CORN in Pet Food

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NATIONAL CORN GROWERS ASSOCIATION

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Acknowledgments

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Top 10 Reasons to Include Corn in Pet Food

1) Corn provides energy AND nutritional value to pets.

2) Dry foods, like extruded kibbles, generally contain between 30-60% starch ingredients. Corn is a great source of starch which helps promote kibble binding and expansion when it is cooked in the presence of water and heat (a process known as starch gelatinization).

3) Including >60% corn in pet food recipes promotes quality stools and high apparent total tract digestibility in dogs, to levels comparable to sorghum and rice.

4) Corn is a great choice for extruded kibbles due to its palatability and structure forming physical properties. It toasts well and forms browning reaction products with rich flavor notes creating aesthetically pleasing kibbles with a desirable texture. In fact, corn is actually preferred over other grains in palatability tests.

5) A moderate intake of starch ingredients like corn adds energy to the diet, besides providing nutrients like fiber, protein and lipids (fatty acids and antioxidants). When whole corn or corn starch are included in a pet food and properly cooked, the starch becomes almost entirely digestible by the end of the small intestine. Any remaining undigested starch passes to the colon where most is fermented. The disappearance of starch in corn is nearly 100% by the point at which it is excreted in feces.

6) Corn is also known to be high in carotenoid antioxidants lutein and zeaxanthin, which if concentrated could provide functional antioxidants that enhance the immune system of cats and dogs.

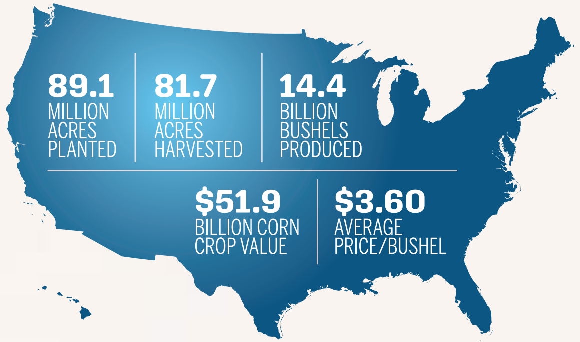
7) Dogs fed a corn-rich diet also produced more short-chain fatty acids in the colon. Short chain fatty acids are supportive to the immune function and homeostasis of the intestine.

8) Corn is an example of a starch ingredient that can be used in dry pet foods due to its physical properties. Other nutrients like fiber and proteins may be more concentrated in corn by-products derived from corn processing, and these confer additional health benefits to the pet diet.

9) Corn is sustainable! Since 1980, yields have increased 64%, energy usage has decreased 44%, soil loss has decreased 68% and GHG emissions have decreased 36% per bushel of corn.

10) Corn is an abundant, available and affordable ingredient.

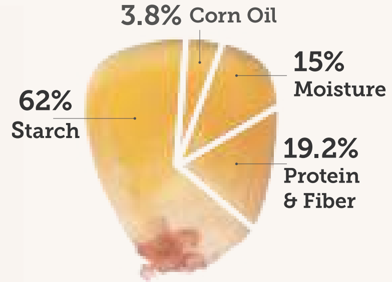
In 2018, corn farmers grew 14.4 billion bushels of field corn. Thanks to technology, farmers continue to produce more per acre on less land using fewer inputs. There were 1,735 billion bushels of U.S. corn ending stocks. The average year over year yield growth is 1.2%.

