problem may be found in many areas of frying research involving heat and/or mass transfer. In this study, heat and mass transfer is entirely investigated during frying of potato strips. The transport phenomena during frying are including: i) Heat convection from the hot oil to the interface via the crust region, ii) Water evaporation at the moving interface at a temperature of 100 ºC, iii) The unsteady state heat conduction in both regions of crust and core, iv) The oil uptake into food. As a result, high temperature and low moisture conditions develop as frying proceeds. Water vapor bubbles escaping from the surface of the food cause considerable turbulence in the oil. Therefore, Heat and mass transfer are dependent on each other during frying process. In fact, heat and mass transfer during frying can be controlled by heat transfer at the product surface. Evaporation rate depends on the temperature difference between oil and boiling point of water. There is little information on modeling, both empirical and phenomenological, for moisture loss and oil uptake during frying. Knowledge of accurate heat and mass transfer parameters is important for modeling processes. Designing of frying processes is possible through the use of mathematical models. The aim of this study is to develop a more completely and realistic approach for determining of heat and mass transfer parameters and their relation to oil temperatures. The main process parameters influencing oil uptake are frying temperature and duration. Heat transfer coefficients for different oil temperatures determined using simple method. Mass transfer of water was assumed to be governed by Fick's law of diffusion. For more details, empirical models were used to describe the mass transport in forms of moisture and oil.

Materials and Methods: The frying operation of potato strips was performed in the fryer that was equipped by thermo controller system with K type thermocouple at three different oil temperature of 145, 160 and 175 ºC for 60, 120, 180 and 240 seconds. The core temperature changes of product recorded on computer during process using T type thermocouple connected to data logger. The moisture and oil content of samples measured for each process time and temperatures. The heat and mass transfer parameters such as kinetic coefficients of moisture (K_m) and oil transfer (K_o), mass transfer coefficient (K_c), effective diffusivity (D) and heat transfer coefficient (h) were evaluated with dimensionless temperature and concentration ratio plots and also empirical equations. Relationship of these parameters to the temperature of the oil investigated using the Arrhenius equation. Thermal conductivity of potato strips during frying determined as a function of moisture content using the Anderson and Spell equations.

Results & Discussion: The results showed that mass transfer Biot number (Bi_m), mass transfer coefficient (K_c) and effective moisture diffusivity (D) increased significantly with increasing in oil temperature. In regression models, the linear correlation between kinetic constant of water loss and oil uptake was observed that is verification on effect of drying pretreatment on reducing oil uptake. In fact, with increasing of oil temperature the kinetic constant of water loss increased and caused increased in kinetic constant of oil uptake. Kinetic models could correctly confirm determination of mass transfer parameters. The heat transfer Biot number (Bi_h), convective heat transfer coefficient (h) and product thermal conductivity (k) decreased significantly with an

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increase in process temperature. With increasing in the rate of evaporation, following greater amount of input energy used for water loss. This would reduce the amount of available energy to increase internal energy of product and thus reduce the convective heat transfer coefficient at high temperatures. Frying process caused remove of water from product and increasing of porosity, thus observed gradually fell in thermal conductivity. Although the minimum thermal conductivity at various temperatures are close together, but two equations of Anderson and Spell showed significant difference for values of thermal conductivity and Spell was more close to published papers. High activation energy is achieved for lower moisture content that is normally due to the strong water-substrate interaction.

Keywords: Frying, Potato strip, Biot number, Mass transfer, Heat transfer