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BEST COMPONENTS & BETTER SYSTEMS

THE RECIPE FOR PERFECT FOOD

Application Example

Feeding, Material Handling and Extrusion in the Manufacture of Meat Analogues

Introduction

Today's increasing global population and rising middle class in emerging markets such as India and Asia have led to an increase in demand for meat consumption while more mature markets such as Europe and the Americas are seeking alternatives to animal protein due to both health awareness and the changing economy. As a result there is an increased interest in plant-based ingredients and consumption of vegetable derived proteins.

Texturized vegetable protein (TVP) – also known as textured soy protein or soy meat – and high moisture meat analogues (HMMA) produced by high moisture extrusion cooking (HMEC) are examples of alternative protein sources, which are not only less expensive but also environmentally friendly. Other advantages of TVP and HMMA include longer shelf life and low fat content.

Coperion, headquartered in Stuttgart, Germany, has had a long working relationship with the German Institute of Food Technologies (DIL) in Quakenbrueck, Germany (www.dil-ev.de). One focus of the cooperation is the research and further development of TVP extrusion technology and the HMEC of textured protein concentrate into a vegetable meat substitute. This application sheet outlines the TVP and HMEC processes, developed initially in a pilot plant and now implemented on a production capacity level , and also describes the technologies involved.

Application and Process Details

Two very different product families of extruded meat analogues have established themselves in the market. For the best results, the production of both types of meat analogues generally involves a co-rotating twin screw extruder, such as Coperion's line of ZSK extruders. As the main raw materials in both cases are vegetable protein concentrate powders and water, the set-up for the material handling and feeding process is similar but differs in proportion. The two process flow diagrams on page 3 show the individual process steps.

Delivery of Vegetable Protein Powders to the Extruder

As an alternative to the direct feed of the protein concentrate to the extruder as shown in the process flow diagrams, in some cases the vegetable flour is mixed with a variety of other ingredients prior to extrusion. In either case, transfer of the blend or the raw ingredients can typically be done via vacuum conveying to a receiver for continuous refill of a loss-in-weight-feeder above a continuously working extruder. This automated handling of the refill ensures consistent flow to the loss-in-weight feeders and thus improves the process quality.

(Note for more details on material handling and ingredient batching processes see Application Sheets A-800310, A-800311, and A-800316)

Conveying Ingredients

Regardless of the type of meat analogue/meat extender, the transfer of raw materials from a variety of sources can be critical to overall production times and efficiencies. The arrival and transfer of dry ingredients to a 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. It is important to note that optimization of the material handling system, particularly with difficult flowing powders such as proteins, is critical for the overall process. The systems engineers at Coperion and Coperion K-Tron have extensive experience with such materials and will ensure that all required options will be recommended to ensure uninterrupted material flow.

Coperion ZSK twin screw extruder with Coperion K-Tron twin screw feeder

Pneumatic Transfer – Vacuum vs. Pressure?

Depending on the volumes required, possible sources of raw ingredient delivery include boxes, sacks, bulk bags or super sacks. In all of the ingredient transfer steps, pneumatic conveying systems can be used. These systems can utilize either positive or negative pressure dilute or dense phase conveying.

Positive pressure conveying systems are typically used to transport bulk materials 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 higher sanitary or dust containment applications. Another advantage of vacuum systems is the simple design for multiple pickup points. However, the distances and throughputs possible with a vacuum system are limited due to the finite level of vacuum that can be generated.

Feeding Ingredients to the Extruder

It should be noted that accurate and continuous feeding of the bulk vegetable protein as well as water and other possible liquid components and steam

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to the extrusion process is crucial to the product quality, process stability and reliability. At any stage of the production process undetected feed rate and proportioning errors waste ingredients and add to overall ingredient costs. For example, within the very sensitive high-moisture extrusion process, feeding inaccuracy can easily cause shut-downs of the line, so that the extruder and special die head which creates the fibrous material characteristics need to be cleaned and restarted again.