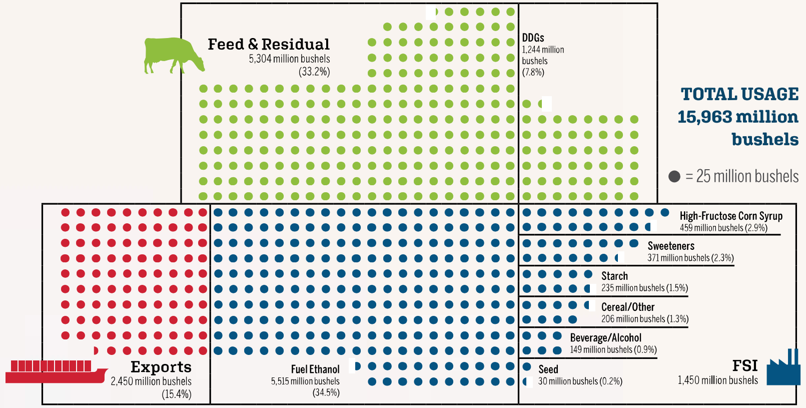


SINCE 2000

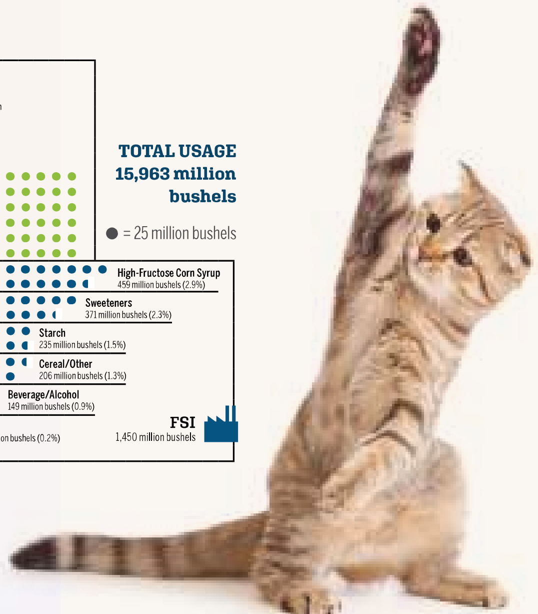
- Corn production up 4.7 billion bushels
- Average yields have grown by nearly 40 bushels/acre
- U.S. total corn production is up 47% and corn yields have increased by 29%

Here's a breakdown of the average composition of a kernel of corn:





Source: USDA, ERS Feed Outlook, Feb. 2019; ProExporter Network, Crop Year Ending Aug. 31, 2019



Corn used in pet foods are usually dent hybrids, or by-products of other corn varieties from the human food chain. Its nutritional composition may benefit both health and different food processes that transform corn or its by-products into a final product. Dry pet foods tend to have around 30-60% starches (Fortes et al., 2010), and corn is a common ingredient found in these diets. The whole kernel can be divided into 3 anatomical parts: the pericarp, endosperm and the germ (Győri, 2010). Some authors also consider the tip as an anatomical part of corn (Lasztity, 1999). The corn endosperm is divided into the horny endosperm, which contains protein and starch, and the floury endosperm, with mostly starch granules. The germ contains high amounts of lipids, and the bran, which includes the pericarp and hull, is the fibrous fraction of corn with primarily insoluble fibers cellulose and hemicellulose, and pectic substances (Győri & Mile, 2002). The corn grain moisture varies according to the relative humidity of the air and temperature (Hall, 1980).

Murray et al. (1999) reported the composition of corn as 5.6% protein, 3.2% fat, 88.3% starch and 3.0% total dietary fiber (TDF). Of course, these values will vary according to corn type and growing conditions.

Corn (kernel) is reported to contain 60-80% starch on a dry matter basis (DMB; Gyori, 2010). The endosperm has large starch granules with a spherical or kidney shape, and smaller granules that are oval. The starch granule is composed of the polymers amylose and amylopectin (Svihus et al., 2005). Amylose is a linear molecule composed of anhydroglucose units linked by α-1,4 bonds, whereas amylopectin is a branched glucose polymer with α-1,4 and α-1,6 bonds. While amylose has a low molecular weight, amylopectin is a more massive polymer (Buléon et al., 1998). There are certain cultivars within species that can have different ratios, such as waxy maize corn with almost 100% amylopectin, or corn with high amylose content comprised of 70% amylose (Koehler & Wieser, 2013; Weber et al., 2009). This amylose-amylopectin ratio will affect extrusion processing, which will be discussed in the *Processing Corn for Pet Food Diets* section.

Corn is included in many pet food recipes. In extruded kibbles, this cereal is commonly used due to its palatability and structure forming physical properties. Besides producing aesthetically pleasing kibbles with a desirable texture, corn must also be considered for its nutritional attributes which may affect the animal's health. Digestibility studies are important to evaluate the efficacy of diets and to determine whether or not nutrients are properly absorbed by the dog or cat. Scientists commonly measure the fecal disappearance of nutrients and calculate apparent total tract digestibility (ATTD) by the difference between intake and output of each nutrient. This can be accomplished by total fecal collection, or by using a fecal marker that requires a small daily fecal sample.

