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Use of biobased materials for modified atmosphere packaging of short and medium shelf-life food products

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ABSTRACT

The research objective was to evaluate the performance of biobased plastics for modified atmosphere packaging (MAP) both on laboratory and industrial scales. Therefore the shelf-life (4 °C) of rumpsteak, ham sausage, filet de saxe, grated cheese and pre-fried fries that were MAP-packed in poly(lactic acid) (PLA) and cellulose-based multilayer packages was evaluated and compared with their shelf-life when packed in conventional materials. Furthermore, tests were performed on industrial packaging lines.

The biobased packages showed sufficient gas-barrier to guarantee the shelf-life of MAP-packed food products, even when materials with lower barrier properties were used, but for rumpsteak and ham sausage, different light permeabilities of the packaging materials led to more discoloration. Furthermore, the biobased materials performed well on the industrial packaging machines, but seemed too brittle to hold larger contents. This study shows promising results toward the application of biobased packaging materials for different food products.

Industrial relevance: Environmental concerns regarding food packaging have led to the development of more sustainable alternatives. One of these alternatives are biobased materials. This research shows that several biobased plastics can contain and protect the food as well as maintaining its sensory quality. The biobased packages showed sufficient gas barrier to guarantee the shelf-life of the MAP packed food products, even when materials with lower barrier properties were used. Furthermore, case studies at different companies (on industrial packaging lines) show that a successful entrance in the market will not be hindered by technical problems.

1. Introduction

Petroleum-based food packaging, such as polyethylene (PE), polypropylene (PP), polyethylene terephthalate (PET) and polyamide (PA) are well known and well established, which are omnipresent in our daily lives. However, their increased importance and use in the food industry raised questions on their environmental impact. This growing environmental awareness together with rising oil prices has led to an increased interest from the food, packaging and distribution industries for the development of alternative biobased packaging concepts. The use of biobased-packaging materials can decrease CO_2 emissions (by the closed loop system) and the consumption of crude oil and makes the industry less dependent on fluctuating oil prices. Furthermore, different types of resources can be used for biobased materials, including resources derived from certain by-products in the food industry. However, like conventional packaging, biobased and/or biodegradable packaging must fulfill a number of important functions, including containment and protection of food, maintaining its sensory quality and safety, and communicating information to consumers (Arvanitoyannis, 1999; Robertson, 2006).

Nowadays several biobased packaging can be or are already used for short shelf-life applications and dry products in case they do not require high oxygen and/or water vapor barrier. Polylactide (PLA) based packaging could be used as a packaging material for whole green peppers (Koide & Shi, 2007), fresh-cut romaine lettuce (Benyathiar et al., 2009) or blueberries (Almenar, Samsudin, Auras, & Harte, 2010; Almenar, Samsudin, Auras, Harte, & Rubino, 2008) and is already used for yogurt (Haugaard et al., 2001) and pasta (Highlights in bioplastics, 2006). Starch-based packaging could be used for fresh cut beef steaks (Cannarsi, Baiano, Marino, Sinigaglia, & Del Nobile, 2005) or whole fresh celery (Ifezue, 2009) and is already used for milk chocolates and

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organic tomatoes (Highlights in bioplastics, 2006). Cellulose-based packaging could be used as MAP packaging for fresh produce and is already used for potato chips and sweets (European Bioplastics, 2013; Makino & Hirata, 1997; Peelman et al., 2013). However, there is an increased need for knowledge how these biobased packaging materials perform when used for MAP applications for different types of food products. MAP is a frequently applied packaging technique in the food industry in order to delay deterioration of foods by retarding or inhibiting microbiological and chemical degradation processes (Arvanitoyannis, 2012). It is of utmost importance that the applied gas atmosphere, which is often a mixture of CO_2 and N_2, is maintained in the headspace of the package during storage. Hence, gas-barrier properties of the used packaging materials should be sufficient to maintain the desired gas composition. Moreover, water-barrier properties are also relevant for MAP conditions, especially for medium shelf-life food products. Due to the need for certain barrier properties, monolayer biobased materials cannot be used for MAP, and therefore, a shift is needed toward multilayer biobased materials, combining biobased materials and coatings to attain both good gas- and water-barrier properties.

In this paper the results of testing two cellulose-based films (Natureflex™N913 and N931) for their applicability as a packaging material (under the form of pouches) for different food products (French fries, ham sausage, filet de saxe and grated cheese) are described as well as the results of PLA trays in combination with a Natureflex™N913/PLA film and/or a Paper/AlOx/PLA film as a topfilm (rumpsteak, ham sausage and filet de saxe). The goal of this research was to evaluate the influence of the use of a biobased packaging material on the quality and shelf-life of different MAP-packed food products compared to their current conventional packaging materials (at laboratory scale) as well as to evaluate their industrial-scale applicability by testing on packaging machines in production environment.

