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Modern milling requires thermostable granular enzymes

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Research has accelerated and yielded a greater understanding of the anti-nutritive properties of cereals and of the enzyme types required to reduce these anti-nutritive effects. Modern enzyme carrier systems have been developed that help the enzymes to withstand higher temperatures and thereby allowing them to survive the rigours of the feed manufacturing processes.

Recent developments in feed processing technology have resulted in increased processing temperatures and pressure (expanders, extruders). This has provided benefits such as improvements in feed hygiene, production efficiency and pellet durability. However, the increases in processing temperatures have also focused attention on thermostability of some of the more heat sensitive feed ingredients such as vitamins, amino acids and enzymes. This has presented an interesting dilemma for the feed industry in striking a compromise between what these ingredients can endure and what process conditions will allow.

Enzymes are susceptible to degradation through environmental factors. Stability can be improved through a selection of enzymes with inherent high stability, a selection of specific carriers and through novel manufacturing techniques. As a result, some granular feed enzymes have been shown to maintain efficacy after exposure to conditioning temperatures above 90°C. However, where processing conditions exceed this temperature, it is generally advised to apply enzymes as liquids, post pelleting, thereby avoiding exposure to high temperatures.

Adding micro-ingredients at a hand tip point is probably the most common practice

Currently, feed enzymes stand alone from many other high value feed ingredients, due to the absence of a validated laboratory assay for their determination when incorporated as granular products processed in-feed. In the absence of an effective in-feed assay, the only reliable method for determining the in-process stability of feed enzymes is the in vivo trial or animal bioassay.

There are two main considerations for the addition of enzymes to the feed in the granular form:

- the incorporation of the enzyme within the mash to ensure the homogeneous distribution of the enzyme throughout the mix and subsequently in the finished feed,
- the stress factor caused when the enzymes are subjected to the thermal stage of the feed manufacturing process.

Adding by hand

The criteria needed for satisfying the nutritional needs of the animal can be specified as:

- homogeneity of the complete mix,
- concentration of the additives in the complete mix,
- level of carry-over from batch to batch.

Table 1 – Analytical results of drug assays in final diet at different dilution levels

	Analytical results		
Dilution ratio	**Mean (gram/t)**	**Range (count)**	**CV (%)**
Control	249	231-300	6.59
1:1	248	224-265	4.34
1:5	247	212-279	6.56
1:10	244	218-268	6.64
1:25	244	220-280	7.17
1:50	243	227-274	4.97

Expected recovery = 246 g/t.
(Source: KSU, McEllhiney and Tangprasertchai, 1983)

Table 2 – Rotary detector analytical results of iron particle counts

	Analytical results		
Dilution ratio	**Mean (gram/t)**	**Range (count)**	**CV (%)**
Control	14.25	10-21	18.82
1:1	13.85	9-22	23.34
1:5	13.85	8-19	22.87
1:10	13.40	8-24	30.09
1:25	14.00	10-19	21.11
1:50	13.50	7-18	25.38

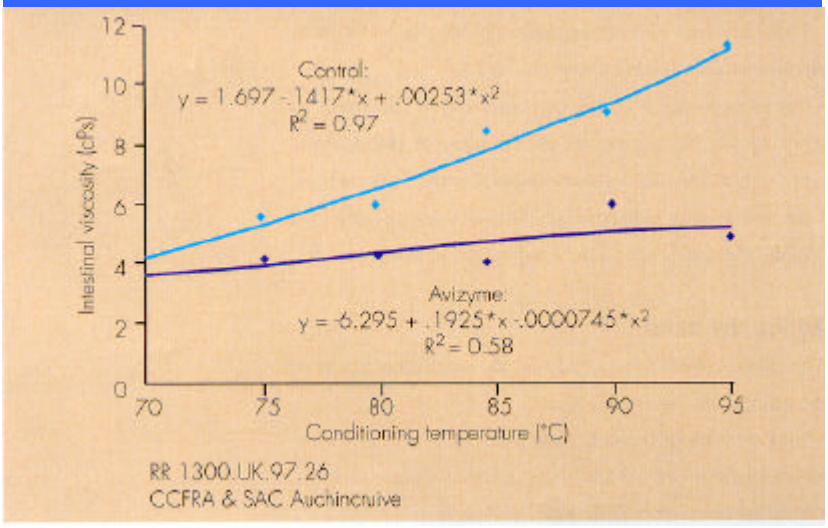
Expected recovery = 12 counts per 50g sample.
(Source: KSU, McEllhiney and Tangprasertchai, 1983)

