Available online at www.sciencedirect.com
SCIENCE DIRECT®
Meat Science 70 (2005) 691–698
MEAT SCIENCE
www.elsevier.com/locate/meatsci

Application of PLSR in correlating physical and chemical properties of pork ham with different cooling methods

Qiaofen Cheng, Da-Wen Sun *

FRCFT Group, Department of Biosystems Engineering, University College Dublin, National University of Ireland, Earlsfort Terrace, Dublin 2, Ireland

Received 20 September 2004; received in revised form 25 January 2005; accepted 4 March 2005

Abstract

Partial least squares regression (PLSR) was applied to understand the relationship between physical and chemical properties of pork leg ham with different cooling treatments, i.e., cold room, air blast and vacuum cooling. The results indicated that overall 69.8% variation of physical matrix was explained by chemical matrix. For the univariate analysis of physical attributes, the results showed that gumminess (88.1%) and hardness (86.5%) were best explained by chemical matrix, followed by springiness (78.7%), Warner–Bratzler Shear force (61.3%), and a^* (60.0%). Graphical display of the regression coefficients indicated that different cooling treatments had different effects on the physical property of pork ham. Therefore, to predict the physical quality with chemical attributes, separate regression formulations should be adopted for different cooling methods. These findings have practical importance in attempts to predict physical properties from chemical components. In addition, they can also be used to control the physical properties by adjusting the components in the meat system.

Keywords: Pork ham; Water bath cooking; PLSR; Chemicals; Physical properties; Air blast cooling; Cold room cooling; Vacuum cooling

1. Introduction

Quality evaluation is one of the critical parts for the development of meat products. There are two ways to evaluate the quality of meat products, i.e., direct measurement and indirect measurement. The former is the most common one used in scientific research, such as using shear force to measure the peak force as indicator of tenderness, and applying compression deformation test to study the softness and firmness. The latter can also be called predicting measurement, which is based on the assumption of the relationship between quality attributes and the tested characteristic (Kramer & Szczesniak, 1973). For example, the chemical methods have been used to estimate the physical quality of vegetable crops (Kramer & Twigg, 1970).

Meat can be considered as a mixture system of different chemical constituents, and each constituent affects the physical quality solely or jointly with other constituents. Therefore, it is reasonable to assume that some relationships exist between chemical constituents (i.e., water, protein, fat, salt and ash) and physical attributes (i.e., tenderness, hardness, springiness, cohesion, gumminess, chewiness and colour) of meat products. Understanding these relationships in the meat system is very important not only for the prediction of physical properties from chemical constituents, but also for the control of the quality of meat products.

The use of chemical methods for estimating meat texture can be dated back to 1965 in the review of Szczesniak and Torgeson (1965), in which collagen content was considered as one of the most important indices for the tenderness of meat. Much research has been

* Corresponding author. Tel.: +353 1 7165528; fax: +353 1 4752119.
E-mail address: dawen.sun@ucd.ie (D.-W. Sun).
URL: http://www.ucd.ie/refrig (D.-W. Sun).

0309-1740/$ - see front matter © 2005 Elsevier Ltd. All rights reserved.
doi:10.1016/j.meatsci.2005.03.004

carried out in recent years. Ruiz-Carrascal, Ventanas, Cava, Andrés, and García (2000) found that fat content was negatively correlated with hardness in dry cured ham. In the work of Crehan, Hughes, Troy, and Buckley (2000), they obtained the same conclusion for the frankfurters. Furthermore, there also exist some interactive effects on texture quality from different constituents in meat products. Murphy, Gilroy, Kerry, Buckleya, and Kerry (2004) showed that increasing the levels of fat (5–30%) in combination with added water (10–35%) significantly decreased hardness ($P < 0.05$). However, combining fat with maltodextrin resulted in no significant difference in hardness, gumminess and chewiness value when maltodextrin was present in reduced-fat (5% and 12%) frankfurters (Crehan et al., 2000). Additionally, certain constituents in meat products can be substituted by other constituents. For example, for the development of low fat meat products, konjac gel (Osburn & Keeton, 2004), the mixture of protein and hydrocolloids (Ordóñez, Rovira, & Jaime, 2001), soy protein isolate concentrate (Chin, Keeton, Longnecker, & Lamkey, 1999), whey protein concentrate (El-Magoli, Laroiab, & Hansed, 1996), seed gums (Ligutom, Mesina, & Ganji, 1999), and soy oil (Muguerza, Ansorena, & Astiasarán, 2003) were all found to be able to partially replace the fat in the formulation. As protein and hydrocolloids both have function to retain moisture and enhance texture characteristics, the loss of juiciness and tenderness caused by low fat content can be compensated. From these studies, it can be seen that the effect of chemical constituents on the physical quality of meat products is quite complex.

