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Testing of polybutylene succinate based films for poultry meat packaging

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ABSTRACT

Overall evaluation of the newly developed materials based on polybutylene succinate (PBS) and polybutylene succinate-co-adipate (PBSA) derived from renewable resources was carried out. This study was focused on the practical examination of two selected double layer materials - i) PBSA/(90% PBS + 10% PBSA) and ii) PBSA/(80% PBS + 10% PBSA + 10% talc), which were applied for vacuum packaging of raw chicken and turkey meat and smoked turkey meat. Physical, chemical and mechanical properties of these materials were compared with commonly used packaging material based on polyamide/polyethylene (PA/PE). Functional parameters of packaging materials such as the film thickness, water vapour transmission rate, oxygen permeability, tensile strength, transmittance and overall migration were tested. Various values of water vapour transmission rate for PA/PE, i) PBSA and ii) PBSA 2.1, 20.9 and 21.0 $g \cdot m^{-2} \cdot d^{-1}$; oxygen permeability 74.7, 115.4 and 85.1 ml (STP)$\cdot m^{-2} \cdot d^{-1} \cdot 0.1\ MPa^{-1}$ (all at 23 °C, 75% relative humidity) and transmittance 82.6, 15.7 and 6.9% were found, respectively. For the packaged meats only minor changes of pH, water activity, microbiological quality, colour and profiles of volatile compounds during the storage throughout their shelf life were found. Results of all experiments confirm that even if the physical, chemical and mechanical properties of commonly used PA/PE and new PBS packaging materials are not the same, there is no significant limitation in the practical application of PBS based films for raw and smoked poultry meats.

1. Introduction

Although the traditional packaging materials made from petroleum-based sources have a diverse range of applications, due to their low biodegradability and high accumulation in the environment is becoming a major environmental problem. At present the packages made of renewable sources pose one of the types of sustainable packages, which are considered as optimal for future development in packaging technology with regard to minimizing environment pollution and exploitation of world stock of fossil raw materials. The packaging materials of this type include also bioplastic, i.e. polymers derived from renewable biomass sources, which can be utilized in food packaging materials manufacturing as substitute for so far widely used synthetic polymers, the production of which come out from petrol derivatives.

Such packaging material should guarantee food safety and quality, to contribute to the microbiological stability of packaged food to maintain appropriate organoleptic and nutritional characteristics of the product and to exhibit the minimum migration of packaging components into food.

Polybutylene succinate (PBS) and its copolymers form a group of biodegradable polyesters. PBS is synthesized by condensation of succinic acid and 1,4-butanediol, the first can be obtained by fermentation of sugar containing media [1–3], for the butanediol the method of preparation from renewable sources is intensively searched [4,5]. PBS is an aliphatic polyester, which has desirable melt process ability and splendid mechanical properties, closely comparable to those of widely-used polyethylene (PE) and polypropylene (PP). Additionally, PBS, from which ester bonds can be chemically degraded by water, has a remarkable reprocess ability,

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which was reported in the previous studies [6–9].

Due to excellent mechanical properties the proposed PBS applications also include the use in the form of food packaging materials, films or semi-rigid bowls. Polymer packaging suitability for food packaging in practice depends not only on conformity with legislative requirements on polymers intended for direct contact with food, but other parameters are important, including mechanical resistance, barrier characteristics, thermal stability, sealability, etc. So far in available literature there is information dealing with PBS recycling possibility [10,11], but almost no information about testing and applications of packaging materials based on PBS for packaging of particular food products. The aim of this study was to evaluate the suitability of PBS and PBSA (polybutylene succinate-co-adipate) for vacuum packaging of raw chicken, turkey and smoked turkey meat.

2. Experimental

2.1. Chemicals

Sodium chloride p.a. (Lach-Ner, Czech Republic); a mixture of n-alkanes $C_8 - C_{20}$ (Sigma-Aldrich, Czech Republic).

2.2. Packaging materials

Coextruded polyamide/polyethylene film (PA/LDPE, thickness 20 μm/70 μm, EK-PACK FOLIEN GmbH., Ermengerst, Germany), which is commercially used for packaging of poultry meat. This film is marked as PA/PE in the next text.

Coextruded polybutylene succinate-co-adipate film, consisting of the first (outer) layer PBSA (FZ91PD, Mitsubishi Chemical, Japan) and the second (inner) layer of the same PBS (90%) with 10% of polybutylene-co-adipate (PBSA - AD92WD, Mitsubishi Chemical, Japan), total thickness 81.0 ± 0.3 μm. The film has been produced using pilot producing equipment by Leygatech (Velfor, France) and the CTCPA (*Centre Technique de la Conservation des Produits Agricoles*) in the framework of the research project SUCCIPACK. This film is marked as PBS C in the next text.

