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Technical Bulletin

Ancient Grains:
What's Old is New Again . . . Nutritional Value for Pets

Key Points

Amaranth, white millet, quinoa and oat groats

1. Well-utilized by adult dogs
2. Provide nutritional value as primary carbohydrate source in complete pet foods
3. Represent viable starch alternatives for manufacturers seeking novel ingredients
4. White millet is more digestible
5. Amaranth and oat groats beneficially shift fermentative end-products which supports intestinal health

Amaranth, white millet and quinoa

1. Reduces fecal putrefactive compounds which may minimize fecal odor
2. Function as high glycemic carbohydrates like brewers rice
3. Recommended for reproduction, growth and sporting dog formulas

Oat groats

1. Attenuates the glycemic response compared with rice
2. Recommended for weight management and senior formulas

Dogs and cats do not require carbohydrates in their food. Nevertheless, carbohydrates are important components in pet foods and treats because they function as the primary sources of glucose and energy for the body. Carbohydrates are also important in pet food manufacturing because the starch component provides processing functionality and structural integrity of the final product. Historically, extruded dog and cat foods have relied on corn, wheat or rice as carbohydrate sources. However, marketing campaigns in the 1990s created brand differentiation by characterizing traditional cereals as cheap, inert fillers and associated them with various allergies and maladies. One outcome of these marketing campaigns was the introduction of grain-free foods using alternative starch sources such as potato, peas, beans, lentils, chickpeas and tapioca. Today, the pet food industry continues to evolve as pet owners seek foods and treats devoid of genetically modified ingredients and gluten. Manufacturers are responding by offering foods and treats formulated with primitive and novel ingredients such as ancient grains. Ancient grains have been used as a food staple for more than five millennia by indigenous people in Central and South America, Africa and India. However, little information is available on the nutritional value of ancient grains for dogs and cats.

Research Study

A feeding study was conducted to assess the nutritional value of quinoa, white millet proso, amaranth and oat groats when used in an extruded adult dog food. These ancient grains were compared to a control food containing traditional brewers rice. The study used 10 adult female Beagles averaging 4.2 ± 1.1 years of age and weighing 11.1 ± 1.2 kg. It was conducted in partnership with the Department of Animal Sciences at the University of Illinois in a USDA-licensed facility according to Animal Welfare Act guidelines and approved by the Institutional Animal Care and Use Committee. Dogs were housed individually in kennels (2.4 x 1.2 m) in a temperature-controlled room with 14 hours of lighting and 10 hours of darkness. The study was a replicated 5 x 5 Latin square with each 15-day feeding period comprised of 10 days for food adaptation, four days for stool and urine collection and one day for blood collections. Each dog received each test food and served as its own control for statistical purposes. Dogs were fed twice daily to maintain body weight, and water was available at all times.

> Pet foods formulated with primitive and novel ingredients such as ancient grains provide new solutions for evolving pet owners' desires.

Table 1. Ingredient composition of extruded dog foods

Ingredient (%)	Rice	Amaranth	White Millet	Quinoa	Oat Groats
Brewers rice	40.0	10.0	9.8	8.3	10.0
Amaranth		40.0			
White millet proso			40.0		
Quinoa				40.0	
Oat groats					40.0
Poultry byproduct meal	34.3	29.1	29.7	30.0	29.1
Poultry fat	8.5	7.6	7.7	8.0	7.0
Celluslose	5.1	0.1	0.6	1.8	1.0
Corn	5.0	5.0	5.0	5.0	5.0
Corn gluten meal	5.0	5.0	5.0	5.0	5.0
Miscellaneous[1]	1.8	2.9	1.9	1.6	2.6
Vitamins & trace minerals[2]	0.3	0.3	0.3	0.3	0.3

[1] Dicalcium phosphate, calcium carbonate, potassium chloride, salt, choline chloride, BHT.