The addition of the micro-ingredients at a hand tip point is probably the most common practice for the charging of micro-ingredients. The hand tip point is simply a hopper with an electric pneumatic slide at the outlet of the hopper; the hopper would also be fitted with a filter unit. The operator charges the hopper with the appropriate micro-ingredients, the slide below the hopper opens when sequenced by the blending computer and the ingredients are discharged into the mixer.

The hand tip point may also be positioned in a different location within the mill to allow the mill operator to perform a number of tasks; this presents the challenge of transferring the micro-ingredients to the mixer. Simply discharging into a conveyor or elevator to transfer the components to the mixer can lead to concentration losses and carry-over. 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 has the advantage of being able to function without a dust filter; this significantly minimises concentration losses and carry-over. 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 added advantage in the ease in which the conveying pipe can be routed to the application point.

Research conducted at Kansas State University showed that the dispersion of micro-ingredients in the finished feed, was not significantly affected by first diluting the micro-ingredients in a premix or by the level of dilution in a premix. *Tables 1 and 2* show the results of two analytical tests; drug assay and iron particle tracer. The two sets of results from the assay show no significant differences for the dilution levels.

Figure 1. Effect of processing temperature on in vivo viscosity

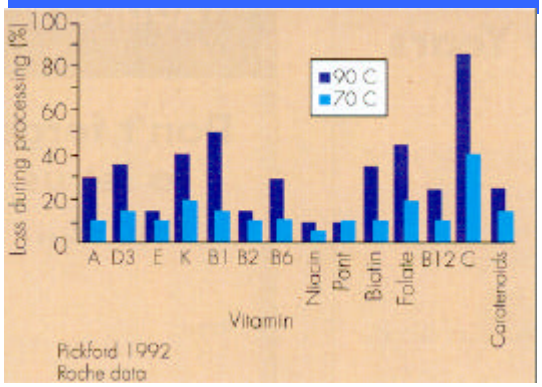


Thermal processing of feed with enzymes

The second consideration is the efficacy of granular enzymes when supplemented to feed that is processed at high temperatures. Due to the inherent procedure, feed processing and processing with heat is strongly denaturing. As a consequence, a stabilisation process is employed during the manufacture of granular products that confers thermostability to the component enzyme activities, thereby maintaining in vivo efficacy up to a maximum conditioning temperature of 90°C for 1-2 minutes. The effect of heat processing is to increase the intestinal viscosity of the animal (broiler, layer swine etc). When enzymes are applied to the diet the effect is to lower the intestinal viscosity, *Figure 1.*

Feed manufacturers heat process feeds for a number of different reasons: increased bulk density,

Figure 2. Effect of processing temperature, 160 and 195 deg F(70 and 90 deg C,) on vitamins



sterilisation, increased feed intake, prevention of demixing of nutrients, etc. While there are benefits to be had by controlled heat processing, there is plenty of evidence heralding the dangers of over-processing. Obviously, the greater the pelleting temperature the greater the loss of nutrients will be, with some nutrients being more susceptible to high temperatures (>90°C) than others, *Figure 2.*

