For extruded products:

Energy savings in drying

BY PAUL TEDMAN, PE

Over the past couple of years, equipment designers and engineers have given a great deal of attention to improving the performance of dryers that are used in aquafeed and petfood extrusion processing. The return on investment (ROI) has proven quite favorable for a dryer that produces a product that is not over-dried and is very close to the target moisture. Aquafeed and petfood processors have realised this return because they are able to incorporate more water in the finished product.

During this period, however, little attention has been given to drying efficiency. For almost two decades, most regions of the world have experienced relatively stable fuel prices and in some regions with growing feed industries fuel prices have been quite low, as in the Middle East. However, in the past year, global energy prices have risen significantly and this is focusing even greater attention on feed mill efficiency worldwide. The USA, for example, has experienced near quadruple increases in the price of natural gas in some areas.

The majority of extruded product dryers used in aquafeed and pet food extrusion processing are heated with some form of hydrocarbon gas—natural gas, propane, etc. We can use an example from the USA to illustrate the annual cost to operate a natural gas heated dryer associated with a 10 ton per hour (tph) extrusion system. As the cost of natural gas approaches US$10 per 1000 cubic feet (US$0.35 per cubic metre), the annual cost for the gas reaches nearly US$250,000.

Evaluating efficiency

In recent years, when American Aquafeed and petfood processors were paying only US$2.50-3.00 per 1000 cubic feet (US$0.08-0.10 per cubic metre), there were not many savings if the efficiency was improved by 10-20%. However, as the price of fuel increased, the savings became more significant. Based on the example, a 10% improvement in gas consumption can save the aquafeed or petfood processor nearly US$25,000 annually as the price approaches US$10 per 1000 cubic feet (US$0.35 per cubic metre).

In the much of the world today, fuel gas prices remain volatile and are higher than what we had become accustomed to in recent years. Many processors are now looking to improve the efficiency of their drying operations in order to lower their operating costs.

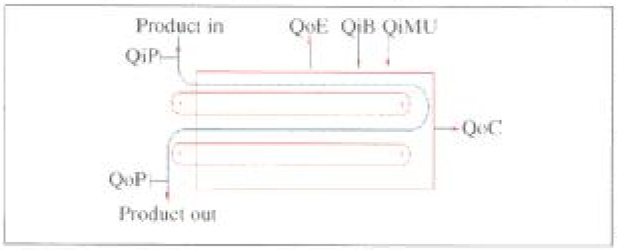

Figure 1. Major energy inputs and outputs for a typical conveyor dryer: QiP—energy entering dryer from the extruded product; QiB—energy entering dryer from the heating system (burners or other source); QiMU—energy entering dryer from the make-up air; QoE—energy exiting dryer from the exhaust stack; QoC—energy exiting dryer due to convective losses; QoP—energy exiting dryer with the finished product.

To evaluate the efficiency of a dryer, one must understand all associated energy gains and energy losses—understanding the 'energy balance' of the equipment (Figure 1). Basically, the energy that enters the dryer must equal the energy that exits the dryer. Therefore, the following can be derived: $QiP + QiB + QiMU = QoE + QoC + QoP$; or, $QiB = QoE + QoC + QoP - QiP - QiMU$.

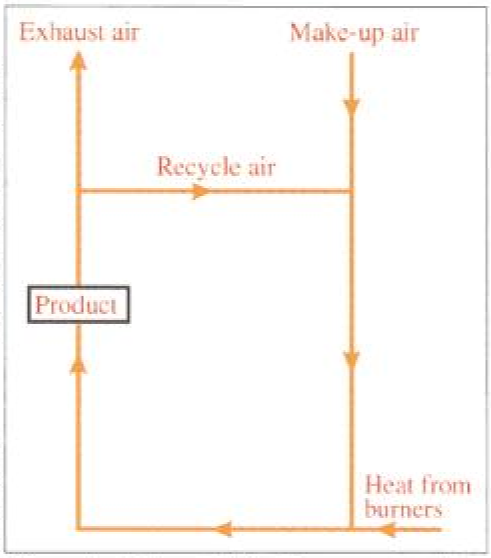

Figure 2. Airflow detail of a conveyor dryer with recycle air.