[2] Manganese sulfate, iron sulfate, copper sulfate, cobalt sulfate, zinc sulfate, potassium iodide, sodium selenite, vitamin A, vitamin D3, vitamin E, vitamin K, thiamine, riboflavin, pantothenic acid, niacin, pyridoxine, biotin, folic acid, vitamin B12

Foods: Foods were formulated to be nutritionally complete for adult dogs and to contain 40% of the corresponding grain source (Table 1). Protein, energy and fiber were equalized by adjusting levels of poultry byproduct meal, poultry fat, brewers rice and cellulose. Corn and corn gluten meal were held constant in all foods. Foods were produced at Wenger Manufacturing (Sabetha, KS) using an X-115 single screw extruder. Extruder conditions used to produce each food are summarized in Table 3 and images of the final foods are shown in Figure 1. The production of foods with rice, amaranth and white millet required similar amounts of specific mechanical energy (SME) ranging from 46 to 49 kW-hr/ton. In contrast, SME was higher for oat groats (58 kW-hr/ton) and quinoa (75 kW-hr/ton), indicating the need for more energy to extrude the foods containing these ingredients.

Total starch content and starch cook were assessed to ensure starch gelatinization was adequate and would not affect subsequent starch digestibility when fed to the dogs. Total starch content averaged 36.7 ± 1.5% for the five foods. Starch cook averaged 90.0 ± 4.3% and ranged from 85.5% (amaranth) to 96.6% (quinoa). Starch cook of the rice-containing control food was 88.5%. These values represent an acceptable starch cook for the five foods based on typical ranges of 90 to 100% for most commercially extruded pet foods. The comparable cook values implied that subsequent test measurements were unaffected by differential starch gelatinization or starch digestibility differences when the foods were fed to the dogs. Laboratory analysis showed all the foods were similar in nutrient composition (Table 2).

Sample collections and analyses: Food intake was measured daily. Body weight and body condition were measured weekly. Stool samples were collected within 15 minutes of defecation during the four-day collection period. Urine was quantitatively collected into acidified containers for the duration of the collection period. A fasting blood sample was collected before the morning feeding on day 15 of each period to assess health status based on serum chemistry and complete blood counts.

Stool samples were assayed for moisture, protein, fat, ash, total dietary fiber, gross energy and fermentative end-products including ammonia, phenols, indoles, short-chain fatty acids and branched-chain fatty acids. Urine samples were assayed for gross energy to calculate metabolizable energy. Total tract macronutrient digestibility was calculated using the nutrient content of foods and stool samples. Stool quality was subjectively evaluated using a five-point assessment scale with individual scores assigned as:

1= hard, dry, crumbly
2 = semi-moist, well-formed, retains shape
3 = soft, moist, formed
4 = soft, viscous, moist, unformed
5 = watery diarrhea

Figure 1.
Extruded adult dog foods

Table 2. Nutrient composition of extruded dog foods

Item	Rice	Amaranth	White Millet	Quinoa	Oat Groats
Dry matter (%)	94.6	94.3	92.3	95.7	95.6
Crude protein (%)[1]	31.3	32.6	32.4	31.4	33.1
Acid-hydrolyzed fat (%)[1]	14.4	14.5	12.3	14.8	14.6
Total dietary fiber (%)[1]	12.4	11.9	10.7	12.9	13.4
Ash (%)[1]	9.3	9.5	9.5	9.4	9.3
Gross energy (kcal/g)[1,2]	5.0	5.0	4.9	5.1	5.1

[1]Dry matter basis
[2]Measured by bomb calorimetry

Glycemic response: An assessment of the post-prandial glycemic response was conducted on day 15 of each feeding period. A baseline blood sample was collected immediately prior to the morning meal. Following a 15-minute feeding period, serial blood samples were collected using a cephalic vein catheter at 30, 60, 90, 120, 150, 180, 210, 240 and 360 minutes post-feeding. Each blood sample was assayed for glucose. Glycemic end-points were determined using the individual blood glucose curves. These parameters included peak glucose concentration, time to peak glucose concentration and area under the curve (AUC). A glycemic ratio was calculated for each ancient grain by expressing its corresponding AUC relative to the AUC for the rice control food.

