# Degree of Starch Access (DSA): Background, Interpretation and Relationship to Starch Digestibility in Dairy Cattle

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## Introduction

Starch, supplied in Midwest diets primarily from high-moisture and dry corn grain and whole-plant corn silage, is an important source of energy for dairy cattle. However, the digestibility of corn starch can be highly variable. Various factors, particle size (fine vs. coarse grind), grain processing (steam flaked vs. dry rolled), storage method (dry vs. high-moisture corn), moisture content of high-moisture corn, type of corn endosperm, and corn silage maturity at harvest, chop length, and kernel processing, influence ruminal and or starch digestibility in lactating dairy cows. Because both physical and chemical properties of starch influence starch digestion, assessment of starch digestibility in the laboratory has been challenging. In an attempt to address variation in starch digestibility, NRC (2001) suggested empirical processing adjustment factors (PAF) to adjust non-fiber carbohydrate digestion coefficients for high-starch feeds. However, since no system to measure variation in processing adjustment factors for feedstuffs is available the PAF's are subjective book values with minimal practical application. For corn silage, Ferreira (2002) developed a kernel processing score (KPS) to assess adequacy of kernel processing of corn silage. But, KPS values have not been related to in vivo starch digestibility measurements. Some commercial laboratories employ in situ or in vitro systems to evaluate starch digestibility, but methods are highly variable between laboratories and relationships to in vivo starch digestion are often not well defined.

## What is Degree of Starch Access?

In an effort to overcome challenges associated with evaluating starch digestibility for corn-based feeds, our laboratory developed the degree of starch access (**DSA**) procedure. The DSA procedure is relatively simple and was repeatable across dry and high-moisture corn grain and whole-plant corn silage samples. The DSA procedure (Blasel et al., 2005) is conducted on feeds in the physical form in which they are fed. A brief description of the DSA procedure is as follows:

- A 5 to 20 g sample of un-ground, un-dried starch containing feed is placed in a large beaker,
- Water and buffer solutions are added and the sample is heated to 95$^{o}$C,
- After heating the sample is treated with heat-stable amylase and stirred,
- After cooling the sample is re-treated with an additional buffer and amyloglucosidase and stirred for 60 minutes.
- The amount of starch converted to glucose is then determined,
- The amount of starch liberated from the un-ground, un-dried sample is then divided by the total starch content of the feed and percentage of starch recovered from the feed in its un-dried, un- ground form is determined.

The starch recovery procedure is extremely sensitive to particle size ($R^2 = 0.99$) and moderately sensitive to moisture content ($R^2 = 0.76$) and endosperm type ($R^2 = 0.59$), which are three primary factors that influence starch digestibility in corn grain.

**What is the Relationship between DSA and Starch Digestibility?**

The starch recovery procedure does not result in a direct estimate of starch digestibility. The laboratory procedure only results in differences in starch recoveries. For example, the DSA procedure would recover 95 percent of the starch in finely ground corn but only 5 percent of the starch in whole shelled corn. Thus, the DSA values provide an index of the variation in degree of starch access among feeds. We reviewed eight research reports in the scientific literature with trials using lactating dairy cows, measuring total tract starch digestibility, which provided information on the particle size, moisture content, and endosperm type of the corns tested. From these data, we estimated their DSA values and evaluated the relationship between DSA and their measures of total tract starch digestibility (Refer to Figure 1). This regression equation can be applied to starch recovery values generated from the DSA laboratory procedure yielding an estimate of total tract starch digestibility (termed Starch $Digestibilit_{DSA}$). Starch $Digestibility_{DSA}$ can then be used in summative energy equations (NRC, 2001) to provide energy values for corn-based feeds on a standardized basis.

**What are the Advantages and Limitations of DSA?**

The DSA assay: is relatively simple, is repeatable, can be adapted by commercial feed testing labs, requires minimal laboratory equipment, and does not require rumen fluid. The DSA assay is sensitive to factors in corn grain and whole-plant corn silage, such as particle size, moisture content, and endosperm type, which are known to influence corn starch digestibility and DSA starch recovery values can be adjusted to the normal range of in vivo starch digestibilities observed in lactating dairy cows. The DSA assay also can determine relative starch digestion potentials of a heterogeneous feed, such as corn silage, or a non-heterogeneous feed, such as steam-flaked corn grain, and evaluate them on a similar scale which to date has been difficult with the available laboratory procedures. Despite these advantages, the DSA procedure does have limitations. At present, there are no data available to establish a direct relationship between a measured DSA value and in vivo starch digestibility, just a regression equation developed from literature reports. Also, the DSA assay may not distinguish the nuances of starch digestion by ruminants, such as the interactions between ruminal and post-ruminal starch digestion. The DSA assay may also be prone to background interferences of mono- and oligosaccharides, which could result in over-estimation of starch digestibility.

