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Short communication

Assessment of gas permeability of the whole packaging system mimicking industrial conditions

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ABSTRACT

Assessing gas permeation of the whole food packaging in industrial conditions (RH, temperature including stretching and sealing effect) is fundamental for predicting the quality changes of packed food during processing and shelf life. Permeability coefficients are usually assessed on a small flat, piece of packaging material which is not representative of the whole pack (usually assembly of tray + lid film or pouches of flexible films sealed on at least 2 or 3 sides) used in the industry. Moreover, conditions used are standardised (temperature of 23 °C, 0%RH) which are not representative of conditions that prevail in real use. This simplified approach may lead to erroneous mass transfer predictions when simplified permeability values are used in calculation. To face this problem, we propose a simple methodology for the assessment of the gas permeability coefficients (N_2, CO_2, O_2) in sealed intact large scale (industrial) packaging (whole packaging) in conditions of temp and RH mimicking the real conditions of use (encountered by the material in contact with the food product). The CO_2 permeability assessed in the industrial-like conditions was significantly higher compared to the one assessed with standard method. The higher gas permeation measured was ascribed to the impact of industrial operations such as shrinking and hot sealing. Our results highlight the necessity to better characterize impacts of industrial conditions such as hot sealing and shrinking on the permeability of the whole pack when prediction of gas permeation through packaging during food processing is needed.

1. Introduction

Contact between atmospheric gases and food products can lead to relevant biochemical (for example, bacterial metabolism) and physical (for example, texture and colour) changes, with a consequent effect on food quality. Modified atmosphere packaging (MAP) has highly increased the quality of food products and it is extensively used in the horticultural, meat and dairy industry (Fallik, 2010; Khoshgozaran, Aziz, & Bagheripoor-Fallah, 2012; McMillin, 2008). Common characteristic of MAP technology includes the use of a packaging material designed for avoiding full contact between the atmospheric gases and the food during the industrial processes and food storage. Therefore the knowledge of gas permeability coefficient of packaging material in real conditions of use, i.e. temperature, relative humidity (RH), mechanical constraint encountered by the pack, is of high importance for the food industry. However the assessment of this coefficient is commonly performed at ASTM standard conditions (23 °C and 0% or 50% RH, relative humidity) which considerably differ from industrial and storage conditions (Jakobsen, Jespersen, Juncher, Becker, & Risbo, 2005). Furthermore the most used methods for assessment of permeability coefficients described in books rely on the measurement of a thin flat film which is just a small part of the industrial packaging (Mathlouthi, 1994) and may not thus well represent the permeation properties of the whole packaging. The permeation properties assessed in such ways may not be used for predicting the permeation properties of the industrial packaging and therefore cannot help the industry in the choice of the most suitable material for their application. Consequently, the aim of the present study was to assess the gas permeability directly on a shrunk and sealed intact large scale (industrial) packaging. The results were used to make illustrative calculations for highlighting the impact of gas permeation measured in real conditions of use compared to those acquired in standard conditions.

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2. Materials and methods

2.1. Packaging material

Co-extruded shrink-bags of industrial size (about 0.25 m^2 of total surface of exchange) used in this research were provided by a food company. The film composition was known in general terms: outer layers of polyethylene (PE) and inner adhesive layers of ethylene-vinyl acetate (EVA) and a barrier layer of polyvinylidene chloride PVDC based polymer, resulting in a very high barrier to water vapour (PE) transfer and relatively high barrier to gases (PVDC) (Robertson, 2010).

2.2. Industrial method for gas permeability assessment

A customized set up was developed for the simultaneous assessment of the permeability of gases (CO_2, O_2 and N_2) through the entire shrunk and sealed bag under industrial conditions (2, 25 and 38 °C 100% RH inside the pack). This method was referred as "industrial method" in the current document, because realized in conditions that mimic industrial and storage conditions compared to standard methods described in literature which use a flat film sample (Mathlouthi, 1994). The method includes the following five steps: an industrial pre-treatment of the foil to mimic industrial processing of the packaging (shrinking operation), foil packing with modified atmosphere to create the pressure gradient, volume measurement, gas analyses, area and thickness measurements.

