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Assessment of the degree of starch transformation in animal feed

1. The notion of starch damage in Animal Feed

Starch is a widely used energy source in animal feed. In its native state, this raw material ingredient has a semi-crystalline granular structure.

In this form, the majority of starches are easily digested by adult monogastric animals. Nevertheless, processes that destroy the crystalline structure of starch granules are necessary where starch products are incorporated into feeds for young animals or carnivores (Champ, 1993). This modification of the structure of starch (a reduction in crystallinity, depolymerisation, an increase in the specific surface area) translates, in these animals, into an increase in the digestibility of this ingredient.

In technical literature, a number of terms are used to convey modifications in the structural condition of starch brought about by processes. The most common terms are: level of damage, degree of gelatinisation, degree of modification, degree of transformation or condition of starch.

2. Laboratory Measurement Methods

Three laboratory methods can be used to determine the starch's level of damage: the starch's susceptibility to hydrolysis by a bacterial alpha-amylase (α-amylase), a solubility-swelling test and differential enthalpic analysis (Planchot, 1994).

It should be noted that there is significant variability in the condition of starch in different raw materials and unprocessed mixes. This requires the level of starch damage to be determined for products prior to processing where you wish to quantify the influence of the process on the starch status.

2.1. Susceptibility to a bacterial alpha-amylase (α-amylase)

As enzymatic hydrolysis is faster when starch is modified, changes in the hydrolysis speed for starch resulting from a bacterial amylase enable the level of starch damage to be determined.

Starch damage is expressed in grams of hydrolysed starch/100 g of total starch as a function of time. Therefore, the curve produced (Fig. 1) can be described by three variables:

- Vi: the initial hydrolysis speed. This corresponds to the level of hydrolysed starch after a period of 5 minutes,
- Vf: the final hydrolysis speed. This corresponds to the level of hydrolysed starch after a period of 120 minutes,
- FFH: the easily hydrolysable fraction. This value is determined by extrapolation, after a period of 0 minutes, of the linear portion of the hydrolysis curve. This is the most commonly used variable for expressing the level of starch damage.

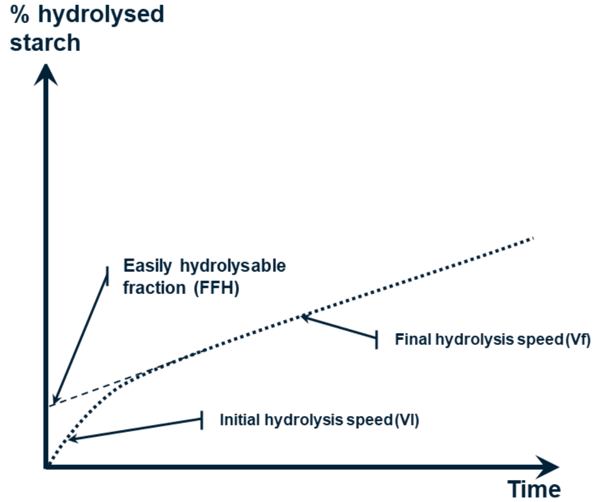

Figure 1: Alpha-amylolysis (α-amylolysis) kinetics in vitro

Measuring susceptibility to hydrolysis using a bacterial alpha-amylase (α-amylase) is accurate, but the origin of the bacterial alpha-amylase (α-amylase) used may have a very significant influence on the measurement results (TECALIMAN, 1995).

It should be noted that the grain size of the sample analysed has a significant influence on the speed of hydrolysis using a bacterial alpha-amylase (α-amylase). Therefore, it is necessary to standardise the grain size of samples prior to analysis.

This method enables the majority of product-process combinations encountered for animal feed to be distinguished: pelleting, high pressure treatment (C.H.P. = expander), flaking, single or twin screw extrusion.

The measurements taken for carnivorous fish reveal that there is a correlation between the susceptibility of maize starch to hydrolysis by a bacterial alpha-amylase (α-amylase) and its in vivo digestibility in trout (Figure 2).

2.2. Differential enthalpic analysis

Compared to a native starch, partially damaged starch has a reduced endotherm, while completely damaged starch no longer has an endotherm.

This method enables the endotherm of the damaged starch to be determined in comparison to that of a native starch and, subsequently, the enthalpy variations to be calculated.

In general, whatever the technological process and the nature of the product processed, the gelatinisation enthalpy of the processed starch reduces in comparison with the enthalpy measured for the unprocessed starch.

The enthalpy variation observed is very low for a pellet feed and becomes significant for flaked products, with this reduction depending on the nature of the flaked starchy product.

For extruded products, no gelatinisation damage of the starch can be detected. In this case, the starch is judged to be fully gelatinised.

