Archives of Veterinary Science **ISSN 1517-784X**
v.23, n.4, p.62-68, 2018 www.ser.ufpr.br/veterinary

ADDITION OF WATER IN THE EXTRUSION ON THE PHYSICOCHEMICAL PROPERTIES AND DIGESTIBILITY OF THE DIET ON DOGS

Adição de água na extrusão sobre as características físico-químicas e digestibilidade da dieta em cães

Fabiane Yukiko Murakami, Ananda Portella Félix*, Cleusa Bernardete Marcon de Brito, Marcelino Bortolo, Alex Maiorka, Simone Gisele Oliveira, Sebastião Aparecido Borges, Carolina Pedro Zanatta

Departamento de Zootecnia, Universidade Federal do Paraná, Curitiba, PR, Brasil.

*Corresponding author: apfelix@ufpr.br

ABSTRACT - The objective was to evaluate the effect of adding increasing water levels in conditioner on kibble's physicochemical characteristics and diet digestibility in dogs. Five adult dogs were used, who consumed diets containing: 1072, 1182, 1293, 1444, and 1565 kg of water/ hour added in conditioner. The design was a Latin Square (5 x 5) and the data were subjected to analysis of regression and correlation. The inclusion of up to 1565 kg of water/ hour in conditioner presented negative correlations (P <0.05) with hardness and density and positive with the water activity, moisture, porosity, and degree of starch gelatinization of kibbles. However, the digestibility and the metabolizable energy of the diets did not are affected by the amount of water added in the conditioner (P> 0.05). Furthermore, the intermediate addition of 1293 kg of water / hour in conditioner resulted in kibbles with larger pores, and increased up to 1565 kg of water / hour result in smaller pores providing lower density and hardness and an increase in starch gelatinization. However, it does not affect the diet digestibility in dogs.

Keywords - conditioner; kibble; starch gelatinization.

RESUMO - Objetivou-se avaliar o efeito da adição de crescentes níveis de água no condicionador sobre as características físico-químicas dos extrusados e a digestibilidade da dieta em cães. Foram utilizados cinco cães adultos que consumiram dietas contendo: 1072, 1182, 1293, 1444 e 1565 kg de água/hora adicionada no condicionador. O delineamento foi em Quadrado Latino (5 x 5) e os dados foram submetidos à análise de regressão e correlação. A inclusão de até 1565 kg de água/hora no condicionador apresentou correlações (P<0,05) negativas com a dureza e a densidade e positivas com a atividade de água, umidade, porosidade e grau de gelatinização do amido dos extrusados. No entanto, a digestibilidade e a energia metabolizável das dietas não foram influenciadas pela quantidade de água adicionada no condicionador (P>0,05). Além disso, a adição intermediária de 1293 kg de água/hora no condicionador resultou em extrusados com poros maiores, sendo que o aumento em até 1565 kg de água/hora resulta em poros menores proporcionando densidade e dureza menores e aumento na gelatinização do amido. No entanto, não afeta a digestibilidade da dieta em cães.

Palavras-chave - condicionador; extrusado; gelatinização do amido.

Recebido em 04/01/2017
Aprovado em 23/10/2018

INTRODUCTION

Extrusion is an important step in dog food manufacturing, as it promotes starch gelatinization, thereby improving diet digestibility (MURRAY, 2001). The addition of water to the mash during conditioning is essential for feedstuff homogenization and cooking, and its addition levels influences the degree of starch gelatinization, as well as kibble density and texture (ROKEY et al., 2010; ZHU et al., 2016).

Water is present in foods as bound water and free water, and their sum is considered total water content (humidity). Free water provides favorable conditions for the development of microorganisms, as well as for enzymatic, oxidative, and hydrolytic reactions in compound feeds (KRABBE, 2009), compromising their nutritional quality and safety.

Considering the lack of information in literature relative to water addition in the conditioner on expanded dog foods, the objective of this study was to evaluate the effect of the addition of increasing water levels during conditioning on the physical-chemical characteristics and digestibility of extruded dog food.

MATERIAL AND METHODS

The experiment was approved by the Committee of Ethics on Animal Use of the sector of Agricultural Sciences of the Federal University of Paraná. A basal diet was formulated (Table 1) to supply the nutritional requirements of adult dogs, according to the AAFCO (2003). The food ingredients were ground in a hammer mill to 1-mm particle size, and the mash was extruded in a single-screw extruder (Ferraz, E-130, Ribeirão Preto, SP, Brazil).

Table 1 - Ingredients and analyzed chemical composition (% of dry matter) of the basal diet.

