Inline process analysis control of the extrusion process

By Thomas Jorgensen, Managing Director, Source Technology

The extrusion process has been the dominating technology for production of feed and food manufacturing for the past 50 years. During this period, the process equipment manufacturers have consistently developed the essential extrusion process equipment in order to cope with the consistent developing requirements from the feed and food producers. In particular, changes in raw material availability and consistency, combined with a price-driven market, have resulted in substantial changes in formulation by means of alternative sources of raw material used. These circumstances have challenged feed and food producers in terms of proper control of the extrusion process, in order to run a profitable business from a manufacturing point of view.

Source Technology has consequently developed inline sampling and analysis technologies, in order for feed and food producers to optimize control of the product quality after each process step. This in order to ensure that both the nutrient and physical quality of the feed and food is according to specifications, thus avoiding substantial rework costs.

The Inline Sampling and Analysis Technology

The inline sampler consists of a mechanical driven and patented sampling cup technology, which is entered into the product flow at any given location of an extrusion plant, collecting either dry of wet extrudates. When a cup, full of product is collected, the sampling cup is removed from the product flow whereupon the actual measuring takes place externally (inside of the sampler, but outside the product flow). Multiple measurements, such as bulk density, moisture, product size etc., can be measured inside the sampler. The actual measured results are calculated by a control system and shown on a display or communicated to a general plant control system.

Overfilled cup after sampling

Scraped cup prior to weighing

The sampler can be fitted with various analytical sensors, depending on the application and specific location in the plant. Figure 1 illustrates that up to eight different analytical sensors, each measuring a unique analytical parameter, can be installed inside an inline sampler. Measuring accuracy of each analytical parameter is mandatory, in order to use the inline analysis results to take over manual labor resources, but at the same time provide as accurate measurements as one would expect from a laboratory.

Figure 2 represents a typical extrusion line for feed and food. The inline analysis samplers are in the same locations, which typical are subject to manual labor resource demanding points of analysis. The most typical frequent labor resource demanding points of analysis are:

- Bulk density (after extrusion)
- Moisture (after drying)
- Lipid absorption (after coating)

When sampling and measuring takes place by means of manual labor resources, both measuring accuracy and sampling frequency are negatively affected. When using inline sampling and analysis technology, the product is analyzed typically every 30-90 seconds and the entire extrusion process can thereby be automated.

Figure 1. Inline sampler with option for multiple analytical sensors to be integrated

