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SIMULATION AND SENSITIVITY STUDY OF POTATO FLAKE FOOD PROCESSING

Abstract

We made a sensitivity study of the potato flake process using the ERRC Food Process Simulator computer program with cost as the primary objective function. The study showed that labor was the largest component of the processing cost followed by capital related expenses. Pilot plant operation demonstrated the feasibility of reducing labor requirements. Capital related expenses could be minimized by using four drum dryers to more closely match the through put of the rest of the process. In addition, the drum dryers should be run as close to 8% moisture as possible without exceeding 8% to optimize the yield of finished product. This study demonstrates the feasibility of using the ERRC Food Process Simulator to do a sensitivity study of potato processing.

Compendio

Se llevó a cabo un estudio de sensibilidad del procesamiento de papa como hojuelas utilizando el programa computadorizado de Simulación Procesamiento de Alimentos ERRC con el costo como la función objetivo principal. El estudio mostró que la mano de obra era el componente más alto del costo de procesamiento seguido por los gastos relativos al capital. La operación de la planta piloto demostró la posibilidad de reducir los requerimientos de mano de obra. Los gastos relativos al capital podrían minimizarse utilizando secadores de cuatro tambores para adaptarse lo más cercanamente posible a todo el resto del proceso. Adicionalmente, los secadores de tambor deberán operar tan cerca de 8 % de humedad como sea posible, pero sin exceder el 8 % para optimizar el rendimiento del producto final. Este estudio demuestra la posibilidad de utilizar el Simulador del Procesamiento ERRC para efectuar un estudio de sensibilidad del procesamiento de papa.

Introduction

Cooking is truly an art form with individual cooks instilling their unique creative talents. We can think of food processing as industrialized

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cooking having its origin in the kitchen. However, the American consumer, indeed the world consumer, expects food processors to produce exactly the same food product each and every time. For example, with the growth of fast foods the world over, most consumers in developed countries expect fries to be identical whether purchased in New York or Japan. This is not an easy task for the processor. Raw materials vary; processes are dynamic. Typical variations occur in steam pressure, process flow rate, process temperature, feed material (composition, size, and physical changes), and the usual unexpected problems.

Before the non-technical community discovered system analysis, chemical engineers used it since the method is inherent to chemical engineering. Systems analysis of food processing may be defined as the study of the interaction of the individual unit operations and their impact on the whole process. We developed a computer program for process engineers to do a systems analysis of food processing (1). The computer program simulates individual unit operations and coordinates them into a whole. The program contains predictive models for a number of unit operations and allow users to add their own models, theoretical or empirical.

We have used a systems analysis approach to study the potato flake process. In this study we used the simulator program to do a sensitivity study of potato flake processing, with cost as the objective function.

Methodology

The Simulator program is designed to calculate the mass, energy, component (concentration), and cost balances for each unit operation and for the process as a whole. The program consists of an executive program and a battery of subroutines. Each subroutine contains the algorithm for one unit operation. There are 3 types of subroutines; non-unit operations, food process unit operations, and cost. The user only accesses the executive program. The program is user friendly and will prompt for needed information.

Non Unit Operations Subroutines—Although not really unit operations they are such in the context of this program. They are used to mix and separate streams. There are two special non unit operations subroutines for performing trial and error calculations - WEGST and TANDE. WEGST uses the Wegstein accelerated trial and error algorithm (2). In practice, a recycle stream is analyzed as two separate streams. One stream is the trial stream and the other the calculated stream for comparison. The two are compared and the trial stream adjusted either by the accelerated method or by direct substitution if the accelerated procedure leads to instability. The user sets the acceptable error to terminate the trial and error.

TANDE is slower but applicable when the trial and error procedure involves three streams. It uses proportion to adjust the trial. Use it when the trial stream is not the stream adjusted to satisfy the trial and error.

Food Process Unit Operations Models—Ideally we would have developed models for all unit operations encountered in food processing. However, to be practical, we used one process as a prototype to set up the methodology which can be expanded to other food processes. We used the potato flake process as the prototype and have models for that process. Of course, many of the models apply to other processes, especially other potato processes. Most are very simple requiring no theoretical development. A perfect example is the TRIM line. For a manual trim, the important parameters are the labor requirement and the fractional trim losses. Good records supply the best and most reliable data.

