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Prediction of sodium content in commercial processed meat products using near infrared spectroscopy

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ABSTRACT

The present study evaluated the ability of near infrared transmittance (NIT) spectroscopy (FoodScan, 850–1050 nm) to predict sodium (Na) content in commercial processed meat products ($n = 310$) as intact and ground samples. Prediction models were built with all samples spectra and with spectra divided in 5 categories according to the manufacturing meat process. Sodium content (%) was determined using inductively coupled plasma optical emission spectrometry. Modified partial least squares regression for the overall samples showed satisfactory predictive ability for intact (coefficient of determination in cross-validation, $R^2_{CV} = 0.93$) and ground samples ($R^2_{CV} = 0.95$). Despite the low number of samples, good specific prediction models were developed for each commercial meat category. In conclusion, NIT is really promising for *at-line* application to predict Na in processed meat products which could help industry to accomplish the new labelling regulation.

1. Introduction

In processed meat products sodium chloride (NaCl) is a cheap ingredient linked to the manufacturing process and consumers custom, and it contributes to texture, color, taste, flavor, cohesiveness, water holding capacity, pH, preservation and several specific physical processing effects (Desmond, 2006; Gou, Guerrero, Gelabert, & Arnau, 1996; Matthews & Strong, 2005). Meat and meat products are the second largest contributor to dietary Na intake, with approximately 21% of the sodium (Na) daily intake (Desmond, 2006; Matthews & Strong, 2005). Sodium content in meat products shows a large variation between and within types (fresh, cured and processed meat) (Desmond, 2006; Matthews & Strong, 2005; Matthews, Blades, & Strong, 2003), being in unprocessed meat <0.1 g/100 g (Matthews & Strong, 2005). Sodium ion is implicated in hypertension and other cardiovascular diseases such as stroke and fatal coronary heart disease (Aburto et al., 2013; Matthews & Strong, 2005). Therefore, Food Standards Agency (FSA), World Health Organization (WHO), European Food Safety Authority (EFSA) and other regulatory authorities pressure food industry to reduce salt levels in processed food to prevent excessive intake, and recommend a daily average consumption of <5–6 g of NaCl or <2–2.4 g of Na (Desmond, 2006; EFSA, 2009; Matthews & Strong, 2005; WHO, 2012).

The new European Regulation 1169/2011 (European Union, 2011), which establishes the general principles, requirements and responsibilities governing food information and in particular food labelling, requires "salt" content to be added to the mandatory nutrition declaration of food products instead of "sodium". However, it defines "salt" as Na × 2.5 (European Union, 2011) which is obtained from the proportion of NaCl (40:60). Although NaCl is the main provider of Na (79%) in processed meat, there are other ingredients that could influence Na content (e.g., sodium tripolyphosphate, sodium nitrite, sodium ascorbate or erythorbate, sodium nitrite) (Desmond, 2006). To accomplish the labelling regulation, the meat industry needs cost-effective, non-destructive, rapid and accurate analyses that allows an at-line Na determination.

Near infrared (NIR) spectroscopy is an objective and nondestructive technique that provides rapid real-time analysis of food composition and quality. Near infrared spectroscopy in transmittance mode (NIT) is currently recognized as an official method by the Association of Official Analytical Chemists (AOAC) International (Rockville, Maryland, USA) to determine moisture, fat and protein in meat and meat products (AOAC, 2007). Near infrared spectroscopy has been used to discriminate between meat origin (Prieto, Roehe, Lavín, Batten, & Andrés, 2009), to predict technological and sensory traits (De Marchi et al., 2011; De Marchi, Penasa, Cecchinato, & Bittante, 2013; De Marchi, 2013; Prieto et al., 2009), fatty acid composition (De Marchi, Berzaghi, Boukha, Mirisola, & Gallo, 2007; De Marchi, Riovanto, Penasa, & Cassandro, 2012; Riovanto, De Marchi, Cassandro, & Penasa, 2012), free amino acids (Prevolnik et al., 2011) and to determine NaCl in pork and beef

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raw meat (Begley, Lanza, Norris, & Hruschka, 1984), pork cured ham (Begley et al., 1984; Collell, Gou, Arnau, & Comaposada, 2011), cooked mixed pork and beef sausages (Ellekjær, Hildrum, Næs, & Isaksson, 1993) and pork dry-cured ham (Prevolnik et al., 2011). The NaCl prediction through NIR spectroscopy is based on the change of water spectra and it is not related to a specific absorption band (Begley et al., 1984; Ellekjær et al., 1993). However, there is lack of information about the application of NIR spectroscopy at industry level to predict Na content in the wide variety of processed meat that consumers find on the market (ground fresh meat, cured meat, boiled sausages, dry meat and bacon). Therefore, the aim of this work was to evaluate the feasibility of NIT spectroscopy to predict Na content in commercial processed meat samples as intact and after milling process.

2. Materials and methods

2.1. Samples

A total of 310 European processed meat products, purchased in commercial stores from October 2014 to February 2015, were sampled and analyzed in the laboratory of the Department of Agronomy, Food, Natural Resources, Animals and Environment (Legnaro, Italy). Products were randomly chosen according to store availability and commercial trend to obtain a representative dataset of the most common processed meat food included into the following 5 categories: fresh meat, cured meat, boiled sausages, dry meat and bacon (Table 1). Samples were packed in aluminum foil, placed in a plastic bag, and stored at −20 °C until analysis.