Dogs and cats have a metabolic requirement for glucose, which can be obtained from dietary sugars or from gluconeogenesis (Tanaka et al., 2005). A moderate intake of starch ingredients like corn adds energy to the diet, besides providing nutrients like fiber, protein and lipids (fatty acids and antioxidants).

When whole corn or corn starch are included in a pet food and properly cooked, the starch becomes almost entirely digestible by the end of the small intestine (ileum; 89.9-99.5%; Gajda et al., 2001; Murray et al., 1999; Walker et al., 1994). Any remaining undigested starch passes to the colon where most is fermented. The disappearance of starch in corn is nearly 100% by the point at which it is excreted in feces (Roseboom and Patton, 1929).

The DM ATTD is a good indicator of overall diet utilization. The DM ATTD in corn based diets has been reported to be high and comparable to other grains like sorghum, and similar or slightly lower than rice (Bazolli et al., 2015; Carciofi et al., 2010; Kore at al., 2009; Carciofi et al., 2008; Twomey et al., 2003). Another study found that DM ATTD of a corn-based diet was similar to rice and wheat-based diets, and higher than barley, potato and a sorghum-based diet when fed to dogs (Murray et al., 1999). Dogs fed corn-based diets were also reported in several studies to produce firm, high quality feces (Kore et al., 2009;

Twomey et al, 2003; Murray et al., 1999; Walker et al., 1994). When comparing different corn species, Gadja et al. (2001) found that DM illeal digestion of extruded high protein corn was higher than conventional, low protein and low phytate corn, high-amylose corn and amylomaize (64.6% vs average 57.8%). These authors concluded that high amylose corn should not be used in dog diets because it had low ATTD and little in vitro fermentation.

When corn starch is digested, it is broken down into small oligosaccharides, disaccharides and monosaccharides, like maltose and glucose. These simple sugars are absorbed in the GI tract and enter the bloodstream, which are then transported into cells with the aid of insulin and other hormones. The extent of processing, inclusion of starch ingredients and type of starches all influence the extent to which glucose is absorbed. High starch diets with highly digestible starches rapidly increase plasma glucose and insulin. Carciofi et al. (2008) reported that dogs fed a diet with 53.5% corn as its only starch ingredient had peak blood glucose and insulin levels just a few minutes after feeding, in a manner similar to dogs fed a brewer's rice diet. So, the notion that corn is an indigestible filler does not appear to be valid based on these results. However, controlling glucose response in rapidly digested corn-based diets might have a benefit for animal health. This can be accomplished by combining different starch sources in the diet and/or modifying the process to favor the retention of slowly digestible or resistant starches.

In fact, many studies in the literature have clearly shown that an excess of 60% corn in pet food recipe promoted quality stools and high apparent total tract digestibility in dogs, to levels comparable to sorghum and rice (Carciofi et al., 2010; Kore et al., 2009; Walker et al., 1994).

Colon health (fiber and resistant starch)

The starch contained in the corn endosperm can be classified into digestible or resistant to digestion. Digestible starches completely disappear by the end of the ileum, and the undigested fraction, called resistant starch (RS), is prone to bacterial fermentation in the colon. As a general rule the more cooked, the more easily starch is digested in the small intestine. Since extrusion is a high moisture/ high energy cooking process, RS tends to be low in extruded foods (Peixoto et al., 2017). Less intensive cooking processes like baking were observed to have lower starch gelatinization compared to extrusion (Gibson and Alavi, 2013). Thus, baked kibbles should retain more RS than the same extruded recipe, but this must be confirmed.

A certain degree of cooking is necessary in most pet foods for food safety, and to improve overall diet utilization. Schünemann et al. (1989) demonstrated that canine ileal digestion of raw corn was increased after cooking. Moore et al. (1980) found no difference in starch ATTD between cooked and uncooked corn. This is likely due to the portion of starch that escaped intestinal digestion in both diets and was fermented in the colon and thereby disappeared in the feces.

