

Application Example

Extruded Breakfast Cereal Manufacture

Background

Today's global breakfast cereal manufacturing industry continues to grow in revenue. Due to an anticipated increase in population and a corresponding increase in the consumption of Ready to Eat (RTE) breakfast cereals in emerging markets such as China and India, manufacturers of these products are searching for efficient and reliable methods of manufacture. The completely integrated material handling, feeding and extrusion systems supplied by Coperion K-Tron and Coperion ensure the optimum in accurate, cost efficient and safe process design.

Coperion K-Tron highly accurate feeders and pneumatic conveying systems are used for transfer, weighing and feeding to the mixer and/or the extrusion step. In addition, Coperion provides food components that fulfill the highest demands in hygiene, easy cleaning and gentle product handling. Coperion high efficiency extruders are used for the production of a variety of cereal types, including cold formed pellets for flaked cereal, direct expanded and coextruded cereals, as well as puffed cereal types. Innovations in material handling and extrusion for RTE cereal manufacture are an integral part of the overall Coperion systems solution.

Batch vs. Continuous

Traditionally breakfast cereal manufacture has been done using batch processes, with transfer of ingredients to a mixer and then to high pressure rotating cookers. The time, temperature and speed of rotation of these cookers can vary with the type of cereal grain being cooked. This batch cooking process can often be a long part of the overall process time, thus resulting in extended manufacturing runs.

Recent technological advances in RTE cereal manufacture fea-

ture continuous processes using twin screw extruders and highly accurate loss-in-weight feeders. The combination of these technologies can considerably decrease the cooking and overall process time. In some cases the preblending step can be eliminated altogether, using the feeders to accurately dose each component of the recipe direct to the extruder.

Ingredient Transfer to the Process

Major ingredients such as grains (corn, wheat, oats, rice and barley) can arrive at the plant in a variety of forms, including railcar, truck and bulk bag systems. These major ingredients are usually stored in specialized silos and then conveyed to the specific weigh batch stations as required for the blend. PLC systems featuring recipe control of multiple ingredients can easily be integrated into this transfer system, in order to allow maximum flexibility for the system.

In addition, specialty design options on the silos and conveying lines can be incorporated to avoid such hazards as moisture and changes in product temperature when entering the plant. These options can include desiccant dryer systems and/or use of heaters on silo fluidizers and system blowers.

Conveying Ingredients: What Method is Best?

Regardless of the type of extrusion required, the transfer of raw materials from a variety of sources can be critical to overall production times and efficiencies. The arrival and transfer of major ingredients to a cereal production line can include a number of different types of conveying systems. The mode of transfer of ingredients is dependent upon a wide variety of process parameters, including material characteristics, distance to be transferred, required rate of transfer, and the



type of container in which the ingredient is originally received. Pressure Differential (PD) trucks and railcars use positive pressure to unload material, whereas other types of delivery to the batching step of process can often be done by either positive pressure or vacuum pneumatic conveying, or a combination of vacuum and pressure conveying.

Dilute Phase Transfer: Vacuum vs. Pressure

Depending upon the volumes required, other possible sources of ingredient delivery include boxes, sacks, bulk bags or super sacks. In all of the ingredient transfer steps, pneumatic conveying systems can be used to transfer these ingredients. These systems can utilize either positive or negative pressure dilute phase conveying. Positive pressure conveying systems are typically used to transport product over long distances and at high throughputs. Applications which involve pressure conveying often include loading and unloading of large volume vessels such as silos, cyclones, railcars, trucks, and bulk bags.

Conversely, vacuum (negative pressure) systems are often used for lower volumes and shorter distances. One of the advantages of vacuum systems is the inward suction created by the vacuum blower and reduction of any outward leakage of dust. This is one of the reasons why vacuum systems are often used in dust containment applications. Another advantage



Coperion K-Tron weighing technology provides accurate feeding of valuable ingredients

of vacuum systems is the simple design for multiple pickup points. It should be noted, however, that the distances and throughputs possible with a vacuum system are limited due to the finite level of vacuum that can be generated.

Rotary Airlocks with Easy Clean Design

In either of these types of ingredient conveying applications, Coperion high efficiency and easy clean rotary airlocks are utilized. These airlocks can be provided for blow through systems or for discharge valves at the bottom of silos or feed bins.

These specialty valves include options for EHEDG certification and ATEX versions, as well as quick clean designs for both dry and wet cleaning to ensure quick turnaround times during product changeovers. In addition, the expanded inlet design ensures high capacities with minimal bridging. Operating pressures as high as 1.5 bar can be achieved, with low gas leakage rates for use in the pneumatic conveying systems outlined above.

