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Safety and quality assessment of ready-to-eat pork products in the cold chain

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ABSTRACT

It is of crucial importance for Ready-To-Eat (RTE) foodstuffs producers to guarantee the quality and safety of their products under the cold chain variations related to different time–temperature profiles. Experimental designs were used to investigate and model the effects of temperature on safety and quality attributes of selected RTE meat products. Three types of RTE sliced pork products (cooked ham, cooked paté and smoked ham) were stored at different temperatures (5, 8, 12 and 15 °C) up to 6 weeks. Microbiological and physico-chemical attributes were followed. Growth parameters of *Listeria monocytogenes* were investigated by challenge testing for the three RTE products at the four temperatures. Two lactic acid bacteria (*Lactobacillus sakei* and *Leuconostoc mesenteroïdes*) were also investigated by challenge testing but only for cooked ham and cooked paté at 8 °C. Changes in quality indicators including colour, texture and water content, water activity and water dripping were evaluated over storage time for the three RTE products. Spoilage experiments were conducted (at 2, 8, 12, 15 °C for 48 days) on cooked ham and the production of ethanol, as a representative volatile deriving from bacterial metabolism, was correlated to bacterial outgrowth. Growth parameters of the three strains for the given food were mathematically modelled and validation tests were performed for *L. monocytogenes* in cooked ham and cooked paté. Physico-chemical attributes were not significantly affected by time–temperature storage. The production of ethanol on spoiled cooked ham was related to growth of lactic acid bacteria, especially *Leuconostoc*. A threshold value of ethanol concentration was defined in relation with a threshold count numbers of LAB under the conditions studied.

1. Introduction

Controlling and improving the quality and safety of chilled foods at all stages of the cold chain have always been among the main concerns in order to reduce food losses and health hazards. Microbial and physico-chemical quality changes may occur in food products according to their time–temperature history, but also according to their composition and properties. This is the case for meat and processed meat products which are ideal for the growth of spoilage and pathogenic bacteria. Pork meat and Ready-To-Eat (RTE) pork meals are the main type of meat consumed in Europe (Mataragas et al., 2008; Verbeke et al., 2010). Moreover, they were identified as one of the food products where the prevalence of pathogenic bacteria such as *Listeria monocytogenes* (*L. monocytogenes*) is the highest along the cold chain (EFSA, 2009; Warriner and Namvar, 2009). This makes the occurrence of *L. monocytogenes* in RTE products of particular concern for food business operators (FBO) and for competent authorities, knowing that the bacterium poses potential human health risks (EFSA, 2013). In addition to *L. monocytogenes*, the pH and high water activity of RTE pork meat products make possible the growth of other types of bacteria under refrigerated temperatures (+2/+4 °C): the lactic acid bacteria (LAB). A part of this LAB flora is responsible for spoilage and quality loss by inducing physico-chemical changes into the food products (Laursen et al., 2009; Hereu et al., 2012). The physico-chemical modifications are often assessed through quality indicators like colour, texture, water holding capacity, flavour and odour compounds (volatiles organic compounds – VOC). Spoilage commonly manifests itself as off-odours and off-flavours due to the presence

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Nomenclature

Latin symbols

a^*	colour parameter; Hunter redness value (–)
a_w	water activity (–)
b^*	colour parameter; yellowness value (–)
L^*	colour parameter; lightness value (–)
Lag	lag time (h)
N	population size (CFU)
t	time (h)
T	temperature (°C)

Greek symbols

γ	gamma factors (–)
μ	bacterial growth rate (h^{-1})

Subscripts

max	maximal
min	minimal
opt	optimal
0	initial

of VOC. These VOC resulted from bacterial metabolism and their production is correlated to bacterial cell growth (Leroy et al., 2009).

