The pelleting process and the recovery of enzymes

OptiPhos® Plus
Beat the Heat

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The pelleting process...

Introduction

Due to the proteinaceous nature of enzymes, they can change structure or lose their structure during heat treatment. As a consequence, enzymes also lose their enzyme activity. This phenomenon is called denaturation.

During animal feed production, heat treatment will take place from mash heating, pelletising, expanding and extrusion. Similarly, enzymes added to the feed mash can show a moderate to high inactivation depending on the severity of the treatment. This results in an enzyme activity which does not meet the specifications of the animal feed, and which may result in less efficient production.

The susceptibility for heat or the heat resistance of an enzyme depends on the origin of the enzyme (its intrinsic heat stability), as some enzymes are derived from more heat stable organisms. Furthermore, a lot of research has been carried out to protect enzymes from heat, for example by granulation or coating, resulting in the development of far more stable enzyme products than in the late 90's. Nevertheless, heat sensitivity of enzymes is still a matter of concern, taking into account the different processing steps and parameters used in animal feed production.

The pelleting process in a nut shell

Conditioning

During pelletising, the feed mixture is heated in the conditioner, in which steam is added to reach a given temperature (Fig. 1). The aim of the conditioning is multiple: it improves pellet quality, it reduces power consumption during compression in the die and it improves the hygienic status of the mash feed as microorganisms will be killed.

Steam is produced at 8-10 bars and reduced to 1.5 to 2 bar gauge pressure by a reduction valve reaching a temperature of 127°C to 134°C (at 1.5 to 2 bars respectively). This steam is dry, meaning it is saturated but contains no condensates. As a rule of thumb, a steam injection of 1% (= 1 kg /100 kg feed mash) is needed to reach a 15°C increase in feed temperature. Thus, the higher the requested conditioning temperature, the more steam needs to be added, and the higher the increase in feed moisture will be. So steam quality, quantity and pressure will affect the amount of water in the mash feed before pelleting. Temperature ranges for pelletising feed may vary from 55°C up to 90°C or even more.

Depending on the specific process properties, the conditioning system can vary from a short time (30 seconds) steam mixer up to a conditioner with extended conditioning time (3 to 4 minutes), or a high pressure conditioning (expansion) with far higher temperatures at the outlet (up to 120°C).

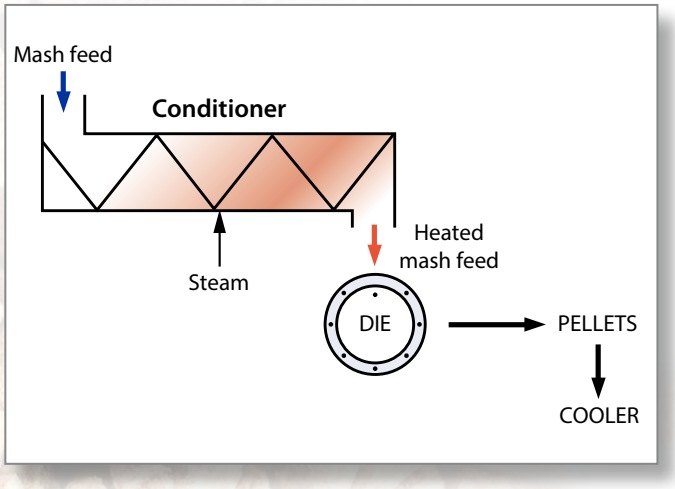

Fig. 1: The different steps of the pelleting process

... and factors influencing enzyme recovery

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Compression in the die

After the feed has been conditioned, it is compressed in a die to form the pellet (Fig. 2). The transfer of the mash feed through the die holes generates friction heat which will increase the temperature of the pellets. In general, the smaller the die hole diameter, and the longer the die hole length, the more the feed will be exposed to friction heat, and the more the enzyme can be damaged.

Fig. 2: A pelleting die

Cooling

After the die compression, the pellets are cooled with ambient air in a vertical countercurrent cooler, where cold air is blown in from the bottom while pellets enter on top. (Fig. 3). Residence time in the cooler depends on pellet temperature and air conditions (temperature and humidity). During cooling, the pellets are also dried. The final temperature should be around room temperature and moisture content should be below 14 %.

