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Use of smart photochromic indicator for dynamic monitoring of the shelf life of chilled chicken based products

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ABSTRACT

This study evaluated the applicability of a photochromic time temperature indicator (TTI) to monitor the time–temperature history and shelf life of chilled boneless chicken breast. The results showed that the smart indicator showed good reproducibility during the discoloring process in all the conditions investigated. The response was not only visibly interpretable but also well adaptable to measurement using appropriate equipment. For an activation configuration of 4 s of ultraviolet light (UV) per label, the TTI's rate of discoloration was similar to the quality loss of the meat samples analyzed. Thus, the photochromic label (4 s UV/label) attached to the samples set out to be a dynamic shelf-life label, assuring consumers the final point of quality of chilled boneless chicken breast in an easy and precise form, providing a reliable tool to monitor the supply chain of this product.

1. Introduction

Temperature is considered the main factor affecting the quality and safety of perishable food products such as meat and chicken (Jedermann, Ruiz-Garcia, & Lang, 2009; Kreyenschmidt, Christiansen, Hubner, & Petersen, 2010; Raab et al., 2008; Smolander, Alakomi, Ritvanen, Vainionpaa, & Ahvenainen, 2004).

To slow the growth of microorganisms and extend the shelf life, the cold chain is widely used in the poultry products market (James, 1996; James, Vincent, Andrade Lima, & James, 2006; Likar & Jevsnik, 2006). However, temperature control during transport, distribution and storage (commercial and domestic) is often flawed, with different conditions from those recommended by the manufacturer (0 to 4 °C), with values that can pass 15 °C (Cárdenas, Giannuzzi, & Zaritzky, 2008; Limbo, Tori, Sinelli, Franzetti, & Casiraghi, 2010; Nychas, Skandamis, Tassou, & KoutsoumaniS, 2008; Rokka, Eerola, Smolander, Alakomi, & Ahvenainen, 2004; Vainionpää et al., 2004; Zhang et al., 2012).

The difficulty of ascertaining the real history of food temperature makes it difficult to predict their shelf life (Shimoni, Anderson, & Labuza, 2001). Thus, an emerging technology used to ensure the validity of food products is the use of smart packaging containing time–temperature indicators (Mai et al., 2011), systems that reflect, in a visual manner, the storage temperature conditions during the shelf-life of the food products to which they are attached (Giannakourou, Koutsoumains, Nychas, & Taoukis, 2005; Kerry, O'Grady, & Hogan, 2006; Taoukis & Labuza, 1989).

The OnVu™ TTI B_1 is an indicator of irreversible time and temperature used for food under refrigeration, whose operation is based on a photochromic reaction in the solid state. Its smart ink changes color from colorless to blue upon irradiation with ultraviolet light (activation). Once activated the ink reverts to the colorless state at a rate that is dependent on time and temperature (Kreyenschmidt et al., 2010; Mai et al., 2011; Verdade, 2010).

The end of the shelf life of the OnVu™ TTI B_1 is defined as the time it takes the blue color of the label to reach a reference color (Mai, 2010; Verdade, 2010). The discoloration is proportional to the amount of light used in the charging process and can be adjusted by controlling the pulse duration and intensity of UV light used to activate the photochromic pigment. The bleaching process of the TTI has to be calibrated taking into account the characteristics, especially the expiry date of the food where the indicator will be placed (De Jong et al., 2005; Kreyenschmidt et al., 2010).

Given the above information, one technological possibility to control the temperature during the supply chain of chicken would be the use of smart packaging. Therefore, the objective of this study was to analyze the applicability of OnVu™ TTI B_1 to monitor in real time the time–temperature history and shelf life of chilled boneless chicken breast.

2. Materials and methods

2.1. Characterization of the time–temperature indicator

The time and temperature sensor examined was OnVu™ label B_1 (BASF patent WO/2006/048412). A manual ultraviolet (UV) charger developed for OnVu™ (GLP TTI, Bizerba, Germany) was used to activate the labels. The charger is equipped with high-power LEDs and a timer for activation times between 0.1 (minimum) and 60 s (maximum).

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Once charged, the labels were covered with an optical filter in the form of a thermal transfer tape to protect them from re-charging by sunlight. The exposure time of the UV irradiation in the label was expressed in seconds (s).

2.1.1. Estimation of the shelf life of the TTI

Six different charging times were investigated to examine the influence of activation time (exposure to ultraviolet light) on the process of discoloration of the label.

The labels were activated under the following conditions: 1, 2, 3, 4, 5 and 6 s of UV light. After activation, the labels were attached on pre-cooled glass plates and stored in an incubator of high precision temperature (Model MA 415/S, Marconi, São Paulo, Brazil) at 3.0 ± 0.5 °C, whose internal temperature was monitored every 2 min by data collectors (Data Logger DHT5012, Perceptec, São Paulo, Brazil).

The room temperature during the activation procedure was controlled at 20.0 ± 1.0 °C. The analyses were performed twice and each activation time was evaluated in triplicate.

The discoloration of the labels was measured daily by using a colorimeter (Chroma Meter Model CR-400/410, Konica Minolta, Osaka, Japan) by the CIELab system (illuminant D_{65}) obtaining the size of the b* *chroma*, a coordinate that quantifies the change of color from yellow (b* +) to blue (b* −). The analyses were discontinued when b* = zero (Fig. 1A), where no additional change in blue color could be measured in the label.