In order to avoid these issues, meat analogue and extender manufacturers are standardizing on highly accurate Coperion K-Tron gravimetric feeders to improve process stability and reliability and to ensure consistent product quality.

Loss-In-Weight Feeding

When designing a continuous extrusion line, accurate delivery of the individual ingredients to the extrusion process is critical to process stability and product quality. For this reason, highly accurate gravimetric feeders are the feed method of choice, since they measure the weight of the material being fed and adjust feeder output to maintain the desired set point. Volumetric feeders do not weigh the flow; they operate by delivering a certain volume of material per unit time from which a weight-based flow rate is inferred by the process of calibration.

The most popular type of gravimetric feeder used in continuous processes is the loss-in-weight (LIW) feeder. LIW feeders are typically either mounted on weigh scales or suspended on load cells. The Coperion K-Tron load cell is a highly accurate instrument, designed specifically for the rate and accuracy requirements of dynamic feeding, and features a resolution as high as 1:4,000,000 in 80 ms. A LIW feeder consists of a hopper and feeder that are isolated from the process so the entire system can be continuously weighed.

As the feeder discharges material, system weight declines. The speed of the metering device is controlled to result in a per-unit-time loss of system weight equal to the desired feed rate.

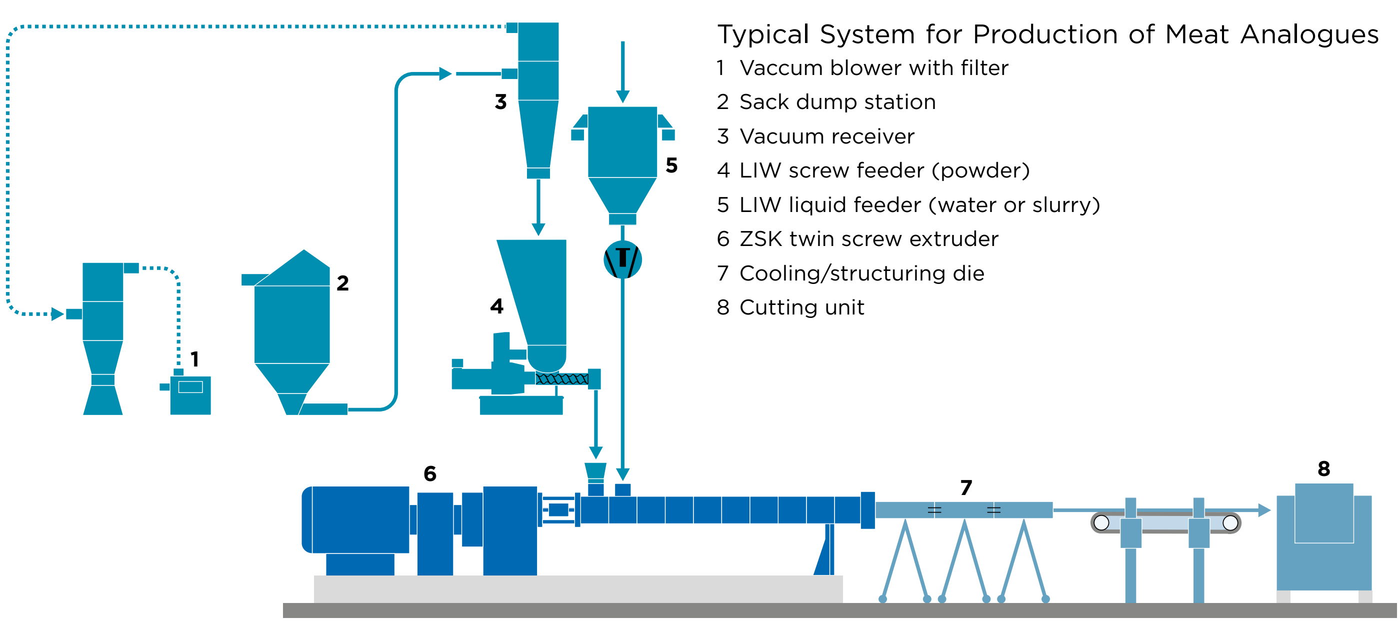
Coperion K-Tron consistently strives to provide innovative solutions for a wide variety of food processing applications, with an emphasis on efficient material handling techniques for even the most difficult to handle ingredients. Many food ingredients, such as protein-based powders, have very poor flow properties, making them difficult to handle and deliver accurately to the process. These material characteristics can cause bridging and ratholing in feeder hoppers and affect overall performance.