Table 3. Extruder conditions and starch cook of extruded dog foods

Ingredient (%)	Rice	Amaranth	White Millet	Quinoa	Oat Groats
Raw Material Information					
Dry Recipe Density (kg/m3)	601	536	568	564	495
Dry Recipe Rate (kg/hr)	495	502	487	490	482
Feed Speed (rpm)	45	46	46	42	54
Pre-Conditioner Information[1]					
Steam (kg/hr)	40	40	40	40	40
Water (kg/hr)	80	80	90	80	80
Discharge Temperature (°C)	93	81	82	80	78
Product Moisture (%)	29.1	26.7	23.7	22.9	22.9
Extruder Information[2]					
Speed (rpm)	370	430	475	500	520
Motor Load (%)	56	51	45	65	51
Motor Power (kW)	24	24	22	37	28
Steam (kg/hr)	0	0	0	0	0
Water (kg/hr)	0	0	20	10	9
Cone-head Pressure (kPa)	209	219	248	250	328
Product Moisture (%)	20.9	21.0	25.5	21.4	23.1
Dryer Information [3,4]					
Exhaust Temperature (°C)	81	74	81	79	81
Product Moisture (%)	6.1	6.6	7.3	4.8	7.5
Final Product Information					
SME (kW-hr/ton)[5]	49	49	6	75	58
Density (kg/m3)	396	404	396	396	400
Total starch (%)[6]	35.9	35.8	39.4	36.2	36.1
Starch cook (%)	88.5	85.5	88.0	96.6	91.6

[1]Mixing intensity (30%), large side speed (263 rpm) and small side speed (377 rpm) were equal for all foods.
[2]Temperatures were equal in all zones (1 = 90°C; 2 = 95°C; 3 = 100°C; 4 = 105°C; 5 = 110°C).
[3]Temperatures were similar in all zones (1 = 133°C; 2 = 70°C; 3 = 96°C) and retention; 4 = 105°C; 5 = 110°C).
[4]Retention times were similar for 2 passes (1 = 20 min; 2 = 7 min).
[5]Specific mechanical energy
[6]Dry matter basis

Table 4. Food intake and fecal characteristics for adult dogs fed extruded foods

Item	Rice	Amaranth	White Millet	Quinoa	Oat Groats	SEM[1]
Food intake (g/d, DM)	155.5	154.7	153.6	160.4	158.7	3.4
Fecal output (g/d, as-is)	51.2[ab]	67.8[c]	45.7[a]	68.8[c]	62.1[bc]	4.7
Fecal output (g/d, DM)	26.0[ab]	26.5[b]	21.1[a]	29.0[b]	27.2[b]	1.8
Fecal score[1]	2.7[a]	2.9[ab]	2.9[ab]	3.0[b]	2.9[ab]	0.1
Fecal ammonia (mg/g)	2.4[ab]	2.4[ab]	2.2[a]	2.0[a]	2.8[b]	0.2
Fecal total phenols & indoles (µg/g)	358.3[a]	248.4[b]	250.6[b]	233.2[b]	300.8[ab]	36.2
Fecal phenols (µg/g)	96.8[a]	27.1[b]	28.5[b]	15.3[b]	29.6[b]	19.2
Fecal indoles (µg/g)	261.5	221.3	222.1	217.9	271.2	23.6

[1] Standard error of mean.
[2] Subjective scores: 1=hard, dry, crumbly; 2=semi-moist, well-formed, retains shape; 3=soft, most, formed; 4=soft, viscous, moist, unformed; 5=watery diarrhea.
[a,b,c] Means within row with different superscripts differ (P<0.05).

Results

All dogs remained healthy throughout the study based on normal serum chemistry and complete blood counts. They also maintained body weight and body condition over the duration of the study.