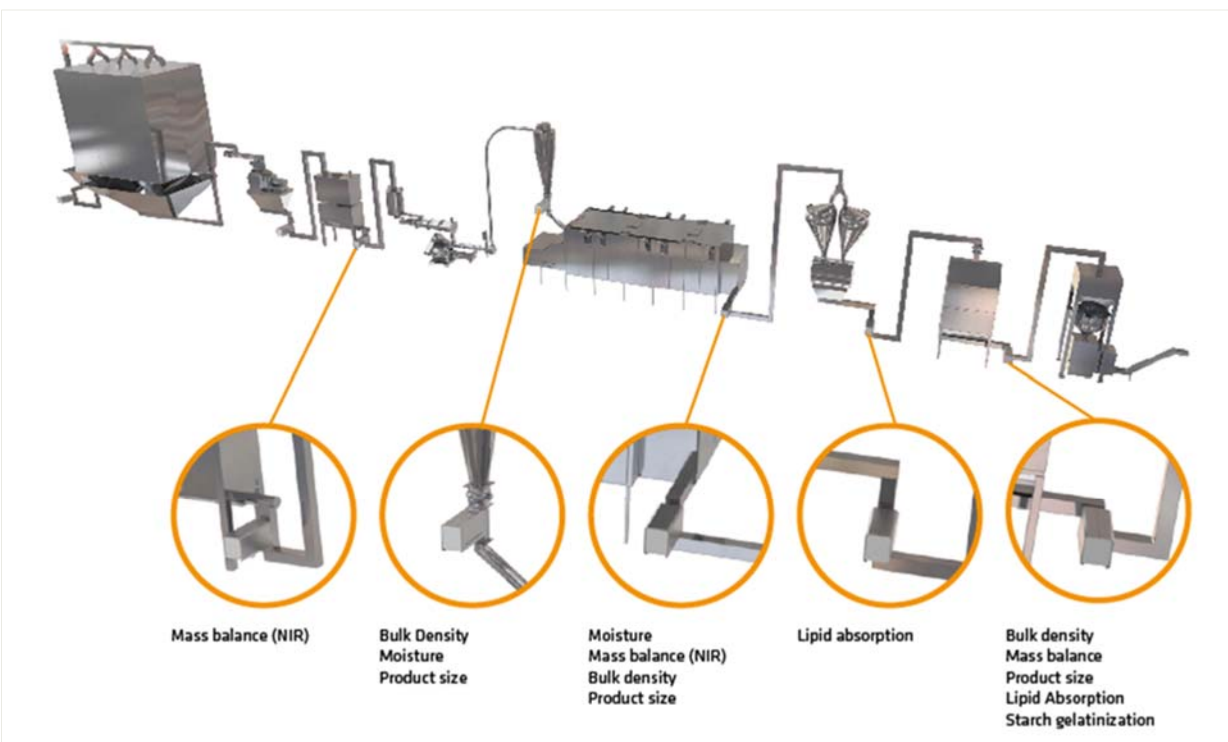

Figure 2. Typical extrusion line for feed and food production.

A control loop can be established between the inline analysis sampler and the upstream process equipment prior to, for example an inline moisture sampler and the dryer. Thereby, a fully controlled automation process without human interference can be operational. In this article, a few of such automated control loops for key extrusion process equipment are described.

Controlling essential key process equipment – Extrusion

During the last decade, new optimized process tools for the extrusion process have been introduced, in order to improve the thermal and mechanical energy input. Improved pre-conditioning processes for increased thermal energy addition as well as devices to improve mechanical energy, are today very typical for a state-of-the-art extrusion system.

In order to optimize for example starch gelatinization levels, new flow restriction systems for increased mechanical energy input inside of the extruder have been developed. When the mechanical energy is controlled, the bulk density of the pellets can be controlled. The bulk density is an important physical measured parameter, which ensures an adequate level of starch gelatinization, thus a texture that allows for lipid absorption in the coating process. The bulk density can also, depending on the application, affect the packing process as bulk density has an impact to the required volume of the bags. The bulk density is measured after the cutting system for the extruder as illustrated in figure 3. The device installed in the extruder to control mechanical energy, is typically placed at the outlet of the extruder, also illustrated in figure 3. By restricting the flow inside the extruder, a greater pressure is established requiring increased energy from the extruder motor, thus more mechanical energy.

