Reproduced with permission of Feed International, Watt Publishing Company, 122 South Wesley Ave, Mount Morris, IL 61054-1497, USA. October 1999

Keeping enzyme dosing simple

BY CLAYTON GILL

Enzymes are fragile proteins-always under threat in the harsh environment of the feed mill. Extremes of temperature, pressure, friction, pH and microbial activity can degrade or destroy enzymes added to feed. This threat-compounded by the trend toward high temperature or super conditioning-encourages enzyme suppliers to recommend the application of their feed grade products in liquid form, downstream from the pellet cooler.

But liquid enzymes are inherently less stable in storage than their dry, granular counterparts. Moreover, post-pelleting liquid micro proportioning and application can be a restrictive and expensive option, due largely to the complexity of the necessary equipment. Single-product liquid enzyme application systems are found in many countries that depend upon wheat or barley as feedstuffs. The multi-additive systems remain most popular in northern Europe, where compounders super condition poultry and pig feeds to kill salmonella and E. coli and to improve pellet quality, simultaneously destroying feed enzyme activity.

This begs the question: If it is not necessary to super condition the feed-that is, to heat the meal above 90ºC-what is the most cost-effective form of enzyme additives? Liquid or dry?

Liquid or dry?

Under conditions of normal steam conditioning-not super conditioning-there is a strong case for keeping enzyme application simple-and dry. The stability of modern granular enzyme additives is much better than for the first such products available a decade ago. Suppliers now select enzymes with inherent high stability, employ new carrier materials and use novel manufacturing techniques such as protective encapsulation.

“As a result,” says an engineer employed by a leading feed enzyme supplier, “some granular feed enzymes have been shown to maintain efficacy after exposure to conditioning temperatures above 90ºC.

“However,” he adds, “where processing conditions exceed this temperature, it is generally advisable to apply enzymes as liquids, post pelleting, thereby avoiding exposure to high temperatures”.

These are the comments of Paul Steen, who has had more than 10 years' experience in feed and food processing and has been employed as a technical services advisor with Finnfeeds. The company is a global speciality ingredients supplier based in the UK, offering both liquid and dry feed enzymes. Finnfeeds' parent company, Cultor Oy of Finland merged earlier this year with Danisco A/S of Denmark, which is also is a global supplier of speciality ingredients, including feed enzymes.

There are two main considerations regarding the use of dry, granular enzyme products, Mr. Steen says. The first is to ensure the homogenous distribution of the enzyme throughout the mix and the finished feed. The second is to ensure that the stress caused when the enzymes are subject to heat during the feed manufacturing process does not exceed the product's limitations. He points out that today there are many variations of steam conditioning and pelleting worldwide-all potentially affecting enzyme stability. Moreover, there is no standardised laboratory assay for dry enzyme activity in feeds.

“In the absence of an effective in-feed assay,” he says, “the only reliable method for determining the in-process stability of feed enzymes is the *in vivo* trial or animal bioassay.”

Attention to the mix

One of the great advantages of using enzymes in granular form is the convenience with which they fit into existing manually operated or automated dry micro proportioning systems. Incorporating granular enzyme products is very similar to adding vitamins, trace minerals and other micro ingredients designed for inclusion directly in a batch mixture or for inclusion in a premix for later batch mixing. Mr. Steen points out that most mixers are capable of adequately mixing micro ingredients to an inclusion rate of 1 kg/metric ton, providing the shape, size and density of the particles are similar to those of the macro feed ingredients. For less efficient mixers and lower inclusion rates, he notes that it is common practice to incorporate feed additives via a higher inclusion premix--either directly or as a component of the vitamin-mineral premix.