Food intake: Ancient grain source did not affect (P>0.05) food consumption based on similar daily dry matter intake (Table 4). Dry matter consumption ranged from 153.6 to 160.4 g/d for dogs. Despite the high inclusion level (40%) of each ancient grain, no discernible acceptability issues were observed for any of the foods.

Fecal characteristics: When expressed on an as-is basis, daily fecal output was higher (P<0.05) for dogs fed amaranth and quinoa compared with dogs fed foods containing rice and white millet. Fecal output (as-is) was intermediate for dogs fed oat groats which was not different from other foods. When fecal output is expressed on a dry matter basis, dogs fed white millet produced significantly less (P<0.05) feces than dogs fed amaranth, quinoa or oat groats. Subjective stool assessments showed stools of acceptable quality were maintained for all dogs based on an average score of 2.9 ± 0.1 (soft, moist, formed). Stool scores were statistically different (P<0.05) for dogs fed rice (2.7) compared with quinoa (3.0), but this difference is not considered biologically relevant.

Ammonia, indoles and phenols are putrefactive compounds that contribute to fecal odor. Fecal ammonia levels were higher (P<0.05) for dogs fed oat groats compared with white millet and quinoa while ammonia levels were intermediate and not different for rice and amaranth. The consumption of the rice-containing food resulted in higher (P<0.05) fecal phenol (96.8 ug/g) compared with all the ancient grain foods (25.1 ± 6.6 ug/g). Fecal indole levels were not different (P>0.05) but were numerically higher for dogs fed rice and oat groats. With the possible exception of oat groats, the ancient grains were associated with an overall reduction in putrefactive compounds compared with rice based on lower (P<0.05) levels of total phenols and indols. This implies a possible improvement in perceived fecal odor when amaranth, white millet and quinoa are used in dog food formulations.

Nutrient digestibility: Foods were considered to be highly digestible based on apparent total tract digestibility estimates exceeding 80% (Table 5). Some digestibility estimates were statistically-significant, but differences were relatively small and may not be biologically relevant. Specifically, dry matter digestibility was higher (P<0.05) for white millet (86.3%) compared with the other foods that averaged 82.8 ± 0.6%. This difference is attributed to reduced fecal output by dogs fed the white millet food. Dry matter digestibility was similar for amaranth, quinoa, oat groats and rice. The same trends and differences were noted for organic matter digestibility. Protein digestibility was equal for white millet and rice which were higher (P<0.05) than amaranth, quinoa and oat groats. Fat digestibility exceeded 90% for all foods with rice higher (P<0.05) than white millet (94.8 vs. 93.2%, respectively). Both of these sources had higher (P<0.05) fat digestibility than amaranth

Table 5. Apparent total tract nutrient digestibility of extruded dog foods

Item	Rice	Amaranth	White Millet	Quinoa	Oat Groats	SEM[1]
Dry matter (%)	83.2a	83.1a	86.3b	81.9a	83.0a	0.9
Organic matter (%)[2]	88.4a	88.4a	91.6b	87.8a	88.8a	0.6
Crude protein (%)[2]	89.0a	86.1b	89.0a	84.8b	87.9b	0.9
Acid-hydrolyzed fat (%)[2]	94.8a	90.3b	93.2c	91.4b	91.6b	0.4
Total dietary fiber (%)[2]	50.8a	65.7bc	72.6c	63.5b	66.6bc	2.4
Digestible energy (%)[2]	89.1a	88.0a	91.2b	87.5a	88.5a	0.7
Metabolizable energy (kcal/g)[1,2]	4.22	4.22	4.24	4.19	4.24	0.04

[1] Standard error of mean.
[2] Dry matter basis.
[a,b,c] Means within row with different superscripts differ (P<0.05)

Table 6. Glycemic response parameters for adult dogs fed extruded foods

Item	Rice	Amaranth	White Millet	Quinoa	Oat Groats	P <
Peak glucose value (mg/dL)[1]	22.2	26.3	26.5	27.1	17.0	0.24
Time to peak value (min)	136	144	120	103	67	0.18
Area under curve (mg*min/dL)[1]	3,846	4,950	4,067	5,300	2,850	0.18
Relative glycemic ratio	1.00	1.29	1.06	1.38	0.74	0.43

