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Management of stored maize by AERO controller in five Brazilian locations: a simulation study

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A simulation model was used to quantify the effect of the AERO controller on dry matter loss, moisture content, grain temperature and required aeration time for five Brazilian States during one year. The application focused on maize because it is the dominant crop in the regions studied, but the analyses can be applied to other grains and locations as well. Decision making of the AERO controller is based on simulation of the aeration process and on real time data acquisition. It proved to be an effective strategy and showed its significant potential as a non-chemical preventative practice for safe storage.

1. Introduction

When grains are placed into storage they are exposed to a broad range of complex ecological factors that work against the stored grain manager's objective of maintaining grain quality. Grain temperature is important because it directly affects grain quality, development of pests and dry matter losses (Maier *et al.*, 1996). But the moisture content is also a significant factor since the lower it is, less susceptible grains are to spoilage by insects, mites or fungi (Longstaff, 1994).

It is usual practice to implement preventive management, rather than to solve specific storage problems once they have occurred. Aeration is a well-known and proven Integrated Pest Management tool for controlling the quality of stored grain. The two primary objectives of aeration are to maintain uniform temperatures inside the bin and keep temperatures below the limits for insect and fungal development (Navarro and Noyes, 2001). However, this technique remains an underused tool in some situations, particularly in warm climates such as in Brazil. Thus, the development of appropriate control strategies will enable aeration to be more widely and efficiently used in these regions.

When ambient aeration is used, it is very important to operate the system during appropriate conditions for efficient storage management. The AERO controller is a promising strategy which was developed with the objectives of maintaining grain quality with minimal energy input, automatically adjusting its set points according to different climates and storage systems based on real time data acquisition and on simulations of the aeration process (Lopes, 2006).

As simulation of a grain storage ecosystem is less expensive and a time-saving alternative to field research, in this study simulations were carried out to evaluate the effectiveness of AERO control strategy for maintaining safe storage of maize in five Brazilian locations.

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Nomenclature

c_a	specific heat of air (J kg^{-1} °C^{-1})
c_g	specific heat of dry grain (J kg^{-1} °C^{-1})
c_w	specific heat of water (J kg^{-1} °C^{-1})
h_v	latent heat of vaporization of water (J kg^{-1})
h_s	differential heat of sorption (J kg^{-1})
U	grain moisture content (% d.b.)
m_s	dry matter loss of grains (%)
Q_r	heat of oxidation of grain (J s^{-1} m^{-3})
T_a	air temperature in equilibrium with the grain (°C)
T	time (s)
u_a	aeration air velocity (m s^{-1})
R	humidity ratio of air (kg kg^{-1})
Y	vertical coordinate (m)
ε	grain porosity (decimal)
ρ_a	density of intergranular air (kg m^{-3})
ρ_b	bulk density of the grain (kg m^{-3})
θ	grain temperature (°C)
M_M	moisture modifier (dimensionless)
M_T	temperature modifier (dimensionless)

Fig. 1 – Geographical location of Brazilian States considered in this study.

2. Methodology

The simulation model used in this work can be applied to several grains and aeration systems. This study focused on maize because it is one of the crops whose production has increased most in Brazil during recent years. In 2007 the area planted with maize was 14.3 million hectares and the national production was 52.3 million tonnes (Conab, 2007).

In Brazil, the first crop of maize is grown during the rainy season, between September and November, and represents 75% of the national production of this cereal. Of this, the South region contributes 40.0% followed by Southeast and Mid-West which represent 34.7% and 12.0%, respectively. State of Paraná is the largest maize producer in Brazil. This State is located in the South region and represents 23.1% of the national production. In Southeast the major producers are the States of Minas Gerais and São Paulo, which represent 22.3% and 11.9% of the Brazilian maize production, respectively. In Mid-West, the States of Mato Grosso and Goiás produce 1.9% and 7.9% of the maize grown in Brazil (Embrapa, 2007).

Thus, simulations were carried out for Paraná (PR), Mato Grosso (MT), Goiás (GO), Minas Gerais (MG) and São Paulo (SP). These Brazilian States (Fig. 1) were represented by the cities of Nova Cantu, Cuiabá, Jataí, Araxá and Taquarivaí, respectively. Cities were selected based on their maize production, as related by Ibge (2008), and on the availability of weather data obtained from Cptec (2008).

Nova Cantu is located at an altitude of 555 m, 24°40′22″ S latitude and 52°34′08″ W longitude. Iapar (2000) classifies the weather of this city as Cfa according to Koppen climate classification. It is humid subtropical with an average temperature in the coldest month less than 18 °C (mesotherm) and in the warmest month greater than 22 °C. Frosts are not frequent and summer is hot and rainy.

Taquarivaí is located at 682 m altitude, 23°55′28″ S latitude and 48°41′35″ W longitude. According to Ferraro (2006), the weather at this location is Cfb by Koppen classification. It is dominated throughout the year by the polar front, leading to changeable, often overcast weather. Summers are cool due to cloud cover, but winters are milder than other climates at similar latitudes. This city has average annual maximum and minimum temperatures around 26 °C and 14 °C, respectively.

Araxá, Jataí and Cuiabá are predominantly Aw Koppen type, presenting two well-defined seasons: a rainy summer and a dry winter. Araxá is located at 1000 m altitude, 19°35′33″ S latitude and 46°56′26″ W longitude. As related by Rocha and Rosa (2007), in this city every month has an average temperature of 21 °C. Jataí is located at 696 m altitude, 17°49′46″ S latitude and 51° 46′ 29″ W longitude. Sousa *et al.* (1997) affirmed that minimum temperatures are around 15 °C during winter and maximum temperatures are greater than 22 °C. According to Curi and Campelo Júnior (2001), Cuiabá is located at 176 m altitude, 15°35′52″ S latitude and 56°5′27″ W longitude with average monthly temperatures ranging from 22 °C to 27 °C.

Ambient dry bulb temperatures and relative humidities of the five Brazilian locations were collected every 3 h, from March 2007 to February 2008 according to data obtained from the Cptec (Centro de Previsão de Tempo e Estudos Climáticos – Center for Weather Prediction and Climate Research), which has 620 automatic meteorological stations located in different Brazilian cities.

Simulations started in March as this is the month in which most of the first maize crop is stored. One year of storage was simulated, corresponding to 8760 h. During simulations the use of the AERO controller was considered for each location. This strategy was developed based on the recommendations presented by Navarro and Noyes (2001), Lacerda Filho and Afonso (1992) and Martins *et al.* (2001). Four conditions are analyzed for the AERO controller using the simulation results