Partial least squares regression (PLSR) is one of the techniques of multivariate regression analysis, and can be used to understand the relationship between two data sets by predicting one data set (Y) from the other set (X) (Martens & Martens, 2001). It not only provides solutions for both X and Y variables, but also attempts to find the best solution of X to explain the variation of the Y variable set. MacFie and Hedderley (1993) considered PLSR as a hybrid between multiple regression and principal component analysis (PCA). Most references to its use can be found in near-infrared reflectance analysis to determine the meat quality (Cozzolino & Murray, 2004; Liu et al., 2003; Realini, Duckett, & Windham, 2004). It has also been employed to correlate sensory evaluation data obtained from panellists and the instrumental data when food products are evaluated (Peppard, Rumus, Witt, & Siebert, 1989; Toscas, Shaw, & Beilken, 1999). Here it is used to understand the relationship between the physical properties and chemical constituents of a cooked pork leg product, namely ham.

PLSR method was applied in order to study the relationship between physical properties and chemical constituents of cooked pork leg ham with different cooling methods.

2. Materials and methods

2.1. Ham processing

Pork legs with pH 5.7–6.0 were used in this experiment. After trimming of fat and connective tissue, the legs were injected at 20% injection level (salt 11.69%; sodium nitrite 0.03%; sodium tripolyphosphate 2.34%; sugar 1.47%; sodium ascorbate 0.13%). The pork legs were continuously tumbled for 3 h, and allowed to 'rest' for 21 h in a vacuum tumbler at 4 ± 1 °C. Finally, the meat was stuffed into netting (Red Micro Netting, GB Miller Fispak Ltd., Ireland) to form ellipsoid shaped pork hams (with average weight of 2.2 ± 0.2 kg). All samples were then stored in a freezer (<−18 °C) until required for evaluation. Samples were thawed for 48 h at 4 °C ± 1 °C before cooking. A water bath (GD120, Grant Instruments Ltd, UK) was used to cook the samples from the initial 4 °C to a core temperature of 72 °C. After cooking, three cooling methods (as indicators used in the subsequent PLSR analysis) were used to cool the samples from 72 °C to 4 °C core temperature, i.e., cold room cooling (CR) (1 °C ± 1 °C, relative humidity >90%, air velocity 2.0 m/s ± 0.1 m/s for fan, and 1.0 m/s ± 0.1 m/s for samples), air blast cooling (AB) (1 °C ± 1 °C, relative humidity >90%, air velocity 2.0 m/s ± 0.1 m/s for fan and samples), and vacuum cooling (V) (final pressure 6.5 mbar). During cooking and cooling, the core temperature of the samples was collected by a data acquisition system (SCXI-1000, National Instruments, USA). Each batch had three parallel cooling treatments, and three replications for each treatment were made to evaluate the relationship between physical and chemical properties of pork leg ham.

2.2. Physical analysis

Ten strips (45 mm × 30 mm × 2.0 mm) from one ham sample were sheared using a rectangular blade (Kramer & Szczesniak, 1973) fitted to an Instron universal testing machine (Model No. 5544, Instron Corporation, UK) at the crosshead speed of 50.0 mm/min, and the peak force value was recorded as Warner–Bratzler shear force. For the texture profile analysis (TPA), 10 cylindrical samples from one ham (D = 25 mm, H = 20 mm) were cored with a cork borer. Using a 60 mm circular flat disk attached to the Instron, the samples underwent two cycles of 50% compression at a crosshead speed of 50.0 mm/min to measure the textural properties (Kramer & Szczesniak, 1973), i.e., hardness, springiness, cohesion, gumminess, and chewiness. The colour of the cooked ham was measured by the CIE $L^*a^*b^*$ (L^* – lightness, a^* – red/green and b^* – yellow/blue) system using a tristimulus colorimeter (Chroma CR300, Minolta Ltd, Japan). Water holding capacity (WHC) was measured using a modified centrifuge method (Lianji & Chen,