Tuesday 16 August 2009

Parallel session 4: Process technology

PS4.02 New technologies for dry-cured meat processing 19.00

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***Abstract*— the aim of this paper is to present instrumental techniques that are currently available to improve green ham selection, salting and drying, and the safety and quality of dry-cured hams, including sliced products. Hams with high pH (>6.2) or very low pH (<5.5) and/or exudative can be detected online by combining pH and Electrical Impedance Spectroscopy (EIS) measurements on the reception of raw material. This system, which is available, dramatically reduces the percentage of hams with texture problems (i.e. pastiness and softness), phosphate-crystal formation and red-ring colorations. Moreover, several technologies could be useful to determine the fat content: Total Body Electrical Conductivity (TOBEC), Dual Energy X-ray Absorptiometry (DXA), Ultrasound measurement, low field NMR, Computed Tomography (CT) and Near Infrared Reflectance (NIR). CT could also help to improve the salting/resting process in dry-cured hams, especially when the amount of salt is reduced. The drying process in dry-cured meat products can be improved if the surface water activity (a_w) is estimated accurately enough using instrumental techniques (e.g. NIR), and then a_w together with air parameters are used as inputs for the control system. At the end of the process, high-pressure treatment in appropriate packaging can help to improve the products' safety, shelf life and texture.**

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***Index Terms* — dry-cured ham, new technologies, quality assessment.**

Dry-cured hams are among the most important traditional meat products in the EU market. Its quality is affected both by the characteristics of the green hams and the technological process. Traditionally, the criteria used to classify green hams are weight and fat content because they determine the processing time. The salting time is fixed for each group according to weight and based on the experience of each manufacturer. The ageing time is affected by the amount of fat. The final product is checked for proper texture and sniffed with a fibula to detect off-flavours. In the last decades bone in sales have decreased and been substituted by sliced products. Recently, several technologies have been developed and improved to assess dry-cured ham quality both during the production and at the end of the process. Despite the fact that the dry-cured ham production system is still based on tradition, there is a tendency to introduce new technologies to improve product quality and safety. The aim of this paper is to present instrumental techniques that are currently available to improve green ham selection, salting and drying, and the safety and quality of dry-cured hams, especially in sliced products.

METHODS TO ASSESS THE QUALITY OF GREEN HAMS

Technological meat quality

Currently, although pH is considered a useful parameter to detect green hams that are not appropriate for dry-cured ham production, its use is not frequent. Hams with pH_{24h}>6.20 are more prone to deterioration and show important appearance, texture and flavour problems [1]. Green hams with pH_{24h}<5.55 have higher incidence of red rings [2], softness and pastiness [3, 4]. The pH is determined usually in the *semimembranosus* muscle with penetration electrodes adapted to industrial production lines [5]. However, pH measurement does not allow for the detection of pale, soft and exudative meat (PSE) in dry-cured hams.

The electrical impedance spectroscopy (EIS) allows for the classification of a high percentage of PSE hams [6], and is useful for targeting hams that could have more pastiness problems at the end of the process [7].

Meat composition

Subcutaneous, intermuscular and intramuscular fat content affects dry-cured ham processing and consumer acceptability. Intramuscular fat prediction requires the development of non-invasive analysis techniques such as low field X-Ray (Dual Energy X-Ray Absorptiometry (DXA)) and low field Nuclear Magnetic Resonance (NMR). In order to develop and calibrate on-line DXA and NMR systems, a reliable reference system such as Computed Tomography (CT) could be useful. CT is a non-destructive 3D-imaging technique, which is based on the differential X-ray attenuation that the different tissues produce. In meat science, the application of CT has almost exclusively been focused on the evaluation of porcine gross body composition *in vivo* and post-mortem [8, 9, 10, 11]. However, this technology presents several drawbacks that prevent its use on an industrial scale; the cost of equipment, maintenance and safety issues, as CT uses X-rays, which are harmful to human beings. Moreover, this equipment is designed to work in clean environments, such as hospitals, and not in meat processing plants.

DXA allows for the prediction of fat content by using X-rays of different energy levels. The attenuation of the different X-rays differs depending on the amount of fat, bone and lean. By comparing the attenuations of the different X-rays, it is possible to obtain a good estimation of fat content. Unlike CT, no special safety measures have to be implemented in facilities where this equipment is used, and it is much cheaper. However, the information obtained is less accurate than that obtained with CT, and the equipment must be calibrated using other technologies. Some firms have already developed equipment based on DXA technology for fat content estimation (http://www.productinspection.co.uk/Fat_analysis_.htm).

The NIR has been used to determine the best type of feeding system for Iberian pig production as an alternative to gas chromatography. NIR can measure the spectra of 120-150 carcasses or animals per hour, which allows for the carcass classification in the slaughterhouse [12]. A prototype of imaging transflectance NIR instrument has been developed for analysis of water and fat content in fish by the Matforsk institute which could be adapted to fat analysis of external muscles in dry-cured ham. Raman spectroscopy could also be useful as a non destructive method to determine the fatty acid profile measured directly from pork adipose tissue and in melted fat [13]. Electromagnetic scanning for total body electrical conductivity (TOBEC) is a rapid and non-invasive method to measure lean content in carcasses. The principle is based on the higher electrical conductivity of lean compared with fat tissue because of the higher water and electrolyte contents of lean tissue. The difference in electrical conductivity between lean and fat tissue is maximized at low frequencies [14].