Some models required quite extensive theoretical development using process and feed parameters. They are water blanching and cooling (3, 4, 5), cooking (6) and single drum drying (7, 8).

COST Subroutine—We used conventional cost estimating techniques but applied them somewhat differently. The cost subroutine calculates only the costs the process engineer can affect - processing costs. The engineer can't change the tax structure or many of the other overhead costs even though they are important. Therefore, they are not in the algorithm.

We treat process costs like the other process variables (flow rate, enthalpy, component flow rate) and determine costs as $/hr for each stream. The potato feed stream is assigned a cost of $0/hr. Costs for the other input streams are determined by the costs to acquire those streams, *e.g.* steam or cooling water. The potato stream picks up the processing costs for each unit operation as it moves through the process. These process costs are those associated with each unit operation such as utilities, labor, and capital related expenses. The other exit streams, *e.g.*, steam condensate, may have value or a disposal cost. To determine the process cost to make the product, the process engineer would add the costs for all exit streams, which are not product streams which can be sold, to the cost for the product stream and add in the cost of the potatoes. (An exit stream which can be sold, maybe peels, would not be added to the product costs but actually subtracted as an asset). Selling price would then be determined from these costs plus the "overhead" costs not included in this program such as taxes and profit margin.

Results and Discussion

Investigating all possible nuances and tradeoffs of a process for systems analysis can be very extensive. We did a limited simulation study of our pilot plant potato flake process. Base line conditions were the normal processing conditions before any optization (7).

Table 1 lists the major unit operations in the pilot plant potato flake process. We will begin the discussion of the analysis with costs, using a Marshall and Swift Index (9) of 894.7 for the second quarter of 1989 as the basis. (The Marshall and Swift Index is a quarterly equipment cost index which

TABLE 1.—*Pilot plant potato flake process.*

High pressure steam peeler
Rod/reel washer
Trim line
Cutter
Vibro spray washer
Blancher
Cooler
Cooker
Drum dryer

accounts for the change in value of money over time. The index has a value of 100 for the year 1926. The index appears in each issue of Chemical Engineering). To demonstrate the analysis, we chose to recycle the effluent water from the cooler to the blancher and the effluent water from the vibrowasher to the rod/reel washer.

Commercial process plants require many people. Pilot plants have even higher labor costs per Kg of material processed. Our was no exception. Figure 1 shows that labor was responsible for most of the processing costs. (Raw material cost for potatoes is assigned no value). We replaced the trim line employing 5 people with a mechanical destoner and depended on the last spreader roll on the drum dryer to accumulate the waste for removal. This technique worked well with good quality potatoes. However, late in the processing season there was a noticeable increase in defects in the flakes. We reduced labor at the drum dryer from 3 to 1 persons and distributed the remaining labor more efficiently throughout the process resulting in reduction of labor from 10.5 to 3 people. Hourly labor costs decreased as shown in Figure 1 which compares the labor costs for the normal and modified pilot plant processes. Flake costs dropped from $4.31/Kg to $2.19/Kg.

Referring to Figure 2, where else can we save money? Water and electricity costs are relatively small. After labor, capital related expenses are next in importance. At this writing we see no way to reduce capital related expenses by deleting unit operations. However, an inspection of the product flow rates through the process showed the drum dryer to be the rate limiting step. We simulated adding drum dryers to the process until the drum dryer unit operation was not limiting. The unit price for flakes drops as we add dryers, Table 2. With four drums, the cooker becomes the rate limiting step necessitating using two cookers. Most commercial plants do use multiple drum dryers.

Referring to Figure 2, we have drastically reduced labor, dismissed consideration of water and electricity, added drum dryers to reduce capital-related expenses. The only factor left is steam. Table 3 gives the distribution of steam consumption using four drum dryers. There is not much we