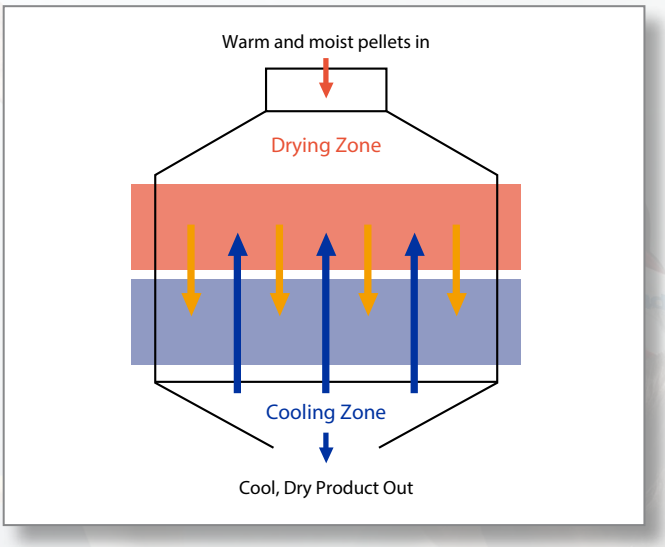

Fig. 3: The countercurrent cooler

Processing factors affecting enzyme recovery

Taking into account the previous process description, the following factors have already been shown to significantly affect the enzyme activity in the feed pellet:

Conditioning temperature and time

Enzyme inactivation increases with temperature in the conditioner. A long term conditioning will have a greater effect than a short term, as enzyme inactivation is a temperature versus time function. Adding enzymes in feed mills using, for example, a hygieniser or extended conditioning will show rather low enzyme recoveries.

Moisture content of the mash feed

Dry heat has less effect than wet heat, thus low quality steam (oversaturated steam containing water droplets) results in more feed moisture and thereby negatively impacts enzyme stability.

Diameter and length of the die

Both affect enzyme stability. Die friction for 2-4 mm pellets will increase temperature at the pellets surface. If all other variables remain equal, small pellets (2 mm) tend to show lower recovery than large (5 mm) pellets. Friction heat also increases with increasing die channel length resulting in higher enzyme inactivation. The L/D ratio (Length on Diameter ratio) of a die is therefore an important parameter: the higher the value, the more friction heat can be expected. For monogastric feeds, die holes are normally 2 to 4 mm with a 40 to 80 mm length.

Feed composition

Minerals and fibre negatively affect the die throughput as they increase friction. An increase in free fat percentage results in a higher throughput (fat is a lubricant even at 0.5 % in the feed formula). Changing the protein and starch content of the feed has less of an impact than fat, fibre and minerals. For this reason, friction heat and thus the effect on enzyme inactivation is remarkably higher in high mineral or fibrous feed mixtures and lower in feed with increased free fat level.

Cooling down rate of pellets

The speed of cooling also determines enzyme recovery as slow cooling means that there is a post-effect of the heat. A cooling (and drying) process in a countercurrent cooler can take up to 15 minutes. However the temperature of the pellet in the cooler drops quickly below 70°C. Below this temperature, the impact of heat on the enzyme is low.

Sampling of feed and calculation of enzyme recovery

Correct sampling of feed

- The aim of sampling is to have a representative portion of feed. This sample should be at least 500 g of mash and pelleted feed.
- From one production batch, 5-10 samples of at least 500 g each from mash and from pellets should be sampled. These samples can either be analysed separately, or pooled into one large sample for analysis. In case of pooling, the subsamples should be mixed vigorously for at least 30 seconds.
- Sampling of the mash should be done during the transfer of the mash to the conditioner (at the conditioner entrance) at regular time intervals.
- Pellet sampling should be done after the cooler as this represents the normal operation of the feed mill. Care should be taken that the sampled pelleted feed is from the same batch as sampled mash feed.
- Pellet sampling at the pelletiser (exit from the die) is discouraged, as these pellets will be very warm and will cool down very slowly, particularly in hot weather conditions. If this is the only option, then it is advised to cool the samples by spreading them on an empty bag laid flat on the floor, in a pellet layer of a maximum of 2 cm height. After complete cool down, the samples can be bagged or pooled into one larger sample.
- The samples should be stored in a cool place until further processing (by preference at 10-20°C). When shipping the samples, make sure that the samples have the shortest travelling time possible, particularly in hot weather conditions.

Correct calculation of enzyme recovery

Ideally, it is good practice to have the background level of enzyme activity in the feed not supplemented with the enzyme (=blank feed) before and after pelleting. Background (endogenous) enzyme levels are lower in pelleted feed than in mash feed due to the poor thermostability of this endogenous enzyme. The correct calculation formula is:

$$\text{Recovery (\%)} = \frac{(\text{activity in pellet} - \text{activity in blank pellet})}{(\text{activity in mash} - \text{activity in blank mash})} \times 100$$

However, in a practical feed mill situation, there is no batch of feed produced without enzymes, so this blank feed is not available. In this case, therefore, the recovery is calculated as:

$$\text{Recovery (\%)} = \frac{(\text{activity in pellet})}{(\text{activity in mash})} \times 100$$

It should be noted that the recovery calculated by the latter formula will always give lower recovery values compared to when a correction for the blank value in mash and pellet feed is used.