The extent of corn grinding (before extrusion) also affects its utilization. Bazolli et al. (2015) found that kibbles with coarse maize tended to be less digested by dogs. They noted that the portion that escaped digestion was fermented and produced feces with lower pH (due to higher lactate production) and more butyrate in comparison to the same diet extruded with fine corn. Thus, these authors found benefits from under-processing the corn. Peixoto et al. (2017) also found that a diet produced with coarser corn and a lower extruder specific mechanical energy (SME) benefitted colon health of geriatric Beagle dogs by generating more fecal butyrate and lowering fecal pH due to a higher lactate production. Additionally, the diet with less processing tended to increase gastrointestinal mucosa crypt depth, which suggests an improvement in nutrient absorption.

Some marketing trends claim that high protein diets are better for pets, but this depends on factors such

as protein quantity, quality, and the amino acid profile. Hang et al. (2013) reported benefits in feeding a high corn diet vs high protein greaves-meal to dogs. Dogs fed the high corn diet produced firm feces with low ammonia and neutral fecal pH, which were similar to those of dogs fed a dry commercial diet (Hang et al., 2013). A low fecal ammonia could indicate that less protein reached the colon for fermentation. The by-products of protein fermentation in the colon, such as polyamines, are indicators of putrefaction, and may be attenuated by the addition of fiber to the diet (Jackson and Jewell, 2018). Dogs fed a corn-rich diet also produced more short-chain fatty acids in the colon (Hang et al., 2013). Short chain fatty acids are supportive to the immune function and homeostasis of the intestine (Corrêa-Oliveira et al., 2016). Butyrate is almost entirely used by colonocytes as an energy source; whereas, acetate and propionate are transported to the liver through the portal vein (Haenen et al., 2013) and converted to energy substrates. Further, butyrate is thought to inhibit the division of cancer cells and proliferation of colonic mucosal cells (Barnard and Warwick, 1993). Thus, a diet rich in fiber and resistant starches that are fermented in the colon might be preferred over a high protein food resulting in undigested proteins reaching the large intestine, which are converted to unhealthy nitrogen compounds like biogenic amines.

Antioxidants

Corn is also known to be high in carotenoid antioxidants lutein and zeaxanthin (Masisi et al., 2015). Other nutrients like fiber and proteins may be more concentrated in corn by-products derived from corn processing, and these confer additional health benefits to the pet diet.

Corn and foods made from it have been classified as high in the carotenoids lutein and zeaxanthin (Masisi et al., 2015; Abdel-Aal et al., 2013). Lutein and zeaxanthin are xanthophylls that have been related to eye protection in humans against age-related macular degeneration due to their antioxidant capacity. Perry et al. (2009) measured xanthophylls in corn and corn products and found that yellow corn is high in

zeaxanthin trans (531 ppm) which is comparable to cooked egg yolks (587 ppm). Conversely, Moreau et al. (2007) found lutein and zeaxanthin in whole ground corn to be much lower (2.63 and 4.59 ppm, respectively). These carotenoids like lutein have been found beneficial to dogs and cats. For example, Kim et al. (2000a) fed dogs crystalline lutein at 5 mg/d, 10 mg/d and 20 mg/d for 12 weeks and detected a significant improvement in the immune system for all treatments relative to a control (0 mg/d) after just 2 weeks. Kim et al. (2000b) also found that crystalline lutein improved humoral and cellular immune responses in cats. In rats, lutein supplementation was reported to decrease leukocyte apoptosis, while increasing tumor cell apoptosis (Park, 2004).

According to the literature, a level of 5 mg of lutein was required to invoke some positive effects in immune function. Whole corn was reported to have 2.63 ppm lutein (2.63 ppm= 0.00026 mg/g). Thus, it would be necessary to concentrate corn-based carotenoids in order to have an antioxidant effect. While not there today, technology might aid concentrating carotenoids in future work.

The process of hydrolyzing cereal protein to enhance antioxidant activity has been well explored in the last decade. Zhuang et al. (2013) hydrolyzed corn gluten meal (60% crude protein) with alkaline protease and measured antioxidant activities of different hydrolysate sizes. They observed that free radical scavenging, metal ion chelating activities and lipid peroxidation inhibition increased as hydrolysate size decreased and was greatest with hydrolysate molecular weight less than 10 kDa. Zhou et al. (2015) also found that the antioxidant activities of corn gluten meal hydrolyzed proteins was highly correlated to small peptide molecules and antioxidative amino acids such as tyrosine, lysine, histidine and methionine. Hence, corn has the potential to produce functional food ingredients high in antioxidants, which could be derived by hydrolyzing proteins from corn gluten meal or from concentrating carotenoids.

