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Pet and owner acceptance of dry dog foods manufactured with sorghum and sorghum fractions

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ABSTRACT

Globally sorghum is an important cereal crop with limited use in the pet food industry. Pet food acceptance and palatability assessments relate to both pet owners as the product purchasers and the pets as the actual consumers. Pet foods containing sorghum or sorghum fractions have not been studied for both animal and pet owner acceptance. The objectives of this study were to 1) understand animal acceptance between sorghum dog food diets and compared to a control, 2) assess consumer acceptance of the dog food products. Thirty dogs of different size and breed were fed three dry dog food diets containing different sorghum fractions and one control diet containing wheat, rice, and maize using the one-bowl in home use test. Results indicated that no difference was observed among diets, and sorghum samples were accepted at the same level as the control diet during the test. A total of 105 pet owners evaluated the samples for appearance, color, aroma, and overall liking. The consumer panel found the whole sorghum and the control samples to be accepted at the same level. These results suggested that sorghum may be suitable for dry dog food formulations.

1. Introduction

The pet food industry is a growing sector of the food industry, which is constantly looking for innovation and new ingredients. Estimated sales in 2016 in USA were $24 billion dollars (APPA, 2016). Sorghum (*Sorghum bicolor* (L.) Moench) is the fifth most important crop in the world after wheat, maize, rice and barley. The United States is the largest producer of sorghum in the world (Sorghum Checkoff Program, 2016). Sorghum, also called milo, originates from Northeastern Africa where it is often used in a porridge-type food (Aboubacar et al., 1999). Sorghum tolerates arid climates with lower moisture and rainfall requirements when compared to other crops such as rice, maize, and soybeans (Aldrich, 2015) and it is one of the most efficient crops in conversion of solar energy and use of water, and therefore considered environmentally friendly (Sorghum Checkoff Program, 2016). Currently it is primarily used for livestock feed and ethanol production, but its potential is considerable in the food industry (Taylor et al., 2006).

Opportunities to increase the use of sorghum may come from targeting industries such as pet food manufacturing. Because of a limited name recognition by consumers and lack of nutritional data and acceptance data by both owners and pets the current use of sorghum by the pet food industry is limited. However, labeling claims such as gluten free and non-genetically modified organism, as sorghum currently is, together with a better understanding of sorghum digestibility and sensory characteristics may contribute to increase its use, especially in pet food specialty markets. Sorghum is also rich in phytochemicals such as tannins, anthocyanins, phytosterols, and policosanols with high antioxidant activity and potential impact on human health (Awika and Rooney, 2004). Some of these factors may cause sorghum to be used less, though, as it may have a bitter and astringent flavor (Kobue-Lekalake et al., 2007). Di Donfrancesco and Koppel (2017) showed that this is not necessarily the case with dry dog foods made with sorghum and its fractions, and in fact that the flavor differences between sorghum-added and a control sample were quite small. Most of the dry pet food produced is processed by extrusion because the adaptability of this process and the functional characteristics that it can impart to the products such as improving texture, detoxifying and sterilizing (Cheftel, 1986). Among these effects, extrusion may also modify other sensory characteristics such as flavor and appearance by increasing friability, crispness, and hardness when compared to baked pet food products (Koppel et al., 2014).

Nutritional and processing properties, palatability, and owners' liking are characteristics that determine the success of a pet food product in the market. Nutritional properties of pet foods manufactured with sorghum fractions have recently been studied by Alvarenga et al. (2018). These authors found that sorghum as a grain source in pet foods

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enables production of comparable nutritional quality to control samples made with corn, rice, and wheat. These authors also found that pet foods that are manufactured with sorghum, can be processed similarly to foods made with other grain sources (Alvarenga et al., 2018). The two principal characters involved in pet food success are the pet owners and the pets themselves. The pet owners need to make decisions on what food to purchase and serve to the pet. Often criteria such as "I think this food will be liked by my pet" is important to pet owners (Di Donfrancesco et al., 2014). The pets then will have a chance to either accept or reject the served food. The pet food industry has been strongly influenced by humanization of pets, where dogs and cats are perceived more as members of the family and pet owners become parental figures. This has led to an increased role of owners 'liking' for product success as compared to the past. Acceptance of owners can be influenced by sensory properties of products such as appearance and aroma (Di Donfrancesco et al., 2014), as well as packaging label information. This can be measured in a central location trial format. However, palatability testing remains an important step in product development for a pet food product and it is often the crucial element for the success of a product in the market (Aldrich and Koppel, 2015). Palatability is not only about the taste of a food, but it deals with other factors such as aroma, mouthfeel, ingestive behaviors, form of the food, and frequencies of feeding (Kvamme, 2003).