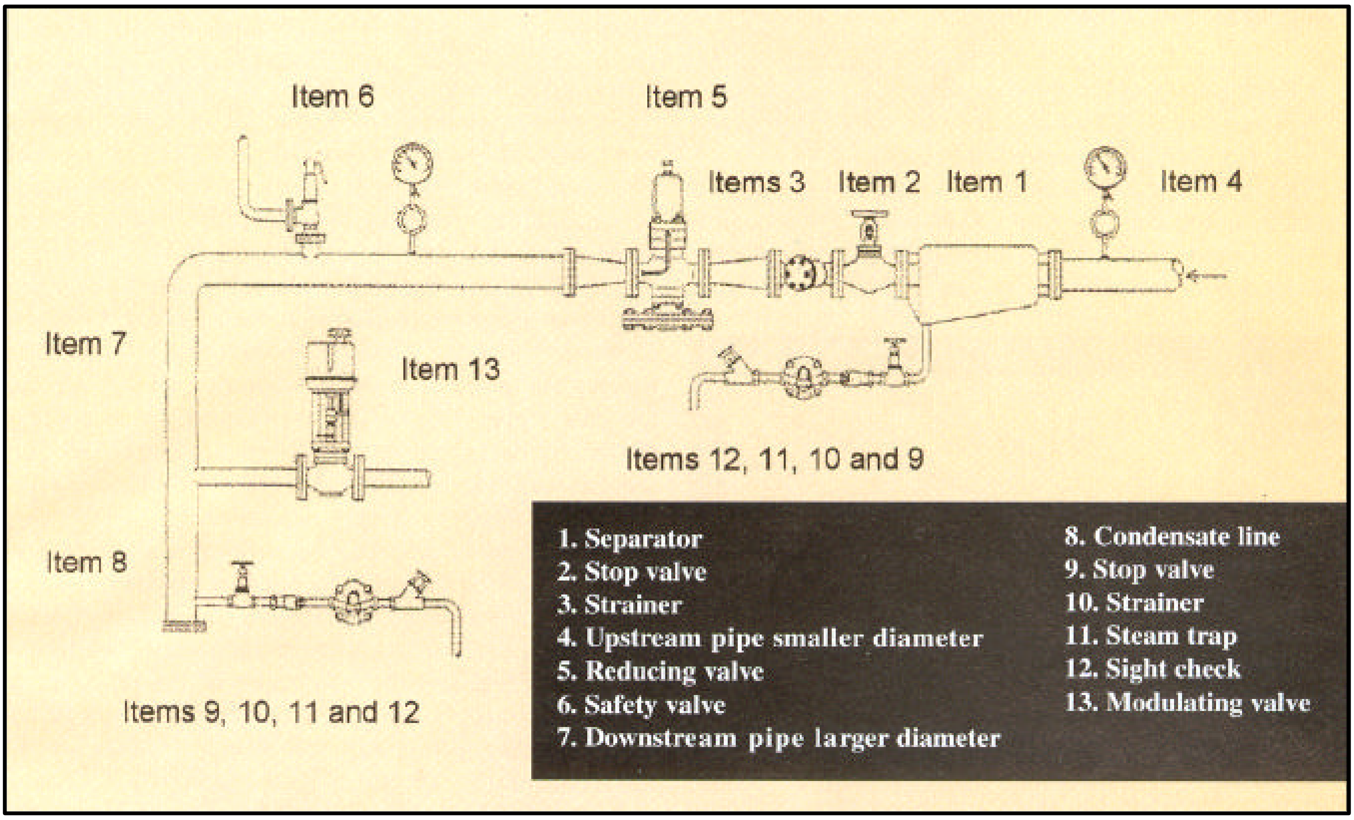

Figure 1. Steam line and pressure reducing valve (PRV) arrangement for typical steam requirements for feed manufacturing capacities of 10-20 metric tons per hour (tph). Source: Adapted from Finnfeeds (1999).

As with other micro ingredients--especially medicated products-it is critical to avoid concentration losses and carryover in handling enzymes. To meet the nutritional needs in the animals, Mr. Steen recommends that feed manufacturers establish mixing criteria and monitor performance, especially for:

- Homogeneity of the complete mix;
- Concentration of the additives in the complete mix; and
- Level of carryover from batch to batch.