The majority of dogs and cats are fed extruded dry kibbles, and market data estimates that the pet food extrusion market will reach $ 72.64 billion worldwide by 2022 (Research and Markets, 2017). Pet food extrusion is a complex and versatile process that involves cooking under pre-determined conditions of pressure, moisture, mechanical and thermal energies. This is a complex process because the final kibble must meet physical specifications, and also be nutritionally balanced to meet the animals' requirements by combining ingredients with different physical attributes, including fats, proteins, starches, and vitamins and minerals additives.

The macroingredients in a diet cause the most impact on extrusion performance. According to the Guy Classification System (Guy, 2001) ingredients can be structure forming, dispersed phase fillers or plasticizers. Structure forming ingredients like starches and (or) vegetable proteins promote binding, homogenization and structuring of the dough. Starchy ingredients like ground corn are the most common structure forming ingredients. At the other end of the spectrum, ingredients classified as dispersed phase fillers or plasticizers do not contribute to matrix forming and can negatively affect the structure quality of the dough. Thus, corn by-products high in fiber or high in overly processed proteins like corn gluten meal tend toward dispersed phase fillers.

As noted above, whole corn or corn starch are structure forming ingredients due to their high starch contents. Prior to extrusion processing, corn like the other dry ingredients must be ground. The grind or particle size may influence the outcome. For example, coarsely ground corn was reported to produce less expanded, denser kibbles due to low particle surface area compared to a finely ground corn (Bazolli et al., 2015; Mathew et al., 1999). During pre-conditioning and cooking in the extruder barrel, water and heat promote starch gelatinization, which increases cold water solubility and starch viscosity, and releases amylose and amylopectin to the food matrix (Cheftel, 1986). The increase in viscosity due to gelatinization aids in food matrix binding and homogenization. Starch gelatinization also improves susceptibility to

enzymatic digestion (Holm et al., 1988). The coarser the corn, the less gelatinized the kibble will be (Bazolli et al., 2015). When the starch-containing dough reaches the end of the extruder barrel, the pressure drop causes kibbles to expand. The addition of more starch ingredients at the optimal particle size generally lead to increased expansion (Geetha et al., 2014; Mercier and Feillet, 1975). Liu et al. (2000) found that as low as 15% of corn flour significantly increased expansion ratio of a corn and oat flour blend. Some expansion is required in pet foods to produce the preferred kibble with the right appearance and consistency. Also, kibbles with less starch and high dietary fiber tend to expand less (Alvarenga et al., 2018) and to be less palatable (Koppel et al., 2015).

The amylose:amylopectin ratio plays an important role in extrusion processing. Waxy starches (low amylose, high amylopectin) have a tendency to form a sticky paste and increase torque (Guha & Ali, 2006) with a light, elastic, and homogeneous texture. Whereas, starches with higher amylose content form a harder and less expanded product (Colonna et al., 1989). Chinnaswamy and Hanna (1988) reported that the expansion ratio of corn starch doubled as amylose content increased from 0 to 50%, but decreased with further increases in amylose. Different corn genotypes may also vary in fiber and protein, which can further influence extrusion. In a study evaluating three different corn samples with similar grinding and extrusion parameters corn variety significantly affected expansion, breaking strength, and bulk density of a pet food (Mathew et al., 1999). Thus, the corn variety, growing conditions, the amylose:amylopectin ratio, and the amounts of each nutrient, can influence food processing.

High-moisture and high-heat extrusion, which is common for pet foods, results in near complete gelatinization of the starch with a significant increase in its digestibility (Svihus et al., 2005; Dust et al., 2004; Murray et al., 2001). Murray et al. (2001) reported that high temperature relative to low temperature extrusion increased the rapidly digested starch fractions of corn, and decreased slowly digested and resistant starch fractions. This finding means that

the more starch is cooked, the easier it is digested. Milder cooking processes like baking and pelleting of kibbles have been reported to result in less starch gelatinization when compared to the same extruded recipe (Inal et al., 2018; Gibson and Alavi, 2013). Pelleting is not a common process for dog food and has been reported to be less palatable than extruded kibbles (Inal et al., 2018). This is likely because of the lower starch gelatinization and different texture in pellets. Wolter et al. (1998) reported that the extent of cooking and gelatinization of the corn starch improved palatability.

