MATHEMATICAL MODELLING OF MOMENTUM, HEAT AND MASS TRANSFER IN GRAINS STORED IN SILOS. PART II: MODEL APPLICATION

A. ARIAS BARRETO[†], R. ABALONE[†,‡] and A. GASTÓN[†,§]

†*FCEIyA, Universidad Nacional de Rosario, Av. Pellegrini 250, 2000 Rosario, Argentina.*
abarreto@fceia.unr.edu.ar
‡*Instituto de Física Rosario (CONICET-UNRosario), 27 de Febrero 210 bis, 2000 Rosario,Argentina*
rabalone@fceia.unr.edu.ar
§*CIC-UNR, FCEIyA, Universidad Nacional de Rosario, Av. Pellegrini 250, 2000 Rosario, Argentina*
analiag@fceia.unr.edu.ar

***Abstract*— A 2D finite element momentum, heat and mass transfer model was applied to predict natural convection flows, temperature distribution and moisture migration in soybean stored in a cylindrical bin without aeration from autumn to spring for the weather conditions of Rosario, Argentina. The effect of the initial moisture content and temperature of the grain (13%w.b and 25, 20 and 15°C) on storability conditions was evaluated. During winter, stronger natural convection flows developed for 25°C, promoting an average moisture migration of 0.4%w.b and average grain temperature decrease of 5°C at the bin bottom. For 20°C, these values reduced to 0.15%w.b and 3°C. For 15°C, safe conditions remained and moisture migration was negligible during winter, but in spring, solar radiation and natural convection increased the temperature of a boundary layer of 1.5 m width above 18°C. Interstitial equilibrium relative humidity remained below the threshold for mold development (ERH > 75%). During spring, natural convection increased as the initial grain storage temperature decreased. Permeability has the strongest effect on natural convection and a five fold increase of this parameter resulted in the development of spoilage areas in the upper part of the bin. Soybean and corn showed comparable moisture migration while for wheat was not significant.**

***Keywords*— grain storage, numerical modelling, natural convection, heat and mass transfer.**

I. INTRODUCTION

Numerical simulation models based on transport principles are useful and inexpensive tools to predict the potential spoilage of stored grain. They can play a major role in the design and evaluation of methods for reducing temperature and moisture gradients in stored grains, which are the two main factors that affect grain quality during storage. Numerous models have been developed for conventional storage systems and applied to analyze the heat and mass transfer process in different grains. A revision of published results can be found in Navarro and Noyes (2002). These authors' remark that the major advantage of validated models is the possibility to conduct "*what-if*" studies and thus predict storage conditions based on different climatic regions of the world. For the climatic conditions of South America, most of the published work refers to Brazil, addressing the analysis of heat and mass transfer of grains without aeration (Andrade *et al.*, 2002) or the performance of aeration strategies for typical agricultural locations (Sinicio and Muir, 1996, 1998; Martins *et al.*, 2001; Lopes *et al.*, 2006, 2008a, 2008b; Khatchatourian and Oliveira, 2006). No references were found in the international literature regarding the simulation of heat and mass transfer, for the climatic conditions of Argentina. Studies on transport phenomena for wheat, from summer to winter were presented in Balzi *et al.* (2008) and Abalone *et al.* (2006).

The aim of this work was to analyze storability of soybean from autumn to summer, for the weather conditions of Rosario (Lat. 32°57'S, Long. 60°38'W), located on one of the most productive agricultural region of Argentina. The effect of initial grain temperature and permeability on the development of natural convection flows, temperature distribution and moisture migration was examined. A comparative analysis of moisture migration for soybean, corn and wheat, the three most important grains cultivated in Argentina, is also provided.

II. HEAT TRANSFER MODEL

A. Mathematical Model

The momentum, heat and mass transfer model described in Part I of present study (Arias Barreto *et al.*,