The end of the shelf life of the TTI was defined as the time it takes the dark blue color of the immediately charged label (Fig. 1C) to reach a light blue, almost gray color (b* = −7.0), considered in this study as the last stage of the visually detectable blue color (Fig. 1B).

2.1.2. Reproducibility of the activation process of TTIs

The reproducibility of the activation process was measured in one hundred and twenty six (126) labels, twenty one (21) for each activation time, corresponding to seven evaluations of charge condition in triplicate. The labels were charged and immediately evaluated using a colorimeter, by the CIELab color system, obtaining the size of b* *chroma*.

2.2. Monitoring the shelf life of poultry products contained in smart packaging

Microbiological analyses of muscle and discoloration measurements of time and temperature indicators attached to the samples packaging were performed. At the end of the expiry date of the meat products, a comparison between the response rate of the labels (under specific activation condition) and the loss of food quality was performed.

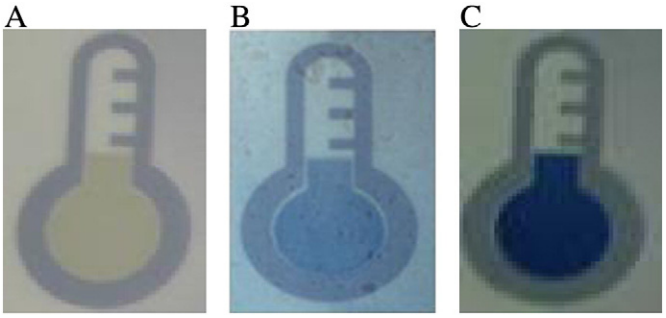

Fig. 1. (A) photochromic brand color when b* = zero; (B) TTI color defined as the end of indicator shelf life, b* = −7.0; (C) Dark blue tone presented by the label immediately after activation with UV light.

2.2.1. Preparation of meat samples

The raw material used was chilled boneless chicken breast, provided by two slaughterhouses under Federal Inspection Service (SIF), located in the state of Rio Grande do Sul/Brazil.

In the slaughterhouses, the samples followed the normal obtaining process; according to the production flow of the respective plants and after packing in the primary packages, they were attached to OnVu™ TTI B_1 labels. The TTIs were activated following the best charge conditions evaluated in Section 2.1 for a maximum storage time of twelve days (shelf life of chilled commercial boneless chicken breast).

The products contained in the activated smart packaging were placed in refrigerated trucks for transport to their final destination, the retail market in the city of Rio Grande/RS/Brazil.

2.2.2. Inland logistics chain of fresh produce

The mapping of the temperature during the distribution of fresh foods was assessed in two routes of land transportation. The first from the city of Morro Redondo/RS/Brazil to Rio Grande/RS/Brazil (Route 1), totaling about 100 km, and the other, from Westfalia/RS/Brazil to Rio Grande/RS/Brazil (Route 2), about 430 km. The temperature was measured using the smart packaged meat products as reference (as per Section 2.2.1) and data collectors, which were applied to measure muscle and environment temperature in the refrigerated truck, respectively.

2.2.3. Storage simulation

After completing the journey, the products were unloaded at their final destination, and the samples were immediately transported in ice coolers, in less than 20 min, until the Laboratory of Food Technology of the Federal University of Rio Grande (FURG)/RS/Brazil.

In the laboratory, simulations of temperature conditions during storage in commercial premises (point of sale) and household refrigerator were performed. For this, the samples were stored in three high precision incubators for twelve days.

The temperatures evaluated were: 3.0 (ideal situation), 7.0 and 10.0 (abusive situation) ± 0.5 °C, and monitored every 2 min by data collectors. Products from the logistics Route 1 were stored at 3.0 and 10.0 ± 0.5 °C, while samples from Route 2 were maintained at 3.0 and 7.0 ± 0.5 °C.

The temperature of 3 °C was chosen because it is the recommended storage condition of chilled products (0 to 4 °C) (Brasil, 1998), while the others were based on work carried out by Zhang et al. (2012), Limbo et al. (2010), Cárdenas et al. (2008), Vainionpää et al. (2004) and Rokka et al. (2004), whose studies featured temperatures around 7 and 10 °C as the temperature profiles that represent the actual conditions of the distribution chain of fresh meat products, from the producer to the final consumer.

2.2.3.1. Microbiological stability of boneless chicken breast. To characterize the loss of quality of the meat samples, microbiological analyses were conducted on boneless chicken breast at 0, 1, 4, 7, 10 and 12 days of storage for each stock condition, with the exception of *Salmonella* spp., performed only at time zero. All analyses were performed in triplicate.

The choice of microorganisms for this study was based on literature (Barbut, 2002; Chouliara, Badeka, Savvaidis, & Kontominas, 2008; Davies & Board, 1998; Franco & Landgraf, 2008; Jay, 2005; Patsias, Badeka, Savvaidis, & Kontominas, 2008) and Brazilian legislation (Brasil, 1998). Analyses were performed using the total count of psychrotrophic aerobes; enumeration of *Staphylococcus* spp.; determination of thermotolerant coliforms at 45 °C and *Salmonella* spp.

A sample (25 g) was taken aseptically from the boneless chicken breast, transferred aseptically to a stomacher bag (Seward Medical, London, UK) containing 225 mL of sterile 0.1% peptone water and homogenized using a stomacher (Lab Blender 400, Seward Medical) during 60 s at room temperature, then serial dilutions were prepared in sterile 0.1% peptone water for the continuation of the analysis. For the enumeration of psychrotrophic microorganisms, *Staphylococcus*