



SORGHUM: A SMART COMMERCIAL PET FOOD INGREDIENT





PRIMARY REASONS TO INCLUDE SORGHUM IN YOUR FORMULATIONS	4
BRANDS USING SORGHUM	5
SORGHUM'S NUTRITIONAL BENEFITS	6
ENHANCING DIGESTIBILITY	7
FECAL QUALITY	10
PROCESSING	11
SENSORY CHARACTERISTICS	13
CONCLUSIONS	16
REFERENCES	17

PRIMARY REASONS TO INCLUDE SORGHUM IN YOUR FORMULATIONS

1

Nutritionally, sorghum compares well to corn, with a higher protein content and slightly lower fat content.

2

Thermal processing, such as extrusion and steam flaking, and chemical treatment with alkali can improve sorghum's digestibility and performance of high-condensed tannin sorghums.

3

Sorghum starch digestibility can increase up to 0.98 percent when feeding dogs extruded sorghum diets.

4

Several studies have shown that starch digestibility of extruded sorghum diets can be similar to that of other grains, such as corn and rice.

5

Fecal scores from diets containing sorghum are within the ideal Waltham Fecal Scoring System range.

6

The insulin response curve was lowered after a meal containing sorghum, more than after meals containing rice or corn.

7

The flavor and aroma profile of dry dog food made with sorghum fractions was similar to that of an extruded dry dog food diet containing rice, wheat and corn with no higher astringency and bitterness.

8

Several palatability tests showed that food intake of sorghum diets can be compared to other grains diets.

9

Consumers accepted the aroma and appearance of an extruded whole sorghum diet similarly to rice, wheat and corn diets.

BRANDS USING SORGHUM

Sorghum's health benefits, price and processing ease into formulations make it a smart choice for pet food manufacturers. In fact, there are more than 130 pet food products containing sorghum. Here are a few of the brands utilizing sorghum in their formulations:

- » Adirondack
- » Blackwood
- » Cool Canine
- » Eukanuba
- » GNC
- » Hills Pet Nutrition
- » Hi-Tek Signature Pet Products
- » IAMS
- » Mr. Bucks Pet Food
- » Muenster Natural
- » Newman's Own Organics
- » Pet Wants
- » Verus
- » Victor Super Premium Dog Food



A TRUSTED INGREDIENT

“Sorghum is a smart choice for our companion animal foods because it is nutritious and pets love it. Our customers want the best for their furry friends. High in fiber and protein and gluten-free, sorghum is a perfect fit.”

— Adirondack & Blackwood

“Ground whole grain sorghum is a digestible, nutrient rich, complex carbohydrate that presents no complications for allergic dogs. The use of sorghum helps satiate dogs even with reduced feeding volume.”

— Verus Pet Food



SORGHUM'S NUTRITIONAL BENEFITS

The USDA Food Nutrient Database identifies sorghum contains 10.62 percent protein, which is higher than corn. Lysine and threonine are the first and second limiting amino acids (Aldrich, 2015). However, sorghum's amino acid content is slightly lower than corn (Wall and Paulis, 1976). The fat content of sorghum is 3.46 percent, slightly lower than corn, and is responsible for a slightly lower metabolizable energy. Linoleic acid (C18:2n6), an essential fatty acid for both dogs and cats, represents more than half of the fatty acids in sorghum. Oleic acid (C18:1n9), which is not an essential fatty acid for pets, accounts for one third of the fatty acid profile in sorghum. The omega-3 linoleic acid (C18:3n3) represents less than three percent of the total fatty acids. Most of sorghum's fiber portion (6.7 percent) is insoluble with appreciable amounts of lignin within the seed coat. When compared to corn, sorghum contains a higher level of phosphorus, potassium and iron with a lower sodium content. The vitamin content of sorghum is similar to several other cereal grains.