Ingredients	**%**
Ground corn grain	26.54
Poultry offal meal	24.48
Broken rice	15.00
Wheat midds	8.00
Soybean meal 48%	6.00
Swine offal meal	5.00
Meat meal	3.84
Fish meal	3.00
Poultry fat	4.00
Flavor[1]	3.00
Mineral-vitamin supplement[2]	0.60
Sodium chloride	0.50
Antifungal agent[3]	0.02
Antioxidant[4]	0.02
Chemical composition (on dry matter basis)	
Crude protein (%)	34.00
Ether extract (%)	7.60
Crude fiber (%)	1.79
Ashes (%)	8.61
Calcium (%)	1.30
Phosphorus (%)	0.90
Metabolizable energy (kcal/kg)[5]	4284.0

[1]Liquid poultry liver hydrolysate. [2]Amount per kg food: vitamin A (retinol) = 10,000 IU, vitamin D3 = 1,000 IU, vitamin E (α-tocopherol) = 24 mg, vitamin K3 = 2.4 mg, vitamin B1 = 2 mg, vitamin B2 = 4 mg, vitamin B12 = 16 mcg, niacin = 28 mg, pantothenic acid = 8 mg, choline = 400 mg, zinc = 100 mg, iron = 100 mg, manganese = 30 mg, copper = 12 mg, and iodine = 1 mg. [3]Ammonium propionate.[4]Butylated hydroxyanisol (BHA) and butylated hydroxytoluene (BHT). [5]Estimated according to the NRC (2006).

Five water levels were added to the conditioner (1072, 1182, 1293, 1444, and 1565 kg water/h), resulting in five experimental diets. Except for water level, the five experimental diets were extruded at identical temperature, velocity, and pressure of 100 ºC, 200 RPM, and 32 kg/cm^2, respectively. After extrusion, all diets were submitted to the same processing steps: drying (110ºC for 20 minutes), coating with oil, cooling, and coating with liquid flavor.

Five adult male and female beagle dogs, with 13.4 ± 1.7 kg average body weight and 5.8 ± 0.1 year of age were evaluated. Dogs were individually housed in stainless steel metabolic cages (0.7 m long x 0.6 m high x 0.5 m deep).

Each experimental period consisted of 10 days, with each diet offered for a five-day adaptation period, followed by five days of total feces collection per period, as recommended by AAFCO (2004). Dogs were fed twice daily (07:30 and 16:30 hours) in sufficient amount to supply their metabolizable energy requirements (kcal/d), according to following equation: 130 x body weight (kg)$^{0.75}$ (NRC, 2006). Water was offered *ad libitum*. Feces were collected at least twice daily, and stored frozen in duly identified recipients.

Fecal score was evaluated always by the same researcher, using the following 1-5 scale: 1 = watery feces (can be poured from the container); 2 = soft and unshaped stools; 3 = soft, shaped, and moist stools; 4 = well-shaped and uniform stools; 5 = well-shaped, hard and dry stools, as proposed by Carciofi et al. (2009).

At the end of each experimental period, feces were thawed, homogenized, and dried in a forced-ventilation oven at 55°C for 72 hours. Diet and fecal samples were ground to 1-mm particle size and analyzed for dry matter (DM), crude protein (CP), ether extract in acid hydrolysis (AHEE), ash, and crude fiber (CF) contents, according to the AAOAC (1995). Gross energy (GE) was determined in a bomb calorimeter.

All diets were examined under an electronic scanning microscope (ESM) at 40x magnitude to determine kibble porosity, defined as pore area relative to total kibble area. Kibble pore area (mm^2) was measured of each diet using the software ImageJ® (Wayne Rasband, National Institutes of Health, Bethesda, MD, USA).

Kibble density was determined as the ratio between kibble weight (g) and volume (L) in five samples per treatment. Samples were homogenized, placed in a 1000-cm^3 test tube, and weighed in a digital scale (2,000-g capacity).

The degree of starch gelatinization was determined according to CHIANG & JOHNSON (1977). Water absorption index (WAI) was determined according to the method proposed by HOLAY & HARPER (1982). Kibble hardness was measured using a TA-XT Plus texture analyzer and considered as the average breaking strength of 50 kibbles per treatment. Water activity was determined by Aqualab® apparatus.

The coefficients of apparent digestibility (CAD) of the dietary nutrients and energy were calculated according to the equation of AAFCO (2003), as follows: CAD% = [(g of nutrient intake – g of nutrient excretion)/g of nutrient intake] x 100 Metabolizable energy (ME) was estimated according to AAFCO (2003), with no urine collection, as: ME (kcal g-1) = {kcal g-1 GE intake – kcal g-1 fecal GE– [(g CP intake – g fecal CP) x 1.25kcal g-1]} / g of feed intake.