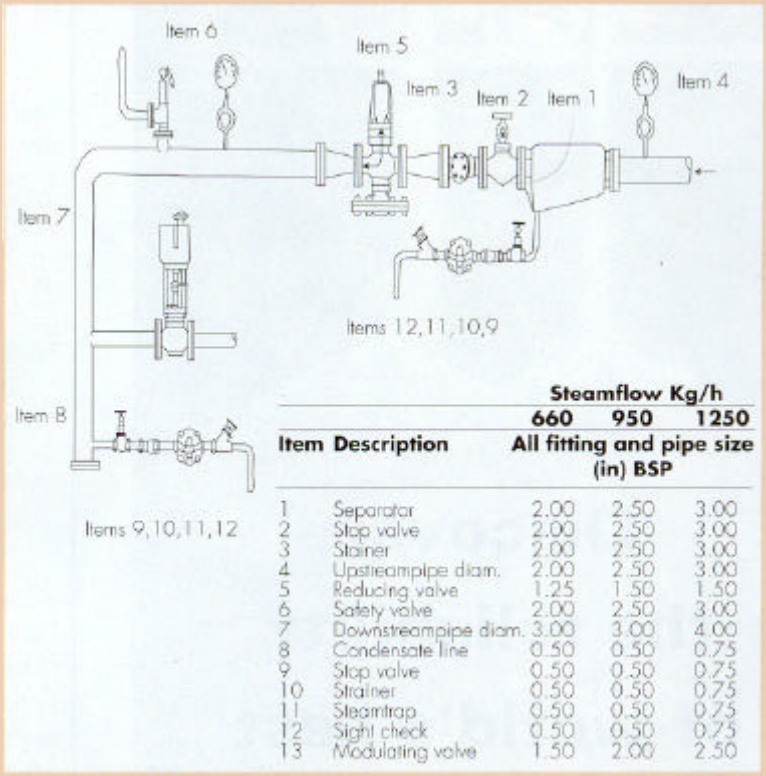
Steam Injection

There are many different types of conditioners and conditioning principles, expanders, compactors, high friction conditioners, barrel conditioner, long term conditioning or SIRT (sterilisation in retention and time). The one common factor to all of these is the addition of steam to the meal.

Conditioning involves the injection of steam into the meal to raise the temperature and moisture level of the meal; a controlled agitation and retention within the conditioner barrel optimises the absorption of the moisture by the meal. 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 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 readily form into the extrudate.

In many feed mills, the steam being injected into the conditioner is too dry. This is a result of a large drop in pressure, incorrectly sized pipework and incorrectly positioned pressure reducing valve (PRV). The steam pressure at the injection point to the conditioner should remain constant; this is achieved by the installation of a PRV in the steam line prior to the conditioner, *Figure 3.* This allows pressure fluctuations upstream of the PRV, caused by the firing of the boiler, but maintains a constant pressure downstream. The positioning of the

Figure 3. Steam line arrangement and pressure reducing valve arrangement, typical steam requirements for manufacturing capacities of 10, 15 and 20 MTPH



		Steamflow Kg/h		
		660	950	1250
Item	Description	All fitting and pipe size (in) BSP		
1	Separator	2.00	2.50	3.00
2	Stop valve	2.00	2.50	3.00
3	Strainer	2.00	2.50	3.00
4	Upstreampipe diam.	2.00	2.50	3.00
5	Reducing valve	1.25	1.50	1.50
6	Safety valve	2.00	2.50	3.00
7	Downstreampipe diam.	3.00	3.00	4.00
8	Condensate line	0.50	0.50	0.75
9	Stop valve	0.50	0.50	0.75
10	Strainer	0.50	0.50	0.75
11	Steamtrap	0.50	0.50	0.75
12	Sight check	0.50	0.50	0.75
13	Modulating valve	1.50	2.00	2.50

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. In cases where the PRV is located too close to the conditioner, the result is a mix of superheated steam (due to the throttling effect through the PRV), high velocity steam and possibly wet steam.

Superheating

The quantity of steam required is determined by the maximum manufacturing capacity or in the case of long term conditioning (LTC), the maximum fill rate to the LTC. This misunderstanding 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 (1.6 bar typical) and the steam velocity (15 m/sec). 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. The other element of this is that the steam will not realise its saturation temperature for the given reduced pressure and a degree of superheating will occur.

