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Effect of the ripening time under vacuum and packaging film permeability on processing and quality characteristics of low-fat fermented sausages

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ABSTRACT

The effect of vacuum ripening of low-fat fermented sausages packaged in films with different permeabilities on their microbiological, physicochemical and sensorial characteristics was studied. High-fat control sausages were produced with 30% initial fat and low-fat sausages with 10% initial fat. The low-fat sausages were separated into: (a) non-packaged (control) and (b) packaged under vacuum on 7th, 12th and 17th day of processing, remaining under vacuum during the ripening period for 21, 16 and 11 days, respectively, in three different oxygen (100, 38 and $\leqslant 5$ $cm^3/m^2/24$ h/1 atm) and water vapour (4.5, <2.5 and 1 g/m^2 24 h) permeability plastic bags. Vacuum packaging reduced ($p < 0.05$) the weight loss, the hardness and extent of lipid oxidation in the sausages, increased ($p < 0.05$) their lightness, but had no effect ($p > 0.05$) on the redness, compared to the control sausages. Packaging low-fat fermented sausages under vacuum for the last 11 days of ripening in packaging film with high permeability increased ($p < 0.05$) the lactic acid bacteria count. The same product packaged in film with medium permeability had a higher ($p < 0.05$) Micrococcaceae count and the same ($p > 0.05$) hardness and overall acceptability as the high-fat control sausages. A ripening time of 11 days and the medium packaging film permeability were the most appropriate conditions for the vacuum packaging of low-fat fermented sausages.

1. Introduction

During the first decade of the 21st Century the five most important health problems associated with nutrition are heart disease, hypertension, obesity, diabetes and cancer. High fat intake is a major factor contributing to the prevalence of these problems. Health organizations all over the world have proposed limits of total fat intake to less than 30% of total calories. Thus, researchers have focused on ways of reducing fat levels in food or replacing part of it by healthier alternatives.

Fermented sausages have a high animal fat content, which is visible in the sliced product. After 4 weeks of ripening their fat content rises up to 45–50% as a result of drying (Wirth, 1988). It is therefore desirable to reduce the amount of pork backfat used in fermented sausages, since it has a high content of saturated fat. However, dry fermented sausages are difficult to produce as far as fat reduction is concerned (Wirth, 1988). Low-fat fermented sausages become harder, have high weight loss and an unacceptable appearance due to intensely wrinkled surfaces and case hardening (Muguerza, Fista, Ansorena, Astiasaran, & Bloukas, 2002).

Koutsopoulos, Koutsimanis, and Bloukas (2008) have applied vacuum packaging at a specific day in the last two weeks of the ripening period for low-fat fermented sausages produced with partial replacement of pork backfat with olive oil and i-carrageenan. They found that it improved the physicochemical and microbiological characteristics of these products and their sensory attributes were similar to or even better than the high-fat controls. However, the ripening period for fermented sausages lasts for at least three weeks and the permeability of the packaging material to oxygen and water vapour could affect the ripening process.

The objectives of this study were to investigate the effect of (a) the ripening time under vacuum packaging and (b) the packaging film permeability to oxygen and water vapour on processing and quality characteristics of low-fat fermented sausages.

2. Materials and methods

2.1. Experimental design

High-fat (30%) control and low-fat (10%), all animal fat, fermented sausages were produced. On the 7th, 12th and 17th day after processing, the low-fat fermented sausages were separated into two groups which were treated as follows: (a) non-packaged (control) and (b) packaged in plastic pouches under vacuum (−1 bar vacuum level) with a Weromatic, model Star, vacuum

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packaging machine (Werner Bonk, Bochum, Germany). Since the ripening period was considered to be from the 7th to the 28th day after processing, the packaged sausages remained under vacuum for 11, 16 and 21 days. Three different tubular plastic pouches were used, with oxygen transmission rates of 100, 38 and $\leqslant 5$ cm^3/m^2 24 h 1 atm (23 °C, 75% RH) and water vapour transmission rates of 4.5, <2.5 and 1 g/m^2 24 h (38 °C, 90% RH), respectively. All treatments, about 5 kg each, were replicated three times from separate meat sources at three different times.

2.2. Sausage formulation and processing

The following raw materials were used per kg of meat mixture for the production of high-fat control and low-fat fermented sausages: beef meat 220 g, pork meat 440 g, pork backfat 340 g and beef meat 296 g, pork meat 591 g, pork backfat 113 g, respectively. The following ingredients were also added per kg of meat mixture in each treatment: sodium chloride 28 g, sodium nitrite 0.2 g, sodium ascorbate 0.5 g, sugar 3 g, lactose 1 g, white pepper 3 g, garlic 0.5 g and starter culture, 0.25 g. Flora Carn SL 200 (Chr. Hansen's Laboratorium A/S, Copenhagen, Denmark) containing *Staphylococcus carnosus* and *Lactobacillus pentosus*, was used as starter culture.

