Borregaard LignoTech

How the type of starch can influence pelleting

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Introduction

Starch is one of the primary ingredients used in feed, together with protein. But starches from different sources offer a range of functional properties that need to be considered, not only from a nutritional perspective but also for technological aspects.

Starch structure and function

Chemically, starches are polysaccharides that consist of repeating glucose units. Starch molecules have one of two molecular structures: a linear structure, known as amylose; and a branched structure, known as amylopectin. Amylose and amylopectin associate through hydrogen bonding and arrange themselves radially in layers to form granules. Starches from different sources vary from one another in the following ways - each of which may affect performance:

Granule size and shape. Starch granules come in a wide variety of sizes ranging from 3 microns to over 100 microns. Wheat starch, for example, has a distribution of both large and small granules while corn starch has a narrow distribution of rather large granules.

Amylose:amylopectin ratio. All starches are composed of varying proportions of amylose and amylopectin. The ratio varies not only among the different types of starch, but among the many plant varieties within a type. Waxy starches are those that have no more than 10% amylopectin. Standard wheat and corn starches contain 25 to 28% of amylose and 72 to 75% of amylopectin, not a big difference for this specific parameter.

Other variations also exist in starches. In general, most such variations consist of the presence of non-starch components in the granule (or close to), such as lipids or protein. Those elements can highly influence gelatinization, even at low concentration.

Corn. Four classes of corn starch exist. Common corn starch has 25% amylose, while waxy maize is almost totally composed of amylopectin. The two remaining corn starches are high-amylose corn starches; one has 55% to 55% amylose, while the second has 70% to 75%. Granules size ranges between 15 microns and 20 microns, quite a narrow distribution.

Potato. Potato starch has about 20% amylose. Its granules range in size from 15 to 75 microns, quite a large distribution.

Rice. Common rice starch has an amylose:amylopectin ratio of about 20:80, while waxy rice starch has only about 2% amylose. Both varieties have small granule sizes ranging from 3 to 8 microns.

Tapioca. Tapioca starch has 15% to 18% amylose. Tapioca granules are smooth, irregular spheres with sizes ranging from 5 to 25 microns (large distribution)

Wheat. Wheat starch has an amylose content of around 25%. Its granules are relatively thick at 2 to 15 microns.

How to characterize starch in pelleting

Starch experts universally agree that starch structure and composition affect performance. However, a direct correlation is not always obvious, and we should consider changes in several traits to explain main differences between starch sources.

A review of what is currently known about how structure and composition affect performance follows. But first, here is a brief review of what happens during starch gelatinization during pelleting:

When starch enters the conditioner, water penetrates the starch granule from the outside inward until the granule is fully hydrated. Once hydrated, the hydrogen bonding between the amylose and the amylopectin maintains the integrity of the granule and it begins to swell from the center. Once gelatinized, the swollen granules may increase the viscosity of the dispersion creating in most cases a good pellet, or when gelatinization is not under control, blocking the dye.

Granule size and structure. Large starch granules tend to build higher viscosity, but the viscosity is delicate because the physical size of the granule makes it more sensitive to shear. But bringing viscosity is not necessarily bad in pelleting. It can provide extra binding capacity, and that's what we ask of starch based raw materials. Thus, more than the granule size, the narrow or large distribution of granule sizes has even more influence on gelatinization. Wheat starch, for example, has a bimodal distribution of both small and large granules, and those granules will, therefore, gelatinize at different moments in the conditioner depending on heat and moisture available. This permits smooth and easy control of the gelatinization. Corn starch has large granules with narrow distribution, and thus gelatinization happens all at once which can create blockage in the dye.

Temperature. Gelatinization temperature windows can vary with raw materials (see below). Wheat is the first starch to get gelatinized, thus making it an easy binder for pelleting. Barley starch is also quite easy to pelletize. However, corn starch only starts to gelatinize at 70 to 72˚C where other polymerization (see paragraph on lipids and proteins) can occur.

Starches	gelatinization temperatures 'C
maize	70-75
sorghum	70-75
rice	68-75
wheat	52-54
barley	61-62
potato	56-69

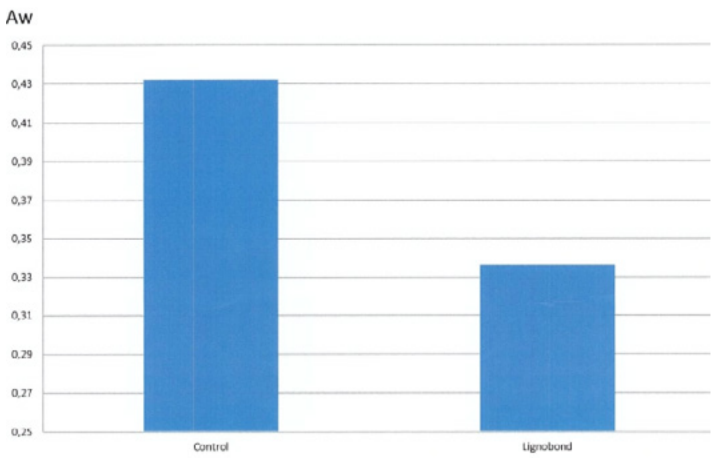
Lipids: Lipids are known to inhibit granule swelling. Wheat contains approximately twice as much lipids as maize and it can be one of the elements affecting the ease with which wheat starch gelatinizes compared to maize.

