Food Research International 44 (2011) 331–337

Contents lists available at ScienceDirect

Food Research International

journal homepage: www.elsevier.com/locate/foodres

Nondestructive assessment of freshness in packaged sliced chicken breasts using SW-NIR spectroscopy

Raúl Grau [a,*], Antonio J. Sánchez [b], Joel Girón [a], Eugenio Iborra [b], Ana Fuentes [a], Jose M. Barat [a]

[a] Departamento de Tecnología de Alimentos. Universidad Politécnica Valencia, Spain
[b] Departamento de Ingeniería de Sistemas y Automática, Universidad Politécnica de Valencia, Spain

ARTICLE INFO

Article history:
Received 2 June 2010
Accepted 8 October 2010

Keywords:
Spectroscopy
SW-NIR
Freshness
Chicken meat
Packaging

ABSTRACT

A technique was developed to predict the freshness of packaged sliced chicken breast employing a nondestructive visible and short-wavelength near-infrared (SW-NIR) spectroscopy method. Spectra were recorded at 0, 7 and 14 days using a camera, spectral filter (400–1000 nm) and a halogen flood lighting system which were developed and calibrated for the purpose. Physicochemical, biochemical and microbiological properties such as moisture (x^w), water activity (a_w), pH, total volatile basic nitrogen (TVB-N), ATP breakdown compounds (K_1 values) and mesophilic bacteria (cfu g^{-1}) were determined to predict freshness degradation. The spectra obtained were related to the storage time of the samples. The best wavelengths for modeling freshness were 413, 426, 449, 460, 473, 480, 499, 638, 942, 946, 967, 970 and 982 nm. A linear correlation was found between the visible and SW-NIR spectroscopy and parameters such as microbiological counts, K_1 and T-VBN indexes.

1. Introduction

Consumption of chicken has increased in many countries as it is related to a more health conscious diet and mainly due to it being a relatively inexpensive protein source, which is ideally suited to the many forms of convenience foods in the modern western diet (Ellis & Goodacre, 2001).

In the meat sector, as well as in other food sectors, there is a demand for fresh and ready to use products, or at least those easy to prepare, which explains the popularity of packaged fresh chicken fillets. The booming demand for sliced packaged chicken requires the intensive handling of the product to give it the necessary format and causes a certain loss of freshness. During processing (quartering, skinning, cutting and boning), bacteria on the skin and in the carcass cavity of the chicken are the main cause of spoilage (Alain & Stéphane, 2008).

Food safety is a main concern for consumers. Present economic trends lead to increasing distances between consumption and productions zones and consequently to an extension of the delivery chain. Considering these changes, it is necessary to set out methods for objective reliable safety control, guaranteeing quality and freshness at all stages of the commodity chain (Dufour, Frencia, & Kanea, 2003).

Freshness is a rather ambiguous term when referring to meat and fish products. Currently there is no methodology to determine meat freshness, but there are non-legislated tests that provide guidance on the subject. Various methods for assessing meat freshness have been developed based on the measurement of postmortem deteriorative changes associated with sensory quality, microbial growth (Barat et al., 2008; Kaneki et al., 2004) and chemical changes, such as pH or total volatile basic nitrogen (TVB-N). The concentration of ATP and its degradation products (inosine-5′-monophosphate (IMP), inosine (Ino), and hipoxantine (Hx)) has been widely used in fish freshness control (Barat et al., 2008; Fernández-Segovia, Escriche, & Serra, 2008; Karube, Matsuoka, Suzuki, Watanabe, & Toyama, 1984; Surette, Gill, & Leblanc, 1988). Watanabe, Tsuneishi, and Takimoto (1989) stated that the analysis of ATP and its breakdown products could be used as an indication of meat freshness. However, the determination of these compounds in meat has been performed mainly to correlate them with sensory qualities or with different postmortem meat quality, or to test the effect of a_w and temperature on the IMP degradation (Flores, Armero, Aristoy, & Toldrá, 1999; Kavitha & Modi, 2007; Mateo, Domínguez, Aguirrezábal, & Zumalacárregui, 1996). Among the ATP derivatives, IMP is predominant in meat extract 24 h after slaughter. This compound is gradually transformed into inosine and hypoxanthine in the meat (Watanabe et al., 1989).