Fresh boneless pork hams, fresh pork backfat and fresh boneless beef cut from the shoulder, were obtained from a local supermarket. Pork and beef meat were trimmed of visible fat, cut in pieces, vacuum packaged and kept frozen at −20 °C for at least 1 week. The meat was thawed on racks for 2 days at 4 °C to remove the separated thaw loss. Representative samples were taken from the thawed meat for the determination of moisture (AOAC, 1990) and after that the meat was vacuum packaged and tempered at −5 °C for 2 days prior to use. Pork backfat was trimmed of adhering skin, cut into pieces and representative samples were taken for the determination of moisture. The pork backfat was vacuum packaged and kept frozen at −20 °C. Prior to use pork backfat was tempered at −5 °C for at least 24 h.

The frozen beef and pork meat were cut and preweighed amounts were chopped for 2–3 s in a Kilia 30 L cutter (Kilia Fleischereimaschinenfabrik, Kiel, Germany) at low speed and mixed with all the other ingredients, except sodium chloride. The pork backfat was added and the meat mixture was chopped for 2–3 s; the cup of the cutter was cleaned, sodium chloride was added and the meat mixture was chopped at low speed to the desired particle size, about 3–5 mm. Immediately after chopping, the sausage mixture was stuffed using a Risco Breveti, model RS 3000 Baby, vacuum stuffer (Risco Breveti, Zane-vi, Italy) into 40-mm diameter Teepak cellulose casings (Teepak N. V. Lommel, Belgium). Sausages were hand linked to standard sizes (0.4–0.6 kg each) and the resultant strings of sausages were placed in the fermentation and ripening room for 30 days. They remained there under conditions similar to those applied in the industry (Table 1). Samples from each treatment were taken for physicochemical and microbiological analyses on the 0, 4, 7, 12, 17 and 28th day of ripening.

2.3. Physicochemical analysis

2.3.1. pH and water activity (a_w) measurements

pH was measured in a homogenate prepared by blending 20 g of sausage with 80 ml of distilled water for 30 s. Readings were taken with a WTW, model pH521, digital pH meter and a WTW, type E56, combination electrode (WTW-Wissensehaftlich Technische Werkstaetten GmbH, Weilheim, Germany). Water activity (a_w) was measured with an AquaLab, series 3, water activity meter (Decagon Devices, Inc., Washington, USA). For each analysis, means of three measurements were recorded.

2.3.2. Weight loss

Two strings of sausages from each treatment were weighed just before the sausages were put into the fermentation room. The same strings were reweighed on the 4, 7, 12, 17 and 28th day. Weight loss was expressed as a percentage of the initial weight. The mean of the two measurements was recorded.

2.3.3. Colour measurement

Colour measurements were taken with a Konica–Minolta chroma meter (CR-400, Osaka, Japan) using a 8 mm port size, illuminant D65 and a 10° standard observer, in a room with fluorescent lighting and after standardization of the instrument with respect to the white calibration plate. CIE L^*, a^* and b^* values were determined as indicators of lightness, redness and yellowness. Five measurements were taken on each cross section from a piece of sausage 5 cm long. The measurements were taken immediately after cutting the sausage. The mean of 10 measurements was recorded for the colour of the sausages.

2.3.4. Lipid oxidation determination

The 2-thiobarbituric acid (TBA) test according to Tarladgis, Watts, Younathan, and Dugan (1960), was used to determine the extent of oxidative rancidity. The amount of residual nitrite in each sample was taken into account and sulfanilamide was added, if needed, to the samples for TBA analysis according to the modifications of Shahidi, Rubin, Biosady, and Wood (1985). Readings were made on a LKB Ultrospec II spectrophotometer (LKB Biochrom Ltd., England) at 532 nm. The conversion factor 7.8 was used in the calculation of TBA numbers. Duplicate determinations were conducted on each treatment.

2.3.5. Instrumental measurement of texture

Texture profile analysis was performed on the 28th day after initial production as described by Bourne (1978) with a Universal TA-XT2i Texture Analyzer. The Texture Expert, version 1,22 (Godalming, Surrey, UK), a computer program by Stable Micro Systems was used for data collection and calculations. Five cube samples ($1 \times 1 \times 1$ cm) for each treatment were compressed twice to 60% of their original height with a compression plate of 75 mm in diameter. The test was done in a controlled

Table 1
Processing conditions for the fermented sausages.

Day	Temperature (°C)	Relative humidity (%)	Air movement (m/s)	Smoke application
Fermentation				
0	20.5	95	0.5–0.7	
1	20	93	0.5–0.7	
2	19	90	0.5–0.7	
3	18	88	0.5–0.7	
4	17	85	0.5–0.7	
5	15	80	0.5–0.7	+
Ripening				
6–30	15	80	0.05–0.1	