RICH IN ANTIOXIDANTS

Some sorghum, derived from the purple bicolor sub-species, is rich in phytochemicals, such as tannins, phenolic acids, anthocyanins, phytosterols and policosanols. Health benefits associated with these fractions, such as antioxidant activity, are comparable to those associated with some fruits (Awika, 2004). All sorghum contains phenolic compounds, but the amount in each cultivar, together with color, appearance and nutritional quality, is influenced by genotype and the growing environment (Dykes, 2005). Condensed tannins are present in cultivars with a pigmented testa. The color alone is not a good indicator of tannin content (Boren, 1992).

ENHANCING DIGESTIBILITY

Since pet food formulations vary considerably due to digestibility factors, selecting a smart ingredient source is paramount. The quality of protein, types of dietary fiber, starch and fat levels are just some of the considerations given as it relates to digestibility and hence, its impact on nutrient bioavailability.

Bednar et al. (2001) observed that the different starch composition between grains and legumes has an impact on digestibility for dogs, and the portion of rapidly digestible starch, such as sorghum, brewer's rice and corn, was higher than legumes like peas and lentils.

A difference in starch digestibility between different diet sources can be related to the different cereal type, a different starch-protein interaction, physical granule form, starch type, digestion inhibitors, and probably the most important, processing methods. In corn and sorghum, a starch-protein interaction may interfere endogenous enzymatic digestion in the gastrointestinal tract (Kore, 2009). The starch-protein matrix formation is also related to the method of processing, and it is an accepted fact that processing a dog food diet by extrusion increases the starch digestibility to 0.90-0.95 (Murray et al. 1999), probably because it facilitated the starch gelatinization, making the starch almost completely digestible (Twomey, 2003). Carciofi et al. (2008) reported that dogs fed extruded diets containing sorghum, cassava flour, brewer's rice, and corn showed a starch digestibility coefficient less than 0.98.

In 2009 Kore et al. conducted a study to investigate the digestibility of samples made of sorghum, pearl millet and corn as alternative to rice in dry dog food. Each of the diets contained 70.5 percent of the specific grain, 25 percent extruded soya, 1.8 percent soya oil, 0.3 percent salt, 1.3 percent dicalcium phosphate, one percent calcium carbonate, vitamins and minerals. Dry matter (DM) digestibility was significantly lower in corn, pearl millet and sorghum when compared to rice. Protein and fat digestibility was similar in rice, sorghum and corn. The fecal DM was significantly lower when dogs were fed the rice sample compared to corn, pearl millet and sorghum. Silva Junior et al. (2005) also reported a lower DM digestibility coefficient when replacing rice (0.87) with corn (0.83) or sorghum (0.81).

Another study by Fortes et al. (2010) compared the nutritional value of broken rice, sorghum, high oil corn, corn germ, rice bran and millet. The ingredient composition of the reference diet (g/kg, as-fed basis) was: 667.7g of corn; 178g of poultry by-product meal; 62.1g of corn gluten meal

(600g crude protein/kg); 36g of poultry fat; 30.4g of dried hydrolyzed bovine liver; 13.3g of dicalcium phosphate; 3.4g of calcium carbonate; 5.6g of vitamin and mineral premix; and 3.6g of sodium chloride. For each of the test diets, 700g of the reference diet and 300g of the test ingredient were combined. The total dry matter, protein and starch digestibility was higher for the reference diet, the high oil corn, sorghum, millet and broken rice diets. Sorghum showed a similar metabolizable energy (ME; MJ/kg, as-fed basis) compared to the high oil corn, millet and broken rice, and were lower than the corn germ diet. Production of feces was similar for the sorghum, high oil corn, broken rice, millet, corn germ and rice bran. Overall, for dogs, sorghum, high oil corn, broken rice and millet had a better digestibility and greater metabolizable energy than wheat bran, corn germ and rice bran.

