Title Perforation-mediated modified atmosphere packaging: Part I. Development of a mathematical model

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Abstract

A space-and-time dependent mathematical model describing perforation-mediated modified atmosphere packages was developed for respiring commodities. The model is based primarily on fundamental laws, with empirical relations used only when no other approach can be devised or when there is a significant advantage from using an empirical approach. The computational domain is divided into four subdomains: a part of the ambient storage environment; the perforation, allowing gas exchange between the package and the ambient; the commodity layer, inside the package; and the headspace above the commodity, but also contained in the package. The package walls are rigid and impermeable to gases but heat conducting. The commodity is treated as a homogenous porous medium with distributed sinks for oxygen consumption and distributed sources for carbon dioxide production due to commodity respiration. The commodity model also accounts for water vapour production due to transpiration and removal caused by possible condensation. The effects of commodity temperature and headspace gas composition on oxygen consumption and carbon dioxide production are accounted through a respiration model. The model permits the determination of the gas mixture velocity as the solution of Darcy's law in the commodity layer and the Navier–Stokes equations in the headspace, perforation, and surrounding ambient storage area. Transport of oxygen, carbon dioxide, water vapour and nitrogen is modelled based on Maxwell–Stefan equations coupled with the Navier–Stokes equations and Darcy's law. Solubility of carbon dioxide within the commodity has been included in the model. Commodity temperature and gas mixture temperature are modelled as solutions of the energy equation in the appropriate subdomains, coupled through transpiration, condensation, and convective heat transfer at the commodity surface.