Compensation of Pinhole Defects in Food Packages by Application of Iron-based Oxygen Scavenging Multilayer Films

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Introduction

Sensitive foods like fats, oils, meat products and snacks need optimized packaging solutions to achieve adequate protection against molecular oxygen (O_2). In case of cured meat products O_2 causes discolouration and rancidity, leading to consumer rejection. High-barrier multilayer films are applied as packaging materials to minimize the permeation of O_2 from the environment into the food packages. To further minimize O_2 concentration in the food packages, modified atmosphere packaging (MAP), for example, using N_2 or N_2/CO_2 atmosphere, is widely applied. For the packaging of meat snacks, actually flow packers with MAP treatment are applied, achieving a residual O_2 concentration in the packages of preferably less than 1% v/v (corresponding to an O_2 partial pressure of approximately 10 mbar). Sealing defects: A weak point of barrier packages are the sealed seams. Sealing defects such as damaged barrier layers at the sealing zone and pinholes in the sealing layer are critical. These defective packages need to be filtered out by quality control procedures to avoid consumer complaints due to oxidative food deterioration. Non-destructive methods for leak detection are necessary for industrial packaging processes. Most relevant for the application in combination with filling machines are gas leak detection methods showing detection limits between 10 and 25 µm. Considering the machine output of 30 packages per minute, pinholes with a diameter less than 10 µm are in particular critical because they cannot be detected with standard leak testers on the basis of CO_2, He or H_2 detection.

O_2 scavengers: An effective option to compensate smaller pinholes up to a diameter of 10 µm is the application of O_2 scavengers (OS). OS incorporated in packaging materials, for example, as an O_2 absorbing layer of a multilayer film structure, could protect foods from oxidative spoilage process and restrain the growth of aerobic microorganisms. It was shown that OS could prevent meat greying, for example, applying the OS 'SHELFPLUS™ O_2 system'. The iron-based system is activated by humidity, provided by the water activity of the packaged food. The humidity is absorbed by electrolytes, for example, sodium chloride, which catalyzes the oxidation of iron. However, O_2 scavenging layers for MAP food have to be incorporated in multilayer structures. They comprise (a) a base layer, (b) a barrier layer, (c) an O_2 scavenging layer and finally (d) a sealing layer.

Experimental

Multilayer film structures were produced in pilot scale. To investigate their O_2 absorption behaviour in case of a pinhole defect size of 10 µm the films were stored in measurement cells simulating the respective O_2 permeation into the cells. The internal O_2 partial pressure was analyzed continuously. A long-term storage experiment was carried out to evaluate the effectiveness of the OS film in combination with an O_2-sensitive food product. O_2 partial pressure was analyzed in the measurement cells simulating 10 µm pinhole size defects for the OS film, the food product and the combination of food and film. In parallel, the quality of the food product stored in the measurement cell and an original packed sample with simulated sealing defects was evaluated. Therefore, colour measurements of the food samples were performed. In addition, hexanal, a volatile compound indicating the status of lipid oxidation process, was quantified in the food samples.

Results and Discussion

Effectiveness of the OS films applied in food packages: The development of the O_2 partial pressure in packages with the snack food, in measurement cells with the snack product, in measurement cells with the OS Al/Scav. 40 µm /PE 7 µm and in measurement cells with the OS Al/Scav. 40 µm/PE 7 µm combined with the snack food were analyzed. All samples were prepared to have a similar O_2 ingress rate corresponding to an O_2 diffusion through a pinhole of 10 µm.

For effective scavenging, the O_2 partial pressure for the combination OS/food must be lower than that for the food itself. The O_2 content in the measurement cells with OS was reduced reaching a minimum after some days. When the OS becomes increasingly exhausted, the O_2 partial pressure increases. From the moment the OS is depleted, the slope of the O_2 partial pressure of the empty package with OS equals the slope of the empty package. However, the depletion of the OS was not reached in this study even after 300 days.