A study by Aldrich (2015), using three sorghum dry dog food diets manufactured with different sorghum fractions (whole sorghum - WSD, flour - FD, enriched mill-feed - MF) and a control sample (CD) containing rice, corn and wheat, observed that the dry matter digestibility was similar for CD and WSD and just slightly less than that for FD (89.9, 88.9 vs. 92.0 percent, respectively). The MF diet dry matter digestibility was the lowest among samples (78.5 percent). Organic matter, energy and crude protein digestibility followed a similar pattern. The sorghum flour diet (FD) provided a slight improvement to digestion coefficients, and the author suggests that this might represent the opportunity for new uses for easy-to-digest products. The MF diet showed the highest amount of wet feces excreted followed by WSD, then CD, and the lowest amount was observed for the FD diet. The amount observed for the MF diet was almost three times higher than that of FD (95.4 vs. 32.6 g/d). The number of defecations per day was similar among the CD, WSD and FD diets, and each fewer incidence than MF. With more feces excreted daily and more defecations per day one may suspect a higher moisture level and perhaps softer stools. However, the MF had the highest fecal scores (3.91 on a 5-point scale in which 4 is firm dry feces). The CD was the lowest fecal score and differed from that of WSD and FD.

Murray et al. (1999) observed a reduced protein digestibility when replacing corn-based diets (crude protein digestion 86.5 percent) with sorghum diets (Total Tract Digestion - TTD 83.3 percent). In this study, the rice-based diet (TTD 84.9 percent) was comparable to both corn and sorghum diets for this parameter. The sorghum, corn and rice diets had 44.2 percent, 43.6 percent and 44.1 percent, respectively, of the specific starch inclusion.

A study by Twomey et al. (2002) found a lower protein digestibility of sorghum diets (0.85 protein digestibility coefficient) and corn (0.83) when compared to rice (0.87), with sorghum having a higher protein digestibility compared to corn. The inclusion rate for the different starch sources was 49 percent for rice, 51 percent for corn and 46.1 percent for sorghum.

Carciofi et al. (2008) investigated the effect of six extruded diets with different starch sources, including sorghum, on dog total tract apparent digestibility and glycemic and insulinemic response. The diets and relative inclusion of the starch source were: cassava flour (42.49 percent), corn (53.49 percent), sorghum (59.27 percent), brewer's rice (45.66 percent), lentils (69.53 percent) and peas (66.35 percent). The sorghum used in this study had a low tannin content (0.57 percent). To obtain balanced diets containing similar percentages of starch, fat, calcium and phosphorus, additional ingredients, such as isolated soybean protein, were added. All dogs consumed the experimental diets with no episodes of vomiting, diarrhea or meal refusal. Dogs fed sorghum-based diets ingested more protein than those receiving lentil-based diets. Dogs fed the sorghum-based diets also ingested less fat than dogs fed the cassava flour diet. Protein digestibility was higher in brewer's rice than sorghum, corn, pea and lentil diets. Starch digestibility was less than 98 percent for all the diets (brewer's rice and cassava flour had the highest digestibility and pea and lentils the lowest). Digestibility of Total Dietary Fiber was higher in sorghum, pea and lentil diets. There was no observed difference in fecal scores among the various treatments. Fecal dry matter was higher for brewer's rice, sorghum and corn than for pea diet.

In the same study, mean plasma glucose concentrations in dogs fed cassava flour and corn diets were lower than those in dogs consuming the other treatments. At 180 minutes after consumption of brewer's rice, cassava flour and corn diets, mean plasma glucose concentrations were not different from basal values. While after 300 minutes, plasma glucose concentrations for sorghum, pea and lentil diets remained above basal values. The post-prandial insulin response curve of the sorghum diet did not return to baseline during the 300-minute observation time. The total Area Under the Curve of insulin (0-300 minutes) was smaller for cassava flour than sorghum. The area under the curve of insulin ≥ 30 minutes was greater after ingestion of sorghum than brewer's rice or cassava flour. This study showed that diets containing sorghum, lentils or peas can add a positive effect on dogs' health, including delaying and lengthening glycemic and insulinemic response.

FECAL QUALITY

Fecal quality is an important factor for pet owners and Twomey et al. (2003) observed that the addition of feed enzyme products containing a mixture of carbohydrates to sorghum diets increased fecal scores making it equivalent to feces of dogs fed rice-based diets. These enzymes cause a slight softening of the feces without making them diarrheic. The specific enzyme was sprayed on the dry diet at a level of 1,000 ml/t and the diets used in the experiment contained 552 g sorghum/kg, 535g corn/kg and 521g rice/kg diet. Although there was a lower fecal score of corn and sorghum without the enzyme addition when compared to rice, the fecal score of all the diets was 'ideal' on the Waltham scale.