Wet or canned pet foods are another common product in the market, but studies exploring different aspects of corn in canning are scarce. Corn starch can be used as a binder in canned loaf format products or to create structured pieces in chunks and gravy recipes. Similarly, a study with buffalo meat nuggets used corn starch as a binder and reported that it produced a more stable emulsion than wheat semolina, wheat flour, or tapioca starch (Devadason et al., 2010). This same study found that corn starch contributed to a firmer texture and more chewiness of the product, resulting in higher sensory scores and overall acceptability for humans. In canned pet foods stronger binders like egg white or swine plasma are often used, thus it would be interesting to verify whether corn is as palatable to dogs and cats as it is for humans, comparing to these different binders.

Like canning, studies using ground corn as the main starch source in baked foods are nonexistent. Corn does not contain gluten and therefore does not bind as efficiently as wheat flour, but might produce quality baked kibbles if a complementary binding ingredient like plasma or gelatin were added to the recipe prior to baking. This will need to be verified in future studies. Nevertheless, corn possesses very positive physical attributes to food processes. Its high starch content promotes particle binding, matrix formation and it helps develop a firm final structure when the starch is properly gelatinized.

Co-products from corn: Application in pet foods and their benefits to pet health

Many sources of corn used in dog and cat foods are secondary products from corn processing for human food or biofuels. Corn as an industrial input is processed by three methods with different primary and secondary finished products: wet milling, dry milling, and dry grind.

Starch is the primary product from the wet milling process and can be converted into fuel ethanol, high-fructose corn syrup, or modified starches. The purified starch can also be included in a pet food formulation. The nutritional composition can be affected by changes in the process, with a reported 91.2% DM, 0.6% crude protein, and 0.9% crude fat (Bednar et al., 2001). Within the starch itself, Bednar et al. (2001) observed that 70.0% was digested very quickly, 20.0% slowly digested, and only 7.9% was resistant starch. This translates into very high (near 100%) starch digestibility with a rapid release of energy in the form of glucose.

Secondary products from corn wet milling include corn gluten meal, corn germ, and corn gluten feed.

Corn gluten meal is a quality protein source in pet foods, reportedly 73.9% crude protein and relatively low ash (1.8%), TDF (0.3%), and acid-hydrolyzed fat contents (7.8% on a DMB; de Godoy et al., 2009). It has been included in extruded experimental diets (34.6% of the diet) for cats and compared to diets containing either chicken meal (35.5% of the diet) or meat meal (30% of the diet). Cats fed the corn gluten meal diet (77.0%) had a lower DM ATTD than cats fed either the meat meal diet (83.3%) or the chicken meal diet (80.2%), while food and water consumption, and urine output on a body weight basis were similar. Further, feces from cats fed the corn gluten meal diet (56.3% moisture) were moister than feces from cats fed the chicken meal diet (52.4%) but did not differ from cats fed the meat meal diet (54.7% moisture). This suggests that corn gluten meal may have a higher water holding capacity than chicken meal and feces from cats fed the corn gluten meal diet may be softer and easier for cats to pass. Cats consuming the corn gluten meal diet exhibited the most acidic urine pH (6.08) and it contained the fewest struvite crystals (114.4 crystals/µL urine). This suggests that these

cats had a reduced risk of urinary blockages due to struvite crystals. One item of note, using corn gluten meal as the primary protein source may require supplementation of arginine compared to meat meal or chicken meal, although the cats remained healthy while consuming the corn gluten meal diet.

Compared, to corn gluten meal, corn germ meal is lower in crude protein (28.4%) but higher in TDF (45.0%) and ash (3.9%) and similar in acid-hydrolyzed fat (6.0% on a DMB) compared to corn gluten meal (de Godoy et al., 2009). The two ingredients were compared in a digestibility study utilizing cecectomized roosters as a model for dog and cat small intestinal digestibility (de Godoy et al., 2009). Cecectomized roosters fed corn gluten meal had higher digestibility of total amino acids (95.4%), essential amino acids (94.3%) and non-essential amino acids (97.0%) than cecectomized roosters fed corn germ meal (79.0%, 80.4%, and 76.8%, respectively). This translated into higher metabolizable energy for corn gluten meal (3,863 kcal/kg) than corn germ meal (1,924 kcal/kg) and is likely due to the lower fiber content of corn gluten meal. However, de Godoy et al. (2009) also observed that the protein efficiency ratio utilizing young chicks was higher for corn germ meal (2.83) than the corn gluten meal (0.76). This may have been due to the more favorable amino acid profile found in germ.

