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Experimental investigation of the effect of conveyor movement and sample's vertical position on radio frequency tempering of frozen beef

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ABSTRACT

In this study, effect of conveyor movement and sample's vertical position on rate and uniformity of radio frequency tempering was investigated experimentally at a fixed electrode gap setting. To do this, tempering of a frozen block of lean beef (2.0 kg) was conducted at three different vertical positions under moving and stationary conditions using a radio frequency oven operating at 27.12 MHz and a maximum power of 2 kW. Effect of employing an inclined conveyor that continuously lowered or raised the vertical position of the frozen beef between the electrodes during conveying was also investigated. Temperature was measured using fiber optic probes at four different internal locations (center, corner, near short edge, and near long edge). Times needed for temperature to increase from about −17 °C to at least −5 °C at all four locations were in the range of about 7–10 min for various settings. Although tempering uniformity appeared to be slightly higher under moving conditions, the improvement was not statistically significant. It was demonstrated that if the sample is correctly positioned between the electrodes, stationary tempering can be both rapid and uniform. The study also showed that downwardly-inclined conveyor configuration may be beneficial in applications where rapid heating at the beginning and a more controlled heating toward the end is desired.

1. Introduction

Further processing of frozen foods in food industry generally requires thawing or tempering. While thawing means to increase the temperature of a frozen food to 0 °C at its thermal center, tempering can be defined as increasing the temperature usually up to −5 to −2 °C. Within this temperature range the frozen food is not completely thawed but softened, and hence can readily be further processed (Yarmand and Homayouni, 2011).

Electromagnetic thawing methods (microwave and radio frequency) have found widespread use in industrial applications owing to the problems associated with conventional methods (contacting frozen food with air or water) (Li and Sun, 2002). Conventional thawing is not only a slow process resulting in quality losses (Seyhun et al., 2009), but may also compromise microbial safety of the product. These disadvantages can easily be avoided through rapid and volumetric heating by using electromagnetic energy. Although both microwave and radio frequency systems can be used for this purpose, radio frequency heating has proven to be more suitable for treating large pieces (frozen blocks of meat and seafood) due to the larger penetration depth of radio waves.

Radio frequency heating has been studied numerically and experimentally by several researchers (Alfaifi et al., 2016; Li et al., 2016; Bedane et al., 2017; Zhang et al., 2016; Zhu et al., 2014; Lau, 2015; Tiwari et al., 2011) who investigated the effect of various processing parameters on RF heating rate and uniformity. In these studies, electrode gap has been repeatedly reported to be the most important parameter affecting power absorption and uniformity of heating. Earlier research (Huang et al., 2015; Tiwari et al., 2011; Birla et al., 2008; Lau, 2015) also discovered that RF heating uniformity increases when the product is vertically moved toward the center of the electrodes, a finding which demonstrates that vertical position of sample plays a role in heating uniformity. As reported by Huang et al. (2016), sample placement between RF electrodes influences heating uniformity by changing electric field distribution within the sample.

Effect of conveyor movement on RF heating uniformity was investigated only by a limited number of researchers (Bedane et al., 2017; Chen et al., 2016, 2017; Wang et al., 2010, 2014). Bedane et al. (2017) experimentally studied radio frequency thawing of frozen

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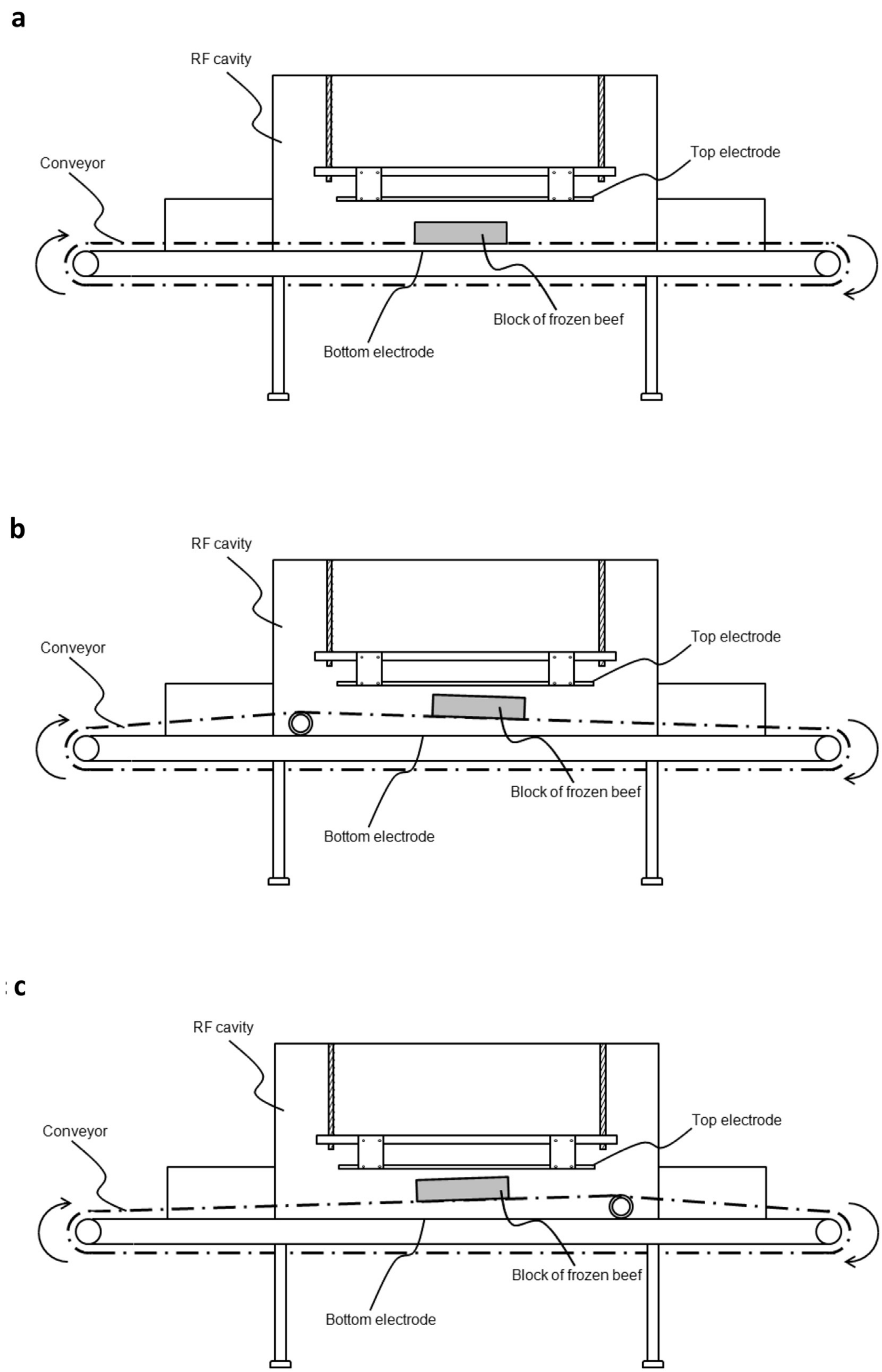

Fig. 1. Schematic of the experimental setup a) horizontal conveyor b) downwardly-inclined conveyor c) upwardly-inclined conveyor.

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