New non-invasive methods such as Pattern Recognition and Image Analysis techniques, based on Magnetic Resonance Imaging (MRI), have recently emerged as an alternative to physical and chemical procedures. MRI is a non-invasive method, which uses high magnetic fields to obtain detailed information of any tissue. This technology is widely used in medical applications for patient exploration. There are several examples of the use of MRI in meat science. For instance, Beavallet & Renou [15] analyzed lipid distribution in meat by means of MRI, while Bonny *et al* [16] characterized the muscle structure using this technique. More recently, Monziols *et al* [17] quantified muscle, subcutaneous fat, and inter-muscular fat in pork cuts. This technique is also used to show water distribution relating to drying [18]. In the case of Iberian pork, MRI can help to classify raw loins [19], it can be used to evaluate sensory features and intramuscular fat in dry-cured loin pieces [20] and to estimate intramuscular fat levels in *Biceps femoris* and *semimembranosus* muscles of Iberian ham [21]. The high correlations obtained via Active Contour techniques and MRI, water content and weight, suggest that these techniques can be used in the different stages of the ripening process of Iberian hams and that water content and weight loss can be monitored and may also be a means for determining the optimal ripening time [22]. However, this technology also presents several drawbacks: equipment and maintenance costs are very high, even for calibration purposes, and safety issues are a serious problem. However, another technology, Low Field NMR allows for the collection of information on tissue composition. This technology is much cheaper, but the information obtained is less accurate and must be calibrated using other technologies.

METHODS TO IMPROVE SALTING AND DRYING TECHNOLOGY

Salt content assessment

The development of improved curing methods for dry-cured meat products is limited by the lack of non-destructive methods for investigating the diffusion and the distribution of the curing ingredients. Two methodologies previously applied for obtaining non-destructive information on salt distribution in meat are ^{23}Na-magnetic resonance imaging (^{23}Na-MRI) [23, 24] and CT [25]. While ^{23}Na-MRI is advantageous because it directly measures one of the nuclei of interest, it is limited by the bore diameter of the magnet, which has to be relatively small (typically 5–10 cm) in order to obtain a sufficiently strong and homogenous magnetic field. In contrast, the gantry opening of a medical CT scanner is approximately 50 cm, allowing for entire cuts to be studied.

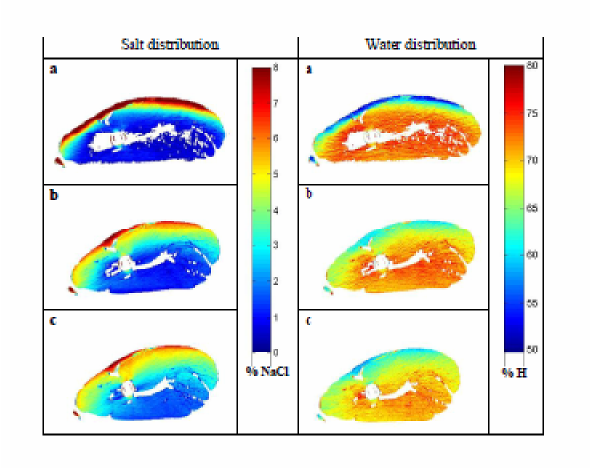

Figure 1. Distribution of salt and water content in a dry-cured ham slice obtained after the processing of data acquired using computed tomography. The Images correspond to slices taken during the elaboration process: A) end of salting, B) 22 days at resting period, C) 45 days at resting period.

Frøystein et al. [25] demonstrated the applicability of CT for studying salt penetration in dry-cured hams and studied differences in salt penetration in dry-cured ham due to freezing of the raw material. These studies have nevertheless not been pursued until recently, perhaps due to the high cost of CT scanners and to insufficient computer processing power for image analysis of the large amount of data which CT scanners produce. CT has been found to be especially interesting for the study of salting/curing processes because it permits the evaluation of the same product throughout the process. Moreover, several authors have recently developed predictive models to quantify salt and water content in dry-cured ham from CT images [26, 27] (Figure 1). It could be a valuable tool for monitoring salt penetration in cured meat and offer an alternative to labor intensive and destructive chemical analysis.

Drying technology

The drying process in dry-cured meat products could be improved if the superficial water activity is estimated accurately enough using instrumental techniques (e.g. NIR) and combined with information from other sensors (temperature, relative humidity, air velocity…). These sensors should be integrated into advanced control architectures and knowledge based systems, so that knowledge from experts can be coded and combined with instrumental techniques. This could lead, in the future, to autonomous control of dryers and help to optimize the drying process by reducing the process time, energy consumption and improve product homogeneity. Recently, water activity was estimated by combining readings of temperature, relative humidity and product surface temperature and this was then used to control the drying process of fermented sausages in a pilot dryer, using an advanced controller as fuzzy control. Results were quite satisfactory [28], but the application of new sensors and advanced control techniques should help in the future to improve the drying process of dry-cured meat products.

Sliced dry-cured ham

There is a tendency in the market to increase the percentage of hams that are sliced or packaged under vacuum or modified atmosphere. These systems pose new challenges to producers in terms of quality, safety and shelf life. High pressure is a technology that has been proposed to improve shelf life, reduce the risk of *Listeria monocytogenes* [29] and texture problems [30]. However, it needs to be adapted in order to minimize the negative effects on quality.

In the near future, it is expected that different techniques will be available to select and classify the raw materials, to improve the homogeneity of the salting and drying process, to obtain products with a more regular sensory quality and to guarantee the safety of dry-cured meat products in the different commercial forms.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the financial participation of the European Community under the Sixth Framework Programme for Research, Technological Development and Demonstration Activities, for the Integrated Project Q-PORKCHAINS

FOOD-CT-2007-036245 and TRUEFOOD FOOD-CT-2006-016264.

. Figure 2. High pressure equipment.

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