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aae32

A new methodology to monitor CO₂ transfer and determine its diffusivity and solubility in solid food

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Carbon dioxide is usually added in modified atmosphere packaging (MAP) to extend food shelf life by reducing microbial degradation with its bacteriostatic properties. MAP simulating tool based on the use of mass transfer models concomitantly with predictive microbiology would be the most appropriate method to allow a correct design and sizing of modified atmosphere packaging systems. Use of this model required first accurate determination of CO₂ solubility and diffusivity in solid food matrices.

Carbon dioxide transfer in food is characterised with a thermodynamic parameter, **solubility**, and a kinetic parameter, **diffusivity**. In the scientific literature, data on carbon dioxide diffusivity in non-respiring solid food matrix are mostly based on indirect measurements, with manometric or volumetric method. This is a method to acquire *in situ* the diffusivity of carbon dioxide in solid matrices.

Materials and Methods

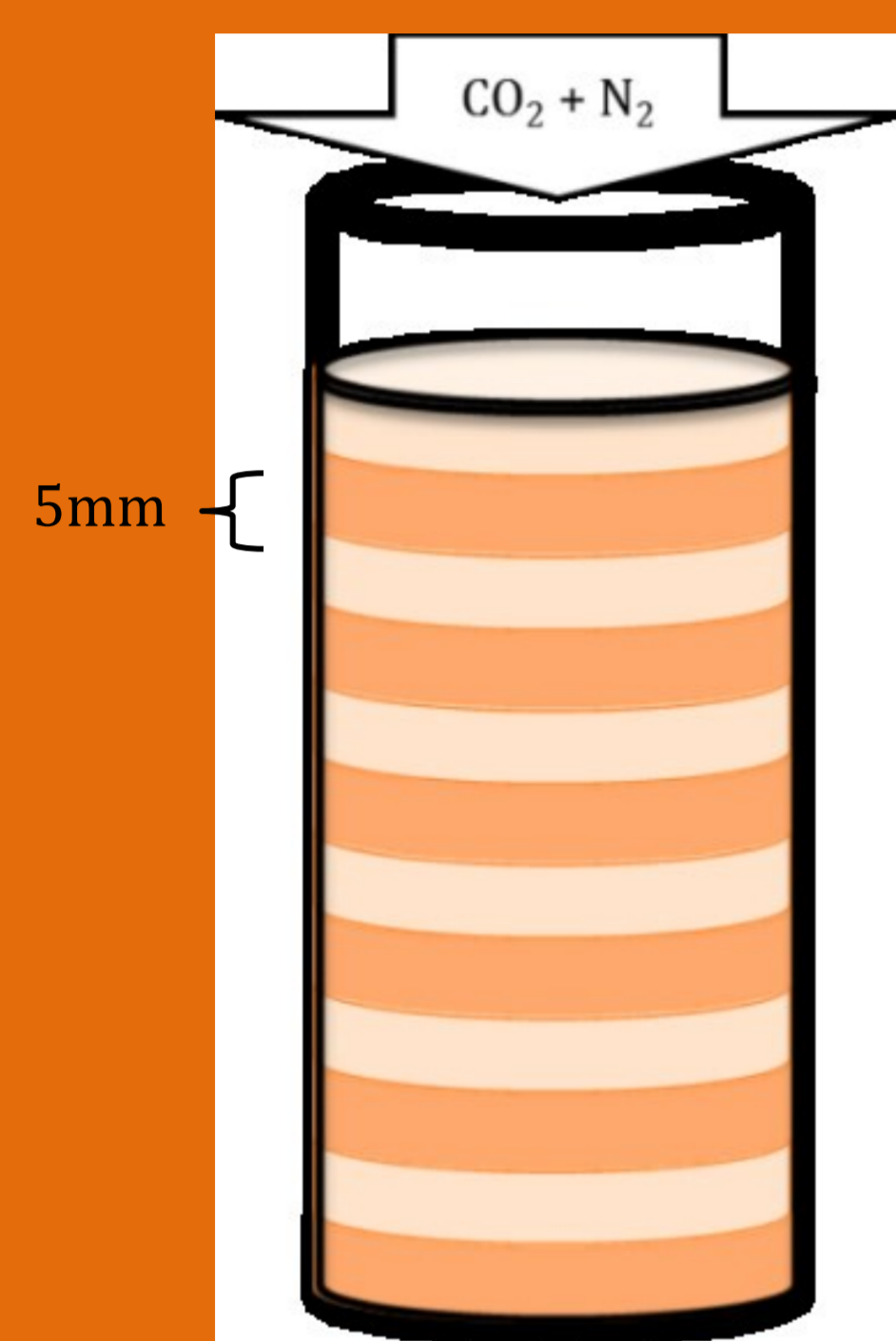


Fig. 1. Experimental set up for determining CO₂ diffusivity in food product

Measurement principle:

