

CHAPTER I¹

1. INTRODUCTION

1.1 BACKGROUND

According to Flores (1988) and Loewer et al. (1994), grain storage facilities are systems designed for the appropriate receiving, cleaning, drying, storing, and dispatching of grains and legumes. In order to perform these operations, several types of equipment and structures such as receiving pits, cleaners, dryers, conveyors, wet holding bins, bins, flat storage and dispatch bins need to be linked in a logical sequence. These systems should also be designed, operated, and managed in a way that product characteristics can be preserved and profits can be earned.

Due to the grain storage facility system's characteristics, such as the complexity of unit operations, stochastic effects regarding external and internal factors, and high long-term investment demand, the design of grain facilities is a difficult task for which the simulation of facility characteristics has become an important tool. According to Lower et al. (1994), improved simulation of grain pre-processing has made it possible to better evaluate the grain drying process, the facility layout and design, and the complete grain storage system.

For the grain drying process, Loewer et al. (1994) lists the following simulation models:

(a) CROSSFLOW (Thompson et al., 1968) simulates drying time, drying rate, cost, and energy requirements for drying either corn or sorghum. This model was programmed using the FORTRAN language for the mainframe environment.

(b) FANMATCH (Thompson, 1975a) determines the fan horsepower requirements needed to move a given volume of air per bushel of grain and selects the fan according to type of bin chosen and type of grain to be dried.

¹ Silva, L. C. 2002. Stochastic Simulation of The Dynamic of Grain Storage Facilities. Ph. Dissertation. Universidade Federal de Viçosa. Viçosa, MG. Brazil

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(c) NATAIR (Thompson, 1975b) calculates how long it takes to dry the top grain to a specified final moisture content given either natural air or low temperature drying conditions and evaluates the airflow produced by the dryer system. NATAIR was formulated to consider corn or grain sorghum characteristics and was originally run using mainframe computers running FORTRAN. Parts of this model have been included in several others.

(d) CONTNBN (Bridges et al., 1984), developed using GASP IV simulation language, makes it possible to evaluate the drying performance of continuous in-bin drying systems.

(e) LAYERD (Bridges et al., 1982) provides a filling schedule for a layer-drying bin based on dry matter decomposition and the possibility of aflatoxin contamination. LAYERD can be used to simulate corn and grain sorghum drying based on input information, such as ambient temperature and relative humidity, drying air temperature, initial and desired final grain moisture content, fan performance data, drying bin diameter and height, and whether the system is to be controlled by a thermostat or a humidistat.

(f) STIRDRY (Bridges et al., 1984), used by decision makers, provides management information and analyzes the advantages of the use of stirring devices in individual layer and batch-in-bin corn systems.

For facility layout and design, Loewer et al. (1994) list the following models:

(a) BNDZN (Loewer et al., 1976a), which is static design model programmed in FORTRAN. It provides the layout dimensions, bill of materials and estimated fixed annual costs for centralized grain storage facilities.

(b) CIRCLE (Loewer et al., 1976b) is a spreadsheet model employed to layout a circular arrangement of storage bins.

(c) FLASTOR (Loewer et al., 1989) gives the facility geometric layout and purchase cost information for a flat storage system. It is a spreadsheet model that can be run on a microcomputer.

(d) DUCT (Bridges et al., 1988) determines duct sizes and duct spacing for aeration of rectangular storage facilities. The design is based on the configuration of the grain mass, desired airflow rate, grain volume, and duct

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spacing criteria that provide a relatively uniform distribution of air throughout the grain mass.

For total system evaluation, Loewer et al., (1994) presents the following models:

(a) CHASE (Bridges et al., 1979) is a static design model that simulates the optimization of the delivery, drying, and storage components for 60 different types of systems and ranks them according to purchase price and annual cost. Physical layout information is also provided. The optimum situation is defined according to the input data, which includes cultivated acreage, yield per acre, row width, harvest season (days), harvest time (hours/day), energy cost, portable drying time (hours/day), travel distance from the field to the facility, labor cost (\$/hour), and initial and desired grain moisture content.

(b) SQUASH (Benok et al., 1981) is structured using FORTRAN and GASP IV and allows the identification of bottlenecks in the system that may arise during harvest, transport, delivery, drying, or storage. This model provides a list of events and a graphic output of grain flow and vehicle activities for a set of equipment and management strategies.

(c) EXSQUASH (Loewer et al., 1990) is an expert system model that helps to identify bottlenecks in the harvesting/delivery and handling/drying/storage systems. This model was developed using EXSYS software.

Several models that simulate part or all of the grain pre-processing system have been developed and implemented in Brazil.

(a) Queiroz et al. (1984) created a simulation of the corn drying process in concurrent flow dryers with countercurrent flow cooling using the Michigan State University drying simulation model.