In 2002, a study by Twomey et al. investigated fecal nutrient digestibility and effect on fecal quality of diets containing rice (49 percent inclusion), sorghum (46 percent inclusion) and corn (51 percent inclusion). A difference was observed in the fecal score among the different treatments with rice having a higher fecal score (looser feces). All the fecal scores were within the ideal range indicated by the Waltham Fecal Scoring System, indicating that sorghum and corn diets did not have a negative effect on fecal quality. Starch digestibility was not different among diets and all the diets had 100 percent fecal starch digestibility. The author indicates that this was probably due to the extrusion process that gelatinized the starch in the sorghum and corn diets, making it more digestible. Fecal protein, fat and gross energy digestibility coefficients were higher for the rice treatment. Thus, the rice diet showed a higher digestible energy content. Even if nutrient digestibility of rice was higher than the other diets, nutrient digestibility of all the diets was above the average digestibility values for commercial dog food according to the National Research Council nutrients requirements of dogs.

An in vivo trial by Kansas State University (Alavi) in 2016 showed that digestibility of sorghum diets (inclusion around 50 percent of the food) was not statistically different to the rice and corn diets. The fiber level of the rice diet was corrected including more beet pulp, since rice has less fiber than sorghum, to obtain similar nutrient composition among diets. This correction is not often performed in published studies even if this may have a role in some of the differences observed in the studies. For fecal production and quality, the study also showed no differences for fecal score, moisture content and production among diets. Moreover, the feces were very close to ideal for all of the diets. Fecal pH was lower for dogs fed red and white sorghum diets. Postprandial glucose analysis showed that there was no difference in glucose mean, maximum, incremental increase and peak concentration among diets.



PROCESSING

Extrusion accounts for 80 percent of dry pet food production. Baking and pelleting represent the other two major types of production processes in the industry (Gibson, 2015). While baking only involves thermal energy, extrusion involves both mechanical and thermal energies, making it possible to have 90-100 percent gelatinization in extruded kibbles (Gibson, 2013). Starch gelatinization observed in baked pet food kibbles was greater than or equal to 60 percent. With an increased starch gelatinization and protein denaturation, extrusion digestibility favors a higher degree of amylose-fat complexes formation. Amylose-lipid complexation (Pilli, 2011) decreases the level of free fats susceptible to oxidation, thus extending the pet food product shelf-life. Moreover, the amylose-lipid complexation slows down starch digestibility, representing a potential health benefit for dogs (Muoki, 2011).

Studies (Gibson, 2015) have also shown that extrusion reduce and kill bacteria in animal feed, but there are currently no studies showing the same effect on animal feed by baking processing. However, studies comparing sensory properties of extruded and baked samples observed

that baked samples were lighter in color with lower levels of attributes related to rancidity (Koppel et al., 2014).

Gibson (2015) observed that an increased amounts of total energy input during extrusion increased starch gelatinization, with lower level of piece density and larger kibble expansion ratio. There was an observed decrease in the amount of APC and Salmonella with an increase of total energy input into the extrusion system.

Research conducted by Gibson (2013), Murray et al. (1999) and Twomey et al. (2002) indicates extrusion processing can increase starch digestibility to 0.90-0.95 percent for dog food diets due to an increased starch gelatinization that makes the starch almost completely digestible (Twomey, 2003). Murray et al. (2009) found that the rapidly digestible starch in sorghum increased from 36.8 percent to 90.3 percent based on percent dried matter basis after high-temperature extrusion (124 to 140°C) and resistant starch in sorghum decreased from 45.6 percent to 2.7 percent (Dried Matter basis) after high-temperature extrusion. A study by Carciofi et al. (2008) observed a 0.98 percent starch digestibility when feeding dogs extruded sorghum diets.