- Impose a gradient of carbon dioxide to the sample and monitor the carbon dioxide transfer kinetic
- Experimental design is to form a cylinder of the food matrix (2<x<8 cm) and apply at one end a flux of CO₂.
- After the phase of CO₂ diffusion (around 20 hours), the food matrix is rapidly demoulded and cut into fine slice (around 5 mm)
- CO₂ content is measured for each slice (time is a constant)

To determine the carbon dioxide content:

- Based on chemical titration used generally to measure the carbon dioxide content in food product and determine the carbon dioxide solubility

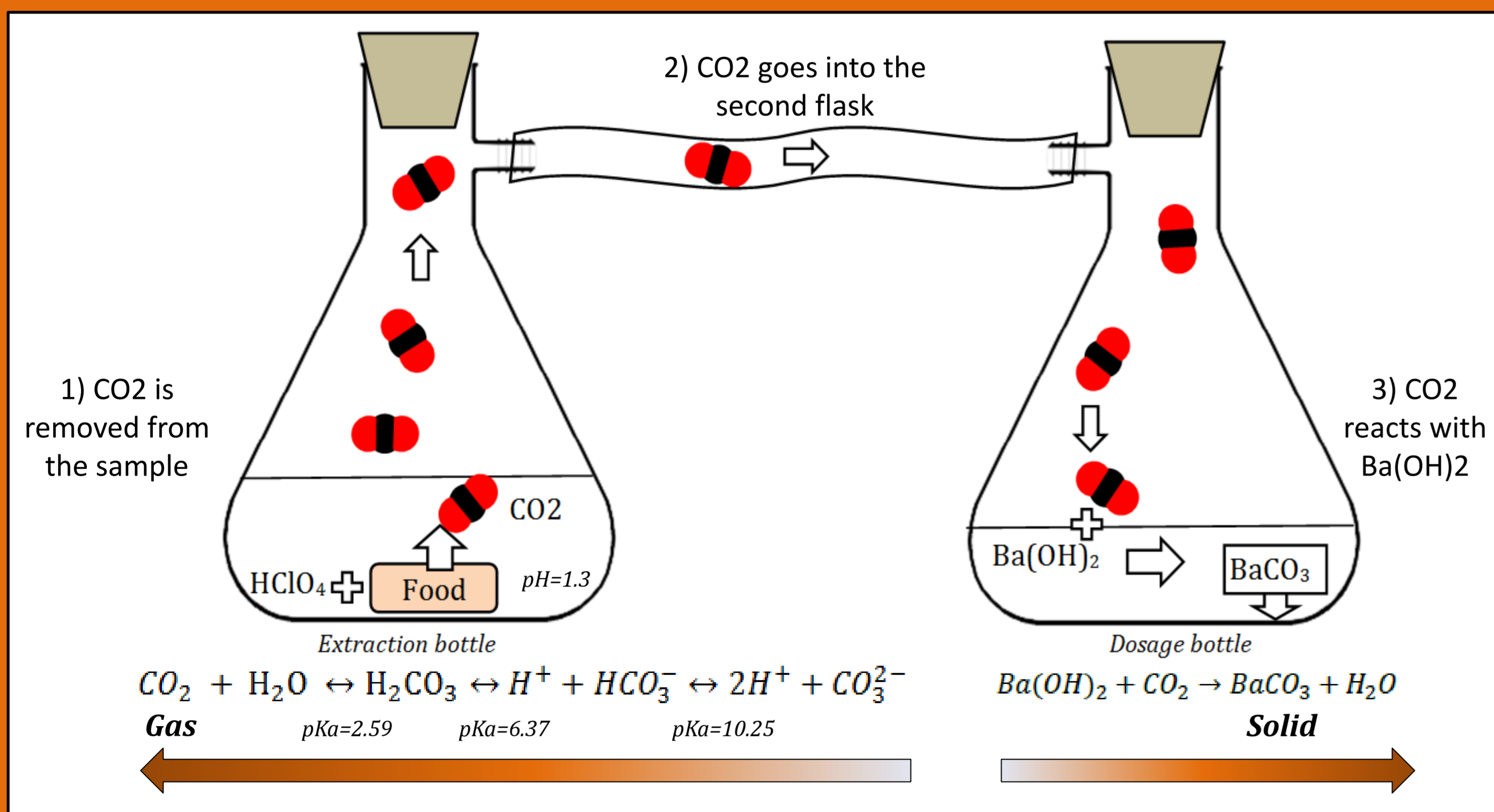


Fig. 2. Experimental set up used to measure CO₂ content: on the left, a bottle "extraction", where CO₂ is released; on the right, a bottle "dosage" where CO₂ is quantified.