OptiPhos® Plus: the highest intrinsic heat stability

Trials on heat stability conducted at research institutes in smaller installations hardly ever mimic the real situation in the field as most of these facilities have no adequate quick cooling with a countercurrent cooler. This is demonstrated by research at the Ghent University which showed the impact of cooling speed on the recovery of OptiPhos® Plus CT (Fig. 4; TB 1). In this trial, the impact of conditioning time and steam pressure was evaluated on the recovery of OptiPhos® Plus CT at 85°C, when samples were cooled instantly (directly during production on cold air) or slowly (properly cooled after production is completely finished). While instant cooling resulted in a recovery of 93-94%, the delayed cooling brought recoveries down to 76%.

In the same trial facility, the impact of fat addition on recovery of OptiPhos® Plus CT was investigated. Increasing levels of fat added to the feed led to improved phytase recovery, as fat is a lubricant causing less friction heat at the die hole. It was demonstrated that by adding 3 % more fat in the feed, the loss of activity when conditioning 120 sec. was even less compared to when adding no fat and conditioning only for 30 sec (Fig. 5, TB 9).

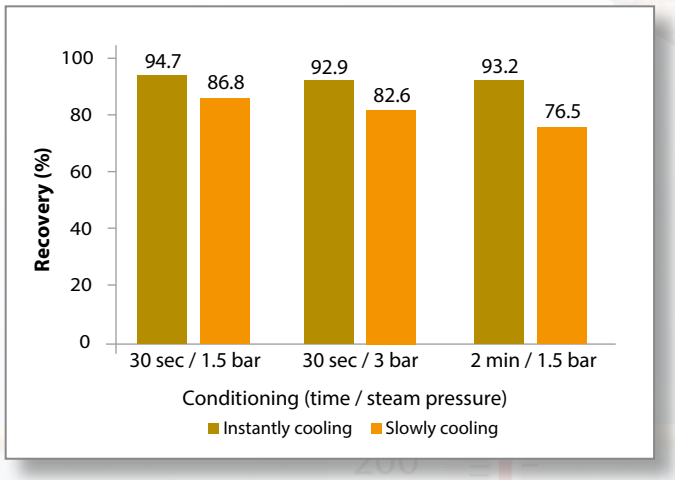

Fig. 4: Effect of conditioning time, steam pressure and cooling (instant or slow) on the recovery of OptiPhos® Plus CT at condition temperature of 85°C

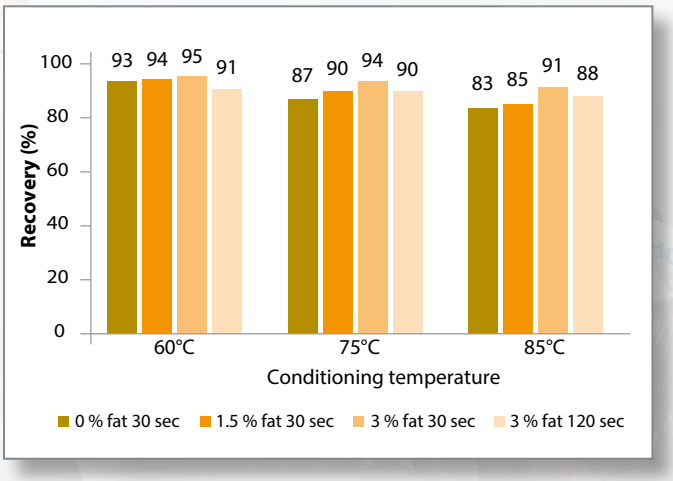

Fig. 5: The protective effect of fat on recovery of OptiPhos® Plus CT at different temperatures

Studies were conducted to compare OptiPhos® Plus (G and CT) to other phytases which are commonly used in feed production. Trial work performed at IFF (Germany) demonstrated that OptiPhos® Plus has much higher heat stability than a *Buttiauxella* and a *A. niger* 6-phytase at 85°C (Fig. 6, TB2).

A similar trial conducted at Tecalimen (France) confirmed the results observed at IFF, also showing OptiPhos® Plus to have higher thermostability compared to a claimed intrinsic heat stable competitor phytase. (Fig. 7, TB3).

