Available online www.ejaet.com

European Journal of Advances in Engineering and Technology, 2020, 7(5):69-72

Research Article ISSN: 2394 - 658X

Direct Feed Production Line: An Innovative Approach to Connect Process and Packaging Operations in Food Confectionery

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ABSTRACT

Today's food processing and packaging lines are going through tremendous automation and technological advancement to match ever-growing and changing customer requirements while effectively and efficiently managing their operations by providing an innovative solution to reduce operational costs associated with labor, storage, and other similar factors. This theoretical study aims to provide a solution to the existing methods of running and managing a processing line along with a packaging line using the direct feed line approach. This will help organizations in the confectionery field to run their overall operations smoothly and efficiently by streamlining the use of available resources. This approach also leads to more scope of automation that can be introduced in line with human intervention to monitor the functioning of the lines. Cross-training on various sections of a direct feed line helps an organization use resources and be resilient to emergencies like a pandemic, where resources must be reallocated to keep the line operational.

Key words: *Direct feed line, kitchen, confectionery, deposition, candy, packaging*

1. INTRODUCTION

Food processing and packaging have been around in various forms throughout history. The current confectionery market and the OEMs that offer equipment to perform these tasks are focused on bringing a unified and streamlined approach to capture all aspects of an entire operation, i.e., processing and packaging, in a single defined linear state. The food processing industry uses various equipment and machinery to process and package food products. Food processing line solutions and equipment enhance food products' taste and shelf life while filling and packaging equipment are used to prepare food safely. The product flow inefficiencies can create a detrimental domino effect within your food and beverage business. When your processing "chain" has breaks and delays, it can cost money, waste time, jeopardize food quality, and introduce safety hazards on the production floor. The ultimate key to success is designing a linear plant so the product moves seamlessly downstream through each step without interruption. The ingredients used during the production runs are not consumed directly after being received in the facility; they are carried to storage or holding areas. These ingredients are transferred to the production line when called upon based on the production order and scheduling. The aim of an efficient process should be streamlining this process and using automation to reduce the need for storage and using innovative supply chain alternatives to use strategies like just in time, etc., to procure and receive material needed for specific production runs directly. The production areas where the processing and deposition occur should follow each other as it reduces the expense of resources to monitor the automation process closely through human intervention. The packaging and palletizing areas should take place in one location as it will eliminate the need to package the product and send it for storage. Then again, being brought to a different line to palletize. Having both operations together helps streamline the process of packaging and palletizing in a single shot. The finished products are then transferred to the warehouse for storage, and as the orders come through customers, they are moved to the distribution center for order fulfillment.

2. PROBLEM STATEMENT

Most of the traditional food processing and packaging companies have both operations run separately or in silos. Sometimes, they even outsource the packaging operations to outside co-packer companies to reduce the cost of operation, etc. When these two operations are run individually, it leads to the following problems-

A. Labor cost

This standalone process requires more labor to manage the finished after the processing line and before it goes to the packaging lines. The labor is needed to move finished products from the shakeout lines and store them in boxes or trays in the warehouse for further storage. The cost associated with managing the arrangement and movement of finished products from the production line to the warehouse incurs additional fees, adding to the overhead production cost.

B. Storage cost of finished goods

The storage space in the warehouse used for finished goods adds extra cost. This requires meticulous planning and scheduling, which sometimes turns into headaches as managing the product flow from the production line to the warehouse and vice versa turns complex. It also affects the shelf life of the finished products as they do not get packaged once produced. The finished product is only packaged once it is requested through demand planning.

C. Efficiency and flexibility

Owners must think about their packaging line holistically to ensure that every square foot contributes to overall efficiency, safety, and cost control. Another consideration is understanding how often you may want to run a line before a changeover or if you will need to switch out for different sizes frequently. Multiple SKUs that need to run on the same line may require equipment selection to handle various adjustments. Additional tool-less or high-speed changeover costs may be justified to support flexibility and minimize changeover durations.