2. Materials and methods

2.1. Chemicals and materials

Neutralized bacteriological peptone, Plate Count Agar (PCA) and MRS (de man, Rogosa, Sharpe) agar were purchased from Oxoid (Hampshire, England). Yeast Glucose Chloramphenicol (YGC) was purchased from BioRad (Marnes-La-Coquette, France). NaCl, thiobarbituric acid (TBA), propyl gallate, and 1,1,3,3-tetraethoxypropane (TEP) were purchased from Sigma-Aldrich (St. Louis, MO, USA). Dichloromethane, HCl (25%), chloroform, potassium iodide, soluble starch, diethylether, KH_2PO_4, ethylenediaminetetraacetic acid (EDTA), Na-acetate·$3H_2O$ and glacial acetic acid of analytical grade were purchased from Chem-Lab (Zedelgem, Belgium). Trichloroacetic acid (TCA) was purchased from Acros Organics (Geel, Belgium). Acetonitrile HPLC grade, methanol HPLC grade and methanol analytic grade were provided by Fisher Scientific (Leicestershire, U.K.). Ethanol was purchased from Tailor Made Chemicals (Rekkem-Menen, Belgium). Phenolphthalein indicator was provided by 3F Chimica (Sandrigo, Italy). NaOH (Titrisol) and $Na_2S_2O_3$ (Titrisol) was purchased from Merck KGaA (Darmstadt, Germany).

2.2. Food products

The tested food products were supplied by different food producers and are shown in Table 1, together with their conventional packaging, the tested biobased packaging, the gas/product ratio, the shelf-life of the food product at 4 °C, the MAP conditions and the analysis that were performed during the storage tests. The shelf-life of the tested food products indicated in Table 1 is the shelf-life currently used by the industrial partners.

The amount of food product that was packed in the bio-package was adapted to the dimensions of the conventional pouches and trays and on the gas/product ratio in the conventional package. If necessary, part of the package was filled with sterile marbles to obtain to correct gas/product ratio.

2.3. Packaging

2.3.1. Packaging materials

The packaging materials (Table 2) were supplied by different companies. More information about the biobased materials (seal properties, mechanical properties) can be found in Peelman et al. (2013). The conventional packaging materials were provided by the respective food company.

2.3.2. Pouch packaging

Pouches of the Natureflex™N913 and Natureflex™N931 films and the reference films of French fries and grated cheese were industrially made by Bastin-pack nv (Wetteren, Belgium) and Segers & Balcaen (Liedekerke, Belgium). The biobased pouches were packed in the laboratory at Ghent University under modified atmosphere using a gas-packaging unit consisting of a gas mixer (WITT MG18-3MSO, Gasetechnik, Germany) and a gas-packaging chamber machine (Multivac A300/42, Sepp. Hagenmüller KG, Wolfertschwenden, Germany). The oxygen, nitrogen and carbon dioxide gasses were delivered by Air Products (Brussels, Belgium). The reference samples for French fries and grated cheese were also packed at Ghent University in industrially made pouches. The reference samples for rumpsteak, ham sausage and filet de saxe were packed at the respective company.

2.3.3. Tray packaging

A Paper/AlOx/PLA film and a Natureflex™N913/PLA film were used as a topfilm on the PLA trays. The packages were filled with the gas mixture and sealed using a tray sealer (MECA 900, Decatechnic, Herentals, Belgium). The reference samples for ham sausage, filet de saxe and rumpsteak were packed at the respective company.

2.3.4. Storage and sampling

All packages were stored in chilled conditions (4 °C) and at around 80 cm from the light source (T8 Luxline Plus, fluorescent light, 3350 lm, 36 W, 103 V, 840 Cool White, Havells-Sylvania, Antwerp, Belgium) using a 12-h dark/12-h light cycle. At analysis date, three packages per package material were sampled and analyzed. Leak pouches, caused by product that ended up in the sealing zone after hand filling in the laboratory, were not taken into account. Data processing was performed using Microsoft Excel 2007. After packaging, a certain amount of samples was returned and stored at the respective companies for sensorial evaluation or they were stored at Ghent University and picked up by the company a day before the sensorial evaluation was performed.

2.4. Analysis

2.4.1. Gas measurements

The gas in the headspace of the package (O_2 and CO_2) was measured in three different packages of the same material by taking a gas sample from the headspace (Checkmate 9900, PBI Dansensor, Ringsted, Denmark).

2.4.2. Microbiological parameters

Approximately 10 g of sample was diluted ten times with peptone physiological solution (PPS, 1 g/l peptone + 8.5 g/l NaCl) in a stomacher bag (Novolab, Geraardsbergen, Belgium) and blended with a stomacher (Colworth Stomacher 400, Steward Laboratory, London, UK). After further dilution in PPS, samples were inoculated on PCA (total aerobic plate count), MRS (lactic acid bacteria) and YGC (yeasts and molds). The plates were incubated for 5 days at 22 °C, after which the number of colony-forming units was counted.