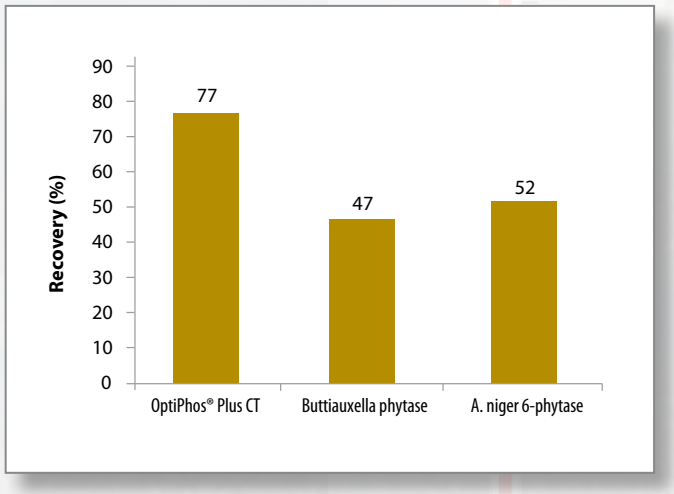

Fig. 6: Recovery of OptiPhos® Plus CT vs competitors at 85°C (IFF, Germany)

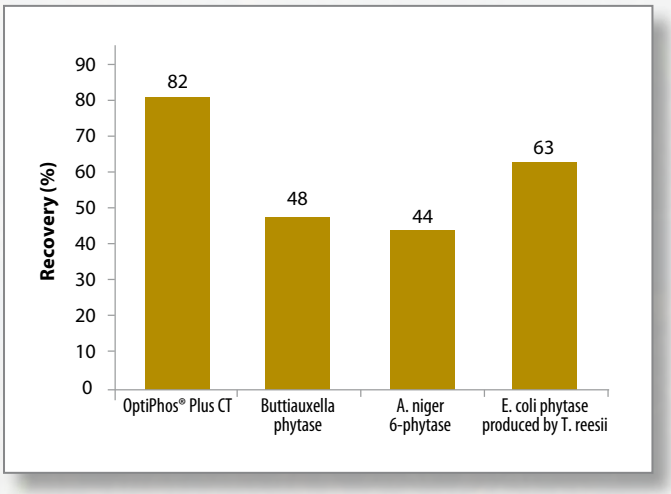

Fig. 7: Recovery of OptiPhos® Plus CT vs competitors at 85°C (Tecalimen, France).

In a series of three trials at the Ghent University (Belgium), the intrinsic heat stability of granular OptiPhos® Plus was investigated in the range of 75 to 90°C (TB5, Fig. 8). It was observed that OptiPhos® Plus G was heat stable to at least 85°C, showing a ± 10 % better recovery at 75, 80 and 85°C, and a 25 % better recovery at 90°C versus a competitor phytase claiming high intrinsic heat stability.

A study at the University of West-Virginia (USA) also demonstrated the superiority of OptiPhos® Plus G and CT on heat stability at 82 and 88 °C versus the competition (TB 6, Fig. 9).

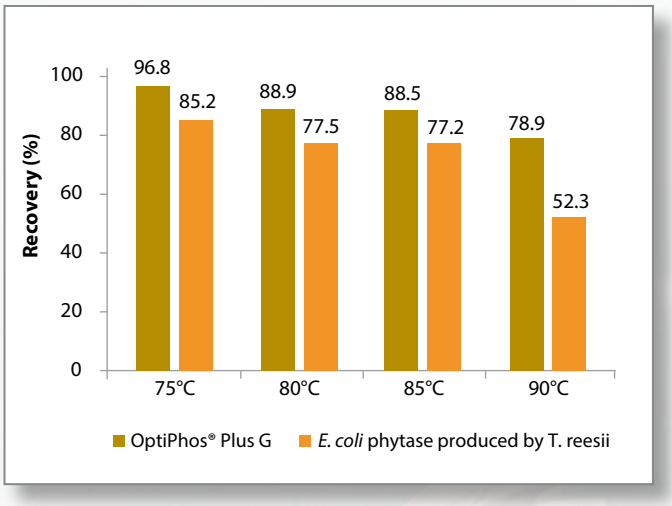

Fig. 8: Average recovery of OptiPhos® Plus G and a claimed intrinsic heat stable and uncoated E. coli phytase