[1] Based on change from baseline

(90.3%), quinoa (91.4%) or oat groats (91.6%). Fiber digestibility was significantly (P<0.05) lower for rice compared with all ancient grain foods. Among the ancient grains, only white millet and quinoa were different (P<0.05) as fiber digestibility was intermediate for amaranth and oat groats. Digestible energy was highest (P<0.05) for white millet (91.2%) compared with the other foods that averaged 88.3 ± 0.7%. Metabolizable energy values based on fecal and urinary excreta collections were similar for all foods averaging 4.22 ± 0.02 kcal/g.

Fermentative end-products:

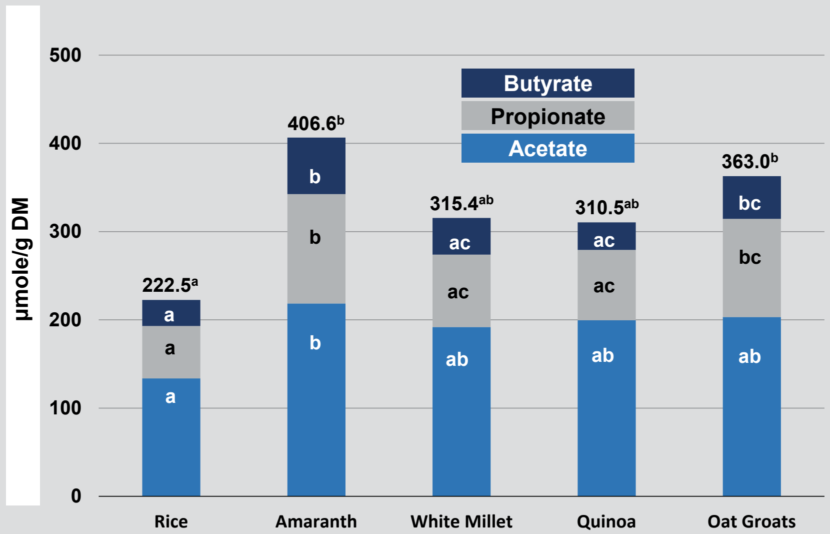
Fecal short-chain fatty acids are derived from hind-gut carbohydrate fermentation. Total short-chain fatty acids levels were highest (P<0.05) for amaranth and oat groats compared with rice while total levels for white millet and quinoa were intermediate (Figure 2). Acetate, propionate and butyrate were all significantly (P<0.05) higher for amaranth compared with rice. Oat groats also resulted in higher (P<0.05) propionate and butyrate than rice. Among the ancient grains, propionate and butyrate levels were higher (P<0.05) for amaranth than white millet or quinoa. Increased butyrate production during hind-gut fermentation is generally associated with a healthier digestive tract because of butyrate's beneficial effects on gastrointestinal function and energy metabolism. These results imply amaranth and oat groats may specifically benefit canine digestive health because of increased butyrate production during fermentation compared with fermentation of traditional rice-based formulations.

Fecal branched-chain fatty acids are derived from the hind-gut fermentation of protein. Total branched-chain fatty acids were significantly (P<0.05) lower for amaranth and quinoa compared with oat groats due to lower (P<0.05) levels of isobutyrate and isovalerate (Figure 3). Fecal valerate was significantly (P<0.05) higher for amaranth and oat groats compared with rice. Overall, the ancient grains minimally impacted hind-gut protein fermentation based on these responses.

Glycemic response: Glycemic index characterizes the ability of an ingredient or food to raise blood glucose levels. This glycemic response is a function of carbohydrate digestion and absorption and the subsequent entry of glucose into peripheral circulation. The assignment of a glycemic index value requires a direct comparison to a control ingredient or food that is also administered to the same test subject. In this study, the rice-containing food functioned as the control for calculating the glycemic response of the select ancient grains.

