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Optimization of process parameters in feed manufacturing using artificial neural network

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ABSTRACT

Feed manufacturing faces enormous challenges and with the demand for good quality feed increasing gradually, it becomes essential to improve the processes in a feed mill. This article provides a brief overview of the different processes in feed manufacturing and identifies the critical process parameters. Five critical parameters are identified where the production rate is the output parameter. Mash feed size, steam temperature, conditioning time and feed rate are the input parameters. Artificial neural network is the methodology which is used to optimize the process parameters. Root mean squared error and coefficient of determination and computation time are used as performance measures and it is observed that Polak–Ribiere conjugate gradient backpropagation training function with log sigmoid – pure linear transfer function combination provided good results among the different available alternatives. The process parameters are then optimized using the appropriate ideal settings of neural network parameters. This model is extremely useful for the prediction of production rate for 1 specific recipe in a feed mill.

1. Introduction

Process parameters optimization has been an active area of research for the past few decades. Different industries face the problem of optimizing multiple, conflicting input parameters to achieve the desired value of the objective function. The objective function may be maximization (e.g. profits) or minimization (e.g. costs incurred). The various techniques of the optimization of process variables have been applied in different contexts and have showed impressive results in the respective areas. The machine setting up tasks in the feed industry are cumbersome. As such, there is no standard operating procedure for setting up of optimum levels of process variables as far as feed mills are concerned. The operations in a feed mill are sequential and require the optimization of process parameters to achieve maximum productivity. Without the knowledge of ideal levels of input parameters, recurrent problems arise day-to-day in the machine setup which ultimately affects the feed mill performance. Thus, the optimization of process parameters in feed manufacturing would help in overcoming these issues and achieve better performance.

The optimization of process parameters is a problem that has been actively studied as far as food processing industries are concerned. Various tools and techniques have been used in this regard to achieve good quality solutions. Ramakrishnan et al. (2004) used simulation as a tool for the prediction of process variables for the intelligent control of tunnel freezers. Arora et al. (2007) present a classic example of optimization of process parameters for milling of enzymatically pretreated basmati rice using response surface methodology. Lamberts et al. (2007) studied the effect of milling on color and nutritional properties of rice through statistical analysis. In another study, Oztop et al. (2007) used Taguchi technique for the optimization of microwave frying of potato slices. Roy et al. (2008) investigated the influence of different operating conditions on overall energy usage and rice quality. Feed processing is not an exception and requires a detailed study and optimization of process variables to achieve good results. Different procedures have been used earlier for the optimization of process parameters in rice milling and allied food processing branches. Due to its successful implementation as evident in the literature, artificial neural networks are utilized to optimize parameters in this case. Agatonovic-Kustrin and Beresford (2000) defined an artificial neural network as a biologically stimulated computational model consisting of hundreds of single units, artificial neurons, connected with weights which constitute the neural structure. Cus and Zuperl (2006) illustrated that a neural network approach can produce significant gains in productivity in the optimization of cutting conditions for materials. Chegini et al. (2008) developed

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a supervised artificial neural network to predict seven performance indices based on three input parameters in the prediction of process and product parameters for an orange juice spray dryer. Hamzaoui et al. (2015) made use of artificial neural network and its inverse to optimize operating conditions in a steam turbine. This model provided a new artificial intelligence approach to optimize process parameters and showed good results. These studies clearly demonstrate the usefulness of neural networks in solving optimization problems.

In one of the earliest studies in the area of feed manufacturing, Behnke (1996) presented the various problems in the feed manufacturing sector. A series of research findings during the late 1990s exhibited the various aspects of animal feed production. Thomas and Van der Poel (1996) put forward the criteria for pellet quality. According to them, animal feed in the form of pellet has many advantages. They are:

- The better flow properties of pellets when compared to the mash, makes transfer in conveyors smooth and damage free.
- Pellets possess high bulk density and so, more tonnage can be carried by truck.
- The formulation of pellets helps to maintain the moisture content and nutrition.