Identify the diffusivity: Mathematical model

Fick's second law is used to model the carbon dioxide transfer and express the variation of the concentration with space (x) and time (t). The system of equations given in Fig 3 is numerically solved and programmed on MATLAB® software. Then the diffusivity (D) is identified by minimizing the sum of squared error between experimental and predict data.

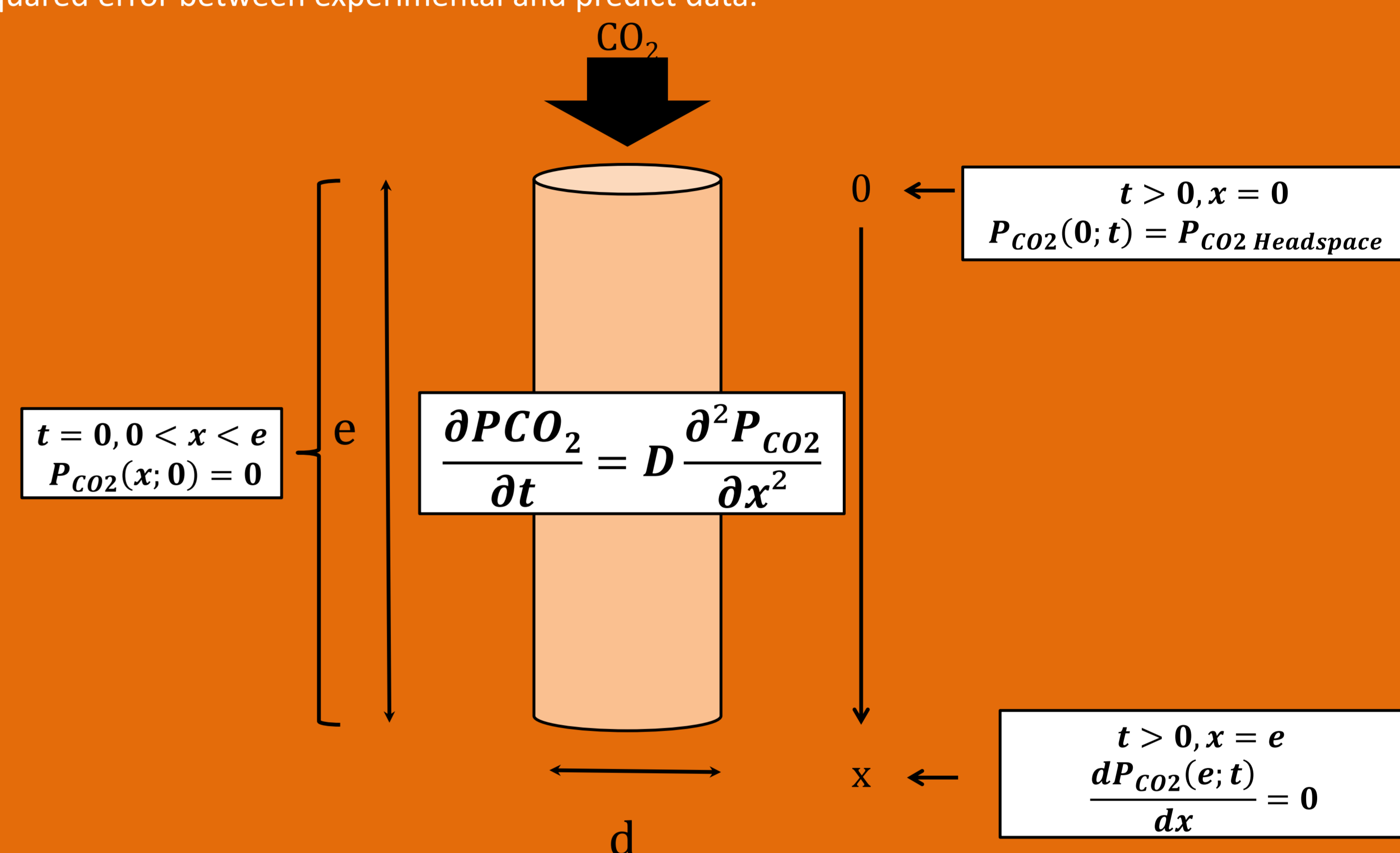


Fig 3. Infinite cylinder type system for the analysis of CO₂ transport in food matrix

