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The effects of ambient temperature and holding time during processing on drip of saithe (*Pollachius virens*) and deepwater redfish (*Sebastes mentella*) fillets

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ABSTRACT

The aim of this study was to investigate the effects of ambient temperatures (9, 16, 21 °C) and holding time (0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0 h) on rate and quantity of temperature changes and drip losses for whitefish fillets. Different types of fillets were used for the experiment, fresh deepwater redfish (*Sebastes mentella*) fillets (105 g) and two sizes of saithe (*Pollachius virens*) fillets (289 g and 634 g). The fillet temperature increased with time, and more rapidly at higher ambient temperatures, particularly with smaller sized fillets. Similarly, the rate and quantity of drip formation were affected by all experimental factors. The effects decreased ($p < 0.05$) in the following order: holding time > type of fillets > ambient temperature. The rate of changes in both temperature and drip loss were greater during the first hour of holding but levelled off with longer holding time. Results indicated that time-temperature abuse, even during relatively short (<1 h) exposure of fillets, may lead to significant economic losses due to weight reduction of the products.

1. Introduction

An important aspect of maintaining yield and freshness of chilled fish products involves optimizing temperatures in the value chain from catch to consumer. A major threat to fresh fish products' shelf life and quality are high ambient and fluctuations in temperatures during processing, storage, and transportation. For example, increases in temperature of products may lead to higher loads of spoilage bacteria and accelerated degradation of muscle (Lauzon et al., 2010; Mai et al., 2012; Margeirsson et al., 2012a,b; Olafsdottir et al., 2006a, 2006b; Sigholt et al., 1997). Accordingly, spoilage and degradation affect the water-holding capacity of the muscle (Olsson et al., 2003). Resulting in the loss of fluids (drip loss), consisting of water and dissolved proteins, which are realised without application of external forces (apart from gravity). Drip loss is widely considered being one of the most important technological quality attributes of fish products (Jennen et al., 2007). For one thing, drip loss can affect undesirable changes in the sensory characteristics of fish, e.g. appearance, juiciness, texture, and flavor (Huff-Lonergan and Lonergan, 2005; Kristoffersen et al., 2007). Also, it may lead to economic losses due to weight loss and reduced yield during the products processing, transportation, and storage (Kristoffersen et al., 2007; Otto et al., 2007, 2006, 2004).

A primary cause of drip loss is attributed to the drainage of fluids located in extracellular spaces from the muscle. Fluids found in extracellular spaces are more likely to be lost than other fluids located in deeper compartments of the muscle. Both perimysial and endomysial gaps form horizontal pathways within the muscle, which connect to the cut surface of the fillet (Huff-Lonergan and Lonergan, 2005; Offer and Cousins, 1992; Offer and Knigth, 1988). Numerous factors affect the distribution of fluid in the muscle and

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its water holding capacity. These factors include the condition of the fish when caught, the rigor mortis stage, handling and processing methods, and the degree of post-mortem degradation of the muscle (Huff-Lonergan and Lonergan, 2005). Rigor mortis occurs by cause of chemical changes in the muscle and contraction of the myofibrils. These changes lead to build-up of pressure differences between the intra- and extracellular compartments, resulting in a higher proportion of fluids flowing into the extracellular spaces. During the rigor resolution stage, enzymatic activity is partially responsible for the degradation of myofiber-to-myocommata and myofiber-to-myofiber. For this reason, pressure gradients are reduced, intra-cellular spaces increased, and portions of the loosely bound water can flow again into the intracellular compartments (Huff-Lonergan and Lonergan, 2005; Kristensen and Purslow, 2001).

The processing of fish and conditions of processing influence drip formation. Cutting the muscle during processing may increase drip loss. Unlike, intact muscles where drip loss is minor. External pressures, such as gravity, may induce drip loss through evaporation at the cut surface and cause drainage of fluids from the muscle (Honikel, 1998; Honikel and Hamm, 1994). Additionally, temperature fluctuations within the value chain, pose a considerable risk to drip formation. Therefore, an essential facet of minimizing the risk of time-temperature abuse and drip loss is associated with efficient production management and temperature control (Giannakouroua et al., 2005; Taoukis et al., 1999; Taoukis and Labuza, 1989). This entails reducing the exposure time of fish during the processing phase and cooling the processing environment when possible. In Iceland, where the experiment was conducted, the cooling of the processing area is in accordance with the Administration of Occupational Safety and Health in Iceland (AOSH) regulations and, therefore, restricted to 10 °C. The upper limit for the ambient temperature is 16 °C (Regulation no 384/2005 as cited by Valtysdottir et al., 2010). However, temperature control and working conditions vary between countries. Thus, the ambient temperature of the processing environment can range from 4 °C to 25 °C (or even higher), particularly in warmer climates (Gudmundsson et al., 2013; Jessen et al., 2014; Thi et al., 2013; Zhang et al., 2004). Moreover, the processing time influences changes in fish temperature, ranging from a brief exposure time of 5–10 min to a prolonged hour or more (Jessen et al., 2014; Thi et al., 2013). For example, temperatures in fish fillets increased by 6–7 °C after being exposed to a 20 °C environment for an hour in a study conducted by Matis (Margeirsson et al., 2010a).

