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Valorisation of industrial cooked ham by-products as functional ingredients

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ABSTRACT

The production of cooked ham on an industrial scale generates two liquid by-products: pork exudate (PE), collected before the salting, has 14% weight dry matter, mainly rich in proteins (90%); ham broth (HB), released after cooking, has 8% dry matter including 50% proteins. The biochemical, rheological and functional properties of these by-products were studied and compared to reference ingredients. PE could form a gel by coagulation at 50°C and had a good emulsifying capacity (324 ± 8 mL of oil per gram of protein) with high stability. Even after cooking, an altering process, HB had the ability to form a gel at low temperature (8–18°C), a good emulsifying capacity (252 ± 7 mL of oil per gram of protein) and foaming ability (ratio of foam to initial volume: 177 ± 14). Both by-products could then be valorised as functional ingredients for delicatessen products.

1. Introduction

Dealing with by-products is a major concern in the food processing industry (Mirabella et al., 2014). This is especially the case in the meat-processing industry, as they can be a source of proteins for food or feed purposes. These by-products can be found in solid form (carcass, skin) or liquids form recovered in wastewaters that require treatment because of their high chemical or biological organic demands (Bull et al., 1982). Solid wastes could find a valorisation as energy vectors after digestion (Hejnfelt and Angelidaki, 2009) or can be hydrolyzed by chemicals (Selmane et al., 2008) or enzymes (Rafieian et al., 2015) into valuable functional proteins. Concerning liquid waste, proteins from red blood cells (Gomez-Juarez et al., 1999) or plasma (Penteado et al., 1979) were also found to have useful functional properties. Since slaughtering represents the main source of waste products in the meat industry, much interest has been raised concerning the ways of dealing with these by-products (Arvanitoyannis and Ladas, 2008). However, there is currently less research on the potential valorisation of by-products generated after another meat processing step, such as the cooking of hams in the delicatessen trade.

In Europe, France is the leader in the production of cooked ham, with particular stress on high-quality products such as Paris or York ham (Spencer, 2003). Each year, around 190,000 tons of cooked hams are produced, but during the manufacturing process more than 13,000 cubic meters of liquid by-products are generated. These by-products, containing proteins, salts and water, are poorly valorised and mainly rejected as effluents into wastewaters, inducing a non-negligible cost of compulsory treatment due to legal restrictions. In this paper, two different effluents from cooked ham processing plants are investigated: ham broth (HB) and pork exudate (PE) with the objective to characterize their biochemical composition, to determine whether they can easily be processed and if their proteins can be valorised as functional ingredients when compared to reference ingredients.

2. Material and methods

2.1. Raw material collection and storage

Effluents were collected in a plant with a 20,000 metric tonnes per year production capacity. A simplified flowchart of the ham

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production process is given in Fig. 1 and detailed in Toldrá et al. (2010). For each tonne of ham produced, around 70 kilos of HB and 8 kilos of PE can be recovered. PE is a reddish-pink by-product recovered from the pork chunk collecting tanks before salting and tumbling. HB, the main effluent, is a light orange liquid which is released during the opening of the moulds after the cooking and maturing of hams. After collection, the effluents were stored at 4°C or −16°C for respectively short or medium-term conservation. For long-term conservation, effluents were converted into powders by freeze-drying (PL6000, Thermo Electron Corp.) with nearly 100% powder recovery or spray-drying (B290, Büchi) with 85 ± 5% powder recovery. Water activity a_w was measured post factum with an a_w-meter (Labmaster, Novasina Ag).

2.2. Raw material characterisation

Dry matter and biochemical composition of each effluent were quantified using different assays. All measurements were done in triplicate.

2.2.1. Biochemical characterisation

Protein content was obtained using a total nitrogen analyser (TNM-1, Shimadzu); collagen was specifically quantified by the Lollar method (Lollar, 1958). The quantities of fats and soluble sugars were respectively measured using the Bligh and Dyer (Bligh and Dyer, 1959) and Dubois (Dubois et al., 1956) methods. Sodium chloride concentration was determined by Charpentier-Volhard titration; other salts such as phosphates or nitrates were included in the ash determination.

2.2.2. Protein qualitative analysis

The proteic fractions of the effluents were qualitatively analysed for their molecular weight and amino acids compositions.