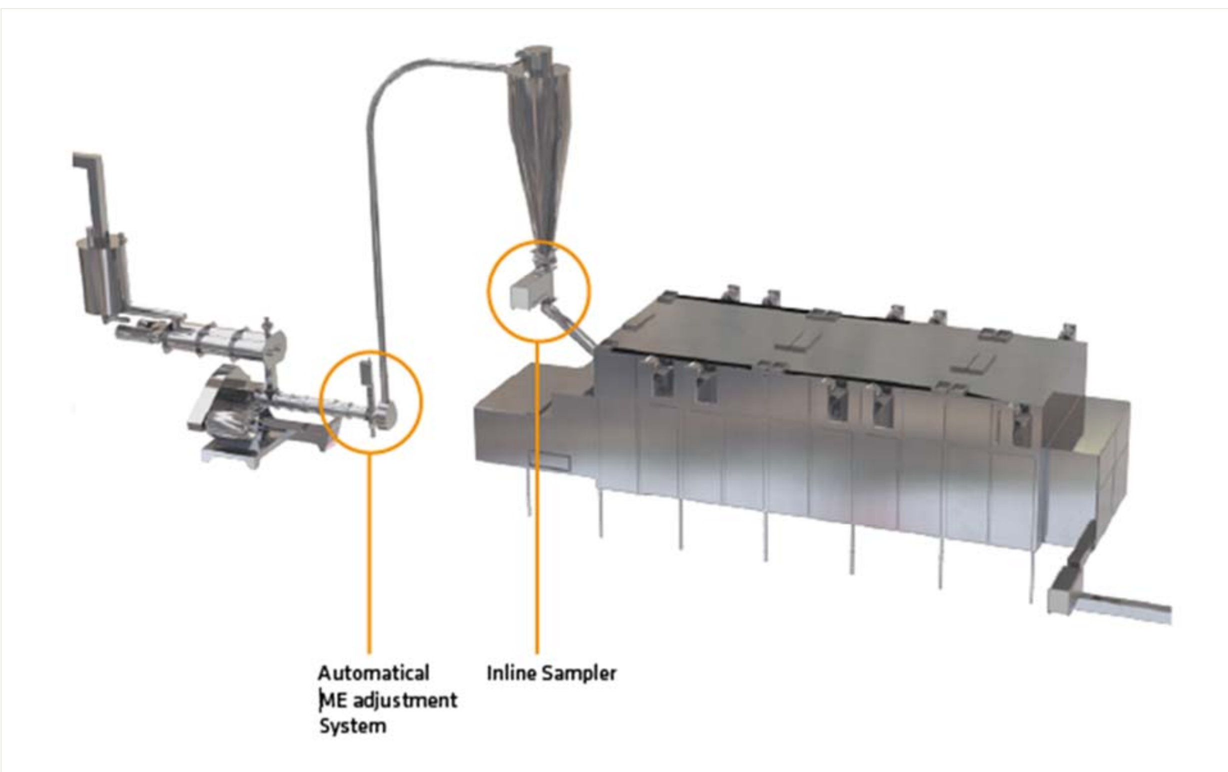

Figure 3.

By means of the inline sampler, a product sample is removed from the process, whereupon an exact bulk density measurement is conducted. The bulk density result can be communicated to the plant extruder control system, whereupon the operator manually can adjust for example the mechanical energy of the extruder, which for example could take place by restricting the flow at the outlet of the extruder. It can however also take place automatically by means of a control loop as illustrated in figure 4.

The operator will typically use a reference bulk density set-point for the specific formula being produced. The sampler will measure the bulk density approx. every 30 seconds and provide feedback via the control system to the flow restriction valve. If there is a difference between the set-point and the actual bulk density, an adjustment of the flow restriction valve is made automatically, until the set-point and the actual bulk density is the same with a tolerance of ±5 g/l.

Figure 4.

Controlling essential key process equipment – Drying

From a nutrient mass balance and production cost point of view, the drying process has a significant impact on the final product quality. If the moisture level is not within specifications, this can result in essential nutrient parameters being out of specifications. Other consequences, such as poor lipid absorption during the coating process or mold, can also occur. From a drying energy cost point of view, there are advantages by accurately controlling the moisture, as too low moisture levels are a result of over-drying, which is wasted energy in form of gas or steam.

By measuring moisture inline, an automatic control loop can be designed in order to control the drying process without human interference. Measuring moisture, both at the inlet and the outlet of the dryer, can take place and provide important information with respect to the moisture levels. Figure 5 illustrates the location of the samplers at the inlet and outlet.