Two main methods to assess the palatability of pet food products are the one bowl or single-bowl test and the two-bowl or split plate test. The one-bowl test is used to assess the acceptability of a product, and it measures food intake of pets, while the two-bowl test is used to determine the preference of one product over another while also measuring food intake. The types of pet panels that can be used to conduct palatability testing can be constituted by 'expert' trained pets in pet centers or untrained pets fed in an in-home test setting (Tobie et al., 2015). The two panels can provide different types of information and they both may be used during the product development process. An expert pet panel can be more accurate because the pets are trained to the testing protocol and perform palatability tests on a daily basis, but the training can be intensive with animals that need to be exposed to a different variety of food. An in-home test can provide additional useful information such as overall acceptance of the food, pet behaviors when interacting with the meal, and feedback about pet food diets from the perspective of pet owners after being exposed to the diets and observing their dog consuming those over several test days (Tobie et al., 2015).

In order to understand both consumer acceptability and pet palatability of extruded dry dog foods manufactured with sorghum fractions, this study conducted both an in-home-use test with dog owners and dogs and a central location trial with dog owners. The objectives of this study were to 1) understand palatability of extruded dry dog foods manufactured with sorghum milling fractions, and 2) assess consumer acceptance of these dry dog foods.

2. Materials and methods

2.1. Samples

2.1.1. Milling process

Red sorghum used in the study was selected from locally grown supplies in the Manhattan, Kansas area during the 2014 crop year. The sorghum used in this study was a "tannin" sorghum according to GIPSA with a red testa. Sorghum was first cleaned of impurities such as straw, weed seeds, soil particles and dust. Then, most of the sorghum used in the study to manufacture samples was milled in April 2015 at the Hal Ross Flour Mill (HRFM; Kansas State University, Manhattan, KS, USA) in order to separate flour, bran (mill-feed) and germ. Sorghum was tempered with water to increase the moisture level to 16% from an initial 14% to promote the separation of the endosperm component from the germ and the hull. The milling process separated the different sorghum components according to particle size and consisted of grinding, sifting and purification steps. The grinding process consisted of 5 break passages that removed the endosperm from the bran portion and successively collected in a bin. A purification step followed, where the bran was cleaned from any residual endosperm particles with the use of purifiers during the sifting process. The clean endosperm was then ground into flour. The mill feed fraction (MF) was composed of bran, shorts (finer bran), red dog (leftovers of the last flour cloth in the mill) and some coarse flour. For the whole sorghum diet (WSD), a portion of the sorghum was not milled to flour in the HRFM, but instead was ground using a hammer mill (#16 standard sieve – 1.191 mm). After grinding the sorghum was passed through a sifter with a 560 micron screen to exclude larger particles.

2.1.2. Diet formulations

Experimental diets that contained different sorghum fractions were extruded in the Kansas State University facilities: whole sorghum (WSD), sorghum flour (FD), sorghum bran enriched mill-feed diet (MF) and the control diet (CD) made with maize, wheat, and brewers' rice in a ratio of 1:1:1. Other than sorghum, rice, wheat, and maize, the diets also contained chicken by-product meal, beet pulp, maize gluten, calcium carbonate, potassium chloride, salt, dicalcium phosphate, choline chloride (60% dry), natural antioxidant (dry), trace minerals premix, and a vitamin premix (Table 1).

Rendered chicken fat (IDF Inc.; Springfield, MO, USA) was preserved with a commercial antioxidant added by the seller (BHA, propyl gallate, and citric acid). The additional ingredients were acquired from a local mill that supplies ingredients for pet food production (Fairview Mills L.P., Seneca, KS, USA). The diets were formulated in order to be iso-nutritional for carbohydrate, lipid, protein, and mineral content (Table 2).

2.1.3. Mixing, grinding, and extrusion processes

The mixing, grinding, and extrusion steps were conducted at the Bioprocessing and Industrial Value Added Program (BIVAP) facilities at Kansas State University, Manhattan KS, USA. After being weighed with a digital scale the ingredients were placed in a 227 kg paddle mixer. Micro ingredients (< 1% inclusion) were first mixed together before addition to the bulk ingredients in the mixer. Ingredients were mixed for 5 min and then finely ground through a hammer mill with an 840 μm screen size to facilitate particle size uniformity for the extrusion phase.

For the extrusion of all the diets, a single screw extruder (Model X-20; Wenger Manufacturing, Sabetha, KS, USA) with a standard pet food screw profile was utilized. The screw profile consisted of inlet screw,

Table 1
Experimental diets composition: control (CD), whole sorghum (WSD), sorghum flour (FD) and sorghum mill-feed (MF).

Ingredients, %	CD	WSD	FD	MF
Brewers' rice	21.21	–	–	–
Maize	21.21	–	–	–
Wheat	21.21	–	–	–
Whole sorghum	–	64.69	–	–
Sorghum flour	–	–	63.11	–
Sorghum mill-feed	–	–	–	67.65
Chicken by-product meal	20.94	20.02	20.00	20.00
Chicken fat	5.36	5.54	6.69	3.30
Beet Pulp	4.00	4.00	4.00	4.00
Maize gluten meal	3.00	3.00	3.00	3.00
Calcium carbonate	0.75	0.35	0.26	0.67
Potassium chloride	0.49	0.52	0.65	0.19
Salt	0.46	0.45	0.47	0.43
Dicalcium phosphate	0.87	0.95	1.27	0.24
Choline chloride	0.20	0.20	0.20	0.20
Vitamin premix	0.15	0.15	0.15	0.15
Trace mineral premix	0.10	0.10	0.10	0.10
Natural antioxidant (dry)	0.07	0.07	0.07	0.08

Table 2
Nutrient composition analysis of diets (as fed) and sample appearance characteristics. Control diet (CD), whole sorghum diet (WSD), sorghum flour diet (FD), sorghum mill-feed diet (MF).