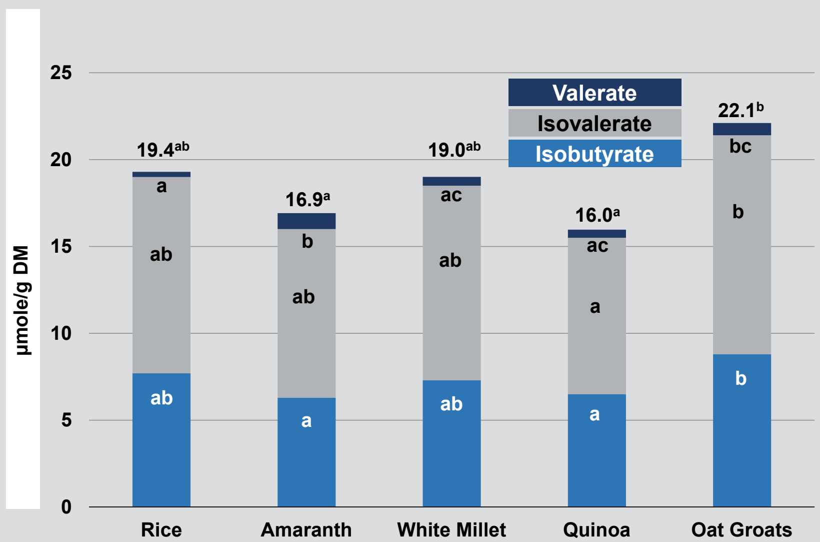
Blood glucose values in Figure 4 are expressed as the average change from baseline at each time-point. Dogs displayed a typical glycemic response based on the rise in blood glucose following meal consumption to peak concentrations between 1 and 2.5 hours post-feeding with an eventual return to baseline by 6 hours. Although there were no statistical differences (P>0.05) for any glycemic parameter, numerical differences are informative (Table 6). Peak glucose values were similar for amaranth, white millet and quinoa averaging 26.6 ± 0.4 mg/dL compared with rice (22.2 mg/dL) and oat groats (17.0 mg/dL). Time to peak glucose concentration was quickest for oat groats (67 min) and slowest for amaranth (144 min) and rice (137 min). Quinoa and white millet were intermediate at 103 and 120 min, respectively. Area under the curve (AUC) was 3,846 mg*min/dL for dogs fed the rice control food. When compared with rice, AUC was greater for dogs fed white millet, amaranth and quinoa (4,067, 4,950 and 5,300 mg*min/dL, respectively). Only oat groats had a lower AUC than rice (2,850 mg*min/dL). The calculated glycemic ratio was greater than rice (1.00) for white millet (1.06), amaranth (1.29) and quinoa (1.38) while oat groats (0.74) was less. Rice is considered a high glycemic carbohydrate thus white millet, amaranth and quinoa can also be categorized as high glycemic carbohydrates based on these responses. In contrast, oat groats attenuated the glucose response compared to rice implying it has a more moderate glycemic index. The fiber content of oat groats is likely responsible for its lower glycemic response.