3. PROPOSED SOLUTION

With the direct feed line approach, production operations like– processing and packaging can be connected and streamlined to provide end-to-end finished and packaged products to the warehouse and the customers without incurring additional operations and storage costs. The three primary individual operations are processing in the kitchen, deposition of cooked candy in tray molds, packaging finished products into bags/pouches, and eventually, in cartons and cases combined to run a smooth and streamlined operation. Table 1 explains the various systems and elements involved in the cooking process. Unlike any kitchen, multiple sections work in a sequence that is controlled through programmable logic control (PLC), also known as the brains of the kitchen, which specifies which ingredient is supposed to be dosed, what temperature the mixture is cooked, which valves to open to move products, which pump comes into operation to deliver product from one section of the kitchen to the another. The ingredients of the product are fed to the system through hoppers and in-line screw augers. These ingredients are then mixed using an agitator in a mixing tank. The mixing speed, adding individual ingredients, etc., are managed through the plc by opening and closing valves and pumps as per the program developed in the plc. Then, it moves to the cooking area, which consists of a cooker coil where the mixed product is cooked. Steam is used as a primary source for boiling the mixture. The process is managed through plc based on parameters like cooking speed and temperature. After cooking, the product is moved into the vacuum chamber/tank to remove air from the product. After this process, the cooked product is pumped through jacketed lines, which consist of dual-walled sanitary piping in which the product flows through the inner pipe. At the same time, hot water is run continuously between the first and second pipes to keep the mixture in a liquid state and prevent it from solidifying. The cooked product is then moved into the station, where colors, flavors, vitamins, and other ingredients are added to the mixture. After this point, the mixture is ready for deposition.

Table -1 Confectionery kitchen elements

Individual sections	Purpose
Ingredient delivery system	This system aims to introduce raw ingredients into the processing of candies like jellies, gummies, or hard candy. It consists of hoppers, in-line screw augers, and pallet delivery systems.
Batching system	This system is responsible for mixing all the ingredients used in the cooking process of candy manufacturing. It includes agitator mixers mounted on tanks supported through load cells to accurately capture each batch's weight and ensure the ingredients are dosed in the correct quantity.
Cooking system	This consists of a stainless-steel coil cooker that uses steam as a fuel to cook the raw ingredients. Several critical control points are utilized to monitor this intricate cooking process, like the cooking speed, cooking temperature, back pressure, and vacuum pressure.
Vacuum system	The section consists of vacuum chambers/tanks that remove air particles from the processed/cooked candy and help deposition clear candy as much as possible.
Blending system	This section includes additional tanks and an injection system that helps introduce ingredients, like color, flavors, vitamins, etc., to the cooked candy mixture.

Table 2 explains the depositing process involved in this direct feed line approach. The cooked product from the kitchen is deposited into the molded cavities of the trays using a depositor pump. The trays with fresh liquid candy are then stacked on pallets through the stacker section of the machine. The pallet of trays is then moved into the curing room, an enclosed area exposed to heating and cooling cycles to solidify the liquid candy in the trays. After the cycle is completed, the pallet of trays is taken out and fed into the feeder section of the machine. The solidified candy in the trays is then emptied at the turning station. The empty trays are again circulated in the same machine with the filling of new molding ingredients, which is used to imprint the cavities using a stamping station. The finished product is taken out of the machine simultaneously using a goods-carrying conveyor.

Table -2 Confectionery depositing elements

Individual sections	Purpose
Feeder area	This section introduces the trays with the final processed candy from the curing areas into the machine.
Tray turning area	This section is responsible for unloading the finished candy from the existing tray and re-introducing the molding agent into the tray for a fresh batch of liquid candy to be deposited into it.
Filling area	This section is responsible for filling the molding ingredient into the empty trays. This consists of a screws and auger system that moves molding material from the conditioning system to the machine.
Printing area	This section of the machine is responsible for creating mold cavities using a print board. This process is controlled through pneumatic controls.
Deposition area	This section consists of a depositing pump, which receives cooked candy from the kitchen through a hopper and deposits it into the molding cavities of the tray.
Stacker area	This section stacks all the deposited trays on a pallet.
Curing area	This area is where all the freshly deposited trays are stored and introduced to the heating and cooling cycle to solidify the candy.
Conditioning, augers, and sifter area	These auxiliary systems support the overall deposition machine by ensuring the molding ingredients in the tray are maintained at the correct temperature and moisture level so the molds are shaped correctly in the trays.