Particle size can have an impact on starch gelatinization, during extrusion of sorghum diets. Putarov et al. (2014) used red and white sorghum milled at three different particle sizes (0.5, 0.8 and 1.0 mm) in premium dog food formulations. Diets were extruded using two different 'specific thermal energy (STE): specific mechanical energy (SME)' ratios: high STE: SME (300RPM/85-90°C) and low STE: SME (400RPM/75-80°C). Bulk density, inversely related to kibble expansion during extrusion, increased with particle size and was higher for the diets extruded at low STE: SME. Starch gelatinization was affected by particle size (93 percent, 85 percent and 82 percent of starch gelatinization for 0.5, 0.8 and 1.0 mm particle size, respectively) but not by processing conditions. A higher starch gelatinization was observed for white sorghum when compared to red sorghum and a control rice diet (89 percent, 85 percent and 80 percent, respectively).





SENSORY CHARACTERISTICS

Appearance, aroma, texture, and flavor are the primary sensory characteristics measured for pet food related studies. Phenolic compounds can be responsible for bitterness and astringency in food and beverages. In sorghum, phenolic compounds such as tannins, anthocyanins and phenolic acids are mainly found in the bran. Type and level of phenolic compounds in different varieties of sorghum are influenced by both genetics and environmental factors.

Kobue-Lekalake et al. (2007) investigated the sensory characteristics of sorghum that contained different levels of total phenolic compounds, condensed tannins or were tannin-free. Infusions and sorghum whole grain rice (cooked sorghum grain) were used in the study. Astringency and bitterness was present in all the sorghum cultivar analyzed but the tannin sorghum was perceived more bitter and more astringent than the tannin-free, which were perceived to be sweeter. The sorghum rice from white sorghum had a harder endosperm and it was less chewy than the other sorghums used. An unexpected result was that the bitterness and astringency of the tannin sorghum cultivar NS 5511, with more than twice the total phenol level, was comparable to those of a tannin-free sorghum sample.

In a study conducted at Kansas State University by Aldrich and Koppel (2015), three extruded dry dog food diets containing different sorghum fractions (whole sorghum, flour, enriched mill-feed) and a control sample containing rice, corn and wheat were manufactured. Diets were formulated to be iso-nutritional. Inclusion for each of the sorghum fractions was approximately 60 percent (64.69 percent whole sorghum, 67.65 percent sorghum bran, 62.31 percent sorghum) with the control diet having 21.2 percent of each corn, rice and wheat. All of the diets contained chicken by-product meal, corn gluten meal, chicken fat, beet pulp, antioxidants, vitamins and minerals. Descriptive sensory analysis was performed using a lexicon previously developed by Di Donfrancesco et al. (2012), and samples were found to be similar between each other for flavor, aroma and texture. Differences were more noticeable for appearance. The mill feed diet (MF, containing enriched bran and red sorghum) had the darkest appearance while the control diet was the lightest. The whole sorghum diet (WSD) showed the highest grainy appearance and had the highest oily appearance together with the flour diet (FD), and had the highest fibrous appearance together with the control diet. The flour diet also the lowest surface roughness value, so it looked smoother than the other samples. For texture, the flour diet was the hardest and WD and control were the highest for grittiness. The MF diet had the highest toasted aroma, musty and dusty flavor and brown aftertaste. The flour diet had the lowest barnyard aftertaste among samples. Sorghum samples did not show significant higher bitterness or astringency when compared to the control diet.

A consumer study (Aldrich and Koppel, 2015) utilized 105 consumers recruited based on several criteria, such as pet ownership, direct involvement in the pet food purchase and type of pet food purchased. The study investigated the overall appearance, color and aroma liking by pet owners. Participants were shown all of the samples and asked to look at and smell them. Results indicated that WSD was the most overall liked as well as the control diet. Results showed that the appearance of samples drove the pet owners liking rather than the sample aroma. The flour and the mill feed diets were not too distant in liking scores, indicating the possibility to increase pet owners acceptance of the products improving appearance characteristics.

In the same study (Aldrich and Koppel, 2015), a one-bowl palatability test was also performed. Thirty dogs of different gender, breed and size (no smaller than 10lbs and no larger than 100lbs) were fed the four diets at home by their owners. Each diet was served five days to each dog and the

amount of food was calculated based on dog’s weight. Results showed there was no statistical difference in the intake between sorghum diets and control diet (Table 1).