As an added benefit for food safety, Coperion rotary valves

Extruded Breakfast Cereal Manufacture

can also be equipped with the innovative Rotorcheck design option, which can detect metal to metal contact between the rotating blades and valve housing, as a function of electrical resistance between the rotating vanes and housing.

Screening and Sifting Operations

In-line or off-line screeners are often used during the raw ingredient transfer process

for the removal of foreign materials prior to introduction into the conveying line. They can also be integrated directly into the conveying line for additional conditioning of the ingredient powder. This sifting method is also used at the end of the process for the proper scaling/sizing of the finished product prior to packaging. Sifters and screeners are an integral part of the overall material handling system for reliable product quality and safety, and are eas-

ily integrated into the overall system design by Coperion and Coperion K-Tron system engineers.

Batching to Mixers

When using a premix process prior to the extrusion step, the ingredients are usually delivered to the batching station after transfer from the material source. This station can include volumetric metering devices, such as screw feeders or valves, which deliver the product to a hopper on load cells. This method is called Gain-in-Weight (GIW) batching.

Alternatively, the station can include gravimetric feeding devices, such as screw or vibratory feeders, mounted on load cells or scales which deliver the product to the process by means of Loss-in-Weight (LIW) feeding. In some cases where small amounts of micro ingredients are required for a total overall batch, both methods are employed: LIW feeders for the micros and minors, and GIW batchers for the major ingredients.

When designing for a batching system, it is important to discuss all aspects of the design requirements, including the expected changeover and cleaning times, as these options can greatly affect the overall system cost, ingredient accuracy and total batching times.

(Note: For more detailed information on all batching techniques prior to mixing see Application Sheet A-800311)

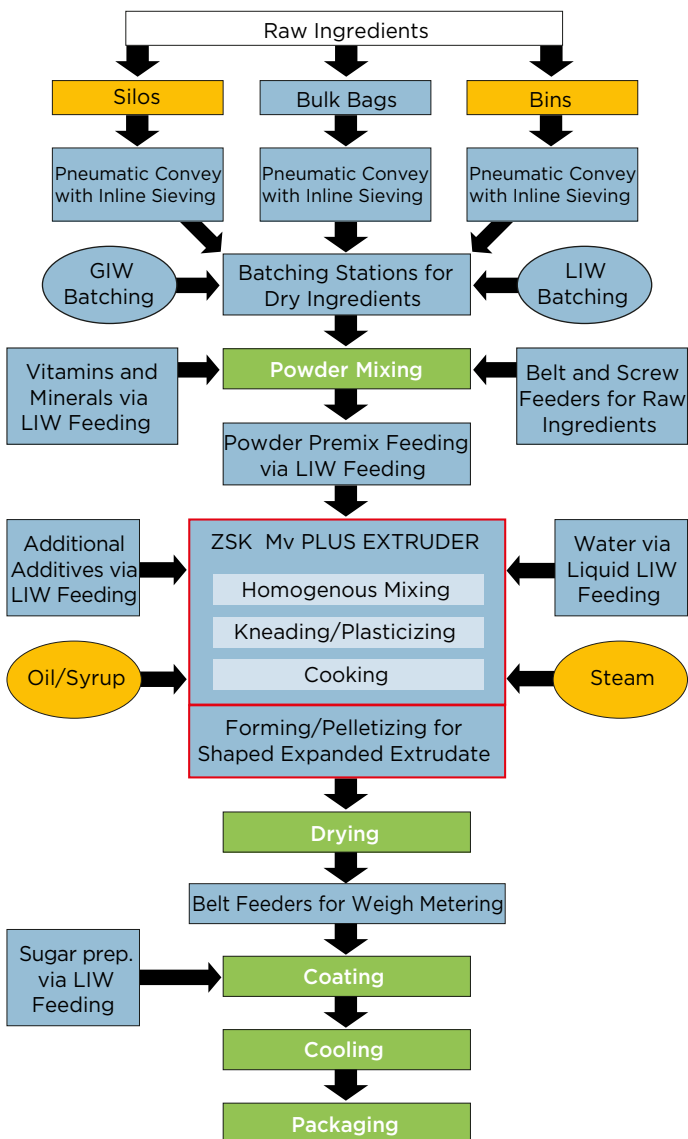
allows for unlimited numbers of ingredients regardless of space issues which may result from clustering multiple feeders around an extruder inlet. However, use of the individual ingredient feeders eliminates risk of segregation of blended product, eliminates added cost and time of the mixing step, and results in higher productivity in the case of fewer dry ingredients and additives.