Nutrient	CD	WSD	FD	MF
Moisture, %[a]	6.91	7.13	5.56	6.17
Dry matter, %	93.09	92.87	94.44	93.83
Protein (crude), %	21.70	21.1	21.5	24.6
Fat (acid hydrolysis), %	11.40	11.7	10.3	9.17
Fiber (crude), %	0.78	1.04	0.38	2.29
Ash, %	6.03	6.15	6.29	6.14
Calcium, %	1.75	1.60	1.46	1.34
Phosphorus, %	0.92	0.99	0.90	0.82
Potassium, %	0.59	0.70	0.66	0.52
Magnesium, %	0.10	0.14	0.10	0.15
Sodium, %	0.30	0.30	0.28	0.26
Sulfur, %	0.31	0.31	0.27	0.30
Copper, ppm	22.9	17.4	16.6	20.1
Iron, ppm	190	184	167	193
Manganese, ppm	24.8	26.3	20.6	31.0
Zinc, ppm	155	178	142	187
Thickness, mm	5.89 ± 0.35	6.57 ± 0.46	5.58 ± 0.26	6.34 ± 0.49
Diameter, mm	12.93 ± 0.35	11.60 ± 0.47	14.09 ± 0.40	10.45 ± 0.34
L (lightness)	38.79 ± 0.03	35.31 ± 0.03	38.33 ± 0.03	33.79 ± 0.02
A (green-red)	7.09 ± 0.02	6.94 ± 0.01	7.32 ± 0.03	6.53 ± 0.01
B (blue-yellow)	19.86 ± 0.02	15.01 ± 0.02	17.97 ± 0.03	12.96 ± 0.02

[a] All properties, except for thickness, diameter, L, A, and B values, were measured in Midwest Laboratories (Omaha, NE, USA).

single flight full-pitch screw, small shear lock, single flight full-pitch screw, small shear lock, single flight screw, medium shear lock, double flight single pitch screw, large shear lock and double flight cut cone screw. After extrusion, the kibbles were conveyed to a dual pass dryer/single pass cooler (Model 4800; Wenger Manufacturing, Sabetha KS, USA) set at 99 °C in order to obtain a final moisture level lower than 10%. After the drying, the kibbles were conveyed to a coating tunnel for the topical addition of chicken fat. Finished experimental diets were packed into ~9 kg poly-lined Kraft-paper bags for later evaluation.

2.2. Sample measurements

The samples were measured for diameter and thickness using a vernier caliper. Total of 20 kibble pieces of each sample were used for this purpose. The samples were also measured for color L (lightness), a (green-red), and b (blue-yellow) using a colorimeter (Konica Minolta CR-410, Tokyo, Japan). This was done in 4 repetitions.

2.2.1. Proximate analysis

The nutrient composition of dietary treatments for moisture and dry matter (AOAC 930.15), ash (AOAC 942.05), crude protein (AOAC 990.03), fat by acid hydrolysis (AOAC 954.02), crude fiber (AOCS Ba 6a-05), total starch (AACC 76-11; mod), gelatinized starch (AACC 76-11), and minerals including calcium, phosphorus, potassium, magnesium, sodium, sulfur, copper, iron, manganese, and zinc (AOAC 985.01; mod) were determined at a commercial laboratory (Midwest Laboratories, Omaha, NE, USA).

2.3. Home use test

The dogs used in the palatability study were screened according to specific criteria. Pet owners from the local area were recruited to participate in consumer and palatability studies managed by the Center for Sensory Analysis and Consumer Behavior at Kansas State University (Manhattan, KS, USA). Consumers already in the Center's database were contacted and additional potential participants were recruited through flyers distribution, advertising on a local newspaper, and on the Kansas State University online bulletin board.

Pet owners in the database were sent an online screening questionnaire using Compusense at-hand software (Compusense Inc., Guelph, ON, Canada). The participants had to be dog owners and their dogs had to be between 2 and 10 years old for health reasons. For gender, the goal was to have a ratio close of 1:1 female and male animals. Dog size was also considered when recruiting pets. Only dogs between 4 kg and 45 kg were considered for the study in order to recruit a heterogeneous group of dogs. Dogs enrolled in this study had to be in a good health status with no allergies and not fed specific prescription diets at the time of selection to be able to be eligible. To be included in the palatability study dogs had to be fed exclusively dry dog food as part of their normal food selection. Dogs fed wet foods were excluded. As well, dogs fed both dry and wet dog food were excluded. Since the study design required one meal per day feeding, only animals that were amenable to this feeding regime were accepted. Further, pets and owners were required to commit to the four different dietary periods totaling twenty days in duration. Out of the 500 pet owners screened 30 qualified and were accepted into the study.

