Keepers of livestock including cattle, pigs and poultry expect a consistently high quality of feed for their animals, regardless of the fluctuating properties of natural raw materials. This customer’s requirement is a top priority for producers. Energy efficiency is becoming an issue due to cost pressure and environmental awareness. Researchers at the University of Bremen are developing an expert system for process control. The system will serve to minimise energy use while at least maintaining product quality.

Producers in the animal feed industry process, depending on market availability, different natural ingredients to form a mixed feed with a constant and controlled quality. Despite fluctuating ratios of the components, the animals receive the exact amount of nutrients such as proteins, fats, trace elements, and vitamins that they require on a daily basis. Not only the ingredients, but also the consistency of the feed has an important effect on usability, and ultimately on animal health. Every delivered batch of raw materials must be individually assessed and analysed for specific product parameters. For best results, many companies go by the principle of “truth is not so much taught as caught”. Depending on the material properties, experienced staff adapt the process and draw upon the intuitive knowledge and instinct gained throughout their long professional experience. For example, they are able to interpret machine noises or literally feel the required fine-tuning by crumbling the feed pellets in their hands. Since pellet quality often correlates with energy expenditure, many plants produce over the required level, and therefore consume more energy than necessary.
Increases in the prices of energy sources increasingly motivate compound feed producers to optimise their energy consumption. An inhibiting effect is that energy consumption is not yet recorded in detail in many stages of the production process. Currently only few compound feed plants in Germany are obliged, according to Section 41 of the German Renewable Energy Sources Act (EEG), to run an energy management system as they consume over 10 gigawatt hours per year.

Energy efficiency and product quality brought together under one roof
In the Fu² expert project, researchers at the University of Bremen aim to increase the energy efficiency of the production process together with a feed producer in Lower Saxony. They are currently developing a computer-based expert system that draws on the experience of the staff for adaptive process control, and which also accounts for and optimises energy flows using a wide range of measurement instrumentation. The system is to recognise the relations between input products, process control and product quality and offer timely recommendations for process control.

From the raw materials to finished products
Shredding, mixing and pressing are the basic processes in feed production whose energy flows were analysed by the researchers (Fig. 2): the different feeds of the participating producer consisted of 12–18 components, including corn meal, soybean meal, and rapeseed meal. Vibrating sieves first separate the fine fractions of the individual raw materials from the coarser components. The latter are uniformly crushed in a hammer mill or a roller mill. Afterwards, a mixer mixes the batch along with liquid ingredients such as fats or acids. With the addition of molasses, the result is a floury feed, as it is mainly used for laying hens. Pellet production has the largest share of specific energy consumption. For a final compaction in the pellet mill, saturated steam heats the middlings to a temperature of about 80 °C. So thermal energy is required in addition to electricity.

Online measurement technology monitors production
Suitable Internet-capable measurement instruments that provide information on energy flows and production parameters are the requirement for optimising the energy efficiency of processes. The researchers installed an energy monitoring system that registers the electrical energy of each machine as well as the thermal energy in certain areas. With the combination of energy monitoring and production control information, it is now possible to relate energy consumption to individual productions and compound feed types.

Energy monitoring is complemented by the monitoring of key production parameters. A near-infrared measurement system in the receiving department directly provides information on the properties of the input materials. It monitors moisture, protein, starch, fibre, and fat content. Additional devices are employed directly in production. In this way, the addition of saturated steam in the pellet press section can be optimised depending on the input moisture content of the milled starting product.

The grain size distribution of the milled raw materials is monitored by a photo-optical particle size analyser (CPA). With this information, the optimal press values for pelleting can be set. The researchers integrated the CPA device between the batch mixer and the molasses mixer directly downstream to the milling units by adding an automated sampler into the product stream. An additional advantage of real-time grain size analysis is...
that inadequate machine settings (e.g., rotational speed of the hammer mill or the gap width of the roller mill) is immediately detected. Wear or defects are also detected by the particle analysis.

**What are the potential savings?**

The researchers examined the entire production chain for potential optimisations. Batch-wise operation, for example, leads to idle processes that can be minimised with intelligent planning. Furthermore, the optimal batch size of a given production batch can ensure an optimal plant capacity utilisation. Energy consumption for the production of compound feed varies between 15 and 80 kWh/t depending on the refinement. As a rough estimate, the total annual consumption of the feed production industry in Germany is about 1.0 billion kWh per year.

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**Energy in the feed industry**

Approximately 22.9 million tonnes of compound feed were produced for the supply of farm and domestic animals in Germany in 2011. The largest share is pig feed with about 44 %, followed by cattle (29 %) and poultry feed (25 %). Following the differing customer requirements, compound feed manufacturers often produce several hundred different feed formulations. Energy consumption for the production of compound feed varies between 15 and 80 kWh/t depending on the refinement. As a rough estimate, the total annual consumption of the feed production industry in Germany is about 1.0 billion kWh per year.

so it is lost as soon as the employee leaves the company or calls in sick. Secondly, too much energy is generally expended with this method, just to ensure that the final product complies with the requirements. Energy consumption can be lowered for various feed formulations – as was demonstrated in test series. Depending on the feed formulation, a few machine parameters must be adapted to the moisture content and particle size of the raw material. For example, sieve size, rotational speed during the milling process, length of the compaction channels in the pelleting process, and finally the steam temperature all play an important role.

**Artificial intelligence makes recommendations**

A newly developed, adaptive expert system is to suggest the formulation-dependent adaptation of machine parameters to the raw material properties, and also specify the necessary machine conversions. In particular, it optimises the application of steam, or rather energy, during conditioning and compacting. To achieve this, the expert system incorporates employee experience, and the evaluation of the test series, into a simple control system. This system is based on fuzzy logic and is able to process fuzzy information, such as “a little more” or “slightly reduce”, and to concretise this in learning processes. At present, the system is in the implementation phase at the compound feed plant of the project partner. It is being systematically evaluated and adapted to the requirements of the users.

**New formulations – new motivation**

Using the results of the test series, the project partners were able to improve the energy efficiency in the areas of milling and pressing. While optimising the product portfolio, the employees contributed their expertise in an intensive exchange of experience, and developed a deeper understanding of the involved energy relationships. The staff were highly motivated to make a major contribution to the improvements. With the integration into production control, they had the ability to track energy use in production in detail. Effects of changes to the process flow became more transparent and verifiable.
Benefits for the food industry

The researchers aim to generalise and modularise the developed concept by systematically abstracting the requirements. New requirements can be better and sooner supplemented by the use of deterministic models. The results of the Fu² expert project can be transferred to production plants in other industries. In particular in the food industry, there are many processes in which the controlled heating and cooling of sensitive raw materials is required. For example, coffee beans are heated to 200 – 220 °C during roasting. Then they must be cooled back down to room temperature as soon as possible. Here, there are again the conflicting targets of quality and minimising energy consumption. An interesting test of the concept would likely be its application in a malt house. The quality of the finished malt product is highly sensitive to changes in input and process parameters. Production is divided into three sub-steps during which the method of the researchers could be used:

First, the barley is soaked for a period of two days until the moisture content of the grain reaches 40 – 45 %. The barley then germinates for three to four days at a temperature of 12 – 15 °C. In the final step, the green malt is kilned. At a kilning temperature of 50 – 95 °C, the moisture content of the malt drops to 3.5 – 4.5 % within one or two days. The entire process currently consumes about 750 – 780 kWh of thermal and 73 kWh of electrical energy per tonne of malt.

Project participants

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Links and literature

- www.fu²-experte.de

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