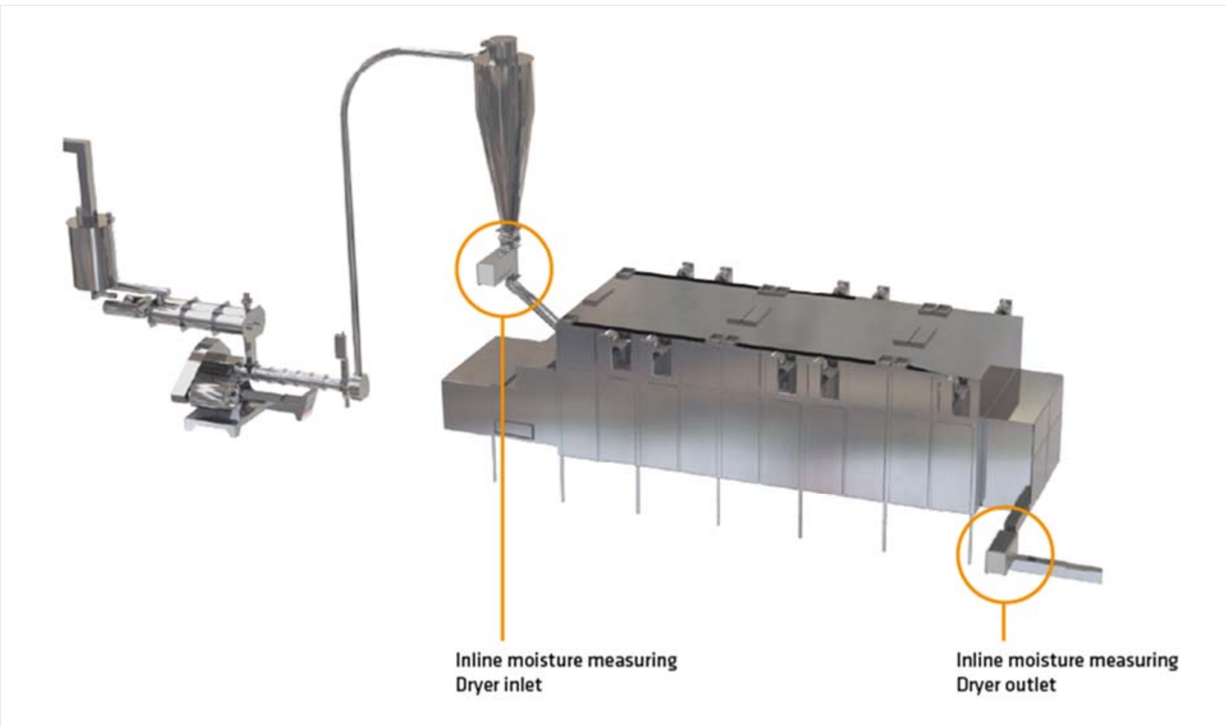

Figure 5.

Depending on the difference between the operator set-point and the actual moisture level measured inline, an adjustment of the drying process can be made. There are typically three parameters, which effectively can be used for the adjustment, being:

- Retention time, controlled by the belt speed (horizontal dryer only)
- Airflow
- Temperature in the specific zones of the dryer

When designing an automatic control loop for a drying system, it must be determined, which of the three essential adjustment parameters are used. Typically, it can be beneficial to use temperature, due to the fast response time, yet this will have an impact to the drying cost.

The operator set-point is typically provided by the specifications of the formula, which is defined, based on an optimal nutrient mass balance as well as costs. The inlet moisture sensor will give the operator an indication to the overall moisture, entering the dryer. The outlet sensor measures the actual outgoing moisture level. If the moisture set-point differentiates more than 0.5%, the dryer settings will need to be adjusted. Figure 6 illustrates the control loop. The temperature is selected as the master adjustment parameter and is therefore gradually increased, until the outlet moisture level is within specifications.

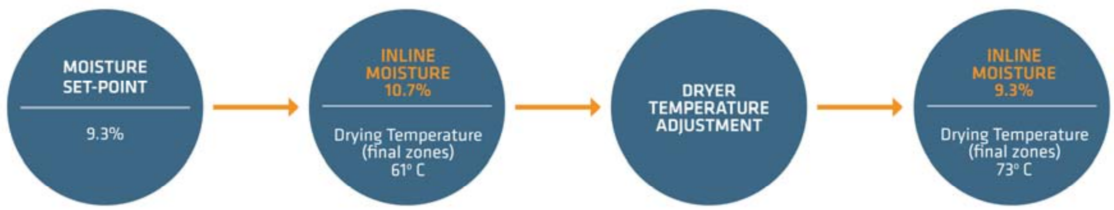

Figure 6.