Thomas et al. (1997) emphasized the need to understand the processes in a feed mill better and quantify the parameters so that high performance levels can be achieved with low cost. Also, they discussed the impacts of variations in process variables on pellet quality which is measured in terms of hardness and durability. The pelleting process considered in this respect was the combination of conditioning, pelleting and cooling. In the following year, Thomas et al. (1998) studied the effect of feedstuff components on the quality of animal feed.

Pathumnakul et al. (2009) consider the application of neural networks for the selection of appropriate feed mix in the feed processing industry. Though the study by Pathumnakul et al. (2009) contributed greatly by applying neural networks to the feed industry, it was not successful in predicting production rate using process parameters because of the consideration of numerous recipes. Hence, the physical–chemical complexity of the interactions among feed ingredients made it not quite possible to obtain the production rate using simple neural network and input factors stated. Our study has only one recipe as stated in Table 1, hence, the complexities have tremendously been reduced. Therefore, our case is possible for recipe specific and easily adoptable. In addition, this work focusses on the study of processes in a feed mill and the critical operations in a feed mill which includes conditioning and pelleting (Thomas et al., 1997).

This article provides an overview of the processes in a feed mill and the significant operating parameters are identified which is explained in Section 2. The methodology to solve the given problem, artificial neural network is discussed in Section 3. For the appropriate settings of the neural network, the optimized process parameter levels are elaborated in Section 4. Finally, Section 5 provides the conclusions of the research.

Table 1
Feed formulation.

Raw material type	Inclusion (%)
Maize	60
Soya	20
Other ingredients	20
Total	100

2. Material and methods

2.1. Operations in a feed mill

There are different types of feed manufacturing facilities which possess certain unique characteristics. The components in the feed mill, the type of arrangement and the general layout are the primary causes of variation in the feed mills. However, the feed manufacturing consists of eight major operations. The feed mill considered in this case possesses vertical layout where the movement of materials is from top to bottom during the course of the operations. This system effectively utilizes the gravity phenomenon, which reduces unnecessary costs for movement.

2.1.1. Raw ingredient receiving

Feed mills typically receive incoming ingredients by both rail and truck. The primary raw materials, maize and soya are received separately using the rail and truck systems. Secondary raw materials are transferred through bulk trucks and pneumatically moved to the storage bins.

2.1.2. Raw ingredient distribution and storage

Screw conveyor is generally used in feed mills as it offers many advantages over other types of conveyors. Screw conveyors not only transport the materials very fast, but also additional functionality of accurate measurement of the ingredients during the transfer process. This leads to significant savings in the production time in the long run. If the raw materials are greater than 50 kg, bins are used for the purpose of storage. Otherwise, bins are not used.

2.1.3. Grinding

Grinding is a process used to ground irregularly shaped raw material particles to fine powdered substances. The advantage of grinding operation is that the finer particles produced in this stage helps in healthy mixing of the ingredients, thereby leading to the production of pellets with accurate formulation. Grinding mills are generally positioned under whole grain storage bins, in a separate apartment within the mill facility. Hammer mills are the most common type of milling equipment.

2.1.4. Batching

In order to produce specific feed combinations, certain materials must be transferred through batches to the mixer. This process is referred to as batching. This is an important operation before the mixing stage and requires all the raw materials to be batched in accurate proportions to manufacture good quality feed. Screw conveyors, which possess very good measurement control and scale hoppers, which are mounted above the mixers are used for this purpose. Bulk bag and hand dump stations are also used to add materials to the feed mix. Proper venting must be provided between the mixer and scale hoppers to maintain steady flow of materials to the mixers.

2.1.5. Mixing

Mixing is one of the important operations in a feed processing plant. The gap between the body of the mixer and the blades must be maintained as small as possible to produce uniform mixtures. Another factor to be considered in this process is the mixing time. Mixing times of 3–5 min are most commonly used to ensure even mixing. Mixing times do not hold much significance in our study as they are already optimal. Mash resides in storage until needed for mixing operation. Ribbon mixers vary in size and are widely used. They operate at a speed of approximately 40 rpm. At the end of the mixing operation, the output is mash. The mash feed size plays a significant role in the quality of feed and production time.