Protein: During gelatinization, if protein is directly available in the near environment of the starch granules, then this protein can get associated with the surface of the granule (polymerization). This creates a protein starch polymer, which increases the viscosity of the feed. This is the case when one uses corn gluten meal in a feed formulation, which is rich in protein and starch. Protein and starch will recombinate during gelatinization and generate a plastic mass into the dye, leading most often to blockages.

How using lignin-based pelleting aid LignoBond can help solve gelatinization problems

Lignosulfonate and lignosulfonic acids are well known surfactants. These polyphenolic macromolecules have an important capability to bind water and thereby reduce water activity. Hereafter, two experiments on water activity:

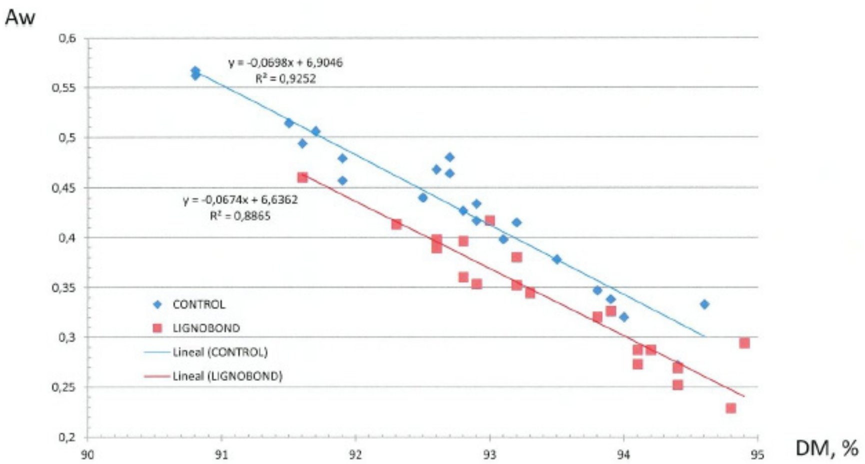
Water activity of feed pellets with or without lignin-based pelleting aid



Graph 1: Water activity of feed pellets without lignosulfonate (Control), and with 1% lignin-based binder (LignoBond) – Moisture content being 13% for both.

One can see that at the same moisture content, water activity is reduced by 22% when using LignoBond in the feed (1%).

Water activity vs dry matter



Graph 2: Water activity (Aw) vs dry matter (DM) – LignoBond effect (1%)

One can see that using 1% LignoBond can help to:

- **Option A:**
  Increase moisture content at constant Aw
- **Option B:**
  Decrease Aw at constant moisture content

This specific property of LignoBond is of great help in starch gelatinization. By catching free moisture and converting it to bound moisture in the conditioner, LignoBond will bring heat and moisture in a smooth and regular manner to the starch granules. LignoBond will start to absorb moisture around 45°C and will help starch to gelatinize gently. LignoBond in that case acts like a moisture absorption regulator, enlarging the temperature window where starch granules can start to absorb steam.

An additional remark: In the case of a challenged formula concerning starch source (a lot of corn gluten meal, no wheat and only maize), it can occur that a standard lignosulfonate won't give provide enough benefit to overcome plastic gelatinization and blockage in the dye. In that case, the solution is to combine the moisture absorption effect with good lubrication of the dye, enabling the feed to pass through easily. A product capable of handling such a challenge is PellTech, the only purposely designed Binder/Lubricant on the market.

Conclusion

Pelleting of feed leads to physical and chemical changes to the ingredients, including the gelatinization of starch. Starch gelatinization is probably one of the three most important and effective drivers for improved pelleting (together with steam management, compression ratio and friction).

The objective of this article was to give a brief overview of the different behaviors of starch derived from various raw materials. In addition, information on starch (type of raw material, date of harvest, how it was stored and/or processed) should be communicated on a very frequent basis within a feed plant, i.e. sharing of information between formulators, production managers and operators. This in order to adjust process parameters in parallel to the reformulation of raw materials.

We can't assume that Formula A – 'Poultry Feed' always has to be conditioned at 65°C. This may have been the case 15 years ago, when composition of the feed was quite stable. Today, however, production of pelleted feed requires an ongoing adjustment of the formulation in order to assure the best performance/cost ratio. Managing a pelleting process also requires regular adjustment of steam pressure, conditioning temperature and binder usage in order to reflect the fast changes in formulation.