2.2. Near infrared transmittance (NIT) spectroscopy

Samples were analyzed with a near-infrared spectrometer FoodScan (FOSS, Electric A/S, Hillerød, Denmark) in transmittance mode to simultaneously determine contents of moisture, fat and protein by AOAC (2007) method 2007.04 for meat and meat products. Samples were thawed at room temperature (20 °C), cut to be adapted to a circular glass cup (diameter 140 mm, depth 17.5 mm) and analyzed as an intact non-ground sample. Samples were then homogenized with a knife mill Retsch Grindomix GM200 (Retsch GmbH & Co, Haan, Germany) and analyzed according to the reference method as a ground sample (AOAC, 2007). The spectrometer operated at room temperature (20 °C) from 850 to 1050 nm with an interval of 2 nm. Each spectrum was an average of 24 sub-spectra recorded at 24 different points by rotating the circular cup automatically in the analyzer and recorded as log(1/Transmittance).

2.3. Sodium reference analysis

Ground samples (1 g) mixed with hydrogen peroxide 30% Suprapur® (107298, Merck, Darmstadt, Germany) and nitric acid 65% Suprapur® (100441, Merck, Darmstadt, Germany) were mineralized with a microwave closed vessel digestion (Ethos 1600 Milestone S.r.l. Sorisole, BG, Italy). Samples were then diluted in ultrapure water to a final volume of 50 mL and refrigerated at 4 °C until analysis. The Na concentration was determined in triplicate using Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) Arcos EOP (Spectro Analytical Instruments, Kleve, Germany) at 589.592 nm wavelength. For calibration, Na solutions with 5% nitric acid 65% Suprapur® were prepared with Na monoelement solution CGNA10-5 (Inorganic Ventures, Christiansburg, VA, USA) at concentrations of 0, 1, 2, 5, 10, 20, 50, and 100 mg Na/L. All instrument-operating parameters were optimized for nitric acid 5% solution with 2 mL/min of sample aspiration rate, plasma power 1350 W, coolant flow 11 L/min, auxiliary flow 0.60 L/min, nebulizer flow 0.75 L/min and integration time of 28 s. Sodium was expressed as percentage.

2.4. Sodium NIT prediction

Spectra information obtained for intact and ground samples was used to develop equations to predict Na (%) for overall products. Although the aim of this study was to develop a prediction equation for Na considering all the dataset, we also tried to build prediction models for each category to enhance the discussion of the results. Other authors have built prediction equations to predict NaCl with low sample size (Boschetti et al., 2013; González-Martín, González-Pérez, Hernández-Méndez, & Alvarez-García, 2002). Calibrations were performed using WinISI software (Infrasoft International, Port Matilda, PA, USA). To optimize the accuracy of the calibration, data underwent to detection of anomalous spectra in the calibration data set using T-statistic: samples for which the difference between reference and predicted values exceeded 2.5 standard deviations were considered outliers and removed from the dataset. Algorithms applied for scatter correction were: no correction (NONE), detrending (D), standard normal variate (SNV), standard normal variate and detrending (SNV + D) and multiplicative scatter correction (MSC). Five derivative mathematical treatments were tested to reduce noise effect: 0,0,1,1; 1,4,4,1; 1,8,8,1; 2,5,5,1; and 2,10,10,1. The first digit is the number of the derivative, the second is the gap over which the derivative is calculated, the third is the number of data points in the first smoothing, and the fourth is the number of data points in the second smoothing (Shenk, Westerhaus, & Abrams, 1989). Modified partial least squares (MPLS) regression analysis was used to correlate spectra with the reference value.

Table 1
Categories of commercial processed meat samples analyzed in the study.

Category	N[a]	Description	Species	Examples of products
Overall	310	all samples	Bovine, pork, turkey, chicken, horse and duck	
Fresh meat	85	Mixes composed of muscle meat with varying quantities of animal fat. Non-meat ingredients are added in smaller quantities for improvement of flavor and binding	Bovine, pork, turkey, chicken and duck	Minced meat, hamburgers, meatballs, sausages, zampone, cotechino, tastasale
Cured meat	89	Made of entire pieces of muscle meat or pieces of muscle meat and animal fat. Different kind of additive could be added for flavouring, preservation and texture	Bovine, pork, turkey, chicken and horse	Baked ham, beef ham, mortadella, porchetta, smoked turkey chest, speck, spice lard, bresaola, salted meat, kebab
Boiled sausages	57	Mainly würstel made with muscle, fat and non-meat ingredients as company recipe	Bovine, pork, turkey, chicken and horse	Würstel, Frankfurter type würstel
Dry meat	48	Uncooked meat products with drying as technological process for preservation	Pork and horse	Salami, raw-fermented sausages, cured raw ham ("prosciutto crudo"), culatello
Bacon	31	Uncooked rashers of pork bell bacon and salt-spices cured bacon	Pork	Fresh bacon, pancetta

[a] N = number of samples.