Corn gluten feed contains 22.3% crude protein, 4.0% acid-hydrolyzed fat, 38.2% TDF, and 6.0% ash on a DMB (Kawauchi et al., 2011). Very little research has been reported comparing the use of corn gluten feed to comparable ingredients in pet food diets. However, research has been published assessing the benefits of using the fiber stream often incorporated into corn gluten feed. Depending on the process used to obtain the corn fiber product, nutrient content will vary from 87.4-96.4% DM, 0.5-1.0% ash, 10.8-14.1% crude protein, 2.4-6.8% acid-hydrolyzed fat, 63.0-88.2% TDF, and 4.7-4.9 kcal/ g gross energy on a DMB (Guevara et al., 2008). Adult Beagles dogs fed diets containing 7% of beet pulp, native corn fiber with or without fines, hydrolyzed corn fiber, or hydrolyzed extracted corn fiber did not show differences in food intake, fecal excretion, stool quality, acid-hydrolyzed ATTD (83.8-94.7%), and crude protein ATTD (81.2-83.5%). Using native corn

fiber increased DM ATTD (82.3%) compared to the other fiber sources, including beet pulp. Additionally, TDF ATTD of the native corn fiber diet (30.9%) was higher than the native corn fiber with fines (19.1%) and hydrolyzed corn fiber (17.8%) diets, with the beet pulp (27.7%) and hydrolyzed extracted corn fiber (20.1%) diets intermediate. While minor differences were observed, these corn fibers appear to have a similar value in pet foods as a fiber source to beet pulp.

The primary product from dry milling is flaking grits. These are commonly used in the human food industry for consumption as corn flakes. Secondary products from this process include corn flour and hominy feed. Corn flour is predominately used by the human food industry in baked products. Hominy feed is comprised of the germ and bran components of the corn kernel and is commonly included in livestock animal diets as a lower protein (12.3% on a DMB; MacGregor et al., 1978) energy source. There is little information about the uses of corn flour or hominy feed in pet food diets as they are utilized well by other industries. But, given the humanization of pets, there might be a potential use for them in pet food in extruded or baked products. More research into their effects on digestibility, pet health, and processing is warranted to investigate these possibilities.

Dry grind corn processing is primarily directed toward ethanol production and produces distillers dried grains with or without solubles as secondary products. Solubles are the product resulting from the evaporation of water from the thin stillage distillation process effluent. These solubles are usually added to the distillers wet grains before drying. Distillers dried grains with solubles (DDGS) composition can fluctuate because it is a secondary product. Composition can range from 27.6-30.1% crude protein, 9.0-15.2% acid-hydrolyzed fat, 2.0-4.3% ash, and 30.5% TDF, on a DMB (de Godoy et al., 2009; Silva et al., 2016).

Amino acid digestibility of DDGS using a cecetomized rooster model was comparable to that of corn germ meal (approximately 81.0%), but

somewhat lower than corn gluten meal (94.3-97.0%). In a chick PER assay, the protein quality ranking of DDGS was similar to corn germ meal (2.63 and 2.83, respectively). In dogs fed incremental levels of DDGS (0.0%, 6.0%, 12.0%, and 18.0%), Silva et al. (2016) observed a reduction in ATTD as the inclusion of DDGS increased. Addition of xylanase did not improve utilization. Further, fecal pH was more acidic when DDGS were included in the diet. This may suggest that DDGS provided substrate for colonic fermentation. The 18.0% DDGS was preferred by the dogs over the control. Clearly, DDGS could be a viable ingredient for pet food if consumer attitudes were more accepting.