Participants were asked to read and sign a consent form. The pet owners received monetary compensation ($120) after completing all 20 days of testing. The research was approved by the Institutional Review Board for Protection of Human Subjects (IRB #7761) and by the Institutional Animal Care and Use Committee (IACUC #3603).

The experiment was conducted as a completely randomized design where each diet was served monadically (as the sole food item in a single bowl) for 5 days to each dog for a total of 20 days of testing. Data were collected from each individual dog and if more than one dog was present in the household, the dog participating in the test had to be separated from the others.

At the beginning of the study each participant picked up the first two diets from the Center for Sensory Analysis and Consumer Behavior. Samples were contained in a ~3.8 liter resealable bag (Ziploc S.C. Johnson & Son, Inc. Racine, WI, USA) marked with diet feeding order number, diet code, owner's name and test day when the diet was to be fed. The amount of food placed in each bag was calculated based on the body weight indicated by the owner. The daily intake for metabolizable energy (ME) for laboratory kennel dogs or active pet dogs was used: 130*BWˆ0.75 (National Research Council, 2006).

Owners were instructed to pour the content of a bag into the bowl normally used to feed their pet and leave the food available for a maximum of 30 min. After which the sample was removed with instructions for the leftover food to be placed back in the original bag. The bags were then returned to the Center for Sensory Analysis and Consumer Behavior and the food weighed and recorded.

If the dog was usually given treats during the day, owners were allowed to continue this practice, but were instructed to not exceed the usual daily amount.

After 10 days of testing, participants returned the bags containing leftover food and picked up their third and fourth diet. They were also asked a few questions about their opinion regarding the two diets they had given their pet. This was done in the form of a short survey. For each of the two diets, they were asked open-ended questions such as how they felt about feeding the diet to their dog, whether they would have fed that diet if currently available on the market, what they liked about the specific diet, and what they disliked.

When participants came in to the Center for Sensory Analysis and Consumer Behavior, after completion of the entire testing procedure to return the leftover diets and receive the monetary compensation, they were provided the second part of the survey. Other than the questions related to the diets noted above, they were also asked open-ended questions about their thoughts on the use of sorghum in pet food product, and about aspects they personally liked and disliked about the diets.

After receiving the bags containing the leftover food, the leftover dog food was weighed and intake was calculated according to formula (1).

$$100 - \left(\frac{leftover\ food}{initial\ amount\ of\ food} * 100\right) \quad (1)$$

A questionnaire with instructions and diet codes specified for each test day and dates was provided to each pet owner. Owners were first instructed about pouring the food into the food bowl and starting the timed process in order to remove the bowl after 30 min. The dog owners were then asked to make a written record of the behavior of their dog right before the meal while they were pouring the food into the bowl, during the meal consumption and right after the meal. If the dog finished all the food provided in the bowl they had to indicate the time it took the dog to finish. Instructions about treat provision at different times from the meal, if that was a common practice with their dog, was also provided. A summary table was provided where participants could check the completed test days and indicate whether they provided treats to the dog, and mark the time elapsed before complete consumption of the diet (if the whole portion was eaten). This summary table was intended to remind owners to provide the required information that they might have forgotten to answer on the single test day questionnaire pages.

2.4. Central Location Test

A Central Location Test (CLT) was conducted in the Center for Sensory Analysis and Consumer Behavior at Kansas State University (Manhattan KS, USA) to assess pet owners' acceptance of the diets. Consumers (n = 105) were recruited from the Manhattan, Kansas area. Part of the participants were recruited from the Center for Sensory Analysis and Consumer Behavior database and part were recruited through advertisements in the local newspaper, and on Kansas State University campus. Participants were screened for their age (> 18 years old), dog ownership (had to own a dog), and direct involvement in the pet food purchase (had to be responsible or share responsibility of purchasing dog food). Furthermore, the participants had to be involved in feeding the dog (had to be the person responsible for feeding the dog or share responsibility with another person).

Data were collected using a tablet computer and questionnaires were administered through RedJade software (RedJade®, Redwood Shores, CA, USA). No more than 12 participants attended one session, for a total of 15 sessions. Samples were served monadically and in a randomized order. About 130 g of sample were placed in a ~240 ml Styrofoam bowl (Dart Container Corporation, Mason, MI, USA), covered with a plastic lid and served to participants. Pet owners were then instructed to remove the lid from the bowl, look at the kibbles and evaluate the appearance of the samples first. After the appearance evaluation they were asked to evaluate the aroma of the diets. Specifically, consumers were asked to rate overall liking, overall appearance liking, color liking, aroma liking, and intensity of aroma. A 9-point hedonic scale was used for the liking questions where 1 = dislike extremely and 9 = like extremely and a 5-point Just-About-Right (JAR) scale was used to score the intensity of aroma where 1 indicated “too weak”, 3 “just about right”, and 5 “too strong”.