Regardless of the method chosen, feeding and proportioning of the preblends or the individual ingredients to the extrusion process are crucial to the product quality and process efficiency. At any stage of the production process undetected feed rates and proportioning errors waste ingredients and add to overall ingredient costs. In addition, the ability to accurately measure and track such ingredients as salt, probiotic or vitamin content is of utmost importance when listing ingredients on product labelling.

Today, more and more breakfast cereal manufacturers are using highly accurate Coperion K-Tron gravimetric feeders to improve process efficiency and product quality. The added integration of the feeding system directly above the Coperion extruder by our experienced system engineers ensures that the feeding, refill and extrusion steps all operate consistently, resulting in a higher quality end product.

Loss-in-Weight Feeding Principle

Coperion K-Tron screw feeders can be supplied in either volumetric or gravimetric designs. However, due to the high accuracy requirements of feeding in continuous extrusion or blending processes, the gravimetric feeding principle via loss-in-weight feeding is mandatory. For example, when feeding materials with high variations in bulk density, volumetric feeders can have relatively high fluctuations in feed rate due



Process Flow: equipment for all process steps in blue are manufactured by Coperion / Coperion K-Tron. Equipment for all process steps green/yellow can be supplied as part of a complete system.

Feeding Ingredients to the Extruder

Ingredient dosing to the extruder via loss-in-weight feeders can be handled either by addition of the premix as stated above or using separate feeders for each individual ingredient. It should be noted that each method can offer specific process advantages. For example, the preblend operation

to fluctuations in the filling of the screws. This fluctuation in feed rate results in inconsistencies in material delivery to the extruder below, thus resulting in variations in end product quality. In the case of cohesive materials, it is possible in volumetric mode to have relatively no material discharging while the screws are running, due to bridge building or packing in the hopper. Since the feed rate in a volumetric feeder is purely a function of screw speed, the feeder, and the mixing process below, have no way of detecting this error. Often even the use of level sensors in the feed hopper may not alert the process of this upset in a timely fashion, and off-spec product may result for a period of time.

Coperion K-Tron's gravimetric feeders utilize load cells with state-of-the-art SFT technology to constantly measure the weight of product delivered to the process below. Loss-in-weight feeding affords broad material handling capability and thus excels in feeding a wide range of materials from low to high rates. In operation, the entire feeder, hopper, and material are continuously weighed, and the feeder's discharge rate (which is the rate at which the

feeding system is losing weight) is precisely controlled to match the desired feed rate. With this technology, a constant mass flow is ensured, thus also ensuring for consistent product output from the extruder.

LIW Feeder Refill

The mode of refill of product to a LIW feeder that is feeding a continuous process (e.g. blending or extrusion) can be almost as critical as the feeder technology itself. Since the objective of feeder refill is to refill as quickly as possible, pneumatic receivers which operate under a dilute phase vacuum transfer principle are often used as refill devices. The pneumatic system utilizes vacuum to draw the material required to refill into a separately mounted and supported vacuum receiver. The receiver is filled to a set level and then holds this material charge until the feeder below requests a refill. The level of fill in the receiver is determined by level sensors. Upon refill request from the feeder below, the discharge valve opens and the receiver contents are discharged into the feeder hopper. While the receiver is discharging a gas pulse is sent through the filter mounted inside the vacuum

receiver, in order to release any entrained particulate or material which may have settled on the filter.

After dumping the material into the feeder hopper below, the discharge valve is closed and then the fill cycle immediately begins, in order for the receiver to be ready for the next refill request. The material source can be bags, drums, IBC's, supersacks, bins or silos.

This series of sequenced "fill and discharge" steps is also known as vacuum sequencing. In all cases it is critical that the overall sequencing of the material pickup and delivery process be coordinated, so as not to interfere at all with the accurate delivery of the LIW feeder to the end process.