(b) Silva (1991) developed a drying model for an intermittent counter flow coffee dryer. The model was according to Thompson et al. (1968).

(c) Rezende (1997) developed a spreadsheet model that can be applied to the design, simulation, and economic evaluation of on-farm grain storage facilities with a receiving capacity of between 500 to 6,000 tonnes. The ideal layout was adopted using corn grain characteristics to develop the model.

1.2 PROBLEM STATEMENT

Due to the influence of external and internal stochastic variables on the performance of grain storage facilities, the use of deterministic simulation models and static methods of analysis can lead to erroneous decisions. Therefore, models are needed that allow simulation of the dynamic behavior of grain storage facilities under the influence of stochastic variables. These types of models allow a better understanding of grain storage facility operations. Moreover, using this type of model, sensitivity analysis, scenario analysis, optimization, and Monte Carlo simulation can be performed to find the best design for a new facility, and the best way to operate or renovate an existing facility.

1.3 OBJECTIVES

This research consists of the development of a simulation tool that will assist decision makers who work in the grain handling industry to: (i) assemble their models according to the configuration of their grain storage facilities, and (ii) modify pre-assembled models to determine the best configurations and operation plans for optimum system effectiveness in terms of (1) electrical energy and firewood consumption, (2) conveyor and processing machine efficiencies, and (3) structure utilization indices.

Due to the characteristics of the simulation language, ExtendTM, used to develop of the simulation tool, users, according to their background and study purpose, will be able to select several types of information from the model reports. This information will allow one to (i) conduct grain storage facility feasibility analyses, (ii) make economic evaluations, and (iii) estimate operational impacts resulting from modifications in the system's configuration and product flow.

Academically, the general objective of this research was to develop stochastic models that simulate the dynamic behavior of grain storage facilities, thereby permitting feasibility analyses. To achieve this objective, the following specific objectives were defined: (a) Develop a group of computational routines for simulating unit operations and processes related to grain storage systems; (b) Implement models that group developed routines for simulating the dynamic behavior of grain storage facilities; (c) Verify and validate developed

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mathematical models using experimental data obtained at pre-processing grain enterprises located in the western region of the state of Paraná, Brazil; (d) Conduct a sensitivity analysis to verify the impact on firewood and electric energy consumption caused by changes in the quantity of grain handled and the initial moisture content of this grain; and (e) Analyze the configuration of the grain storage facility's drying sector through use of scenarios.

1.4 ORGANIZATION OF THIS STUDY

This thesis contains six chapters. Chapter I, INTRODUCTION, presents an outline of the general vision of this study, previous studies in this area, the reasons for doing this research, the organization of this work, and the study's limitations and scope. Chapter II, A SIMULATION TOOL FOR MODELING GRAIN STORAGE FACILITIES, describes the development of the "*Grain Facility*" simulation tool and gives an example of its use. Chapter III, VERIFICATION AND VALIDATION OF THE GRAIN STORAGE FACILITY MODEL, delineates the procedures used to verify and validate the model's output. Chapter IV, SENSITIVITY ANALYSIS USING A GRAIN STORAGE FACILITY MODEL, presents a study that shows that the quantity and initial moisture content of raw product received can affect grain storage facility performance. Chapter V, SCENARIO ANALYSIS RELATED TO DRYING SECTOR'S CONFIGURATION, shows how changes in the drying capacity can affect grain storage facility performance according to engineering parameters. Chapter VI, CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH, contains the main conclusions arrived at from this study and recommendations for future work. Appendixes and supporting information are included at the end of the study.

Chapters II, III, IV, and V were written as a research paper.

1.5 LIMITATIONS AND SCOPE

1.5.1 LIMITATIONS

This study has the following limitations: (a) Only data related to the crop year of 1999 was made available by the agricultural cooperative COAMO – "*Cooperativa Agropecuária Mourãoense Ltda*". Therefore, in the verification and

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validation studies, there is a comparison between simulated and experimental data for only one year of grain storage facility operation. (b) In the developed model, there are options for corn, soybeans, and wheat only (c) Data related to moisture content, foreign material content, truck capacities, and interval between truck arrivals were considered according to empirical distributions defined according to modeler experience and informal data. (d) Simulation time is restricted to the maximum of 1 year (8640 hours). (e) In the simulation process, one year was considered to be 360 days, made up of 12 months each 30 days long, and each day has 24 hours.

1.5.2 SCOPE

The general subject matter covered in this thesis includes computer simulations, modeling procedures, grain storage facility descriptions, and a simulation applied to pre-processing grain system. The major focus is Brazilian grain storage facility systems with storage capacities of more than 6,000 tonnes. In general, these systems belong to private enterprises, agricultural cooperatives, or governmental agencies and grain is stored in flat storage structures made of concrete or cylindrical bins made of concrete or corrugated metallic sheets.

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