Size-exclusion chromatography (SEC) was implemented using an Akta FPLC (Amersham Biosciences, UK) device equipped with a UV/VIS detector. Samples (0.1 mL) filtered at 0.2 μm were loaded at 0.5 mL/min on a Superdex TM 200 column (GE Healthcare, Life Sciences) eluted with a 50 mM phosphate buffer (pH 7) supplemented with 150 mM NaCl. A standard protein mixture (Bio-Rad Laboratories), including thyroglobulin (670 kDa), γ-globulin (158 kDa), ovalbumin (44 kDa), myoglobulin (17 kDa) and B12 vitamin (1.35 kDa), was used for calibration. Eluted proteins were detected at 280 nm and quantitatively quantified in each elution peak.

Sodium dodecyl sulphate-polyacrylamide gel electrophoresis (SDS-PAGE) was carried out according to the method of Laemmli (1970) in 12% acrylamide gels. The proteins were stained with a Coomassie blue R-250.

Amino acids were quantified by ion-exchange chromatography with post-column ninhydrin detection (Hitachi L 8900). Prior to amino acids analysis, samples were submitted to basic or acid hydrolysis using NaOH 6 M for tryptophan quantification or HCl 5.5 M for the other amino acids.

2.3. Functional properties

The functional properties of PE and HB proteins were compared with commercial ingredients used in food formulations such as sodium caseinate Na-Cas and whey protein isolate WPI (Armor Protéines, France).

2.3.1. Rheological behaviour and gelling properties

A stress-controlled rheometer (AR-G2, TA Instruments, USA) equipped with a double gap Couette or plate-plate system and a Peltier circulator for temperature control was used to determine two types of properties.

Measurements in flow conditions were applied with shear rates in the range of 1–1000 s^{-1} in order to determine PE and HB viscosities in native solutions. Experiments were performed at 20°C.

Dynamic oscillatory shear tests were carried out to obtain the gelling properties of the native solutions at low and high temperature. A low-amplitude deformation (1% strain) was applied at an oscillation frequency of 1 Hz. For low temperature gelation, the temperature was decreased from 20 to 1°C with a ramp of $-0.1°C \cdot min^{-1}$. The gelling temperature was detected at the crossover of the curves of storage modulus G′and loss modulus G″ versus temperature. For high temperature gelation, the temperature was increased from 20 to 90°C with a ramp of $0.5°C \cdot min^{-1}$. The gelling temperature was deduced from a rapid increase in the storage modulus G′ versus temperature curve.

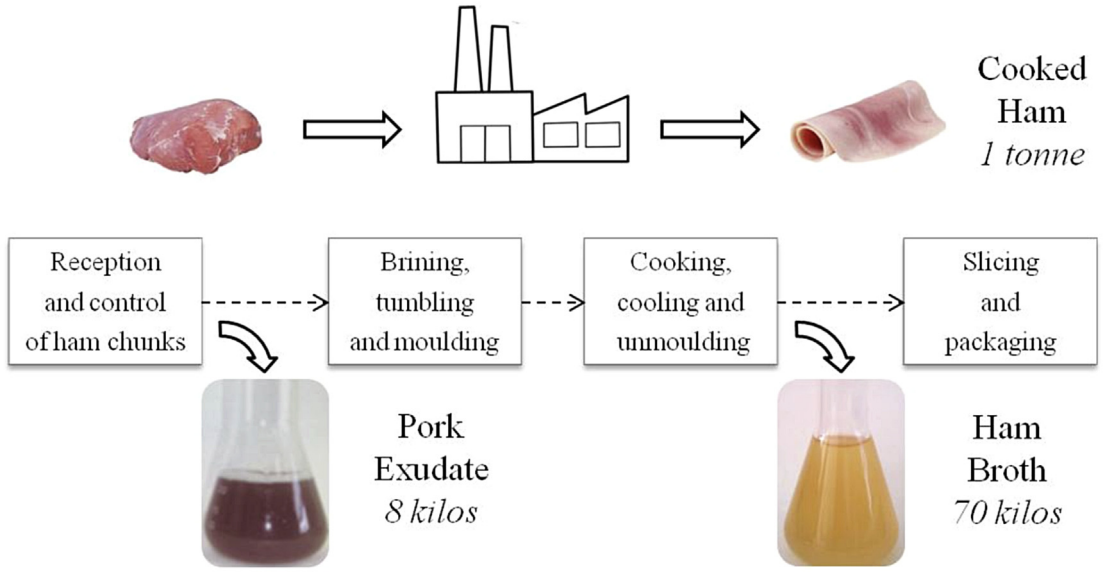

Fig. 1. Flowchart of the ham production process with the potential recovery of effluents.