The snack package showed a similar behaviour to the measurement cell with the snack (both without OS), indicating that the measurement cell simulates well the conditions in a closed package. The reduction of the O_2 partial pressure in the cells with the OS was higher compared with cells with snack product. As the scavenger absorbed more O_2 than the food sample alone, the OS was able to protect the food from reaction with O_2.

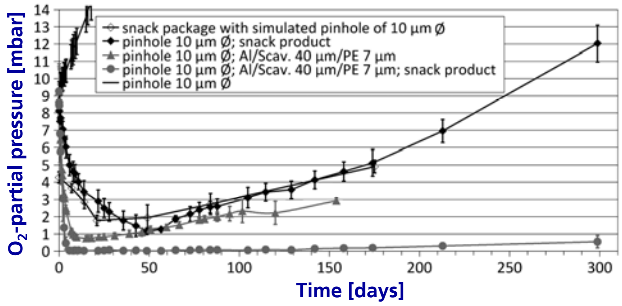

Figure 1: Course of the O_2 partial pressure in a snack package with a simulated pinhole of 10 µm diameter and in measurement cells with an O_2 ingress rate resembling a pinhole with a diameter of 10 µm 85% RH in measurement cells (Fraunhofer IVV, internal results)

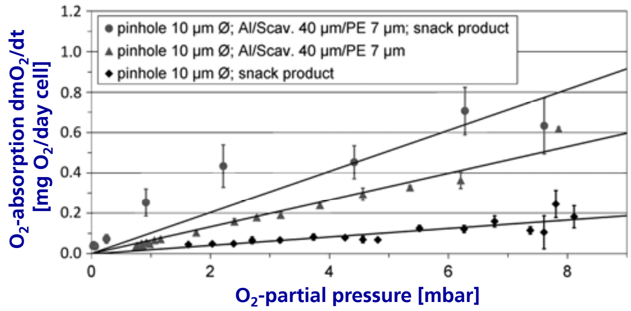

Figure 2: Differential coefficient from the absorbed O_2 (dmO_2) and the time (dt) of measurement cells, cells with an O_2 ingress rate resembling a pinhole with a diameter of 10 µm, results for the first 40 days of measurement, 85% RH (Fraunhofer IVV, internal results).

The combination of OS and snack product showed the fastest reaction and the lowest O_2 concentration. These results indicate that the OS did not fully prevent the reaction of the food with O_2, but it reduced significantly the oxidation reactions of the snack product. To study the kinetics of the reaction system the differential coefficient of absorbed O_2 dm O_2/dt was calculated. The initial absorption velocity was higher for the test series with the OS, indicating a higher contribution to the absorption of the OS in comparison with the food.

The linear gradient of the oxidative reaction of the scavenger and the food indicate that the reaction follows first-order kinetics. Consequently, the gradients comply with the reaction constants K:

(1) snack product: K1 = (0.021±0.002) mg (O_2) mbar $(O_2)^{-1}$ day^{-1}
(2) scavenger film: K2 = (0.066±0.003) mg (O_2) mbar $(O_2)^{-1}$ day^{-1}
(3) scavenger film and snack product: K3 = (0.102±0.010) mg (O_2) mbar $(O2)^{-1}$ day^{-1}

For example, a value of K1 = 0.021 mg (O_2) mbar $(O_2)^{-1}$ day^{-1} implies that the snack product absorbs 0.021 mg O_2 per day at an O_2 partial pressure of 1 mbar. The results show that the scavenger film with an area of 250 cm² is approximately three times faster than the snack product with 50 g weight and that within the error of measurement the reaction constant of K3 (scavenger film and snack product) is approximately the sum of the single reaction constants K1+K2.

Reference

S. Sängerlaub, D. Gibis, E. Kirchhoff, M. Tittjung, M. Schmid, K. Müller, Compensation of pinhole defects in food packages by application of iron-based oxygen scavenging multilayer films. Packaging Technology and Science, **2012**, in press, doi: 10.1002/pts.1962

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