Electrical Properties of Fish Mince During Multi-frequency Ohmic Heating

H. Wu, E. Kolbe, B. Flugstad, J. W. Park, and J. Yongsawatdigul

ABSTRACT

A multi-frequency ohmic heating system with 30 Hz~1 MHz range which could deliver 250 watts was developed for measuring electrical conductivity and absolute dielectric loss of food samples. Pacific whiting surimi paste and stabilized mince in the 20~70°C range were tested at frequencies from 55 Hz to 200 kHz. Sample impedance decreased slightly with frequency. The DC electrical conductivity (σ_{dc}) and absolute dielectric loss (ϵ'') of Pacific whiting surimi paste increased with temperature and salt concentration; σ_{dc} and ϵ'' of the stabilized mince increased with temperature. Empirical models of electrical properties for surimi paste (moisture content 79% and salt at 1, 2 or 3%) and stabilized mince (77% moisture and 0.74% salt) were derived. Electrolytic corrosion diminished with frequency.

Key words: fish mince, dielectric properties, ohmic heating, conductivity

INTRODUCTION

LARGE QUANTITIES OF PACIFIC WHITING (*Merluccius productus*) are utilized in the form of surimi, a washed mince which contains a Cathepsin L protease with maximum activity at 55°C (Seymour et al., 1994). This activity causes a breakdown of myofibrillar proteins and inhibits development of a 3 dimensional gel structure (Niwa, 1992). Research and subsequent industry practice have shown that 1~1.5% of a beef plasma protein (BPP) would ensure maximum surimi gel strength, a major functional property influencing its value (Morrissey et al., 1993; NFI, 1991).

Another product form of Pacific whiting is unwashed mince stabilized in frozen storage with various cryoprotectants (Simpson et al., 1994, 1995). Enzyme concentrations measured in such minces are about 10x those of washed and stabilized samples (An et al., 1994a, b). Thus enzyme inhibition in unwashed mince may require inhibitor concentrations far greater than the 1~1.5% BPP typically used in commercial surimi.

Enzyme inhibitors such as BPP have some disadvantages due to labeling restrictions, cost, or sensory effects. Studies, therefore, have been initiated to thermally inactivate the protease enzyme by very rapid heating.

Ohmic, or electrical resistive heat generated internally due to electrical resistance of the sample occurs rapidly (deAlwis and Fryer, 1992; Palaniappan and Sastry, 1991a). Gel strength of surimi from walleye pollock, white croaker, threadfin bream, sardine, or Pacific whiting has been improved when cylindrical samples were ohmically heated, as compared with those heated in a 90°C water bath (Shiba, 1992; Shiba and Numakura, 1992; Yongsawatdigul et al., 1995b). It was shown that 1.9 cm diameter cylindrical samples heated in a 90°C bath could take up to 6 min. to reach 70°C (Yongsawatdigul et al., 1995b), where the protease would be completely inactivated (Seymour et al., 1994). During 2 min. of this process, the center was within the range 40-60°C, during which the protease hydrolyzed myofibrillar proteins and destroyed gel structure. Protease activity was virtually stopped when similar samples were heated ohmically.

Most ohmic heating systems have used 50-60 Hz alternating current. Research has sought to define temperature- and composition-dependent values of electrical conductivity, the critical factor influencing heat generation rates (Halden et al, 1990; Palaniappan and Sastry, 1991a, b; Shreier et al., 1993; Yongsawatdigul et al., 1995a). One constraint of 60 Hz ohmic heating, however, is that electrolytic reactions can take place at the electrode surface, leading to product burning and corrosion of electrodes made from common food-grade metals (Shiba, 1992). To overcome this, increasing electric signal frequency has been suggested; Uemura et al. (1994) and Reznik (1996) reported reduced electrode corrosion when cooking at alternating current frequencies approaching 10 kHz.

Biological materials act as "lossy media" considering their ability to store and dissipate electrical energy from an applied electromagnetic field (Von Hippel, 1954). These properties result from electrical charging and loss currents generally related to the electrical capacitance and resistance of the material. They are defined by fundamental dielectric properties which can be expressed as direct current (DC) electrical conductivity σ_{dc}(S/m), absolute dielectric constant ϵ'(F/m), and absolute dielectric loss ϵ''(F/m).

Inductive materials also have magnetic characteristics related to their inductance and resistance and are defined in terms of absolute complex permeability μ^*(H/m). However, natural biological materials are noninductive dielectrics, do not couple magnetic energy, and hence have a magnetic permeability near that of free space. Thus magnetic coupling effects may be neglected in biological materials (Mudgett, 1985).

To apply ohmic heating of Pacific whiting minced products in higher frequency ranges, our objective was to characterize the properties: DC electrical conductivity σ_{dc}; absolute dielectric constant ϵ'; and absolute dielectric loss ϵ'', during ohmic heating at various frequencies to 200 kHz.

MATERIALS & METHODS

Sample preparation

Surimi paste. Washed mince of Pacific whiting was taken from the process line of a local manufacturer and mixed with 4% sucrose, 4% sorbitol (ICI Specialties, New Castle, DE) and 0.3% sodium tripolyphosphate (B.K. Ladenburg Corp., Cresskill, NJ) to make surimi at the OSU Seafood Laboratory (Astoria, OR). No enzyme inhibitors were added. Samples were packaged in ~450g containers, frozen in a -30°C room, then brought to our lab in Corvallis, OR and kept in a -30°C room until the experiments. Two packages of surimi were taken from frozen storage, thawed at room temperature (~23°C) for around 2h., then cut into small pieces (about 3 cm cubes). Three batches of surimi paste representing one moisture content (79% wet basis) and three NaCl concentrations (1, 2 and 3% w/w) were prepared. Due to three washing cycles and dewatering during surimi-making, ionic constituents originally present in the fish were removed with wash water, resulting in a low ion concentration in the surimi (Lin, 1992). The sodium concentration of Pacific whiting surimi without enzyme inhibitors was 0.002% (Chung et al., 1993), negligible considering the amount of

Authors Wu and Kolbe are with the Dept. of Bioresource Engineering, Oregon State Univ., Corvallis, OR 97331. Author Flugstad is with Flugstad Engineering, P.O. Box 5036, Charleston, OR 97420. Author Park is with Oregon State Univ. Seafood Laboratory, 2001 Marine Drive, Astoria, OR 97103. Author Yongsawatdigul is with Suranaree Univ. of Technology, Nakhon Ratchasima, Thailand. Address inquiries to Dr. E. Kolbe, 1200 NW Naito Pkwy., Suite 520, Portland, OR 97209-2800