Energy inputs—Qi variables

The energy that enters the dryer from the product and associated moisture (QiP) is dependent on extrusion processing. A significant amount of energy is added to the product during the extrusion process to in the form of mechanical and thermal energy. The mechanical energy is added from the friction created in the extruder barrel. The thermal energy is added primarily by saturated steam. These energy inputs are necessary to cook and expand the product. Although some of the thermal energy is lost as the extrudate expands at the die, some of the energy is retained in the

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form of 'sensible' heat. This is very beneficial to the drying process, as less energy is needed from the remaining energy inputs (QiB and QiMU).

The amount of energy that enters the system from the 'make-up' or added air (QiMU) is primarily dependent on the ambient conditions. The operator has little control of this variable. As the ambient air temperature increases, less energy is needed from the gas 'burners' or gas-fired heaters (QiB). As the ambient air temperature decreases, more energy will be required from the burners.

Table 1.

Energy gains and losses of a typical conveyor-type extruded product dryer (%).

Energy gains (inputs)		Energy losses (outputs)	
QiP	19.0%	QoP	6.5%
QiB	66.0%	QoC	2.5%
QiMU	15.0%	QoE	91.0%
Total	100.0%	Total	100.0%

Note: Data taken from field application involving extruded petfood. Burner energy was measured at 1406 BTU/lb. (781 kcal/kg) of water evaporated.

Where integral cooling devices are used, additional energy is added to the make-up air (QiMU), further reducing the energy required from the burners (QiB). However, most aquafeed and petfood processors use separate cooling equipment downstream from fat and slurry digest coating. It is not desirable to reintroduce this energy to the dryer as the air is usually laden with oils that can build-up in the dryer.

The amount of energy required from the burners (QiB) is dependent on the aforementioned variables, as well as the energy losses that exist in the drying process.

Energy outputs—Qo variables

There are three major energy losses in the drying system. The largest loss is from the burned gas exhaust (QoE). Every drying process has an exhaust system that is used to extract the air and water vapor mixture that is generated from the drying process. This is the most significant energy loss in the system, which will be addressed in more detail.

Convective energy losses (QoC) occur in all dryers, although most dryers are insulated very well. The convective losses are greater for dryers in cold ambient conditions compared to those in warm ambient conditions. However, overall convective losses are usually not significant when compared to the other losses.

An energy loss also occurs as the product exits the dryer (QoP). This loss depends on the temperature of the product and its moisture content. Fortunately, this loss is less than the energy gain from the hot, moist product that enters the dryer. The reason for this is that the evaporation temperature is much less than the temperature of the product as it enters the dryer. In addition, a large portion of the moisture is removed from the product in the dryer. Integral cooling devices further help reduce the energy loss from the product. Currently, however, these devices are not being used as much as they were in the past due to other processing considerations.

The energy gains and losses 'balance' in a typical drying system and can be shown as percentages (Table 1). In our example, the energy loss out of the exhaust stack is by far the most significant energy loss in the system. Referring back to the heat balance equation (QiP + QiB + QiMU = QoE + QoC + QoP), it can be seen that excessive heat loss from the exhaust duct must be equalised on the left side of the equation by an energy gain. The only variable that can make up the difference is QiB, which is energy input from the burners.

True efficiency

Dryer manufacturers in often express the efficiency of drying based on the amount of energy it takes to evaporate a certain mass of water evaporated (expressed as BTU/lb. or kilo-calories/kg of water). They also describe efficiency by the amount of fuel used over a specific period of time (BTU/hour, kilo-calories/hour or watts). In addition, by knowing the wet moisture content, the dry moisture content and the production rate, the rate of evaporation can be determined (water lb./hour or kg/hour). Dividing the fuel consumption by the evaporation rate will yield the energy required to evaporate the unit mass of water (lb. or kg). Typical figures for aquafeed and petfood dryers will be in the range of 1200 BTU/lb. to 1500 BTU/lb. (667 kcal/kg to 833 kcal/kg).