Figure 2. Fermentative end-products: Short-chain fatty acids



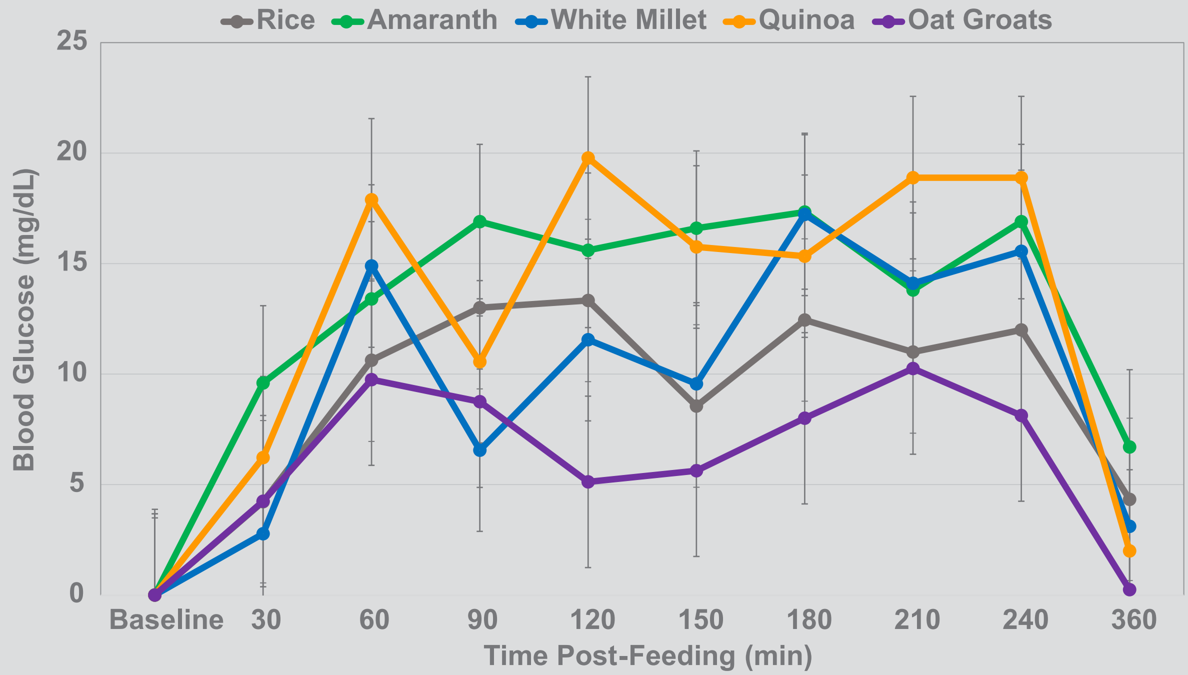
a,b,c Different superscripts within a short-chain fatty acid are different (P<0.05).

Figure 3. Fermentative end-products: Branched-chain fatty acids



a,b,c Different superscripts within a branched-chain fatty acid are different (P<0.05).

Figure 4. Glycemic response: blood glucose change from baseline for each post-prandial time-point



Summary

Study results demonstrate amaranth, white millet, quinoa and oat groats are all well-utilized by adult dogs when used as the primary carbohydrate source in a nutritionally complete, extruded food. No ancient grain compromised diet acceptance or nutrient digestibility. All were equally utilized by the dogs resulting in minimal differences in nutrient digestibility. White millet was the most digestible of the ancient grain sources. Amaranth and oat groats beneficially shifted fermentative end-products associated with improved intestinal health. Amaranth, white millet and quinoa also reduced fecal putrefactive compounds which may minimize fecal odor. Glycemic responses of amaranth, white millet and quinoa were comparable to rice, implying each source can be categorized as a high glycemic carbohydrate. In contrast, oat groats are more representative of a moderate glycemic carbohydrate based on its attenuated glucose response compared with rice.

Practical Applications

The nutritional value of the ancient grains evaluated in this study are similar to brewers rice based on nutrient digestibility, fermentative end-products and glycemic responses. Amaranth, white millet, quinoa and oat groats can be successfully used as the main carbohydrate source in nutritionally complete dog and cat foods. Each ancient grain source represents a viable starch alternative for manufacturers seeking novel ingredients to meet changing consumer demands. Glycemic responses of amaranth, white millet and quinoa demonstrate these ancient grains are appropriate carbohydrates for dogs and cats requiring a readily-available source of glucose and energy. As such, they are recommended for formulations supporting reproduction and growth. They are also appropriate for sporting dog formulas as they can meet the increased energy needs of canine athletes. In contrast, oat groats are not recommended for these applications due to a more moderate glycemic response. Oat groats are more appropriate in weight control and senior formulas due to the need for improved glucose and weight management in obese and elderly pets. ■