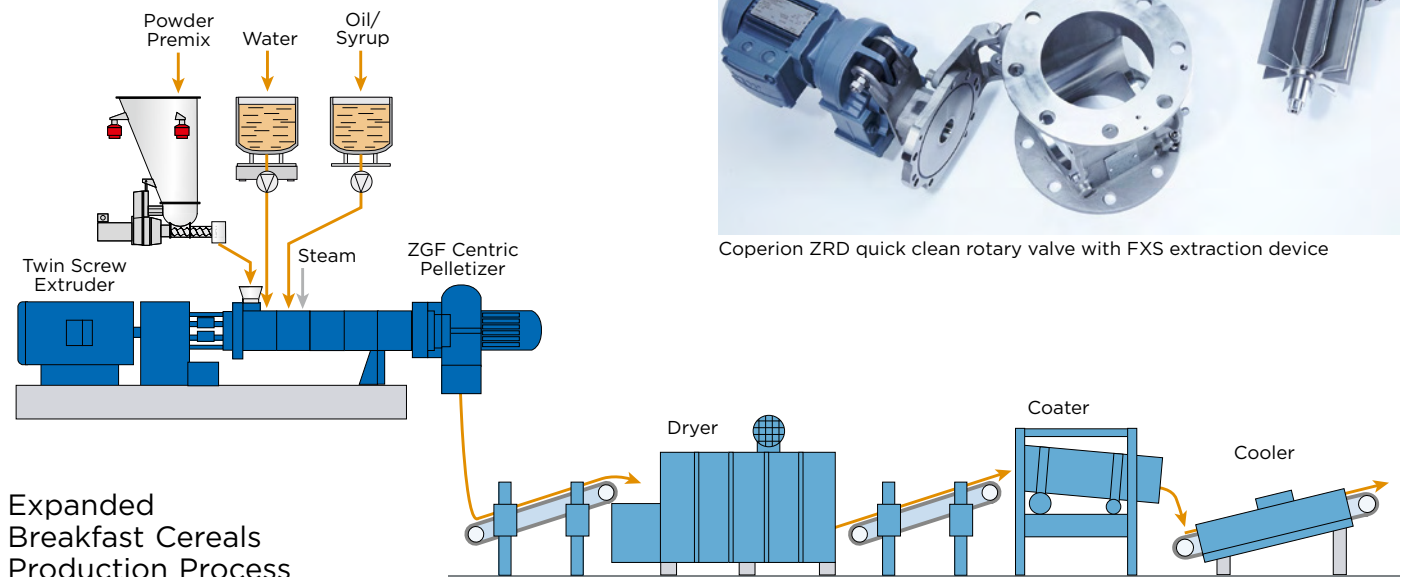
the process complexity and the amount of feeding inlets required for raw materials the process length can vary between 16 L/D and 28 L/D (L = screw length, D = screw diameter). Each barrel is about 4 L/D which means that 4 to 7 barrels are necessary to design a proper process.

The barrels and screws are designed as a modular system which offers the possibility to set up a custom configuration tailored to the process requirements. All materials of construction which are in direct contact with the product conform to food standards and are resistant to abrasion and corrosion.

For processing direct expanded breakfast cereals the typical process steps are shown in the process diagram on page 2. First the premix of solid ingredients (mainly based on starch or flours) is fed via Coperion K-Tron LIW feeders into a hopper fixed above an open barrel of the ZSK extruder. Usually these raw materials have a bulk density between 0.2 and 0.7 kg/dm³, making them difficult to feed. Coperion's twin screw extruder series ZSK MEGA-

Extrusion of Direct Expanded Breakfast Cereals

Twin screw extrusion is well known to be a suitable High Temperature Short Time (HTST) process for direct expanded breakfast cereals. Depending on



Coperion ZRD quick clean rotary valve with FXS extraction device

Extruded Breakfast Cereal Manufacture



volume PLUS with D_o/D_i (outer to inner diameter) of 1.8 is the twin screw extruder with the highest free volume on the market. This enables our customers to run higher throughputs than on other machines with similar screw diameters.

After the premix is fed into the process section of the ZSK extruder one or more liquids are injected. Typically water is added to achieve a total moisture content of about $20\% \pm 5\%$ (moisture of raw material plus added water). The water is necessary for starch gelatinization. Furthermore, liquid sweeteners or flavors can be added.

The performance of the extruder strongly depends on the feed rate of both the solid and the liquid raw materials. The extruder is generally referred to as the "slave of its feeders". It depends on consistently reliable feeding equipment to supply a constant flow of material. Gravimetric loss-in-weight feeders are state-of-the-art and are in most cases the best choice for a continuous extrusion process.

After all ingredients have been fed into the extruder, they must be mixed homogeneously. Usually this can be done by one or more mixing zones, which consist of combinations of different types of kneading blocks. Depending on the raw materials, special mixing elements might also contribute to a satisfactory result. During mixing the product is also sheared, which adds mechanical energy and increases product temperature.