Sensory evaluation is, in most cases, subjective and costly. Microbial methods estimating bacterial spoilage (Dalgaard, 1995) and chemical methods encounter problems in measuring early postmortem deterioration, so that rapid and simple methods for meat freshness estimation are required (In-Seon, Yong-Jin, & Namsoo, 2000; Kaneki et al., 2004; Zhang, Jin, Dong-hui, & Yu-bin, 2008).

Spectroscopic methods have gained importance in the evaluation of food quality attributes during the last decades (Nádai, 1983; Nádai & Mihályi-Kengyel, 1984). The fact that NIR spectra reflect several parameters of the material suits the method for evaluating complex

* Corresponding author. Tel.: +34 96 3877362; fax: +34 96 3877369.
E-mail address: rgraume@tal.upv.es (R. Grau).

0963-9969/$ – see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.foodres.2010.10.011

quality (Williams & Norris, 2001). Short-wave near-infrared (NIR) spectroscopy shows promise for fast and nondestructive analysis of biological materials (Wu, He, & Feng, 2008). As they have high reflectance ability in the region of 780–1040 nm, the short-wave NIR spectra are being applied to construct excellent detectors for the nondestructive component determination in biological materials. The short-wave NIR region allows NIR energy to penetrate more deeply into a sample with much less heating effect than the long-wave NIR region (1100–2500 nm). Also, short-wave NIR spectra can be measured with inexpensive light sources (tungsten lamps) and detectors (silicon diode array) (Mayes & Callis, 1989). Various near-infrared spectroscopic methods have also been published on prediction of sensory quality criteria (Warm, Martens, & Nielsen, 2001), evaluation of freshness (Nilsen, Esaiassen, Heia & Sigernes, 2002) or detection of fish spoilage (Lin, Mousavi, Al-Holy, Cavinato & Rasco, 2006). Diffuse reflectance spectroscopy has also been used to evaluate the quality of frozen minced red hake (Pink, Naczk, & Pink, 1999), detection and quantification of microbial spoilage of chicken meat (Ellis, Broadhurst, Kell, Rowland, & Goodacre, 2002; Lin et al., 2004) and monitoring the shelf-life of dairy products (Sinelli, 2006; Sinelli, Barzaghi, Giardina, & Cattaneo, 2005). However, in most of these studies samples were manipulated (minced, placed in Petri dishes, etc), thus changing their structure and the format in which the meat is marketed. The aim of this study was therefore to develop and evaluate the feasibility of visible short-wavelength near-infrared (SW-NIR) as a nondestructive method for determining the freshness of sliced and commercially packaged chicken breasts.

2. Materials and methods

The study was carried out using 50 broiler chicken breasts, which were obtained directly from a local poultry processing plant 24 h after slaughter. The pieces, without fat and skin tissue, were cut, to replicate commercial slices, into slices of 200 g each with a thickness of 20 mm. Three slices per chicken breast sample were handled aseptically and packed randomly in a plastic tray sealed with plastic film ($n=45$).

During the shelf-life study, the quality of the broiler chicken cuts was evaluated as a function of film packaging and storage time. The time points for the evaluation were 0 days (immediately after packaging) and after 7 and 14 days of storage at 4 °C.

Image analysis (visual and SW-NIR) was carried out at day 0 in all samples before and after packaging and before and after opening ($n=10$) at 7 and 14 days. Opening was done in aseptic conditions in order to take samples for the microbiological analysis. The unpackaged samples were also used for the subsequent analyses (physicochemical and nucleotides monitoring). Additionally, the 15 remaining samples were used for microbial and nucleotides monitoring at days 3, 9 and 12.