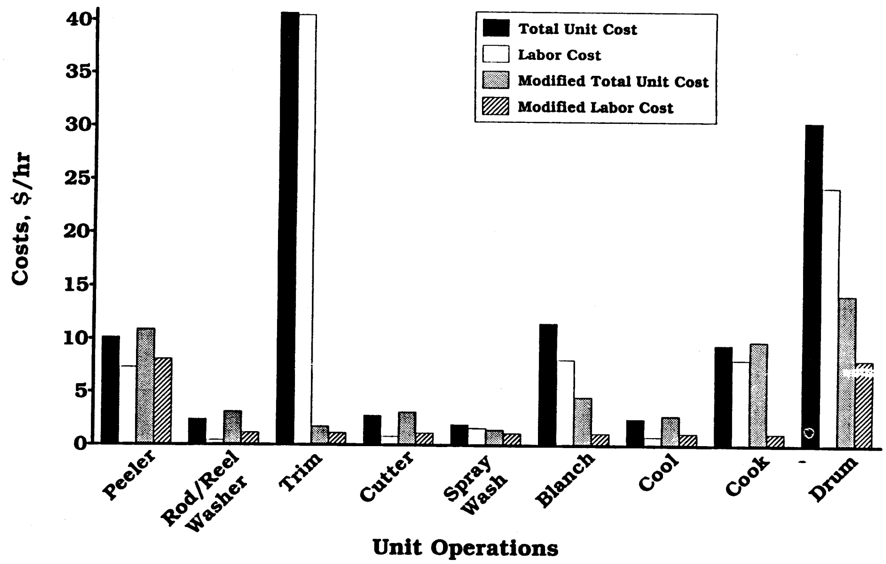

FIG. 1. Simulation of processing costs for the potato flake pilot plant process; normal and with reduced labor requirements.

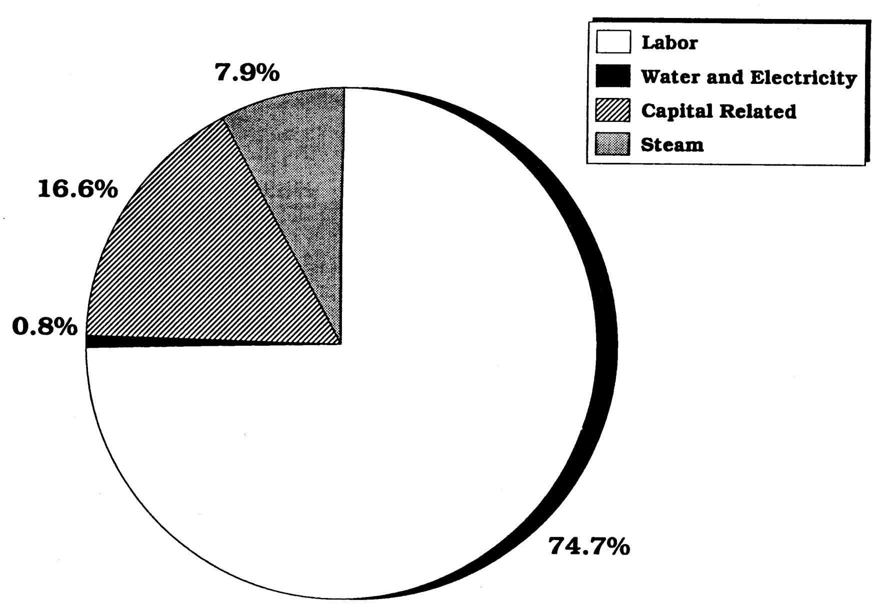

FIG. 2. Simulation of utility costs for the potato flake pilot plant process.

can do short of recovering waste steam. Steam losses to the atmosphere are not included in the program since they are specific to individual plants.

The more raw potato entering the plant that leaves as finished product the more profitable the process. Where are the potato losses in the process? Figure 3 graphically shows where potato losses are in the process. Most of the losses are peels removed by the peeler and rod/reel washer. Pilot plant losses of 25% in lye peeling were not uncommon. With the acquisition of a high pressure steam peeler, losses rarely exceeded 10%. Short of finding a market for these peels this is a nonrecoverable loss.

The other major source of potato loss is the blancher. This is a controlled loss. Sugars in the potato react with the amino acids to cause off colors - nonenzymatic browning (10). To minimize this, processors leach out some of the sugars at the blancher. Product quality dictates the amount of loss taken. When a new lot of potatoes comes on line the process engineer, using experience and judgment, adjusts the blancher (*i.e.* flow rates, temperature) to maintain the desired sugar level in the potatoes. The engineer could combine experience and judgment with the simulator and calculate, not only the "ideal" blancher parameters, but also see the effect on the rest of the process.

There is yet another subtle source of product loss - water. The water lost from the drum dryer is an economic loss. Hence it is advantageous not to overdry. Figure 4 illustrates the effect of flake drying in the plot of cost per kg of flakes versus the moisture content of the flakes. The practice in the industry is to dry to 7.5 - 8.0%. As shown in the plot of the simulation, it is best to dry as close to 8% as possible.