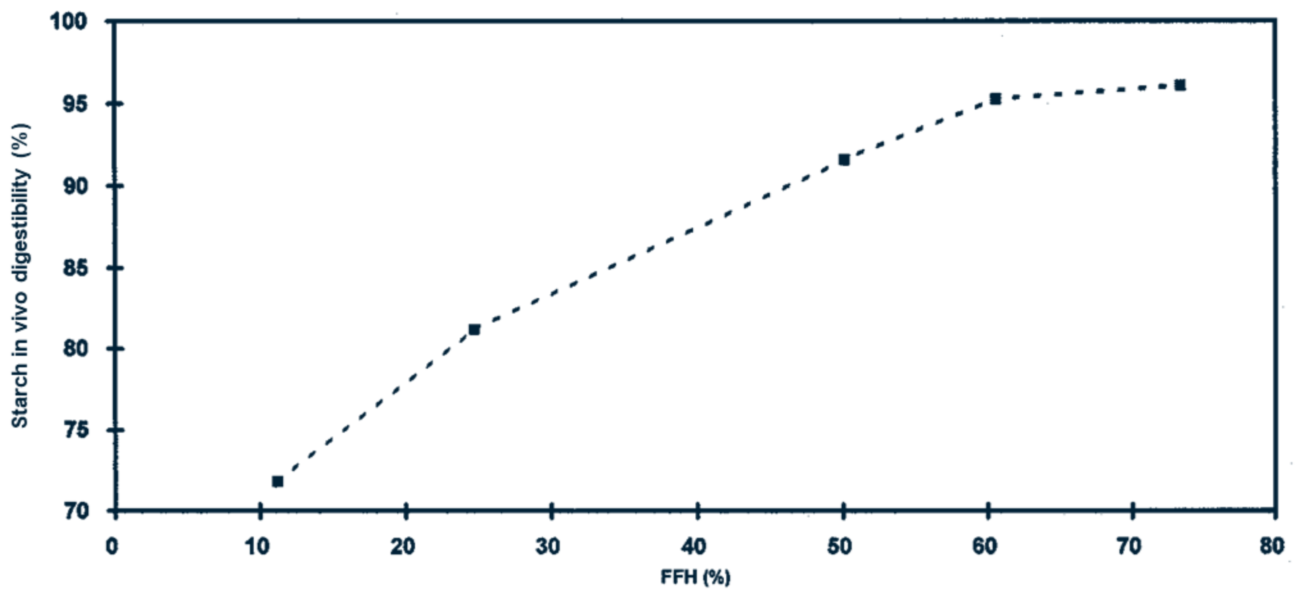

Figure 2: Correlation between in vivo digestibility in trout and susceptibility to an alpha-amylase (α-amylase) of a flaked maize

2.3. Solubility and swelling test

Determining solubility and swelling is based on the disappearance of the crystalline structure of starch granules during the course of a process, which initially permits the massive absorption of water and, subsequently, the exudation of some of the components on the outside of grains. This phenomenon depends on the intensity of the technological process.
The swelling and solubility capacities of the starch grain are measured using the centrifuging method, with an excess of water (the size of particles and the temperature are two experimental parameters that need to be accurately monitored).
Solubility equates to the percentage of dry matter solubilised from a suspension of ground and measured product in the supernatant following a centrifuging stage, after a given time and at a given temperature.
The swelling rate is the hydration level of the pellet obtained after centrifuging, it is expressed in grams of water per gram of pellet material.
These two characteristics do not follow the modifications observed previously, with a susceptibility to a bacterial alpha-amylase (α-amylase) and differential enthalpic analysis.
This method for measuring the level of starch damage is suitable for cooking-extrusion, i.e. for monitoring the most significant modifications in starch grains.

2.4. Conclusions

It is possible to select a method for measuring the level of damage by adopting the analytical method that provides the maximum amplitude of variation.

For cooking-extrusion, determining the swelling capacity and the solubility of the starch in an aqueous medium enables a clear distinction to be made between samples. This is a relatively easy method to implement.
For flaking, pelleting, C.H.P. and C.H.P.-pelleting, susceptibility to enzymatic hydrolysis is the most appropriate method. It should also be noted that this method enables the level of damage to be quantified for extruded products.

Differential enthalpic analysis enables a distinction to be made between all product-process combinations, but it is a complex method requiring specific and expensive equipment.

3. Application of the hydrolysis method using a bacterial alpha-amylase (α-amylase) with a type of product manufactured by the animal feed industry

Various technological processes for animal feed are known to cause modifications in starch. These are hydrothermal treatments that combine the action of water, heat and time; this action is frequently supplemented by a mechanical process that disrupts the material (Melcion, 1988). Depending on the application procedure and the combination of these three factors, it is possible to distinguish between four technological processes: pelleting, flaking, cooking-extrusion and high pressure conditionning (C.H.P.) combined with pelleting, or not.

