Technical Bulletin

Amylose and amylopectin in pet foods & treats:
How well do you know your starch?

Key Points

- Starch sources have different functional properties based on their amylose and amylopectin content.
- The structure of amylose is mostly linear, whereas amylopectin is a highly branched molecule, which contributes to the different physical, chemical and functional properties of starch.
- The ratio of amylose to amylopectin in starch sources can vary greatly, from 0.01 to 3.00.
- Pet food formulations containing a high amount of amylopectin have greater kibble expansion during extrusion but may have more fines than formulations with a high amount of amylose.
- Balancing amylose and amylopectin in a formula is critical for producing extruded kibble that is structurally sound and achieves the desired shape, size and density.

Starch is extensively used in many food applications as a thickener and texturizer due to its ability to gelatinize to form pastes when heated in water. Starch thickens, binds water, controls moisture, and creates viscosity. Starch is an important component of pet foods for both its functional and nutritional properties. When cooked, starch is highly digestible and provides a readily available energy source for dogs and cats. In most applications it is difficult, if not impossible, to create a finished pet product with the desired texture and appearance without one or more starch sources in the formulation.

Given the importance of starch in producing dry kibble and wet foods that are appealing to both pets and their human companions who purchase the food, it is important for pet food manufacturers to know their starch from the inside out.

The building blocks of starch: Amylose and amylopectin

Starch is an insoluble, non-structural carbohydrate synthesized by plants and stored in granules to provide a source of energy for seed germination. Starch granules are composed of two distinct glucose polymers – amylose and amylopectin.

The structure of amylose is mostly linear and consists primarily of α-1,4 glycosidic bonds. Amylose is free-floating in the starch granule and is not part of the granule structure. Amylose is prone to retrogradation which occurs when gelatinized starch reorganizes to form more ordered structures. This can result in water loss (syneresis) and altered product quality and shelf-life.

In contrast, amylopectin is a structural component of the starch granule. It is a highly branched molecule that has both α-1,4 and α-1,6 glycosidic bonds. The branching increases water binding which results in higher water holding capacity and promotes greater viscosity compared to amylose. Amylopectin is less susceptible to gelling and water loss than amylose.

Starch granules vary in their size and shape in different plants and in their content of amylose and amylopectin. Because of the different molecular structures of amylose and amylopectin, the amount of each polysaccharide present in the granule significantly affects the physical, chemical and functional properties of starch. Table 1 provides a summary of the structural and functional characteristics of amylose and amylopectin.

Table 1. Characteristics of amylose and amylopectin components of starch

Characteristic	Amylose	Amylopectin
Shape	Mostly linear	Branched
Linkage	α-1,4 (some α-1,6)	α-1,4 and α-1,6
Molecular weight	< 0.5 million g/mol	50 – 500 million g/mol
Film forming	Strong	Weak
Gelling	Firm	Soft
Color with iodine	Purple/Blue	Reddish brown

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Starch analysis

Not only does the amylose and amylopectin content of high starch foods vary between plant sources, but the amylose content can also vary due to differences in geographic origin, growing conditions, and crop variety. Thus, knowing the amylose and amylopectin content of the specific starch sources used in a pet food formulation is important to help predict how the finished product will perform in terms of texture, structure, appearance, mouth-feel, and viscosity.

Starch composition affects functionality

At ADM, we can help customers determine the amylose and amylopectin content of starches along with other analytical techniques to assess starch functionality in order to achieve the desired finished product characteristics.

Two methods are typically used to analyze the amylose and amylopectin content of starch. In the first method, iodine is used to test for the presence of starch. A starch-iodide complex absorbs light at a different wavelength resulting in an intense purple color. Iodine complexes preferentially with amylose, thereby allowing for colorimetric determination of the amylose content. However, this method is subject to uncertainties that can lead to an overestimation of amylose, requiring corrections to be applied. A second analytical technique involves the formation of amylopectin complexes with the lectin, concanavalin A (Con A). This method is not subject to the uncertainties of the iodine test. This assay is commercially available and can be used for milled grain or seed samples, whereas the iodine procedure requires prior purification of the starch.