Coextruded polybutylene succinate-co-adipate (PBS) film with a structure similar to PBS C, where the inner layer is composed by mixture of 80% PBS + 10% PBSA + 10% talc, total thickness 80.1 ± 0.3 μm. The film has also been prepared using pilot producing equipment by Leygatech (Velfor, France) and the CTCPA in the framework of the research project SUCCIPACK. This film is marked as PBS D in the next text.

2.3. Packaging materials testing

Water vapour transmission rate (WVTR) was determined gravimetrically at 23 °C and relative humidity of 75% in agreement with requirements of standards ČSN 770332 and DIN 53 122. Five parallel samples were tested for each packaging material.

Oxygen permeability was determined using OxTran 2/20 MH measuring system (MoCon Inc. USA) at 23 °C and relative humidity of 75%. Thickness of tested films was determined by micrometer (L&W type 051, AB Lorentzen & Wettre, Sweden). Two parallel samples were tested for each packaging film.

Tensile strength in cross as well as in machine direction was determined as the force needed for film sample (100 mm × 15 mm) breaking with a 250 mm·min^{-1} rate of deformation using Instron 5544 machine (Instron Corporation, Great Britain). Ten parallel samples were tested for each packaging material.

Transparency of packaging films was measured as transmittance by UV/VIS spectrophotometer Lambda 25 (Perkin Elmer Inc., USA) at the range from 260 nm to 750 nm against the air as a blank.

Overall migration was determined at the temperature 20 °C at least 10 days into food simulant A in agreement with requirements of Commission Regulation (EU) No 10/2011 and standard ČSN EN 1186.

2.4. Meat

Chicken, turkey and smoked turkey meat (breast) were bought at a retail butcher shop. Meat was immediately transferred in chilled containers at 4 °C to the place of packaging and vacuum packaged.

2.4.1. Preparation of packaged meat samples

Each kind of meat (approximately 500 g) was vacuum packaged in flat pouches (25 cm × 30 cm) made of all three above mentioned types of packaging films. Meat was packaged in a processing line of meat processing company Radev Ltd. (Prague, Czech Republic) on vacuum packaging machine (Vac-Star S 240 DK, VAC-STAR AG, Switzerland) using following sealing conditions (temperature: 140 °C, time: 0.8 s, vacuum level 98%). The packaged meat was stored at 4 °C for 5 days and 15 days considering fresh and smoked meat, respectively.

2.4.2. Packaged meat analyses

pH value was measured directly in meat using puncture pH electrode coupled with thermometer (both Mettler Toledo, Switzerland).

Water activity (a_w) of packaged meat was determined by water activity meter (AquaLab Series 3, Decagon Devices, Inc., USA).

Colour of meat (on the surface) was determined by CM-2600d spectrophotometer (Konica Minolta, Japan). Parameters of measurement: spectral range 260–750 nm, specular component included (SCI) method in CIE L*a*b* colour space without sample preparation. Five parallel tests were performed and the difference of colour of meat was evaluated statistically using Student's t-test (α= 0.05).

Sensory evaluation of packaged meat was aimed at comparative evaluation of changes during storage. Overall appearance, colour and aroma for raw meats and additionally also flavour for smoked meat during all storage periods were assessed by six trained evaluators applying descriptive analysis.

Microbiological analysis was based on standard procedures according to ČSN EN ISO 4833-1. Total Mesophilic Bacteria: an index of the total number of viable aerobic bacteria present in the sample at the sampling time. Aliquots (0.1 ml) of serial dilutions of the sample were plated onto the surface of the solidified nutrient media PCA and then incubated for 48–72 h at 32 °C. Single viable bacterial cells (or clusters) grew to become visible colonies that were counted. Psychrophilic Bacterial Count: an index of the total number of psychrophilic bacteria present in the sample. Aliquots (0.1 ml) of serial dilutions of the sample were plated onto the surface of the solidified nutrient media PCA and then incubated for 10 days at 4 °C. Single viable bacterial cells (or clusters) grew to become visible colonies that were counted.

Results of functional parameters of packaging film and quality of packaged meat were calculated for each of the upper parameters only except transmittance of tested material. Results were expressed by average ± standard deviation.

HS-SPME/GC-MS analyses of volatile compounds. The CombiPal autosampler for automated extraction and injection processes (CTC Analytics, USA) and the fiber 50/30 μm divinylbenzene/carboxen/polydimethylsiloxane (DVB/CAR/PDMS) supplied by Supelco (Bellefonte, PA, USA) were used for extraction by head space solid phase microextraction. GC/MS analysis was performed on a TruTOF HT system consisting of an Agilent 7890A gas chromatograph