Results

CO₂ kinetics in cheese matrix at 20°C

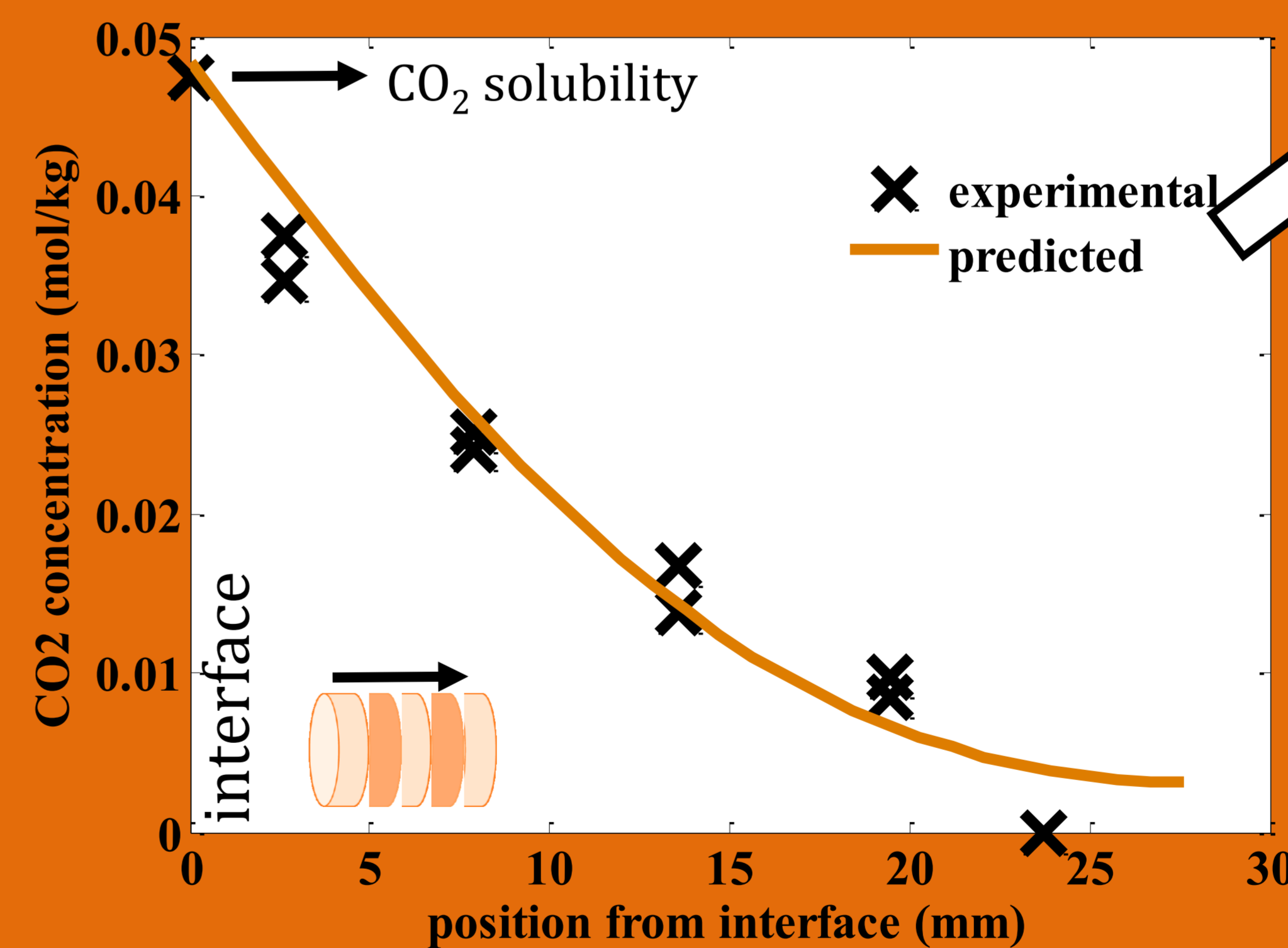


Fig 4. Experimental and predicted CO₂ profiles in cheese matrix by distance of the interface