Sixteen product-process combinations are examined using a typology created by TECALIMAN and the INRA in an industrial setting (TECALIMAN, 1995).
On the basis of the samples analysed, with all the appropriate restrictions for limited sampling, classification of the severity of processes in relation to the level of modification of the starch is: Twin screw extrusion > single screw extrusion > flaking > pelleting = "C.H.P. + pelleting".

During the course of flaking peas and maize, the easily hydrolysable fraction (FFH) increases by approximately 15 and 45 % respectively, while, for these same products, it increases by more than 75 % following a boiling-extrusion process.

The increase in the level of starch damage in compound feeds during the course of pelleting, high pressure treatment or high pressure treatment combined with pelleting is generally lower. It is of the order of 17 to 27 FFH points (Figure 3).

These results would need to be confirmed by additional measurement campaigns. However, it appears that pelleting and, in certain cases, high pressure treatment are not processes that result in a significant modification in the level of starch in comparison to flaking and cooking-extrusion processes.

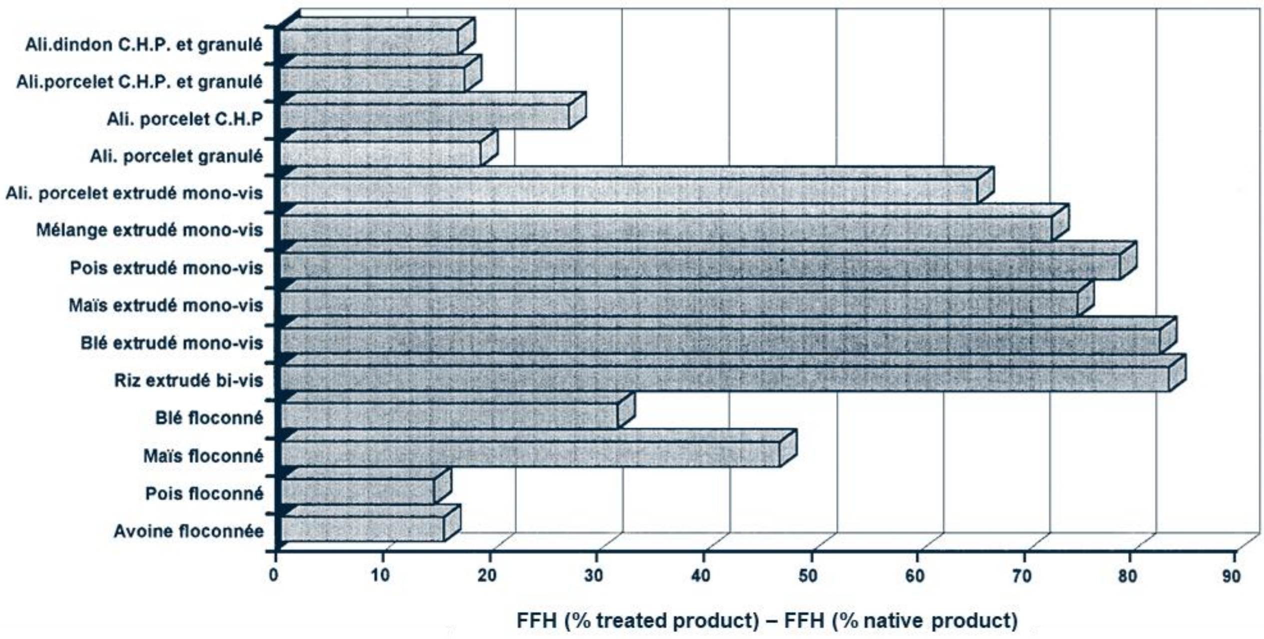

Figure 3: Increase in the FFH during the course of processing

4. Bibliography

CHAMP M., COLONNA P., 1993.
Importance de l'endommagement de l'amidon dans les aliments pour animaux, INRA Prod. Anim., 6, (3), 185-198.

PLANCHOT V., COLONNA P., SAULNIER L., 1994.
Dosages des glucides et des amylases, Guide Pratique d'Analyses dans les Industries des Céréales, Ed. B. Godon and W. Loisel, Lavoisier.

MELCION J.P., 1988.
Traitements thermiques et hydrothermiques des graines oléoprotéagineuses, i'Doc_M1, i'Doc_M6 et i'Doc_S10 TECALIMAN

TECALIMAN, February 1995.
Evaluation du degré de transformation de l'amidon en Alimentation Animale, i'Doc_M4 TECALIMAN