TABLE 2.—*Flake cost as a function of number of drum dryers.*

# Drums	Flake Cost, $/Kg
1	2.19
2	1.48
3	1.24
4	1.15

TABLE 3.—*Steam consumption.*

Unit operation	% Consumption
Cooker	57
Peeler	19
Drum dryers	18
Blancher	6

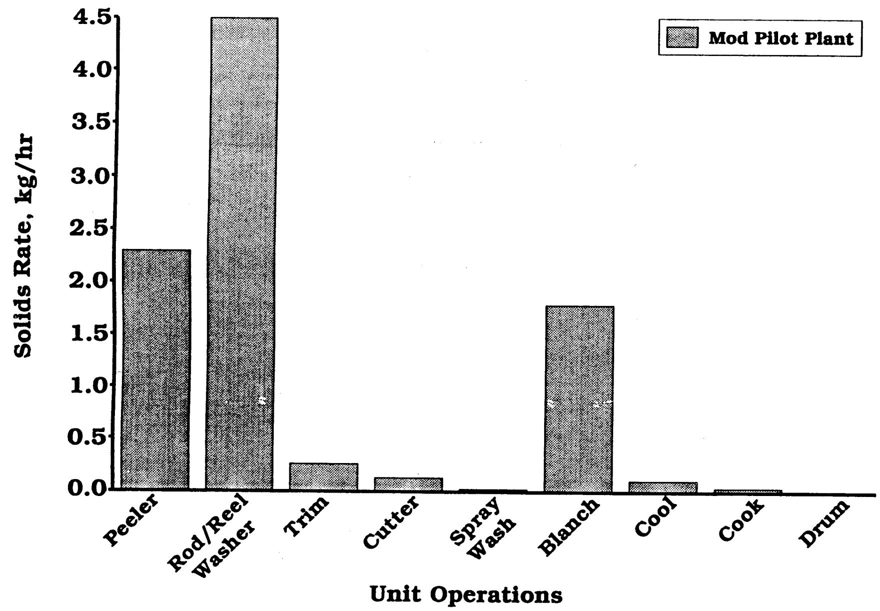

FIG. 3. Simulation of effluent from the potato flake pilot plant process.

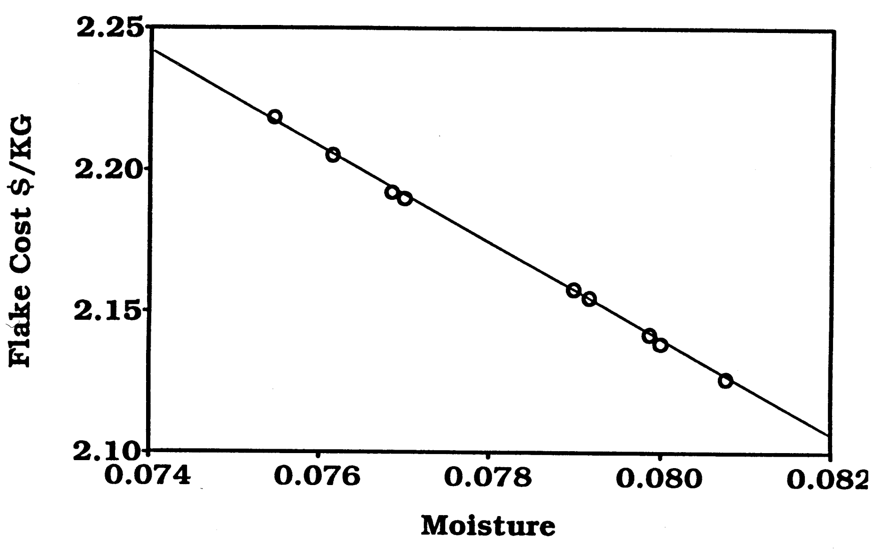

FIG. 4. Simulation of potato flake cost as a function of flake moisture.

Conclusions

The simulator program provides a convenient method for doing a sensitivity study of costs using a systems approach. Our study showed the greatest savings in making potato flakes can be achieved through labor saving strategies, optimizing the capacities of the process units, and drum drying as close as possible to 8% moisture.

Acknowledgment

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