Table 2 shows the typical amylose and amylopectin content of ingredients commonly used in pet foods and treats analyzed at the ADM James R. Randall Research Center. In the table, a range is provided along with the typical value when amylose or amylopectin content is known to vary significantly within the same crop. The typical values are used to calculate the amylose to amylopectin ratio. The starch sources are ordered in the table based on the ratio, from lowest to highest, which shows the wide range of values from 0.01 to 3.00.

The balance of amylose and amylopectin within the starch granule of the grain determines the extrusion responses and the finished kibble characteristics. The ratio of amylose to amylopectin provides some guidance relative to the expected use of these grains in extrusion. Starch sources with low ratios will generally trend towards responses driven by amylopectin while high ratios will generally provide results elicited by amylose.

Table 2. Typical starch composition of pet food ingredients

Source	Amylose, % Total Starch	Amylopectin, % Total Starch	Amylose to Amylopectin Ratio
Corn (waxy)	1	99	0.01
Amaranth	11	89	0.12
Quinoa	11	89	0.12
Barley (hulled)	15	85	0.18
White millet (proso)	16	84	0.19
Buckwheat	17	83	0.20
Potato	22	78	0.28
Wheat	23	77	0.30
Tapioca/Cassava	24-26 (25)[a]	74-76 (75)[a]	0.33
Corn	20-28 (25)[a]	72-80 (75)[a]	0.33
Sorghum	28	72	0.39
Oat groats	30	70	0.43
Chickpeas	30-35 (33)[a]	65-70 (67)[a]	0.49
Yellow pea (smooth)	24-49 (35)[a]	51-76 (65)[a]	0.54
Corn (high amylose)	50-90 (75)[a]	10-50 (25)[a]	3.00

[a]Range (typical value used to calculate amylose to amylopectin ratio)

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Starch and extrusion processing

In extrusion, starch is the component primarily responsible for kibble expansion. Heating (130-160°F, 55-71°C) disrupts the crystal regions in the starch granule causing the granule to absorb liquid and swell. During extrusion, amylose is more resistant to hydration than amylopectin making it less susceptible to denaturation (uptake of water) due to its linear structure. High amylose starches may require increased water injection, elevated barrel temperatures and increased shear to enhance cook. In general, the higher the amylose content of the starch granule, the higher the gelatinization temperature. Conversely, the branched structure of amylopectin results in higher water holding capacity which makes it more susceptible to denaturation and requires less extruder water, decreased shear, and lower temperature than amylose.

As extrudate exits the die, the degree of expansion is determined in large part by the polysaccharide composition of the starch granule. Amylose has high gelling characteristics resulting in less expansion and a more durable kibble after exiting the extruder die due to tight polymer formation. This results in reduced finished product fines due to the increased strength of the extruded product. On the other hand, amylopectin forms a more viscous, sticky dough that is more difficult to cut by the knives as the extrudate exits the die thereby resulting in more deformed finished product. In addition, a high amylopectin extrudate produces increased post-extrusion retrograde expansion due to more random polymerization. As such, the finished product is more fragile and generally results in increased fines compared to a high amylose product. Thus, a balance of amylose and amylopectin is critical to produce kibble that is structurally sound and achieves the desired shape, size and density. Table 3 provides a summary of the effects of amylose and amylopectin during extrusion and on final kibble quality.

Pet food formulations containing a high amount of amylopectin have greater kibble expansion during extrusion but may result in more fines than formulations with a high amount of amylose.

Table 3. Summary of amylose and amylopectin effects on extrusion and kibble quality

Starch Type	Hydration	Gelatinization	Retrograde Expansion	Kibble Strength	Fines
Amylose	More resistant	↑ Temp/H_2O	↓	↑	↓
Amylopectin	Less resistant	↓ Temp/ H_2O	↑	↓	↑

Summary

Knowing the amylose and amylopectin content of the starch sources used in a pet food formulation is essential to achieving the desired finished product. When developing a new extruded pet food, the kibble shape may be a factor in determining how much amylose needs to be in the formulation. For example, a star-shaped kibble is more fragile than a cylinder, so a higher amylose content may help to prevent fines and kibble breakage. For legacy formulations, if issues suddenly arise during extrusion or kibble breakage becomes a problem, investigating if there have been any changes in the amylose and amylopectin content of the starch sources may help to identify the source of the problem. Partnering with an ingredient supplier who understands starch from the inside out will help to ensure your pet food and treat formulation success.