To address these issues and improve the ease of cleaning the feeder and hopper, Coperion K-Tron has developed the ActiFlow® bulk solids activator, a smart flow aid device which operates in conjunction with the LIW feeder controller and its load cells.

ActiFlow eliminates the need for traditional vertical agitation or flex wall agitation in LIW feeders. This unique device eliminates head-room concerns, reduces cleaning and product change-over times and in turn lowers overall production labor cost. It works in conjunction with the LIW feeder controller and digital weighing system to determine by weight when a change in material flow is occurring, before it becomes a problem. Once the ActiFlow controller detects a potential problem with material flow, vibration is applied to the hopper and is continually adjusted to get the material moving efficiently without impacting feeder performance. In addition, it avoids compaction of the ingredient and ingredient blend because only the necessary amount of vibration is applied to the material to assure uniform material flow.

LIW Feeder Refill

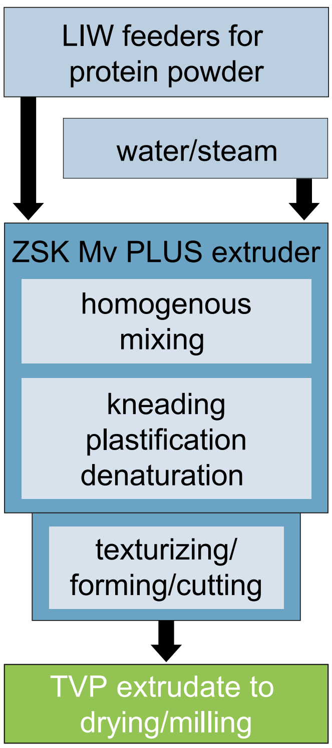
Refilling a LIW feeder in a continuous process (such as extrusion) can be almost as critical as the feeder technology itself. Since the objective is to refill as quickly as possible, vacuum sequencing receivers which operate using a dilute phase vacuum transfer principle are often used as refill devices. The bulk material is transferred via vacuum from the source to a vacuum receiver mounted above the LIW feeder. The receiver is filled to a set level and then holds this material charge until the feeder below requests a refill. Upon refill request from the feeder below, 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



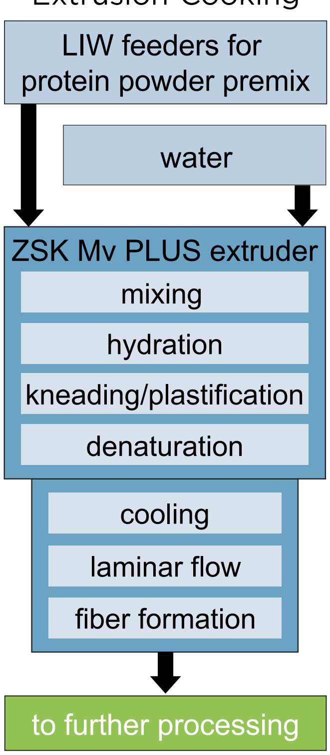
Typical System for Production of Meat Analogues

1 Vaccum blower with filter
2 Sack dump station
3 Vacuum receiver
4 LIW screw feeder (powder)
5 LIW liquid feeder (water or slurry)
6 ZSK twin screw extruder
7 Cooling/structuring die
8 Cutting unit

Extrusion of TVP



High Moisture Extrusion Cooking



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

Once the receiver is empty the discharge valve is closed and the fill cycle immediately begins again, in preparation for the next refill request. This series of sequenced "fill and discharge" steps is also known as vacuum sequencing.