$$D_{CO_2} = 0,85 \pm 0,20 \times 10^{-9} \text{ m}^2 \cdot \text{s}^{-1}$$

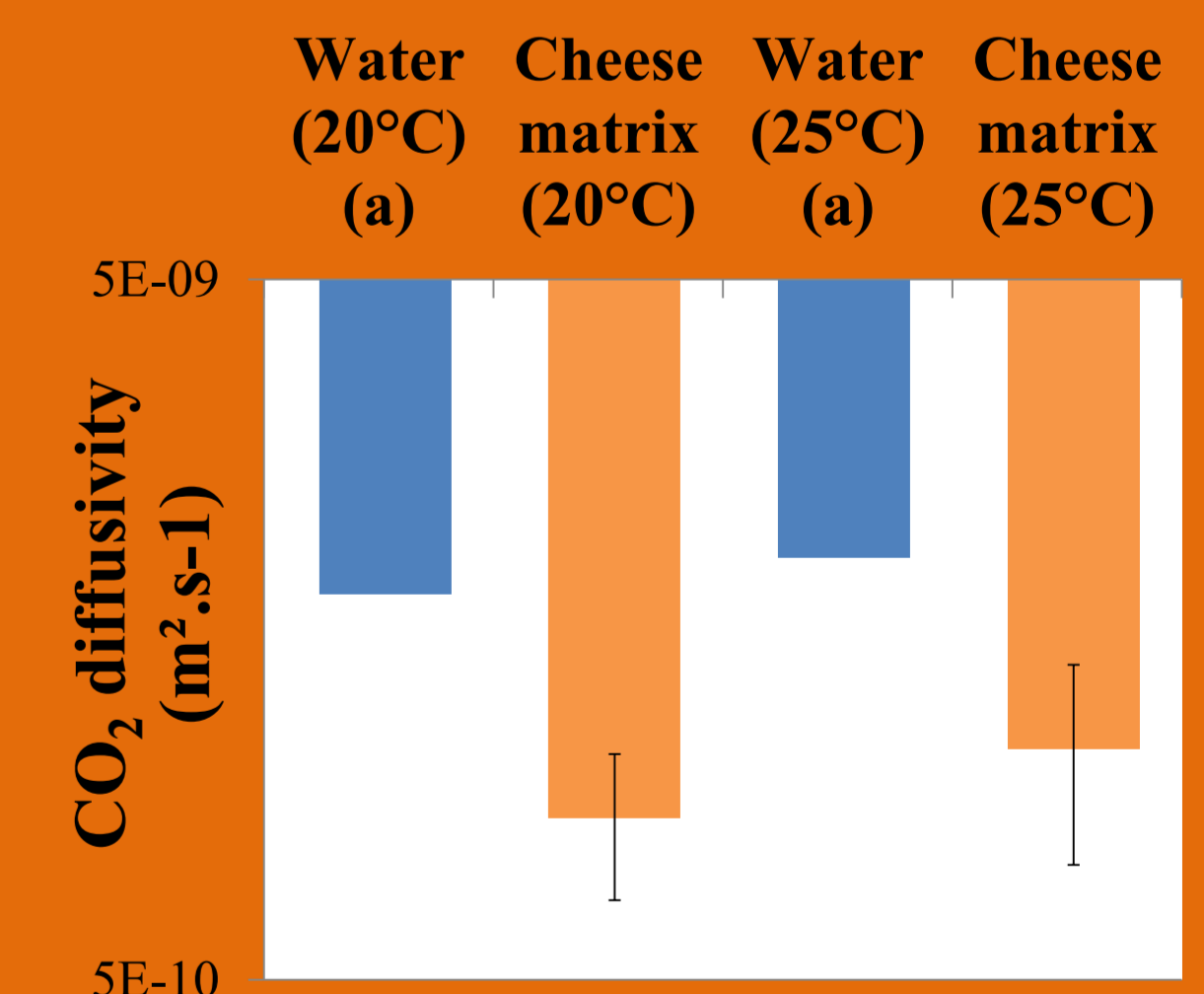


Fig 5. Data diffusivity of CO₂ in the literature versus experimental

Discussion

This method to determine the CO₂ diffusivity is easy to implement and not expensive. It allows an evaluation of the kinetics of transfer of CO₂. The values obtained by this method are in agreement with various literature data, including the existing data of carbon dioxide diffusivity in water (a) and are in the same order of data in other food products, such as fish (b) or meat (c).

However, experimental efforts must be pursued to have the lowest measurement error. One of the steps is critical: the cheese is cut in slices out of a controlled atmosphere, and each slice is weighed before desorption. This should be done in the shortest time possible.

This work presents an easy and inexpensive method, to measure carbon dioxide kinetic in solid food. CO₂ concentration is measured for each slice at constant time. Diffusivity is identified from a mathematical model based on Fick's second law. The first results obtain are in agreement with scientific literature data.

This work is done in the project MAP'Opt (2011-2015), funded by the French National Research Agency, whose full name is "Equilibrium gas composition in modified atmosphere packaging and food quality".