The addition of the micro ingredients at a hand tip point probably is still the most common practice. However, simply discharging into a conveyor or elevator to transfer the components to the main mixer can lead to concentration losses and carryover.

"A more practical approach is to transfer the components to the mixer via a closed loop conveying (CLC) system. The CLC is a sealed pneumatic conveying system specifically designed for the conveying of hygroscopic, friable and hazardous products."

The CLC functions without a dust filter, Mr. Steen points out, which significantly minimises concentration losses and carryover: "Any dust carried over from the cyclone is centrifuged out of the air in the modified first stage of the fan. The dust returns to the cyclone via a bypass pipe to mix with the bulk of the components entering the cyclone. The CLC also has the advantage of the ease with which the conveying pipe can be routed to the application point."

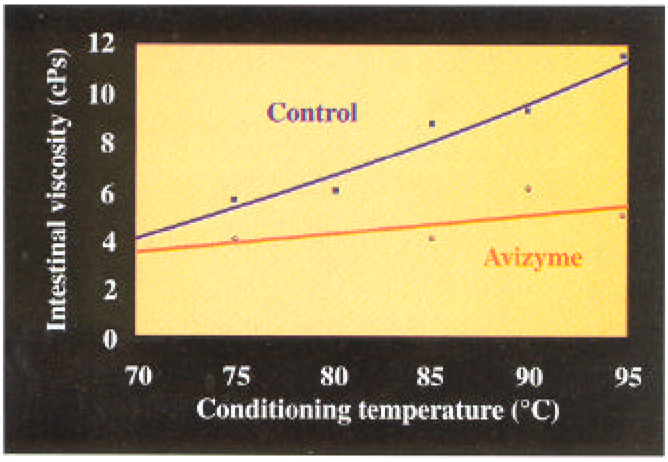

Figure 2. Processing temperature of wheat-based diet with commercial enzyme additive (Avizyme 1300 from Finnfeeds) and *in vivo* intestinal viscosity in poultry. Source: Finnfeeds (1999) after CFRA (France) and SAC Auchincruive (UK)

Another option, favoured by an increasing number of feed manufacturers, is to handle granular enzymes in FIBCs (flexible intermediate bulk containers-usually 1 metric ton 'bulk bags') and incorporate them via a micro system into the mixer. These systems offer improved dosing accuracy, inventory control, guaranteed inclusion and other advantages, including reduced exposure to mill employees of potentially harmful additives.

"Given an efficient mixer," Mr. Steen states, "the use of the micro ingredient system to add directly into the mixer small quantities of micro ingredients demonstrates that there is no significant advantage to having micro ingredients diluted in premixes."

Controlling thermal 'stress factors'

The destructive effect of modern feed processing-generated through heat, pressure and shear-also is a factor determining whether dry or liquid enzymes should be used. This stress on enzyme activity strikes mostly during the conditioning and pelleting phases of processing. Even today's conventional pelleting temperature range of 65-90ºC can have denaturing effects on unprotected enzyme additives. The stress factor warrants a closer look at steam conditioning, the most common method to heat the feed meal prior to pelleting.

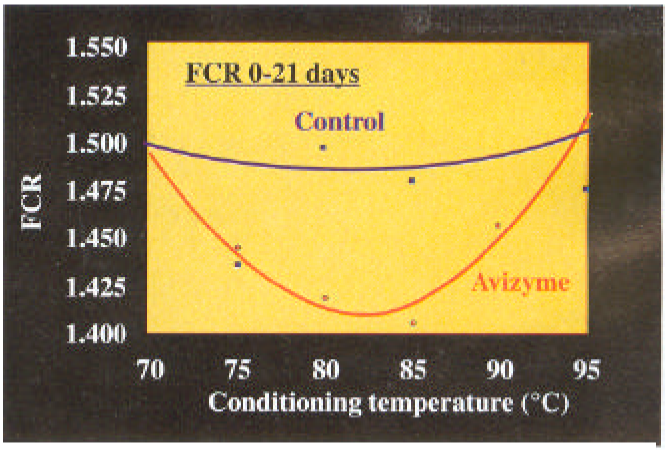

Figure 3. Processing temperature of wheat-based diet with commercial enzyme additive (Avizyme 1300 from Finnfeeds) and poultry feed conversion. Source: Finnfeeds (1999) after CFRA (France) and SAC Auchincruive (UK).