Table 3 explains the shakeout system responsible for removing the finished product from the depositing machine and moving to the next operation phase. The finished product is transferred to an oiler or sanding machine that introduces oil or sugar ingredients, providing a glossy finish to the candy. Then, it is moved to the sorting system, segregating the defective candy pieces based on shape and size. In a traditional production line approach, after this step, the finished product is stored in a tray and moved to the warehouse for further storage. As per the new direct feed line approach concept, this step is connected to the packaging operation through conveyors and bucket elevators that carry the finished products to the scales.

Table -3 Shakeout system elements

Individual sections	Purpose
Finished product takeout conveyor	This system consists of multiple conveyors that move finished candy from the machine to the next phase.
Oiling/Sanding area	This area consists of an oiler or sanding machine that provides a glossy finish to the candy or adds sugar confections on the candy's surface based on the manufactured product.
Sorting system	This unique system is responsible for sorting finished candy from the detective ones based on shape and size.

Table 4 explains the packaging operations that are the second section of the direct feed line approach. The finished product is introduced to the scales designed to make combinations using different pieces of candy to satisfy the weight limit set into the scale program as per the product desired to be run on the line. The combination of this finished candy is then dropped into a vertical bagger machine that makes pouches using the plastic film that is fed into it. This vertical bagger consists of a metal detector installed right before the candy is transferred to the bagger machine to detect any metal contamination during the previous steps. The pouches/bags are made and sealed with the candy, then moved to the next operation through conveyors. The pouches are then introduced to the sales, feeding a carton machine and filling boxes and bags. The boxes were then moved to the casing machine that put these inner boxes into an outer carton and closed them. The cases are arranged on pallets and wrapped using a robot palletizing system. The wrapped pallets with casings are then moved to the warehouse for storage. These pallets are transferred to the distribution center for order fulfillment based on the customer's order.

Table -4 Packaging system elements

Individual sections	Purpose
Scales	The finished candy is introduced into the scales, which can make combinations of individual pieces based on the weight limit setup for each bag.
Metal detectors	This equipment detects any metal contamination before the finished product is introduced into the bags for sealing.
Timing hoppers	This equipment is responsible for introducing the combination of the finished candy into the bags and ensuring that multiple combinations are not introduced in the same bag.
Vertical bagger	The vertical baggers are the machines that make pouches using plastic film and seal them after the candy is introduced into these bags through the forming tube. The vertical baggers have multiple sub-sections, such as printers, feed for film, cutting section, sealing section, etc.
Car toning	After the candy pouches/bags are made, they are moved to the scales for the cartooning machine using a conveyor system. This machine introduces blank box cartons and forms them into boxes using the pocket brackets. The pouches are then introduced into these boxes, which are closed and glued together.
Case packing and palletizing	These boxes are then moved to a casing machine that puts them into the outer carton and arranges them on pallets using robots. The pallets are then stored in the warehouse and moved to customers per the orders.

4. CONCLUSION AND FUTURE SCOPE

The use and application of the direct feed line concept in an existing or a new production setup in the food confectionery industry can lead to streamlining the overall process of processing and packaging finished products. The various elements in the individual processes can seamlessly be linked with one other to offer automation. They can be managed and monitored efficiently through human intervention, one of the critical aspects of the industry 5.0 revolution. It helps organizations reduce production costs and storage costs of finished goods and drives them towards lean manufacturing principles of running lines with higher efficiency to produce and deliver products as per the customer demands. This also helps an organization eliminate the issue of the shelf life of finished products that are stored in the warehouse. Some additional benefits of this approach are maintaining the uniformity of products, higher standards of a safe working environment, optimization of resources, and providing flexibility to production runs. Using PLC and other monitoring software can provide additional tools to maintain the accuracy of the processes and reduce the chances of error, as it would lead to production loss and equipment failure.

A few challenges and copes that can be researched in this area include setting up contingencies in case one of the links in the direct feedline is out of operation, as it would disrupt the whole operation and affect production. As stated in the industry 5.0 revolution, the digital twin concept can serve as an opportunity to set up systems to overcome these contingencies.

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