The correlation between kibble characteristics and levels of water addition to the conditioner was analyzed by Pearson's correlation analysis using the CORR procedure of SAS statistical package (2001). Data relative to CAD and ME content were submitted to polynomial regression analysis according to a 5 x 5 Latin square experimental design, with five replicates per treatment, using the REG probability (SAS, 2001). Differences were considered significant at 5% probability level. Fecal scores were compared by the test of Kruskal Wallis (n = 5, P<0.05), as the data did not present normal distribution.

RESULTS

The amount of water added to the conditioner (1072 to 1565 kg/h) was negatively correlated (P<0.05) with kibble hardness and density, and positively correlated (P<0.05) with starch gelatinization, and with porosity (Figure 1), moisture, and water activity (Tables 2 and 3). However, water absorption index (WAI) was not affected (P>0.05) by water addition levels. There was no effect of increasing water addition levels to the conditioner on food intake, diet digestibility, or dietary ME content (P>0.05, Table 4). Fecal score was not affected by the treatments (P>0.05, Table 4).

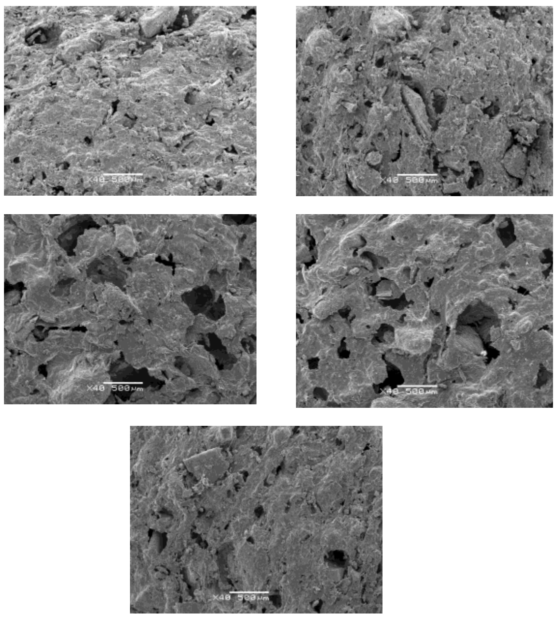

Figure 1. Scanning microscopy (from left to right) of diets 1072, 1182, 1293, 1444, and 1565 kg of water / hour added in the conditioner, respectively. 40x magnification. The pores in the kibble may be seen.

Table 2 - Average starch gelatinization degree (SGD), hardness, porosity, density, water activity (Aw), humidity, and water absorption index (WAI) of dog foods extruded with increasing levels of water addition to the conditioner.

Diets (kg water/h)	SGD (%)	Density (g/L)	WAI (%)	Aw	Humidity (%)	Hardness (kgf)	Porosity (mm^2)
1072	88	462	493	0.27	5.6	7.83	0.43
1182	82	450	500	0.38	6.3	7.44	0.77
1293	70	444	499	0.46	6.9	7.94	1.16
1444	94	446	495	0.62	8.5	7.08	0.81
1565	94	432	498	0.68	9.9	6.02	0.76

Table 3 - Correlation between water addition level to the conditioner and kibble characteristics.

Parameters	Level of water addition to the conditioner
Density	-0.5336**
Hardness	-0.3077**
Starch gelatinization degree	0.4311**
Water absorption index	0.2260
Porosity	0.3762**
Water activity	0.9509***
Humidity	0.9398***

P<0.01*P<0.001

Table 4 - Dry matter intake (DMI, g/dog/d), coefficients of apparent digestibility, metabolizable energy content (ME, kcal/kg), and fecal characteristics of dogs fed diets extruded with increasing levels of water addition to the conditioner.

	Water addition level (kg/h)					SEM	P		
Item	1072	1182	1293	1444	1565		L	Q	R^2
DMI	306	292	294	284	284	7.05	0.12	0.86	0.03
Coefficients of apparent digestibility (%)									
DM	80.3	82.7	79.6	79.6	80.9	0.68	0.34	0.81	0.09
CP	85.1	88.1	85.6	85.5	86.4	0.51	0.49	0.72	0.07
AHEE	87.5	87.9	88.2	89.9	88.6	0.51	0.07	1.00	0.27
GE	84.4	87.2	83.8	83.8	85.5	0.56	0.96	0.99	0.01
ME (kcal/kg)	3891.6	3939.7	3874.8	3838.2	3942.0	28.81	0.63	0.32	0.03
Fecal characteristics									
FS[1]	3.0	4.0	3.0	3.0	3.0	-	-	-	-
DMf	37.6	37.4	36.3	38.2	37.4	0.81	1.00	0.99	0.07

SEM: Standard error of the mean; P: probability of linear (L) and quadratic (Q) effects; DM: dry matter; CP: crude protein; AHEE: ether extract in acid hydrolysis; GE: gross energy; R^2: coefficient of determination; [1]FS: fecal score (P = 0.909 by the test of Kruskal Wallis); DMf: fecal dry matter.