Thermal processing of the meal can improve feed digestibility, increase intake and conversion, boost bulk density, prevent particle segregation or de-mixing, and reduce or eliminate pathogens. To do this, feed manufacturers usually apply steam directly or indirectly in conventional unpressurised conditioners or in super conditioners-screw type expanders, compactors, high friction conditioners, jacketed barrel conditioners, long-term conditioners or 'ripeners' and other specialised equipment for pasteurisation or sterilisation. Super conditioners typically heat the feed meal above 90ºC-which helps to assure its pasteurisation, but which also destroys enzyme activity in many products, prompting plant managers to opt for downstream application of liquid enzyme products.

Conventional conditioning also involves the injection of steam into the meal to raise the temperature and moisture level. It also involves a controlled agitation and retention within the conditioner barrel that optimises the absorption of the moisture by the meal. But, unlike super conditioning, the thermal and physical stress of conventional conditioning-if properly controlled-does not 'over-stress' modern, granular enzyme products.

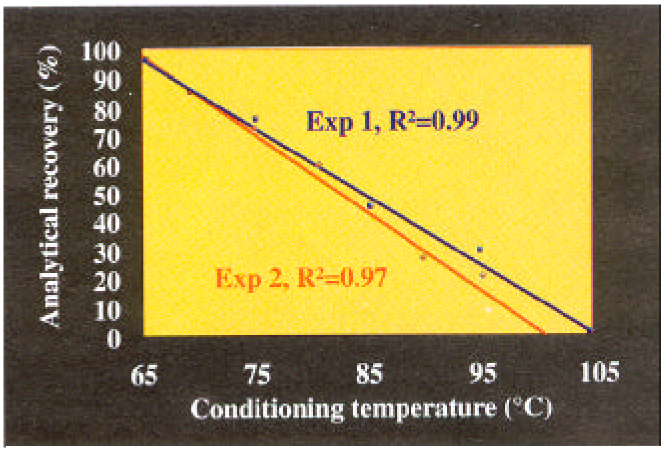

Figure 4. Processing temperature of wheat-based diet and analytical recovery of xylanase. Source: Finnfeeds (1999) after SAC Auchincruive (UK).

Conditioning steam too dry?

"In steam conditioning", Mr. Steen says. "it is important to get the correct balance between heat and moisture. The heat injected with the steam causes a chemical and physical reaction within the feed mix, causing the gelatinisation of starches and plasticising of proteins. The moisture causes the meal particles to adhere to other meal particles. It also moistens absorbent raw materials, softening them so they are readily formed into pellets."

However, the steam injected into many conditioners is too dry. Typically, Mr. Steen says, this is a result of a large drop in steam pressure, incorrectly sized piping and an incorrectly positioned pressure reducing valve (PRV).

"The steam pressure at the injection point to the conditioner should remain constant. This requires a PRV in the steam line prior to the conditioner, which allows pressure fluctuations upstream of the PRV, caused by the firing of the boiler, but maintains a constant pressure downstream (Figure 1).

"The positioning of the PRV is critical to the quality of the steam. If the PRV is located too close to the conditioner, the steam does not have adequate time to stabilise and reach its saturation temperature. What results is a mixture of 'superheated' steam-due to the 'throttling' effect of passage through the PRV-as well as high velocity steam and possibly wet steam."

Mr. Steen reminds us that the quantity of steam required is determined by the pelleting line's maximum manufacturing capacity or, where a ripener is installed, the maximum fill rate to the conditioner.