2.5. Data analysis

2.5.1. Home use test

Analysis of variance (ANOVA) was performed (SAS version 9.4, The SAS Institute Inc., Cary, NC, US) using the PROC GLIMMIX procedure for mixed models. Means were separated by Fisher's Least Significant Difference (LSD) post-hoc to determine statistical significant ($P < 0.05$) differences between the diets for intake using diet as a fixed effect and dogs and test days as random effects. Each daily intake value was used as a different replication for each diet and each dog.

2.5.2. Central Location Test

Analysis of variance (ANOVA) was performed (SAS version 9.4, The SAS Institute Inc., Cary, NC, US) using PROC GLIMMIX for sensory characteristics (using sample as a fixed effect and panelist and replicate as random effects) and for liking scores by consumers (using samples as a fixed effect and consumers as a random effect). Fisher's Protected Least Significant Difference (LSD) post-hoc means separation was used to determine specific significant ($P < 0.05$) differences among the diets.

Principal Components Analysis was used for internal preference mapping using the individual dog food intake values for each of the treatments as input. This was complemented with pet owner acceptance data as supplementary variables. Internal preference mapping was run on XLStat software (vs. 2015.3.01, Addinsoft, New York, NY, USA).

Penalty analysis using the JAR data and the Overall liking data was also run on XLStat software (vs. 2015.3.01, Addinsoft, New York, NY, USA).

3. Results

3.1. Experimental diet composition, shape, and appearance

Experimental diets all achieved the target moisture of less than 10% (Table 2). The intent was that the diets were similar in nutrient composition. The MF diet appeared to have a slightly higher concentration of crude protein and crude fiber, but lower fat than the other diets. The CD and FD kibbles were thinner and had a larger diameter than the WSD and MF. The color lightness and color characteristics values for CD and FD were lighter than samples MF and WSD (Table 2). The MF sample also had a more yellow color than the other three diets. By visual inspection of the products by the researchers, there were clear differences among these four experimental diets.

3.2. Dog panel composition

Male dogs represented 47% of the panel and females 53%. Total of 67% of the dogs were older than 6 years old and the remaining 33% were from 2 to 5 years old. Ten of the dogs weighed from 4 to 10 kg, 10 from 11 to 20 kg, and another 10 of the dogs weighed more than 20 kg (Table 3).

3.3. Food intake

The proportion of daily food allowance in the 30 min of presentation did not differ ($p = 0.179$) among dietary treatments (Table 3). However, variability among dogs was high, as some dogs ate most of the food provided and a few ate a small amount of sample. However, the test day seemed to have no effect on the intake (data not provided). The expectation was that in the first test days with a new diet the dogs might be more suspicious, and thus intake might be lower. Among the treatments the average proportion of food allowance consumed during the 30 min was 53–58% (Table 3). A total of five dogs ate less than 40%. Four of these dogs were small in size (< 5 kg). Eight dogs consumed more than 70% of the diets overall. Feedback from a portion of dog owners indicated that their dogs were usually fed an amount of food lower than the daily allotment calculated for the test. Clearly some animals became full before the bowl was empty or were actually adapted to a multi-meal feeding regime. Only one dog ate 100% of all of the diets (female, 9.1 kg). Eighty-eight times (out of 600 eating occasions) the diet was completely finished by the dogs (data not shown).

The overall intake among all four diets was not different within size, age, or number of people in the household (data not shown).

Table 3
Dogs' food mean intake % (n = 30) for each of the diets control (CD), whole sorghum (WSD), flour (FD) and sorghum mill feed (MF).

Dog ID	Gender	Size, kg	Age	CD	WSD	FD	MF
D1	M	40.8	6–10 years	59.1	49.3	55.3	49.6
D2	F	4.4	2–5 years	14.0	14.0	15.0	14.4
D3	M	5	6–10 years	28.4	31.5	16.7	11.8
D4	F	10	2–5 years	55.4	41.1	48.4	49.5
D5	M	11.8	6–10 years	N/A	39.2	N/A	34.0
D6	F	8.2	6–10 years	49.1	58.6	25.0	33.6
D7	M	5	2–5 years	16.7	10.3	6.4	8.9
D8	M	22.7	6–10 years	79.5	64.5	72.5	68.0
D9	M	4.5	2–5 years	46.1	30.9	29.2	48.6
D10	F	16.3	2–5 years	70.4	70.7	69.3	90.4
D11	M	27.2	2–5 years	50.5	55.5	40.3	49.5
D12	F	16.8	2–5 years	47.8	67.8	51.6	73.2
D13	F	6.8	6–10 years	83.0	82.6	60.6	95.3
D14	M	4.5	2–5 years	85.6	94.3	97.4	100.0
D15	F	27.2	6–10 years	46.2	56.1	56.9	75.9
D16	M	20.4	6–10 years	57.7	47.0	33.6	60.0
D17	F	20.4	2–5 years	43.4	28.6	44.0	44.7
D18	F	22.7	6–10 years	37.6	44.9	51.4	65.6
D19	M	18.1	2–5 years	66.2	61.3	91.8	67.0
D20	M	22.7	6–10 years	43.3	39.5	41.4	47.1
D21	F	25.2	6–10 years	49.9	65.8	54.8	60.4
D22	F	15.9	2–5 years	58.8	67.0	53.8	54.7
D23	F	5	6–10 years	53.0	48.9	44.4	50.0
D24	F	15.9	6–10 years	57.7	65.0	70.9	84.0
D25	F	18.1	6–10 years	48.3	53.4	57.0	52.2
D26	M	24.9	6–10 years	59.6	78.8	75.4	37.8
D27	F	9.1	2–5 years	100.0	100.0	100.0	100.0
D28	M	19.1	6–10 years	100.0	48.0	100.0	55.4
D29	M	20.4	2–5 years	100.0	100.0	69.8	100.0
D30	F	11.8	2–5 years	65.9	53.8	35.5	43.0
Average*				57.1	55.6	53.4	57.5