2.1. Destructive analyses

2.1.1. Analytical determinations

Moisture (x^w) was measured by oven drying to constant weight at 100 °C (UNE –EN ISO 1442:1979). Water activity (a_w) was analyzed with an Aqualab GB-X Fast-Lab (GBX, Romans-sur-Isère, France) equipment, working at a temperature of 25 °C. For the determination of pH, solutions of 10 g of homogenized chicken meat and 90 ml of distilled water were measured with a portable pH meter MM40 (Crison Instruments S. A, Alella, Barcelona, Spain) following the procedure proposed by Fuentes, Barat, Fernández-Segovia, and Serra (2008). Total Volatile Basic Nitrogen (TVB-N) was determined according to the procedures described by Malle and Tao (1987).

2.1.2. Nucleotides analysis

The ATP-related compounds, consisting of inosine-5′-monophosphate (IMP), inosine (Ino) and hipoxantine (Hx), were assayed by HPLC according to the method described by Barat et al. (2008), with some minor modifications.

- Extraction of nucleotides

The method used to the extraction was similar to that described by Burns and Kee (1985). The entire extraction procedure was performed at 4 °C. Five grams of muscle was mixed with 50 mL of 0.6 M $HClO_4$, and homogenized for 4 min in a masticator (IUL Masticator, Barcelona, Spain). The contents of the stomacher bag were immediately transferred to a centrifuge tube and centrifuged at 12,000 ×g for 10 min in a refrigerated Medifriger BL centrifuge (JP Selecta, S.A., Barcelona, Spain). The supernatant was filtered through glass wool, neutralized with solid potassium carbonate and left to stand in ice for 5 min. The neutral extract was centrifuged at 12,000 ×g for 10 min. The supernatant was stored at −20 °C until analysis.

A total of 2 extracts were obtained per sample.

- HPLC analysis

The analysis was conducted on a liquid chromatograph Jasco (Milano, Italy) with pump (model PU-1580), auto-sampler (model AS-1555-10), ternary gradient unit (model LG-1580-02), degasser unit (model DG-1580-54), and diode array detector (model MD-1510). Data acquisition was performed with ChromPass software version 17.403.1 (Jasco). Separations were achieved on a reverse-phase Ultrabase C_{18} 250×4.6 mm, internal particle diameter of 5 μm (Análisis Vínicos, S.L., Tomelloso, Spain). A guard column containing the same C_{18} packing as above was positioned in front of the analytical column to protect it from contamination.

The composition of mobile phases was different for Hx and for both Ino and IMP analyses. To analyze Hx, mobile phase A was 0.1% of trifluoroacetic acid (TFA) in water; mobile phase B was 0.085% of TFA in 60% acetonitrile in water. For the Ino and IMP analyses, mobile phase A was 0.01 M dipotassium hydrogen phosphate buffer, pH 4.5; mobile phase B was 60% acetonitrile in water. Flow rate of mobile phase was 0.9 mL/min in all cases. Injection volume was 20 μL. The elution program in both cases is shown in Table 1. The chromatograms were monitored at a wavelength of 254 nm.

- Identification and quantification

Compounds were identified using retention time comparison of unknowns with those of standards and by standard addition or "spiking" (Johnson & Stevenson, 1978). IMP, Ino, and Hx standards were obtained from Sigma-Aldrich (St. Louis, MO, USA). Standard solutions were prepared in 0.6 M $HClO_4$ neutralized with solid potassium carbonate.

IMP, Ino, and Hx were quantified according to the external standard method, using calibration curves of peak area of compound *vs* concentration of compound, under identical chromatographic conditions. K_1 values were calculated according to the Eq. (1):

$$K_1(\%) = \frac{\text{Ino} + \text{Hx}}{\text{IMP} + \text{Ino} + \text{Hx}} \times 100 \quad (1)$$

where IMP is inosine 5′-monophosphate; Ino, inosine; Hx, hypoxanthine.

Table 1
Elution program for HPLC analysis.

Time (min)	Mobile phase A (%)	Mobile phase B (%)
0	98	2
15	93	7
16	0	100
26	0	100
27	98	2
42	98	2

A: 0.1% of trifluoroacetic acid (TFA) in water for Hx analysis, and 0.01 M dipotassium hydrogen phosphate buffer, pH 4.5, for Ino and IMP analysis.
B: 0.085% of TFA in 60% acetonitrile in water for Hx analysis, and 60% acetonitrile in water for Ino and IMP analysis.