High Accuracy Addition of Liquids

As shown in the process flow diagrams, in addition to the solid ingredient being fed via dry bulk LIW feeding, water is also introduced using a Coperion K-Tron liquid LIW feeder. Liquids are typically fed via a type of piston pump with a variable speed drive. The mass flow rate can be measured and controlled by placing a liquid tank on a weigh scale and using the same loss-in-weight control algorithm described for powder feeding. Instead of changing the screw speed, the same signals are used to control the pump speed/stroke to increase or decrease the throughput flow rate.

Liquid minor components like flavors or other slurries can be injected to the extruder by the same principle of LIW feeding. The appropriate feeding pump has to be chosen according to the liquids' properties.

The benefits of this gravimetric arrangement as opposed to a mass flow meter include easier calibration, and most importantly, higher accuracy in feed and control.

Extrusion of Meat Analogues

Co-rotating twin screw extruders are used for the production of both TVP and HMMA, although the set-ups for both products are totally different. The process section of Coperion's highly efficient ZSK Mv PLUS twin screw extruder is designed as a modular system. It consists of several barrels in which the co-rotating screws operate. These screws also consist of different screw elements which can be combined individually. The advantage of this modular principle is the inherent maximum flexibility in the extrusion process.

It should be noted that Coperion's ZSK Mv PLUS series has an outer to inner working screw diameter ratio (D_o/D_i) of 1.8, thus making it the highest free volume extruder available on the market. Its high free volume allows for a much higher capacity within a lower overall space and reduced energy profile. It is particularly beneficial when working with difficult to feed powders, such as proteins. The ZSK Mv PLUS series can be run with screw speeds up to 1,800 rpm which is also unique to the market and offers new perspectives e.g. for the extrusion of HMMA.

In addition, direct steam injection into the extruder is often applied to reduce the mechanical energy input and increase the thermal energy input by process volume. For direct steam injection, continuous temperature, pressure and flow velocity measurements of the hot steam are used to achieve high accuracy. An automatic valve regulates the flow and controls the feed rate.

Advantages of Coperion's ZSK Mv PLUS

- Max. screw speed of 1,800 rpm
- Large free volume – important for feed limited products
- Precise temperature control and protocol of process section barrel temperatures

Extrusion of Texturized Vegetable Protein TVP

TVP – also called dry texturate – is used as meat substitute or meat extender. It can be produced and used in different sizes and forms for different applications as smaller pellets or larger chunks, broken down or ground. TVP is a dry, porous (expanded) product with a long shelf life in normal ambient conditions. Before it can be used, it has to be soaked in water/ liquid.

Soy, legume and wheat protein as well as cotton seed and other proteins are used. It is important to note that protein functionality and concentration in the bulk material is important for good results. Quality parameters for TVP products include water uptake of the extrudate and fiber texture and length.

For TVP extrusion processes, the extruder is set up with a medium length process section and Coperion's centric pelletizer ZGF. The bulk raw protein material is continuously fed into the main inlet of the extruder, and immediately after that, water is injected via Coperion K-Tron LIW liquid feeders. In some cases, direct steam injection to the process section is applied as well. Inside the extruder's process section, the material is mixed and, hydrated, then kneaded, plasticized, cooked and denatured under high energy input.

At the end of the extruder process section, the product exits through a special die head, inside which a certain alignment of the product is achieved to ensure a porous, foamy structure with orientated fibers. It is cut immediately by the rotating knives of the ZGF pelletizer. The TVP granules then need to be dried to be stable for long storage.

TVP can be run at high production rates and large extruder sizes.