There have been some modifications to the process of producing DDGS which concentrate the proteins. These "next-generation" distillers dried grains (NG-DDGS) contain greater protein concentration and have been evaluated in a diet for dogs. The first evaluation in pet food by Smith et al. (2018) reported that the composition was 54.4% crude protein, 4.2% crude fat, 4.4% crude fiber, and 4.6% ash on a DMB. Adult Beagle dogs were fed diets containing 20.5% from corn gluten meal, 24.8% from soybean meal, or 25.0% from NG-DDGS. They observed that dogs had lower DM, organic matter, crude fat, crude fiber, and gross energy digestibility when they consumed the NG-DDGS diet. The feces from these dogs were of acceptable firmness and consistency. In palatability tests, dogs preferred the corn gluten meal diet over the NG-DDGS diet but did not have a preference for soybean meal vs. NG-DDGS. On the other hand, cats preferred diets with NG-DDGS or soybean meal relative to corn gluten meal and had no preference between soybean meal and NG-DDGS. These results suggest that NG-DDGS may be used with success in diets that traditionally contain soybean meal or corn gluten meal.

Even though secondary products from corn processing have been stigmatized as "fillers" or low-quality by-products, peer-reviewed research suggests otherwise. Depending on the specific ingredient, a corn secondary product can be a quality source of protein and/or fiber.

Myth: Corn is bad for pets.

Fact: *Corn has been used in pet foods for decades with no issues or concerns regarding pet health.*

Myth: Corn causes allergies.

Fact: *Veterinary reports have shown that the main cause of allergies are peptides or glyco-proteins, and that grains cause less than 1.5 % of all food allergy cases (Laflamme et al., 2014).*

Myth: Corn has gluten.

Fact: *Corn does NOT contain glutenin and gliadin, the protein molecules found in various cereal grains that cause celiac reactions.*

Myth: Corn is a "filler" ingredient with no nutritional value used only to lower costs.

Fact: *While it is true that corn is an economical ingredient compared to other common starch ingredients, it is far from an indigestible filler. In fact, many studies in the literature have clearly shown that an excess of 60% corn in pet food recipe promoted quality stools and high apparent total tract digestibility in dogs, to levels comparable to sorghum and rice (Carciofi et al., 2010; Kore et al., 2009; Walker et al., 1994). Corn is also known to be high in carotenoid antioxidants lutein and zeaxanthin (Masisi et al., 2015). Other nutrients like fiber and proteins may be more concentrated in corn by-products derived from corn processing, and these confer additional health benefits to the pet diet. Even though secondary products from corn processing have been stigmatized as "fillers" or low-quality by-products, peer-reviewed research suggests otherwise.*

What Role Can Corn Play in U.S. Pet Foods

Corn has many benefits when included in pet foods. The references section contains various studies where pets have been fed corn-containing diets and demonstrates their nutritional value. There are very few indications of any health or nutritional problems. In addition, corn processes well in extruded dry kibble diets and there are many areas for corn use in pet diets that could be explored further. This includes the opportunity for corn or corn secondary products to be used in treats, raw foods, thermally processed wet, or alternatively processed foods. While extruded products represent the majority of pet food products sold in the US, these formats are the most popular and still have potential opportunistic markets for corn. Given the quantity of positive findings for corn use in pet food applications, it appears obvious that limitations are due to perceptions in the market, which might be improved with enhanced education and communication to consumers regarding the positive attributes corn brings to bear. The most prominent approaches are likely to emphasize the value to carotenoid or proteins concentration for antioxidants and their impact on immune health, as well as enhance corn fiber/resistant starch for colonic fermentation and gut health.

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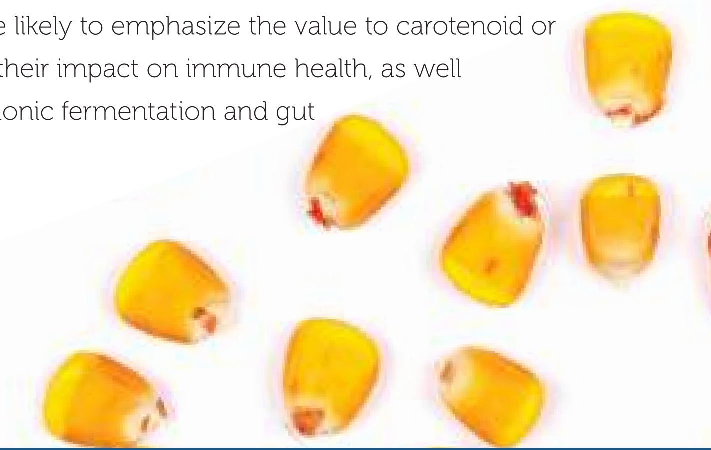

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