TABLE 1. Dog panel (N=30 from 680 screened) of pet food samples acceptance by dogs (intake %) control (CD), whole sorghum (WSD), flour (FD) and sorghum mill feed (MF) containing diets with a one-bowl in-home palatability test.

Item	CD	WSD	FD	MF	p-value
Intake (%)	57.06	55.62	53.44	57.50	0.1729

In another study done in 2016 at Kansas State University (Alavi), extruded sorghum diets manufactured with white and red sorghum (inclusion 50 percent) and a control diet based on corn and rice were fed to 36 adult kennel dogs (both male and female of various races). No statistically significant differences were observed in the intake of these diets.

Studies, such as Kore et al. (2009), showed that the mean daily DM intake by dogs as a whole (g day⁻¹) and relative to their body weight (g kg⁻¹ BW) of rice (140.2 ± 5.2 and 22.9 ± 1.5), maize (129.2 ± 2.0 and 21.9 ± 1.7), pearl millet (122.4 ± 10.2 and 19.8 ± 3.0) and sorghum (140.7 ± 2.9 and 22.3 ± 1.5) diets were not significantly different. Also, Carciofi et al. (2008) and De-Oliveira et al. (2008) obtained similar results when feeding corn, sorghum and brewer’s rice extruded diets for dogs and cats.





CONCLUSIONS

- » Several studies showed digestibility performance of extruded sorghum diets equivalent to that of other grains with better fecal quality and a lower glycemic index. However, some studies showed a possible lower protein digestibility of sorghum when compared to rice or corn.
- » Extrusion can increase starch digestibility of sorghum diets up to 0.98 percent in dogs.
- » Extruded dry dog food diets made with whole grain sorghum as the main ingredient was accepted by pet owners at the same level of control diets containing rice, wheat and corn and no sorghum.
- » Improving appearance factors of diets manufactured with other sorghum fractions can increase acceptability with pet owners.
- » Palatability studies have shown no differences in food intake between extruded sorghum diets and diets manufactured with other grains, such as corn, wheat and rice.
- » Through enhanced seed-breeding techniques, USDA-ARS has recently developed new sorghum genomic lines with significantly higher protein and protein digestibility levels, which should be considered as part of further pet food research studies.

REFERENCES

- Alavi, S. 2016. Use of Grain Sorghum as the Primary Cereal Ingredient in Premium Pet Food Products. Report to Sorghum Checkoff.
- Aldrich, G. 2007. Sorghum: poor-man's corn or novel carb? *Petfood Industry*, 49, 2, 38-39.
- Aldrich, G., Koppel, K., Di Donfrancesco, B., Alvarenga, I. 2015 Introducing New Profit Streams for Grain Sorghum: Milling Characteristics and Inclusion Considerations for Use in Pet Foods. Report to Sorghum Checkoff.
- Awika, M.J., Rooney, W.L. 2004. Sorghum phytochemicals and their potential impact on human health. *Phytochemistry* 65 (2004) 1199-1221.
- Bednar, G.E., Patil, A.R., Murray, S. M., Grieshop, C.M. et al. 2001. Starch and fiber fractions in selected food and feed ingredients affect their small intestinal digestibility and fermentability and their large bowel fermentability in vitro in a canine model. *J Nutr.* 2001 Feb; 131 (2):276-86.
- Carciofi, A.C., Takakura, F.S., De-Oliveira, L.D., Teshima, E., Jeremias, J.T., Brunetto, M.A. Effects of six carbohydrate sources on dog diet digestibility and post-prandial glucose and insulin response. *J Anim Physiol Anim Nutr.* 92:326-336 (2008).
- Da Silva Junior, J.W., De Oliveira Borges, F.M., Solis Murgas, L.D. 2005. Digestibility of diets with different sources of carbohydrates and your influence in the blood glucose and blood insulin in health dogs. *Ciênc. agrotec., Lavras*, v. 29, n. 2, p. 436-443.
- De-Oliveira, L.D., Carciofi, A.C., Oliveira, M.C.C., Vasconcellos, R.S., Bazolli, R.S., Pereira, G.T. Effects of six carbohydrate sources on cat diet digestibility and postprandial glucose and insulin response. *J Anim Sci* 86:2237-2246 (2008).
- Di Donfrancesco, B., Koppel, K., Chambers, E. IV. 2012. An initial lexicon for sensory properties of dry dog food. *J. Sens. Stud.* 27: 498-510.
- Dykes, L. and Rooney, L.W. 2005. Sorghum and millet phenols and antioxidants. *Cereal Foods World* 52, 105-111. Boren, 1992
- Gibson, M. 2015. Physico-chemical and shelf-life between baked and extruded pet foods. K-REx. Electronic Theses and Dissertations.
- Gibson, M., Aalavi, S., 2013. Pet Food processing - Understanding Transformations in Starch during extrusion and baking. *Cereal Foods World*, 58, 5, 232-236.
- Kobu-Lekalake, R., Taylor, J.R.N., De Kock, H.L. 2007. Effects of phenolics in sorghum grain on its bitterness, astringency and other sensory properties. *J Sci Food Agric* 87:1940-1948.