**How are Starch $Digestibility_{DSA}$ values Interpreted?**

A summary of Starch $Digestibility_{DSA}$ values observed for common corn-based feeds is presented in Table 1. The Starch $Digestibility_{DSA}$ values for processed dry grain range from 98 percent for very fine-ground corn to 84 percent for cracked corn. This 14 percentage unit difference in Starch $Digestibility_{DSA}$ would translate into a 10 percentage unit difference in the $TDN_{1x}$ values for these corns calculated using a summative energy equation. At a 10 lb. dry

matter per cow per day feeding rate of corn, failure to account for this difference in energy values could cost about 3 lb. of milk per cow per day.

Typical Starch Digestibility$_{DSA}$ reference values are as follows:

| Starch Digestibility$_{DSA}$ (% of Starch) | Reference |
|---|---|
| > 96.0 | Very High |
| 96.0-93.0 | High |
| 93.0-90.0 | Medium |
| < 90.0 | Low |

Beware of potential for milk fat test depression and(or) subacute ruminal acidosis when feeding corn-based feeds with "very high" Starch Digestibility$_{DSA}$ in diets containing low neutral detergent fiber (NDF) from forage or low effective NDF, especially when in conjunction with sub par bunk management practices.

**References**


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Figure 1. Relationship between Starch Digestibility$_{DSA}$ as predicted from DSA starch recovery and total tract starch digestibility in lactating dairy cattle. Relationship is based on starch recovery estimated from particle size, moisture content and corn endosperm data from eight published research trials which evaluated total tract starch digestibility in lactating dairy cows.

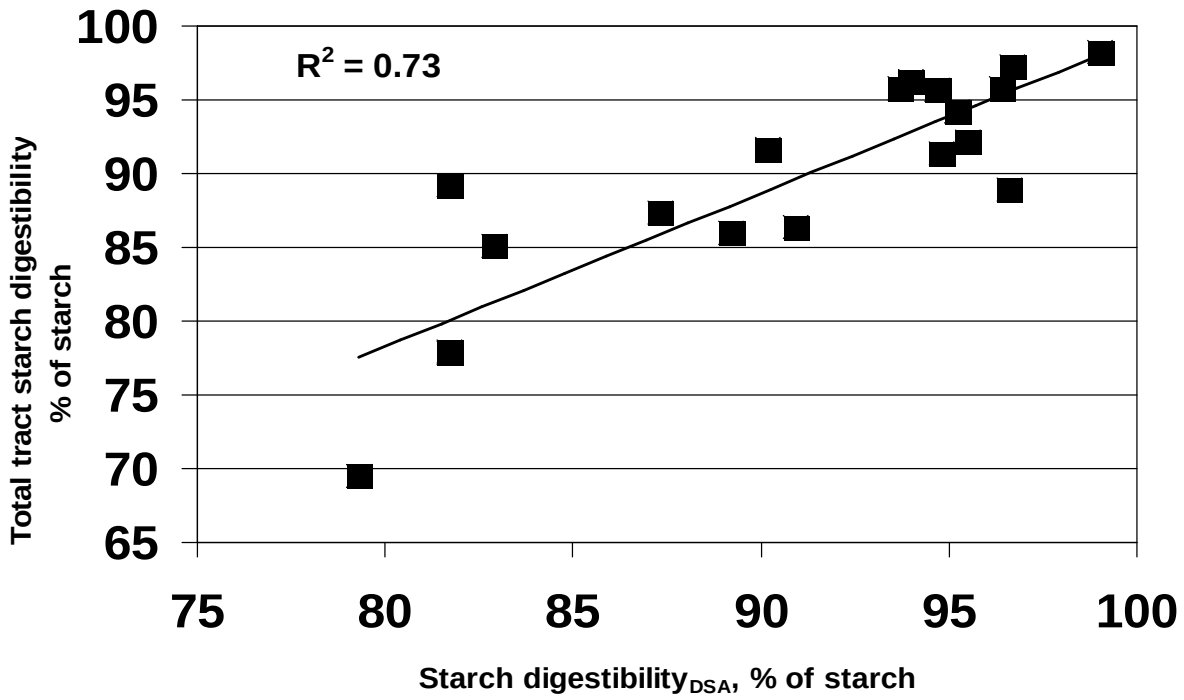


Table 1. Potential range for Starch Digestibility$_{DSA}$ of corn-based feeds commonly fed to dairy cattle.

| | | Starch Digestibility$_{DSA}$ (% of Starch) | | |
|---|---|---|---|---|
| **Feed** | **Starch % of DM** | **Minimum** | **Maximum** | **Average** |
| | | | | |
| Corn Starch | 95.2 | 97 | 98 | 98 |
| Shelled Corn | 68.2 | 79 | 98 | 92 |
| Steam-Flaked Corn | 71.7 | 92 | 98 | 95 |
| High-Moisture Corn | 67.6 | 81 | 98 | 93 |
| Corn Silage | 27.7 | 80 | 98 | 94 |