"Misunderstanding the steam requirement has led to a number of installations being incorrectly sized. The required pipe diameter after the PRV is calculated by the quantity of steam needed, the injection pressure of the steam to the conditioner and the steam velocity. As the steam pressure drops after passing through the PRV, the volume of steam will increase. If the pipe diameter is not increased, then the steam velocity will increase, travelling at high velocity into the conditioner. Also, the steam will not realise its saturation temperature for the given reduced pressure, so a degree of superheating will occur."

What is superheated steam? First consider saturated steam, Mr. Steen advises. This is steam in contact with the water from which it has been generated.

"If heat is added to the saturated steam and the pressure maintained, its condition changes to superheated steam. The properties of the superheated steam-temperature, heat content and volume-are greater than saturated steam at the same pressure. Superheated steam does not give up its latent heat or moisture as easily as saturated steam. This leads to the meal being exposed to a higher temperature for a longer period of time, thus affecting heat liable nutrients."

To avoid superheated steam, Mr. Steen recommends positioning the PRV about 10 metres upstream from the point of application. This distance is necessary to allow the steam to stabilise after pressure reduction and realise its saturation temperature.

Temperature rise during pelleting

In conventional steam conditioned pelleting, the feed absorbs most of its thermal energy during conditioning, prior to pelleting. However, passage from the conditioner through the pellet die also heats the feed. Mr. Steen points out that many factors can contribute to the temperature rise through the die: Feed formulation, die thickness, die speed, die specification (hole size and shape), initial processing temperature, pelleting capacity, etc.

By this point in the pelleting process, steam conditioning may have contributed to the 'binding' of the enzyme to the targeted substrate-usually carbohydrates-which may provide some degree of 'thermal shielding' to protect the enzyme. But how this takes place is not well understood and such effects are not reliable means to protect enzyme activity. The enzyme-substrate binding phenomenon, Mr. Steen says, does make the extraction of the enzyme from the finished feed more difficult. This is a major reason that *in vivo* animal performance trials are used to determine enzyme efficacy.

When to adjust conditioning – or use liquids

Thermal processing of conventional wheat-based and barley-based monogastric diets typically increases the intestinal viscosity of the chicken or pig. When enzymes are incorporated in the diet, the effect is to lower the intestinal viscosity (Figure 2), while improving feed conversion (Figure 3). The 'absolute' feed conversion ratio (FCR) or 'feed efficiency' tends to deteriorate beyond 85ºC, although positive effects may be apparent up to 90ºC.

The analytical recovery of enzymes in the feed-xylanase in pelleted feeds, for example-does not yield a conclusive picture of the efficacy of enzymes in the animal. But, Mr. Steen points out, it is possible to use xylanase recovery to check whether conditioning temperatures are excessive (Figure 4). He advises to compare the amount of xylanase actually recovered versus the amount predicted to be recovered according to the desired processing temperature.

"Analytical recovery of xylanase gives a good indication of intensity of processing, but on its own does not reflect enzyme stability and efficacy in the gut. Binding to the feed matrix seems to prevent quantitative recovery of xylanase from heat-treated feeds. Digesta viscosity and bird performance give the only direct proof of enzyme efficacy"

To provide greater thermo-stability during feed processing, at least one supplier now uses a patented stabilisation process for component enzyme activities. This process, Mr. Steen reports, assures in vivo enzyme efficacy up to a maximum conditioning temperature of 90ºC for 1-2 minutes or up to 85ºC for 15 minutes.

"When processing conditions exceed 90ºC, the recommendation is to apply enzymes downstream of the heat treatment. The most practical solution is to apply the enzymes in liquid form sprayed onto the finished feed.

"However '" Mr. Steen cautions, "unlike other liquid micro ingredients that are applied upstream at the batch mixer, successful application of feed enzymes as liquids demands special attention and consideration by the supplier and feed manufacturer." **fi**

KEY WORDS: Liquid, thermostability, processing, Avizyme1300