Controlling essential key process equipment – Coating

How much lipid has to be absorbed by a given extruded product depends on the product characteristics. Typically, both bulk density, texture as well as the moisture level of the product will have an impact on the absorption. It is typically not a problem to apply the level of lipids (oil or fat) required by the formula, but to achieve an acceptable absorption can be more demanding. If the absorption is not properly completed by the time of packing, multiple consequences such as poor visual appearance, lumping, contamination etc. can occur. Therefore, it is imperial that the operator in charge can assess whether the lipids are sufficiently absorbed. However, since the level of absorption is an individual visual assessment, the approval of an acceptable level of absorption may vary from operator to operator.

By using a sampling technology, combined with vision technology (camera), an automatic control of the lipid absorption can be made. The system removes a sample from the product flow, typically after the coater (see figure 7) or alternatively after the cooler, and take a picture of the coated product, subject to software analysis.

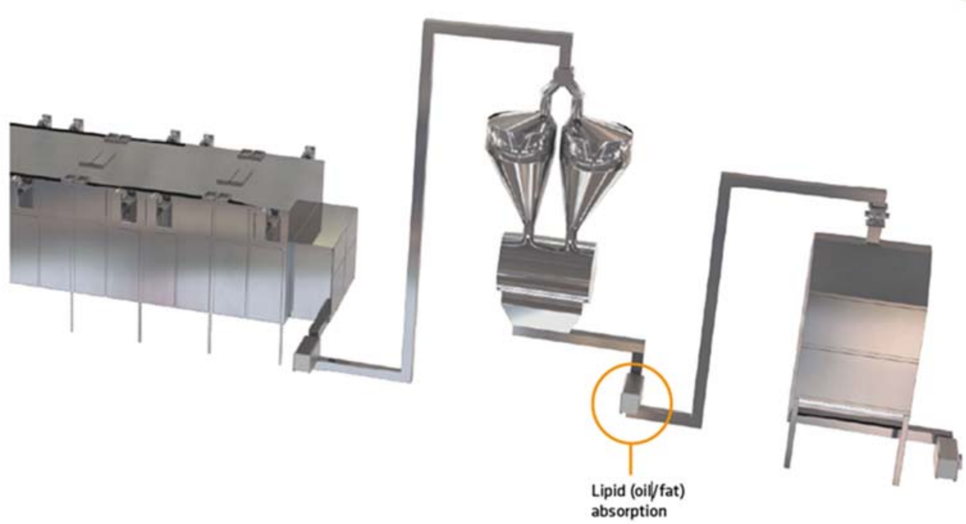

Figure 7.

The shininess of the feed or food product is converted to a percentage value between 0-100% where 0% is a complete dry product and 100% is a very wet, not properly coated product. Figure 8 illustrates the different levels of absorptions.

Figure 8.

An automatic control loop between the sampler and, in this example, a vacuum coater, can be established. The formula will ask for a given percentage of lipid, which the operator will try to achieve in order to ensure the final nutrient mass balance of the product. However, maybe or maybe not, the product will be able to absorb the added amount of lipid. Figure 9 illustrates the control loop. A set-point for the level of absorption required is made by the control system. The sampler analyses the product and provides an actual absorption level. If there is a difference between the set-point and the actual value, adjustments of the vacuum coater is required. In this example, the vacuum pressure is automatically adjusted, until the required level of absorption value is achieved.

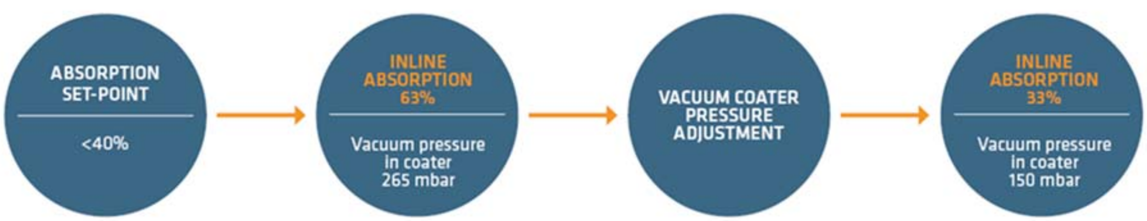

Figure 9.

More information

Thomas Jorgensen, Managing Director, Source Technology