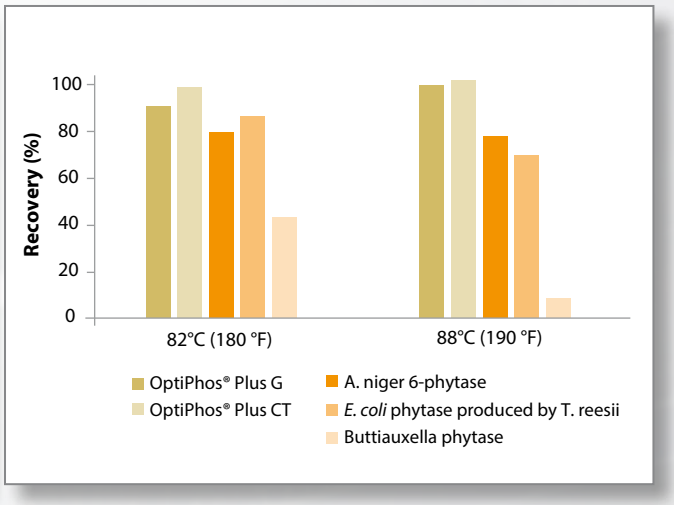

Fig. 9. Average recovery of all phytases after pelletisation at 82°C and 88°C.

A total of 14 pelleting studies were conducted in Europe and 6 in the US evaluating the heat stability of OptiPhos® Plus CT and G versus competitors (a *Buttiauxella* phytase and a claimed intrinsic heat stable *E. coli* phytase), using 10 trial locations in the period 2017-2019. With all the data gathered, it was possible to plot a best fitting curve on the recovery of all phytases versus temperature either as recovery or as percentage of label claim (i.e. taking into account overage is present to compensate for losses) (Fig. 10 A, B and TB8).

On average, the response of OptiPhos® Plus G on increased temperature was linear till 85°C, showing high intrinsic heat stability. OptiPhos® Plus CT showed thermostability until at least 90°C whilst recoveries at 95°C were also still acceptable. Both OptiPhos® Plus G and CT were much more heat stable than the competitors tested and still give more then 100 % recovery of the feed label claim at a temperature higher than 85°C.

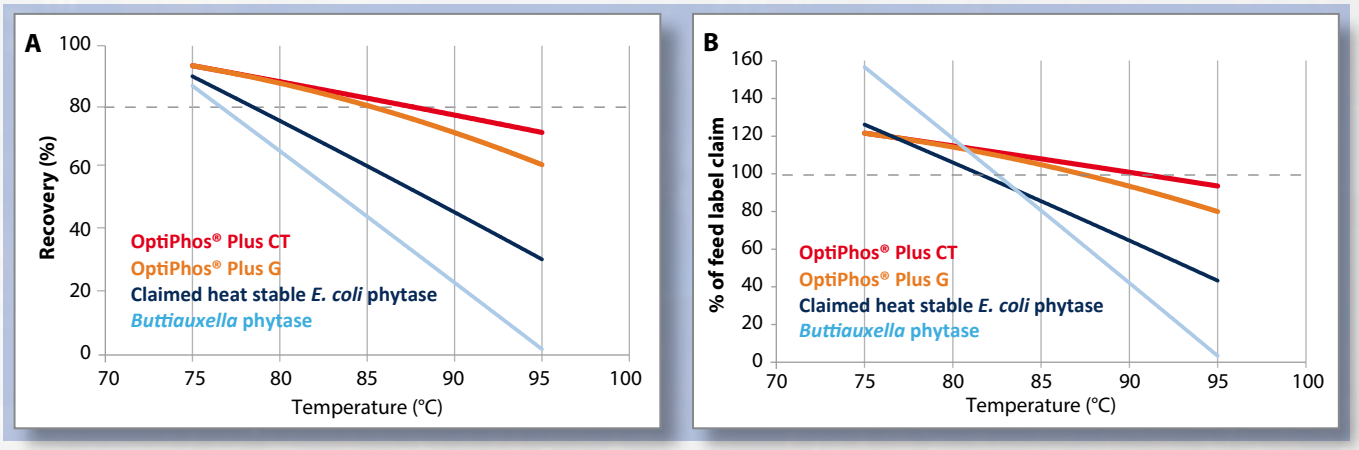

Fig. 10: Average recovery of OptiPhos® Plus CT and G versus a claimed intrinsic heat stable E. coli phytase and a Buttiauxella phytase

Conclusion

Many factors are involved in the recovery of enzymes after pelletisation. OptiPhos® Plus has consistently demonstrated, independent of the pelleting conditions, to have a very high intrinsic heat stability. This makes OptiPhos® Plus your number one choice for pelleted feeds.

OptiPhosPlus.Br.6p.EN03.0920/GI

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