High Moisture Extrusion Cooking (HMEC) of Meat Analogues

HMEC aims for high-end meat analogue products used in ready to eat dishes. Different structures simulating different meat types (such as pork, poultry or beef) can be achieved by

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adjusting recipe and processing conditions. One of the most important advantages from both the consumer's and manufacturer's point of view are that HMMA products are amazingly similar in appearance and texture to genuine meat. In fact, in some cases, the differences can be indistinguishable!

For HMMA production, the water content is similar to lean meat, about 50 to 80% extrusion moisture. Consequently, the final products need to be stored in a refrigerator or freezer and are as sensitive as meat. The protein sources used for high HMMA are mainly legume proteins such as soy, lupine and pea. In some cases – such as when used for actual meat extenders – reduced amounts of genuine meat, fish, milk or wheat proteins are added to the recipe.

In the HMEC process, the process section of the extruder must be quite long and a special cooling die designed by DIL is attached directly to the extruder. Raw protein materials are fed into the inlet of the extruder and water is injected directly after that. Inside the process section of the twin screw extruder, the mass is mixed thoroughly, then the proteins are hydrated, kneaded, plasticized, and denatured under high mechanical energy input. The plasticized mass can achieve temperatures up to 180°C. The mass is pushed by the extruder into the cooling die where it is cooled down and forced into laminar flow. Here the transformation to solid phase takes place, building fibers by "freezing" the laminar flow profile into meat-like structures. The meat analogues usually exit the die as a rubbery strand or ribbon. This ribbon-like material is then conveyed to further processing steps.

Unique advantages of the cooperation between Coperion and DIL:

- Comprehensive process and product know-how
- Tailor-made extrusion system (Coperion) and cooling/structuring die head (DIL)
- Possibility for intermediate meat analogue production facility until delivery of ordered extrusion line with cooling die

Hygienic Equipment for Material Transfer

In each of the transfer processes outlined above, Coperion K-Tron and Coperion pneumatic conveying systems and material handling components are utilized for the transfer of the raw ingredients prior to extrusion as well as for the transfer of the extruded product exiting the pelletizer or cooling die. The conveying systems provided include both positive pressure and vacuum, dilute and dense phase. The hygienic valve designs ensure contaminant-free transfer as well as easy-to-clean designs for both wet and dry cleaning applications. These valves include a variety of critical options including EHEDG approved and certified designs, complete CIP construction, and diverter valve designs to 5 bar, rotary valve designs to 1.5 bar.

Summary

The production of both TVP and HMMA gives the vegetarian or vegan consumer a variety of options, while at the same time offering a low cost, high nutrition meat extender for non-vegetarian consumers. The comprehensive TVP and HMMA material handling and extrusion processes provided by Coperion K-Tron and Coperion give manufacturers a one source option from a systems engineering group with extensive application experience. Features such as quick-clean designs for ease in changeovers and increased efficiencies, as well as use of the versatile high capacity Coperion ZSK Mv PLUS twin screw extruders and Coperion K-Tron LIW feeders for high ingredient accuracy ensure process and ingredient cost savings.

Coperion Advantage

- Complete systems design integration of the TVP and HMEC manufacturing process for one source supply.
- Global systems engineering group with extensive application experience for the entire TVP and HMMA processing line ensures optimal design with an emphasis on product quality, process stability and reliability.
- Engineered material handling and feeding solutions from both Coperion and Coperion K-Tron reflect extensive experience in hygienic and sanitary design standards, including CIP/COP, EHEDG, FSMA, GFSI, USDA, and 3A where applicable.
- 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, process stability and reliability as well as constant product quality.
- Innovative, custom engineered Coperion rotary and diverter valves ensure reliable, long-term, and safe operation.
- Use of Coperion's high efficiency ZSK extruders ensure maximum throughput and best quality due to high screw speed.
- Control system of Coperion extruders allows for precise control of each single barrel temperature, monitoring and protocol of product temperature. Recipe management and traceability of product batches (order management) according to food regulations possible.
- Superior global service network to ensure 24-7 support and coverage of your complete meat analogue processing line.

Coperion K-Tron twin screw feeder with ActiFlow

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