*Average intake p = 0.1729.
N/A: dog did not complete test for diet.

3.4. Dog behaviors during feeding

The participants were instructed to fill-out a questionnaire while watching their dog eat the experimental diets during each day of the test. The majority of the observed behaviors, were not linked to a particular diet, but were still common among dogs. For instance, common behaviors observed before the meal and while the owner was pouring the food in the bowl included: excitement associated with tail wagging, jumping, licking lips, salivating, and in some cases barking. Some dogs exhibited a suspicious approach to the new food, sometimes consisting of sniffing the sample and lack of interest. After the meal observations included: lying down and sleeping, and were common across dogs and diets.

3.5. Mid- and post-study survey

Pet owners completed a survey in the middle and at the end of the test on their perception of test diets. Overall all diets received positive feedback on the shape, size, and color of the kibble. When asked if they would feed a diet to their dog if available on the market, more than one participant answered that it would depend on the price (n = 3) and ingredients (n = 4) of the product. Overall, each of the diets received a majority of positive responses from the owners that actually answered this specific question in the survey. The attitude of participants toward use of sorghum in pet food was overall positive, as long as the diet followed the proper nutritional requirements. Participants that indicated a negative response mentioned possible allergies of their dog, or they just did not know much about sorghum in order to express an opinion.

Table 4
Consumer panel (N = 105) of dog owners evaluation of “liking” (1–9 hedonic score; 1 = dislike to 9 = likes extremely) control (CD), whole sorghum (WSD), flour (FD) and sorghum mill feed (MF) containing diets.

	CD	WSD	FD	MF
Overall Liking	6.44^{a}	6.59^{a}	6.17^{b}	6.08^{b}
Overall Appearance Liking	6.60^{a}	6.67^{a}	6.23^{b}	6.00^{b}
Color Liking	6.46^{a}	6.59^{a}	6.34^{ab}	6.12^{b}
Aroma Liking	5.89	6.09	5.91	5.91

*Means with the same letter are not significantly different ($P < 0.05$). Scores not sharing the same letter were significantly different ($p < 0.05$).

3.6. Central Location Test

3.6.1. Consumer panel

The pet owner panel (n = 105) was composed of 24% males and 76% females between the ages of 18 and 65. Total of 9% of consumers had 1 dog, 21% 2 dogs, and 70% had 3 or more dogs.

3.7. Acceptability and aroma intensity scores

Consumer acceptance was significantly different among samples for overall liking (6.08–6.59 average range), overall appearance (6.00–6.67 average range), and color liking (6.12–6.59 average range) (Table 4). Aroma liking was not different among samples. This is in agreement with the sensory profile from descriptive sensory analysis that showed there was little difference among samples for aroma (Di Donfrancesco and Koppel, 2017). Control (CD) and whole sorghum (WSD) samples were the most liked overall and for the appearance of the kibbles. For color, the sample with the darkest kibbles (MF) was the least liked. Average liking scores were > 6.00 and < 7.00, indicating that all of the samples were somewhat liked even if at a different degree.

Correlation Analysis indicated that overall liking, appearance liking, and color liking were highly correlated ($r > 0.95$) with each other while aroma liking showed a lower correlation with all of them ($r < 0.7$).

Samples CD and FD were both perceived by 38% of consumers as having a “too weak” aroma (Table 5). A total of 63% and 60% of participants, respectively, indicated that the WSD and MF samples were “just about right.” Whereas, samples overall were not perceived as having a “too strong” aroma. Penalty analysis is a method used in sensory analysis to understand how the intensity of a specific attribute, as perceived by consumers, can affect the consumer liking. The results indicated that for MF sample the penalty was statistically significant showing that consumers penalized the samples when they considered the aroma too weak (mean drop 0.93). Sample FD was penalized when the sample was “too strong” (mean drop 1.01 in 8.57% cases). This penalty was not statistically significant for sample FD. Sample WSD was penalized when perceived as “too weak” by consumers (mean drop 0.75, 29.52% of cases).

Table 5
Response (%) to aroma as ‘Too low’, Just About Right (JAR), or ‘Too high’ by % of consumers for control (CD), whole sorghum (WSD), flour (FD) and sorghum mill feed (MF).