Figure 4. Effect of processing temperature on bird performance, wheat-based diet, meal conditioned in a short term conditioner, steam pressure 22 psi (1.5 bar)

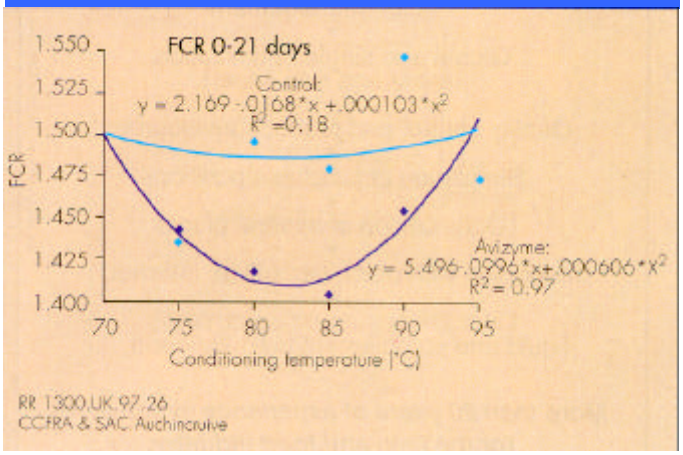
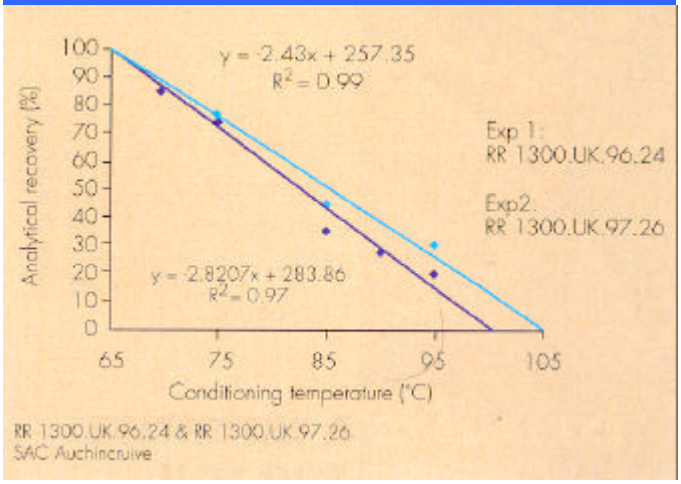


Figure 5. Effect of processing temperature on analytical recovery of xylanase



So what is superheated steam? Steam in contact with the water it has been generated from is saturated steam. If additional 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 the saturated steam for the same temperature. 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 so effecting heat liable nutrients. The positioning of the PRV should be located approximately nine metres upstream from the point of application. It is considered that this distance is necessary to allow the steam to stabilise after pressure reduction and realise its saturation temperature.

Another area of consideration is the temperature rise of the meal when extruded through the pellet die. There are numerous contributing factors to the temperature rise through the die that makes this topic so diverse; feed formulation, die thickness, die speed, die specification, initial processing temperature, pelleting capacity, etc. In the case of enzymes at this point in the process, the 'binding' of the enzyme to the targeted substrate provides the enzyme with some degree of 'thermal shielding'.

Analytical recovery of enzyme activity

Figure 4 shows the effect of conditioning temperature on bird performance. The FCR effects of the stabilised enzyme being demonstrated at temperatures up to 90°C.

Absolute FCR performance tends to deteriorate beyond 85°C, although even in this trial the positive effect on FCR is still apparent up to 90°C.

The analytical recovery of xylanase does not give a conclusive picture of the efficacy of the enzyme in the animal. It appears that heat treatment, *Figure 5,* makes it more difficult to extract the enzyme from the feed due to a binding effect of the enzyme with its substrate. However, this does not mean that it is worthless to analyse the feed for xylanase activity. One can assess the determined xylanase recovery versus the expected recovery according to the processing temperature stated by the feed producer to check whether this fits, or whether conditioning may have been at higher temperatures than indicated.

Analytical recovery of stabilised enzymes 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, *Figure 5.* Digesta viscosity and bird performance give the only direct proof of enzyme efficacy, as seen in Figure 1. They prove the stabilised enzyme to be efficient at conditioning temperatures up to 85°C for 15 minutes or 90°C for 1-2 minutes.

When processing conditions exceed 90°C, 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. Unlike many other liquid micro-ingredients (those applied at the batch mixer), successful application of feed enzymes as liquids demands special attention and consideration by the supplier and feed producer.

Key Words

Avizyme 1300, Avizyme 1310, liquid