2.2.1. Industrial pre-treatment

Firstly, the simulated food (solid protein-based network containing about 42% w/w moisture and 26.5% w/w fat) was packed inside the industrial bag and the shrinking operation took place under industrial conditions (about 80–90 °C and 5–10 s). This has been done to mimic the industrial packing conditions and to study the effect of shrinkage that could alter the material properties and lead to irreversible effect on permeabilities. Secondly, the pack was opened by cutting one edge off and the food was removed to avoid possible gas production or absorption which would have led to bias in the measurement of the permeability coefficient. Given the type of food, the short contact time with the packaging (<1 min), we considered that no contamination (by fat or proteins) would have affected the analysis. Thirdly, a known quantity (about 200 ml) of water was poured inside the shrunk bag for simulating the high relative humidity conditions imposed inside the pack when the food was present (about 100% relative humidity in the present experiment and about 95–99% in most packed fresh products).

2.2.2. Foil packing with modified atmosphere

The shrunk bags were packed under modified atmosphere, with about 90% CO_2 and 10% N_2 for a total volume of about 7–9 L including the aforementioned 200 ml of water. This gas composition is realistic compared to industrial situation for food products packed under modified atmosphere (Khoshgozaran et al., 2012) and it allowed to speed up the permeation process thanks to the high gradient between internal and external atmosphere. The relatively high gas volume inside the packaging enabled to consider negligible loss of volume during the gas analysis due to gas-chromatography measurement. However the total gas volume inside the packaging surface should not be too high (the packaging should not be stretched) for avoiding overpressure inside the pack, because we assume to work at constant absolute pressure (1 atm). The modified atmosphere packaging (MAP) operation was carried out with pilot plant equipment (hot sealing performed at 134 °C during 3 s and at atmospheric pressure on one cutting edge). All CO_2 present in the sealed pack was assumed to be in gaseous form due to the low pH of the water solution (about 5.32–5.42 at the temperatures used in the analyses (Daniels, Krishnamurthi, & Rizvi, 1985). The sealed bags were therefore sent to the laboratory facility where they were received about 48 h after MAP. Fig. 1 described the successive pre-treatments made on the industrial bag before gas permeabilities measurements.

2.2.3. Volume measurement

After reception of the bags, the volume of the sealed packaging was measured by immersion of the packaging in a rigid container full of water (temperature = 20 °C). The volume of the displaced water was assumed to equal the volume of the immersed packaging. The displaced water was hence weighted (coefficient of variation of the measurements equalled about 1%) and converted in volume units considering water density of 1 g cm^{-3} at 20 °C. After the measurement, the packaging bag was gently and accurately patted dry with tissue paper and placed in the temperature controlled cabinet at the analysis temperature.

2.2.4. Gas analyses

The sealed packaging was measured for the first time after 12 h of conditioning and for four times during 6–15 days, for higher and lower analysis temperature respectively. The gas composition measurement was carried out by inserting a 0.5 mm diameter needle inside the packaging through an auto adhesive septum (Dansensor, white, hard type, for shelf life studies) and injecting 10 ml of head space volume inside a micro gas chromatography unit with thermal conductivity detector (MicroGC 3000, SRA Instruments). A new adhesive septum was used each time to avoid contamination from atmospheric gases. The gas chromatography unit was previously calibrated with gas bottles of known composition. Few millilitres (about 2.5) of headspace gas were injected into the gas chromatography unit before each measurement in order to ensure a homogeneous sampling and for avoiding atmospheric gas contamination (purge). This destructive measurement led to a loss of 10 ml of sample volume at the end of the experiment (4 gas analyses during time per each plastic bag). This loss of volume was considered not to relevantly affect the assessed

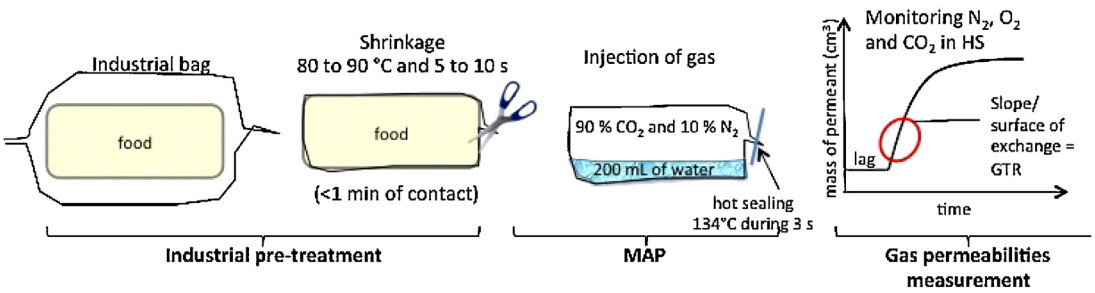

Fig. 1. Description of the pre-treatments made on the industrial bag before gas permeabilities(GTR stands for gas transmission rate and HS for headspace).