In this context, assessment of the impact of the food cold chain on microbial growth and quality attributes of RTE pork meals has become important in order to improve their shelf life and their safety. It is also essential to have tools and methods that allow the quality and safety of foods to be accurately evaluated. Predictive modelling is one of these tools. Several predictive models have been developed in order to quantify the effect of various factors on *L. monocytogenes* load evolution in various food products (Rosso et al., 1996; Dalgaard and Vigel Jørgensen, 1998; Zuliani et al., 2007; Couvert et al., 2010; Mejlholm et al., 2010; Huang, 2013; Polese et al., 2014). These mathematical models were based on the different phases of bacterial growth: lag; exponential; and stationary (Buchanan, 1993). They are used through software as decision support systems for food technologists. Modelling of quality deterioration during food processing and storage has also been extensively studied (Saguy and Karel, 1980; Labuza, 1984; Van Boekel, 2008). Kinetic modelling allows the rate of deterioration reactions in foods to be characterized as a function of temperature. Rapid assessment of RTE products spoilage can also be achieved by VOC analysis which could constitute an alternative method to microbiological analyses.

There are software packages for predictive microbiology available (Couvert et al., 2013; Tenenhaus-Aziza and Ellouze, 2013). In our knowledge, no such tool has been developed that combines both safety and quality models of foods. This is one of the objectives of the European FRISBEE project (Food Refrigeration Innovations for Safety, consumers' Benefit, Environmental impact and Energy optimisation along the cold chain in Europe) which aims to provide new tools and concepts for improving refrigeration technologies. The project has developed novel and innovative Quality and Energy/Environment Assessment Tools (QEEAT) that combine food quality and safety together with energy and environmental aspects. These tools were based on mathematical modelling as well as on a knowledge database gathering measured data of the cold chain performance, among others, in terms of food temperature, and change of quality and safety attributes.

This work is part of the development of QEEAT and focuses on the following three representative RTE pork meat products: cooked ham (a RTE cooked meat product in which the original structure is still recognisable), cooked pâté (a RTE cooked and mixed meat product) and smoked ham (a RTE meat product in which the original structure is also still recognisable). The objective was to develop kinetic models for safety and quality of the selected food products. The paper presents the protocols and experiments implemented in order to develop kinetic models for bacterial growth and quality attributes changes. It presents also a potential alternative method to plate counting for detection of microbial spoilage.

2. Materials and methods

Microbial growth experiments were performed in real products for selected bacterial isolates (*L. monocytogenes* and LAB flora) as a function of storage time and temperature. Physico-chemical attributes such as texture, drip-loss and colour were also experimentally determined. In addition, experiments were carried out to relate volatiles production to microbial population growth according to storage duration and temperature, in order to study a potential, alternative method for detection of microbial spoilage of products which has the advantage of being faster than classical plate counting.

2.1. Ready-to-eat pork meals products

Three types of RTE meat products were studied: (i) cooked ham, (ii) pâté, (iii) and smoked ham. They were under modified atmosphere packages (Pothakos et al.) with 50% CO_2 + 50% N_2 gas mixture.

2.2. Microbiological study

2.2.1. Bacteria strains

The selected strain of *L. monocytogenes* (n° 352 Aérial (F)) was isolated from environment of a meat industrial plant and was a reference strain of the French program in predictive microbiology: Sym'Previus (Couvert et al., 2010). Two strains were chosen for LAB, *Lactobacillus* (*Lb.*) *sakei* (n° 1322 Aerial) and *Leuconostoc mesenteroïdes* (N° 74 Aerial), provided from the Aerial collection (stored at −80 °C), isolated from chilled pork meat products.

2.2.2. Optical density measurements

Measurements of optical density allow the cardinal temperature values to be estimated. They describe the effect of temperature on the growth through: (i) the minimal temperature for growth (T_{min}); (ii) the optimal temperature for growth (T_{opt}) and (iii) the maximal temperature for growth (T_{max}) (Neysens and De Vuyst, 2005). The methodology used was adapted from Membré et al. (2005) to the two LAB strains using Elliker medium (Biokar) for incubation. Turbidity growth curves of the strains were generated with a Bioscreen C reader (Labosystemes Honeycomb 2 France). Eleven static temperature levels between 2 °C and 40 °C were studied; pH and a_w of the medium were kept at optimal levels, namely at 6.8 and at 0.98 respectively.

2.2.3. Microbiological challenge-tests

Challenge tests in the food products were performed for the strain of *L. monocytogenes* and for the two strains of LAB, using a method adapted from Augustin et al. (2011):