Several studies describe the effects of temperature abuse during storage and transportation of fish products (Lauzon et al., 2010; Margeirsson et al., 2012a, 2012b; Olafsdottir et al., 2006a, 2006b; Sigholt et al., 1997). Conversely, information on ambient temperatures impacting increased fillet temperatures and their subsequent effects on yield and quality during processing is scarce. The objective of this study was to monitor changes in temperature and drip loss for deepwater redfish and saithe fillets, kept at different ambient temperatures (9 ± 1 °C, 16 ± 1 °C, 21 ± 1 °C) for up to 3 h.

2. Materials and methods

2.1. Raw materials, processing, and sampling

The saithe (*Pollachius virens*) and deepwater redfish (*Sebastes mentella*), used in the experiment, were caught by a trawler at 63.12 °N, 24.34 °W. While the saithe were bled, gutted, and stored in slurry ice on board the trawler for five days before processing, the deepwater redfish was stored whole in crushed plate ice and gutted before processing. Both species were processed at a fish processing plant in Iceland. After processing, skinned fillets were randomly collected and marked with numbered plastic tags.

The samples were split up into three different trial groups. Two different size groups of saithe fillets were used for measuring temperature, “large” (634 ± 192 g) and “small” (289 ± 65 g). The third group was composed of deepwater redfish fillets, which were smaller (105 ± 12 g) and thinner than the saithe fillets. After temperature and weight determination, six fillets (n = 6) of each trial group were placed in a specific type of plastic tray commonly used in the whitefish processing industry. Thereafter, the trays with the fillets were stored at different ambient temperatures (9 ± 1 °C, 16 ± 1 °C, 21 ± 1 °C), for a holding time of 3 h. During the holding period, temperature and weight changes of each fillet were monitored, as well as the ambient temperature.

2.2. Temperature measurements

The temperature of gutted fish and fillets after processing was measured with a thin, sharpened probe connected to a handheld thermometer (Testo 926, Germany). The probe was inserted into the gutted fish close to the dorsal fin with at least 75–100 mm depth (Torry Research Station, 2001). In measuring the fillets, the end of the probe was inserted into the thickest part of the loin. Temperature changes were recorded during the holding time by using temperature loggers (DS1922L, iButton®, Maxim Integrated, USA). The loggers were inserted inside the saithe fillets. However, due to the low thickness of the redfish fillets, the logger was inserted between the redfish fillets and the plastic tray, on which they were laid. The ambient temperatures were recorded with HoBo U12 loggers (Onset Computer Corporation, Bourne, MA, USA), at 10-min intervals.

2.3. Drip loss determinations

The fillets (n = 6) of each trial group (large saithe fillets, small saithe fillets, and redfish fillets) were weighed directly after sampling and with 0.5-h intervals during the holding period. The difference in weight (g) was divided by the initial weight of the fillet (g) and the drip loss is expressed as g/g % (Arnþorsdottir et al., 2008).

$$\text{Drip loss } (\%) = \frac{\text{Initial weight } (g) - \text{Weight after holding } (g)}{\text{Initial weight } (g)} \times 100$$

2.4. Statistical analysis

The data collected in this study was entered into Excel 2013 (Microsoft Corporation, Redmond, Washington) and imported in NCSS 2007 (Hintze, 2007) for statistical analysis (General linear modeling (GLM) and ANOVA). Multiple comparison tests were carried out using Tukey's Kramer test. The significance level was set at 95% ($p < 0.05$), if not stated elsewhere.

3. Results and discussion

3.1. Temperature changes in the fillets during processing and holding

Before processing, the temperature of the gutted saithe was 0.1 ± 0.5 °C and 0.1 ± 0.1 °C in the whole redfish. During processing, the temperature increased to 0.8 ± 0.3 °C and 1.8 ± 0.8 °C in the saithe and redfish fillets, respectively. Further increases in temperature occurred during tagging and weighing of the fillets, and in