Theoretical energy requirements can be obtained from a saturated steam table. At an atmospheric pressure of 14.696 lbs. per square inch (PSI, or 1 bar), the total required energy to evaporate 1.0 lb. of water is 1150 BTU (or 639 kcal to evaporate 1.0 kg of water). This includes both the sensible heat and the latent heat of vaporization. In the extrusion process, the product enters the dryer at elevated temperatures, sometimes as hot as 200°F (93°C). This means that a significant amount of the sensible heat remains in the product. Therefore, it is probably more appropriate to use only the latent heat of vaporisation in the efficiency calculation, which would be 970 BTU/lb. (539 kcal/kg).

The true efficiency can be calculated by dividing the latent heat of vaporization (970 BTU/lb. or 539 kcal/kg) by the actual energy needed to evaporate 1.0 lb. (or 1.0 kg) of water. So if it takes 1200 BTU/lb. (667 kcal/kg), then the true efficiency would be (970/1200) X 100% = 81% ([539/667] X 100% = 81%). At 1500 BTU/lb. (833 kcal/kg), the efficiency would be 65%.

Improving efficiency

Most modern dryer designs recycle a portion of the exhaust air (Figure 2). This is possible because there is a large volume of air that passes through the product, and it is usually not completely saturated with moisture. The 'recycle air' is mixed with make-up air and reheated. Therefore, energy is conserved. The key to this process is understanding how much air to exhaust and how much to recycle.

The amount of air to be exhausted depends on the temperature of the exhaust air. Exhaust air temperatures typically range from 140°F to 190°F (60°C to 88°C) for most aquafeed and petfood dryers. The amount of water vapor that can be carried by the air at these temperatures also varies. Effi-

Understanding the dynamic 'energy balance' of the extruded product dryer is vital to improving drying efficiency while maintaining necessary processing flexibility.

cient dryers will exhaust air that is moderately saturated. Completely saturated air can create condensation problems along the ceiling and in the ductwork.

Dryer manufacturers design to achieve a certain specific humidity of air for various exhaust temperatures. The specific humidity is the amount of water vapor in the air (mass of water per mass of dry air). As the temperature increases from 140°F to 190°F (60°C to 88°C), the specific humidity increases from 0.060 to 0.129 (Table 2). This simply means that less air needs to be exhausted at higher temperatures, which in turn, improves efficiency.

Table 2.

Exhaust air temperature and specific humidity at 90% ASR.

Exhaust temperature	Specific humidity
140°F (60°C)	0.06
150°F (66°C)	0.071
160°F (71°C)	0.082
170°F (77°C)	0.097
180°F (82°C)	0.113
190°F (88°C)	0.129

Note: ASR—adiabatic saturation ratio.

Many aquafeed and petfood dryers have been 'oversized' in the past to ensure that there will be sufficient retention time to dry the product. If the dryer is larger than necessary, then it is likely that the unit is operated at low temperatures. This necessarily results in low exhaust temperatures, and in turn, dryer efficiency is poor.

For example, some operations have multiple extruders feeding a single dryer. At times, only one extruder may be in operation, which essentially results in an oversized, inefficient drying operation. Some extrusion operations today process a multitude of different products. A single line may produce some products at 4 tph and produce other products at 8 tph. In addition, the wet and dry moisture contents of the products may vary significantly. These types of processing conditions make it difficult to have efficient drying operations. Aquafeed and petfood processors who produce products that are very similar are likely to have more success in improving efficiency than those who process a wide range of products.

In all cases, the key to an efficient drying process is to reduce the major energy loss as much as possible, which is the energy that is exhausted from the dryer (QoE). This can be done by properly sizing the dryer and the exhaust system. Many dryers in operation today can be improved by simply evaluating the exhaust system and 'tuning' it or adjusting it precisely for specific processing conditions. When planning a new installation, careful consideration should be given to all processing variables. It is important not to 'undersize' a dryer in relation to the production rate of the extrusion system or the plant as a whole. However, from an efficiency standpoint, it is critical not to oversize the dryer. **fi**

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