	CD	WSD	FD	MF
Too Weak	38	30*	38	30*
JAR	57	63	53	60
Too Strong	5	8	9	10

*Penalty analysis statistically significant ($P < 0.05$).

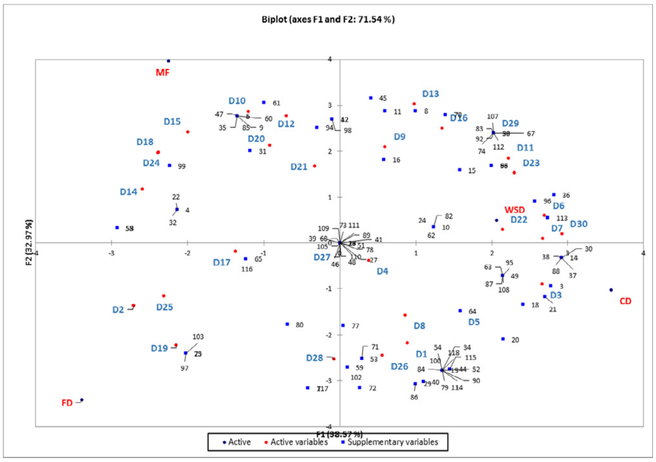

Fig. 1. Internal Preference Mapping of dog acceptance and pet owner acceptance as supplementary variables. D1-30 – individual dogs, Numbers – individual consumers; control (CD), whole sorghum (WSD), flour (FD) and sorghum mill feed (MF).

3.8. Internal preference map

Internal preference mapping was conducted in order to understand which diets the dogs accepted more and how those results related to pet owner acceptance (Fig. 1). The results indicated that the dogs were spread throughout the map. Samples WSD and CD were positioned close to one another, which indicated somewhat similar sensory properties. Samples FD and MF were positioned on the left hand side of the map, and these samples were separated by the 2nd dimension as well. Dogs D27 and D4 positioned in the center of the map, as these dogs' intake was the same for all 4 diets. There were fewer dogs located in the lower left quadrant, suggesting that sample FD might have been less accepted among dogs.

Pet owner acceptance data was added to the map as supplementary variables. Most consumers positioned on the right-hand side of the map, which suggested they liked samples WSD and CD better than FD and MF. Overall these results suggested that WSD and CD diets were similar in their sensory properties and that no diet was rejected by the dogs or by dog owners.

4. Discussion

The results from this study indicated that extruded samples manufactured with different sorghum fractions had some perceivable variations, but were quite similar to a control sample that did not contain sorghum. Aroma, flavor, and texture profiles of samples seemed close based on dog acceptance. This aspect can definitely be interpreted as a good signal for an increased use of extruded products containing sorghum in the pet food market. Moreover, pet owners' acceptance of products indicated the whole sorghum diet was liked at the same level as the control diet. This was mostly due to the appearance of the products. This study indicates the potential for an increased use of sorghum, regardless of component, in dry dog food. Similar results have been found by Alvarenga et al. (2018) regarding nutritional and processing characteristics of pet foods manufactures with sorghum fractions. Moreover, the results from this study demonstrated that a dog food containing appreciable quantities of the bran rich fraction has potential to add fiber and phenolic antioxidants to the diet with ready acceptance by both pet and owner all things being equal. Prior to this work, the assumption was that the astringency of the bran layer might be a deterrent to animal acceptability and thereby lead to rejection by the pet owner.

According to our findings, the appearance of the products varied. The CD and FD diets were lighter in appearance, while FD kibble was bigger in diameter. These differences were likely to be caused by the different ingredients in these dry dog food formulations that have an effect during the extrusion and result in a slightly different appearance of the final product. Product appearance is one of the key characteristics in dry dog foods, as was found by Di Donfrancesco et al. (2014). Those authors found that dry dog food kibble that is too light or too dark in appearance may receive lower overall liking scores from potential product purchasers. It is likely that this happened in the current study as well. Recent research in human foods area has indicated that sorghum addition to biscuit-type products is challenged, as consumers tend to prefer wheat-based products that have a lighter appearance and more acceptable sensory characteristics (Dovi et al., 2018). Jafari et al. (2018) found that inclusion of sorghum flour at a low rate into wheat bread with additional extrusion conditioning might prove to be a more acceptable approach to human consumers. The results from the current study indicated, however, that the pet owners (based on pet food appearance alone) are not as discriminating among products, and further, the complex character, formulation, and processing of pet foods reduces most of the dominating sensory characteristics in pet foods made with sorghum fractions, which was supported by the results from the palatability study.