Next the mixture is plasticized and gelatinized within a shear-intensive cooking zone. This step can also be described as "shear-assisted melting" which is defined by process parameters as well as the recipe of the product.

Within this zone, combinations of elements are used which cause high mechanical energy input. Pressure, shear forces and temperature increase lead to a plasticized starch matrix.

After a total residence time of a few seconds up to one minute (depending on the length of process section, screw speed, screw configuration and throughput) the material is pushed through the orifices of the die plate. Due to the immediate decrease in pressure the water within the plasticized mass evaporates and forms bubbles. The product strands expand and the resulting steam dries the surfaces.

Now the strands can be cut by using the Coperion centric food pelletizing system ZGF. The size of the extrudate can be adjusted through the selection of the number of knives and the rotational speed. Usually the product is pneumatically conveyed to the next processing step (e.g. drying).

Coating the Cereals

After the drying or baking step, additional coatings may be added to the breakfast cereal product. These coatings can be both in the form of powder blends (such as in dry mixed coatings) or liquids (such as in coatings which include both liquid flavorings such as sugar, honey, or even liquid vitamins). In both of these coating types, Coperion K-Tron liquid and powder feeders are used to deliver the precise amount of coating to the RTE cereal product. Coatings are usually sprayed on the product in coating drums or simply delivered to the product on a conveying line below.

In the case of the coating drum, Coperion K-Tron weigh belt

feeders are used to deliver the uncoated cereal to the drum. The weigh belt feeder totalizes the cereal throughput and provides a real time weight based flow rate signal used to accurately proportion the spray rate of the liquid loss-in-weight feeder coatings.

Proportioning of Multi-Component Cereal Blends

In the production of multi-component cereal blends such as muesli or cereal flake mixtures with oat flakes, raisins, nuts and/or sugar, Coperion K-Tron weigh belt feeders are used to ensure the accurate proportion and desired ratio and rate. The use of these highly accurate devices ensures product quality and has proven to be an added benefit in overall ingredient cost savings.

Continuous or batch proportioning systems employ component feeding devices appropriate to the individual ingredient handling requirements. Coordinated proportioning is achieved through centralized recipe control or via programmed master/slave relationships between each of the ingredient feeders.

For example, if one ingredient is an extruded breakfast cereal (e.g. corn flakes), the mass flow rate is normally measured by a weigh belt meter and the other ingredients are fed in the correct ratio, as defined by the recipe, onto a belt or vibratory conveyor which is installed after the weigh belt meter.

If no extruded breakfast cereals are used, all ingredients are fed directly in the correct ratio, as defined by the recipe, onto a belt or vibratory conveyor.

Coperion Advantage

- Complete systems design integration of the breakfast cereal manufacturing process for one source supply.
- Global systems engineering group with extensive application experience for the entire breakfast cereal processing line ensures optimal design with an emphasis on product safety, quick product change-over, and increased efficiency.
- The Coperion K-Tron line of feeders provides for the highest degree of accuracy in ingredient and product delivery in order to optimize ingredient cost savings.
- Use of the Coperion line of high efficiency ZSK MEGA volume PLUS extruders ensures maximum throughput.
- Innovative, custom engineered Coperion rotary and diverter valves ensure reliable, long-term and safe operation.
- Highly accurate extruders, feeders and pneumatic conveying components designed to meet highest hygienic requirements.
- Extensive material handling knowledge in a wide variety of ingredients by the engineers at Coperion and Coperion K-Tron ensures the most efficient means of product transfer.
- Superior global service network to ensure 24-7 support and coverage of your complete breakfast cereal processing line.

Main offices:

Coperion GmbH
Compounding & Extrusion
Theodorstrasse 10
70469 Stuttgart, Germany
Tel.: +49 (0) 711 897-0
Fax: +49 (0) 711 897-3999

Coperion GmbH
Materials Handling
Niederbieger Strasse 9
88250 Weingarten, Germany
Tel.: +49 (0) 751 408-0
Fax: +49 (0) 751 408-200

Coperion K-Tron Salina, Inc.
606 North Front St.
Salina, KS 67401, USA
Tel +1 785 825 1611
Fax +1 785 825 8759

Coperion K-Tron Salina, Inc.
Sewell Office
590 Woodbury-Glassboro Rd
Sewell, NJ 08080, USA
Tel +1 856 589 0500
Fax +1 856 589 8113

Coperion K-Tron (Switzerland) LLC
Lenzhardweg 43/45
CH-5702 Niederlenz
Tel +41 62 885 71 71
Fax +41 62 885 71 80