- Koppel, K., Gibson, M., Alavi, S., Aldrich, G. 2014. The effects of cooking process and meat inclusion on pet food flavor and texture characteristics. *Animals* 2014, 4, 254-271.
- Kore, K.B., Pattanaik, A.K., Das, A., Sharma, K. 2009. Evaluation of alternative cereal sources in dog diets: effect on nutrient utilization and hindgut fermentation characteristics. *J Sci Food Agric* 2009; 89: 2174-2180
- Muoki, P. N., De Kock, H. L., Emmambux, M. N. 2011. Effect of soy flour addition and heat-processing method on nutritional quality and consumer acceptability of cassava complementary porridges. *Journal of the science of food and agriculture*, 92(8), 1771-9.
- Murray, S. M., Fahey, JR., G. C., Merchen, N. R., Sunvold G. D., Reinhart, G. A. 1999. Evaluation of selected high-starch flours as ingredients in canine diets. *J. Anim. Sci.* 77:2180-2186. Fortes et al. (2010)
- National Research Council, 1985: Nutrient Requirements of Dogs. National Academy Press, Washington, USA.
- Pilli, T., Derossi, A., Talja, R., Joppila, K., Severini, C. 2011. Starch-lipid complex formation during extrusion-cooking of model system (rice starch and oleic acid) and real food (rice starch and pistachio nut flour). *European Food Research and Technology*, 517-525.
- Putarov, T., SA, F.C., Joseph, M., Carciofi, A., Alavi, S. 2014. Sorghum-based extruded pet food: impact of particle size and process conditions on physico-chemical attributes. *Cereal Foods World*, 59, 6S, A28-A29.
- Sorghum Checkoff. http://sorghumcheckoff.com/wp-content/uploads/2012/06/2014_09_18_UpdatedNutritionInfo_FJ1.pdf
- Twomey, L.N., Pethick, D.W., Rowe, J.B., Choct, M., Pluske, J.R., Brown, W., Laviste, M.C. 2002. The use of sorghum and corn as alternatives to rice in dog foods. *J. Nutr.* 132:1704s-1705s.
- Twomey, L.N., Pethick, D.W. Rowe, J.B., Choct, M., Pluske, J.R., Brown, W., Laviste, M.C. 2002. The use of sorghum and corn as alternatives to rice in dog foods. *J. Nutr.* 132:1704s-1705s.
- Twomey, L.N., Pluske, J.R., Rowe, J.B., Choct, M., Brown, W., Pethick, D.W. 2003. The replacement value of sorghum and maize with or without supplemental enzymes for rice in extruded dog foods. *Animal Feed Science and Technology* 108 (2003) 61-69.
- Wall, J.S., Paulis, J.W. Corn and Sorghum Grain Proteins in *Advances in Cereal Science and Technology*, Vol 2. Pomeranz, Y., Ed., American Association of Cereal Chemists, St. Paul, MN, 1976.





SORGHUMCHECKOFF.COM