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Developing a shelf-life predictive model for dry foods packed in biobased materials: the case study of coffee capsules

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The use of biobased packaging for dry foods is encountering some pitfalls, which are strictly related to the water vapor permeability. Furthermore, the barrier properties of these novel materials seems to be deeply affected by environmental storage conditions. The hierarchy of the physicochemical parameters influencing the quality of ground coffee packed in biobased materials was identified, and allowed to lay the foundation for a shelf-life prediction model.

Sviluppo di un modello di previsione di *shelf-life* per alimenti secchi confezionati con materiali bioplastici: il caso studio delle capsule di caffè

L'utilizzo di materiali di imballaggio per alimenti di tipo *biobased* presenta alcune criticità legate alla loro permeabilità al vapor d'acqua. Tale proprietà sembra essere influenzata dalle condizioni ambientali di conservazione. In questo lavoro è stata individuata la gerarchia dei parametri chimico-fisici che influenzano la qualità del caffè confezionato in capsule *biobased*. Questi risultati hanno consentito di porre le basi allo sviluppo di un modello predittivo di *shelf-life*.

Key words: ground coffee, shelf-life, dry foods, food packaging.

1. Introduction

The transition from petrol-based packaging materials to biobased ones represents a promising trend in the perspective to minimize environmental plastic pollution. However, biobased materials seem to exhibit a moisture sensitivity that is absent in conventional ones. This peculiar behavior is opening new and unexpected criticalities in the management of dry foods packed in biobased materials since these products might have a much shorter shelf-life than expected (Del Nobile et al., 2003). To face this emerging problem, the development of suitable shelf-life prediction models accounting for both the packaging dynamic performances towards environmental relative humidity (ERH) and the food moisture sensitivity are urgently required. The case study of roasted ground coffee packed in biobased capsules is here described.

2. Materials and Methods

Capsules made of polybutylene succinate (PBS), *i.e.*, bio-based, or polypropylene/ethylene-vinyl-alcohol/polypropylene (PP/EVOH/PP), *i.e.*, petrol-based, containing 7 g of freshly produced roasted coffee powder were prepared in an industrial packaging plant. Samples were stored in dark condition at 20 °C and 23, 54, 65 and 75% ERH. During storage, the coffee powder was retrieved from the capsules and analyzed for: a) water activity (a_w) at 25 °C by means of AQUALAB 4TE hygrometer; b) moisture (M) by gravimetric method according to AOAC (2000). At different storage times, capsules were picked up and used to obtain a coffee brew by using a domestic espresso coffee machine. After extraction, coffee brews were rapidly cooled down at 23 °C by means of a blast chiller and their pH was measured with a pH-meter (Basic20, Hach Lange Spain S.L.U. Riera Principal, Alella, Barcellona). The results reported are the average of at least 3 replicates.

Additionally, unpacked ground coffee powder was equilibrated at 20 °C and 11, 32, 43, 65, 75, 87, and 97% ERH by means of static, gravimetric method (Wagstaffe and Jowitt, 1990). M and a_w of coffee were analyzed and data were modelled using the Guggenheim-Anderson-De Boer (GAB) equation.

3. Results and Discussion

Figures 1a and 1b show the effect of packaging material on moisture uptake and a_w evolution of coffee samples stored at 75% ERH and 20 °C. There is a noteworthy difference between the two chosen packaging solutions: samples stored in PBS capsules reached the equilibrium within few months for both M and a_w parameters. Similar trends were obtained at 23, 54 and 65% ERH (data not shown). Conversely, slight changes were detected in M uptake and a_w evolution for coffee packed in PP/EVOH/PP capsules. These results confirm the ineffectiveness of the bio-based packaging in protecting coffee from moisture uptake compared to the petrol-based packaging.

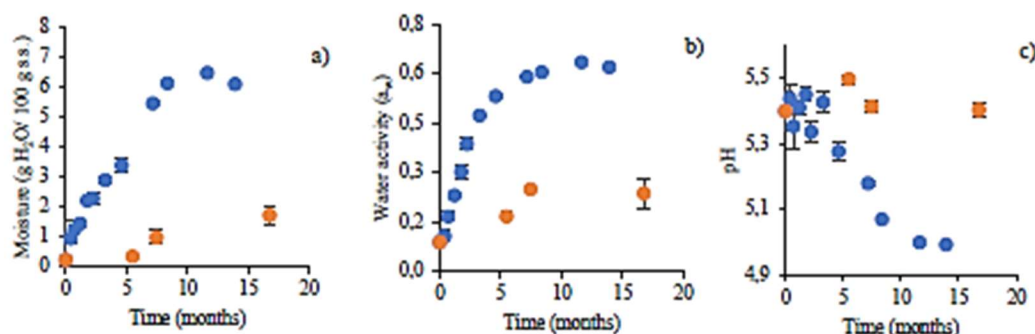


Figure 1 Moisture uptake (a), a_w evolution (b), of ground coffee packed in PBS (•) and PP/EVOH/PP (◻) capsules and stored at 20°C and 75% ERH. pH (c) of coffee brews obtained from coffee capsules having different storage time at 20°C and 75%ERH.

Table 1 Values of the GAB parameters obtained by fitting the experimental data.

| Parameter | Estimated values |
|---------------------------------------|------------------|
| m_0 (g H ₂ O/100 g d.b.) | 3.11 |
| $\alpha_{w,0}$ | 0.42 |
| k | 0.94 |
| C | 2.10 |
| R^2 | 0.97 |

Observing *Figure 1a* and *1b*, coffee packed in PBS capsules reached the monolayer in 3 months while samples packed in PP/EVOH/PP ones did not reach this limit within the 15-month observation time. Since the water content of the coffee powder is expected to affect the pH of the coffee brew, capsules having different storage times at 75% ERH were extracted and the obtained brew was analyzed for the pH value (*Figure 1c*). The pH of coffee brews obtained from PBS capsules showed a biphasic behavior: after a 3 month-lag phase, a decrease in pH values was detected. By contrast, negligible pH changes were detected for coffee samples packed in PP/EVOH/PP. It is noteworthy that for PBS capsules, the pH lag phase corresponded to the period of time required for coffee moisture to approach the monolayer. Data relevant to coffee moisture uptake and pH evolution of the brew extracted from samples packed in PBS and stored at 20 °C and 23, 54 and 65% seem to confirm this hypothesis. In fact, in all cases, the pH decrease of the coffee brew started only when the moisture content of the coffee powder approached the monolayer (data not shown). The time needed to reach the monolayer was strongly dependent on the ERH (4 and 9 months at 54 and 65% ERH, respectively). Thus, the development of a shelf-life prediction model for coffee packed in PBS should take into careful consideration the effect of ERH on packaging moisture permeability. The latter not only strongly affects coffee moisture uptake but also triggers coffee staling upon monolayer approach. To this purpose the following function (Eq. 1) should be considered in developing a shelf-life model of coffee packed in PBS capsules:

$$SL = f\left(pH\left(a_w(P(ERH))\right)\right) \quad (1)$$

where SL is the ground coffee shelf-life, pH is the critical indicator referred to the brew and related to the ground coffee quality, a_w is the physicochemical parameter that triggers coffee staling, and P is the water vapor permeability coefficient of the adopted packaging material. All these information will be used to predict the shelf-life of ground coffee packed in PBS capsules.

4. References

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