Dogs tend to prefer foods that are higher in moisture (Kitchell et al., 1975) and fat and lower in fiber (Aldrich and Koppel, 2015). The milling of sorghum fractions with resulting split between flour and bran/pericarp ostensibly shifted the composition of the finished kibbles counter to this direction. This was not totally unexpected despite efforts to produce a diet of similar nutrient composition. The change in physical measures for thickness and diameter, and the darker color were in keeping with these differences. Increasing fiber into the extruded food will shift the expansion of the material resulting in a denser product, with a harder texture, and a darker color. All observations that occurred in this study. Further, we observed that several dogs did not eat all of the diet while others consumed all of the diet. This variability was amplified by testing with a home use test (HUT) panel where untrained dogs were utilized. Several dogs consumed less of the experimental diets in the allotted time compared to the usual amount of food provided as their customary diet. This rate of intake reduction during the experiment was accompanied by intermittent reports of a suspicious behavior toward the new food or disinterest for it. This may be related to neophobia, a mechanism thought to be evolved to reduce exposure to danger. A study also showed that dogs may have a lower interest for novel objects, in this case food, when compared to other canids (Canidae family) such as wolves (Moretti et al., 2015). Furthermore, an opposite dog behavior was also observed; wherein, some of the dogs were extremely excited by the introduction of the new diets and higher intake values were recorded. Together with genetic factors (Kvamme, 2003), food preference can be affected by previous exposure to a particular flavor in dogs (Bradshaw, 1991). When the new food is not rejected, but preferred over a usual diet, we can refer to a novelty effect or neophilia.

Tobie et al. (2015) described a lower reliability for quantitative data occurring when conducting tests using untrained dog panels. An untrained dog panel is typically not exposed to a variety of foods. Griffin et al. (1984) showed that, when testing canned food, home-dogs and kennel dogs performed similar but when testing semi-moist and dry food, differences were observed. In that study the causes of these differences were related to a difference in feeding history prior to the test.

With home use tests, there is also a lower level of control over testing conditions and the possible introduction of biases by dog owners. For these types of tests, a higher number of dogs, when compared to what is recommended for an expert dog panel (at least 30 dogs), should be recruited to improve the test reliability (Tobie et al., 2015). Palatability can also be influenced by factors such as temperature of food, socialization and group feeding (Kvamme, 2003). All these factors may play an important role when conducting home-use tests where the pet owners feed their dogs without a constant control by researchers.

If a HUT provides less control over the test protocol and utilizes untrained animals, it may also offer advantages. For example, the location where the test is conducted represents the environment where food is normally consumed (Vondran, 2004; Pound et al., 2000). A main reason to choose a HUT over a test with a trained kennel panel is that this kind of setting creates an opportunity to gather meaningful feedback about owners and dogs, in a 'real life' situation (Tobie et al., 2015).

Previous studies using kennel dog food palatability testing of sorghum versus other types of grain based diets have been conducted. These studies reported a good performance of this grain ingredient with no difference in intake when compared to other starch sources (Kore et al., 2009; Murray et al., 1999; Fortes et al., 2010). In the current experiment the diets did not contain any additional flavor added to the formulation such as processed meat, yeast or oil-based flavors. Additional flavors may have an effect and increase the food intake by dogs. Kibbles were only coated with chicken fat and this can still be considered a good flavor enhancement, although added for calories and essential fatty acids in this case. The addition of fat was done in order to produce diets similar to actual commercial product available on the market normally consumed by dogs. Providing diets too different from a typical commercial diet could have misrepresented the 'real life' home-use-test setting.

Association between the dogs acceptance towards the diets studied and the overall liking of the sample by consumers indicated that the diets were accepted well overall and that the dogs did not discriminate among the diets. The FD and MF diets were a bit less liked by the pet owners and the reasons behind that may be in the different color and size characteristics of these samples. FD sample was larger in its diameter and MF sample was the darkest in color. Data association techniques have been used previously to associate sensory and instrumental data such as Vazquez-Araujo et al. (2011) to determine the musty characteristics in sorghum grain. Another example is from a study done by Koppel et al. (2015) in determining the sensory characteristics that drive fiber preference among dry dog foods. Overall association analysis among different types of pet food has been infrequent, mainly because pet preference is typically measured using a paired preference test, which makes comparison of multiple samples time consuming and laborious. This is an area that could be researched and developed further.

Not many studies have compared sensory characteristics of dry dog food products and owners' acceptance and there was no literature found about this type of investigation made with dry dog food manufactured with sorghum. This study represents a first step for future research opportunities to understand the sensory properties of pet food manufactured with a major inclusion of grain sorghum. Limitations of this study might be the low sensory variation in the samples tested. A higher sensory variation might have helped to better understand what was driving the consumer liking. When manufacturing a larger sample set, the addition of samples containing palatants used in commercial products might improve the variation of sensory characteristics of the samples. This would help understand how the sensory properties and consumer acceptance might vary with different formulations. Moreover, the information presented in this paper needs to be compared with results from palatability tests with pets, testing the animal acceptance and studies testing the digestibility of dry dog food with grain sorghum inclusion. Another limitation to the study was the small number of dogs constituting the panel when considering the problems associated with an in-home testing environment. The collection of owners' feedback with exclusively open-ended questions created a fragmented data set that was a limiting factor when trying to interpret and quantify consumer opinions.

The results from this study showed that diets manufactured with different fractions of tannin (red) sorghum performed equally in an HUT palatability acceptance study where dogs were fed by their owners and consumed the diets in their usual environment. The control diet made with starch sources typically used by the pet food industry such as maize, rice, and wheat did not perform better than the sorghum diets.

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