DISCUSSION

High-density foods typically present low water absorption and small number of pores, which often indicate poor expansion, inadequate starch gelatinization, and lower nutrient utilization (CAMIRE, 1998; TIWARI and JHA, 2017). However, in the present study, although the higher water addition level (1565 kg/h) resulted in kibbles with the smallest pore area, this diet presents high SGD (92%), according to Lin et al. (1997).

Diet digestibility and fecal scores were not affected by water addition levels, demonstrating that these levels did not influence diet homogeneity or cooking, and were enough to hydrate the starch granules of the feedstuffs. When in contact with high temperature and humidity, starch granules expand, absorb water, and are reorganized, providing the desired structure to the extruded product (HARPER, 1990). The starch gelatinization results of the present study (Table 2) indicate that, independently of the water addition levels, cooking was relatively uniform. In a study with extruded sweet potato and soybeans, the addition of 18-30% water to the conditioner did not change the SGD of the extruded products (BORBA et al., 2005). On the other hand, Lin et al. (1997) observed that the SGD of pet foods containing 50 g of tallow or poultry fat/kg decreased as a function of increasing levels of water addition during extrusion increased, as a result of lower mash temperature decreased, and consequently, of mash cooking efficiency. Some authors suggest that SGD lower than 75% indicate deficient processing, with negative impacts on the digestibility of dog foods (BAZOLLI, 2006, LOUREIRO et al., 2014). However, despite the lower starch gelatinization value (70%) obtained in the present study, digestibility was not significantly affected.

One of the functions of water addition to the conditioner is to create bubbles in the mass, which affects the expansion rate of the products, according to THYMI et al. (2005) and YOVCHEV et al. (2017). Those authors observed a negative correlation between water addition level and expansion rate, i.e., expansion rate decreases as the amount of added water increases. The reason is that water acts as a lubricant, negatively influencing extrusion, and consequently, the expansion of the resulting products when added at high levels (LIN et al., 2002). In the present study, an optimal range of water to expansion ratio was observed. The diets expanded with the intermediate levels of water addition presented higher pores (Table 2), indicating levels of up to 1293 kg/h increased kibble porosity (Figure 1). The kibbles produced with the highest level of water inclusion (1565 kg/h) presented the lowest porosity; however, their density and hardness were lower compared with the other diets.

It was also observed that water activity and diet humidity proportionally increased with increasing water addition to the conditioner. Water activity is an indication of food preservation as it is directly related to fungal growth (Brito et al., 2010), and therefore, special care should be taken during the drying step of foods manufactures with higher water inclusion levels in the conditioner.

The results of this study show that different levels of water addition to the conditioner influenced the physical-chemical characteristics of kibbles, particularly their porosity, density, and starch gelatinization degree, but not diet digestibility.

CONCLUSION

The addition of 1293 kg of water/hour to the conditioner increases kibble porosity. The kibbles produced with addition of 1565 kg of water/hour presented smaller pores, resulting in lower density and hardness and higher starch gelatinization degree compared with the other evaluated levels. None of the evaluated levels of water addition influenced the digestibility and the metabolizable energy content of dog foods, or the fecal texture of the dogs.

REFERENCES

ASSOCIATION OF AMERICAN FEED CONTROL OFFICIALS - AAFCO.

Official Publications. Association of American Feed Control Officials, 2003.

ASSOCIATION OF THE OFFICIAL ANALITICAL CHEMISTS - AOAC. **Official and tentative methods of analysis**, 16. Ed. Arlington, Virginia: AOAC International, 1995.

BAZOLLI, R. S. **Influência do grau de moagem de ingredientes amiláceos utilizados em rações extrusadas sobre os aspectos digestivos e respostas metabólicas em cães.** 2007. 71f. Tese Doutorado. Faculdades de Ciências Agrárias e Veterinárias, Universidade Estadual de São Paulo, Jaboticabal, São Paulo. 2007

BORBA, A. M.; SARMENTO, S. B. S.; LEONEL, M. Efeito dos parâmetros de extrusão em farinha de batata-doce. **Ciência e Tecnologia de Alimentos**, v. 25, n. 4, p. 835-843, 2005. Available at < http://www.scielo.br/pdf/cta/v25n4/27660.pdf> Accessed on: April 16, 2013.

BRITO, C.B.M., FELIX, A.P., JESUS, R. M., FRANÇA, M. I., KRABBE, E.L., OLIVEIRA, S.G., MAIORKA, A., 2010. Digestibility and palatability of dog foods containing different moisture levels, and the inclusion of a mould inhibitor. Animal Feed Science and Technology, v.159, p.150-155, 2010.

CAMIRE, M. E. Chemical changes during extrusion cooking. Recent advances. **Advanced in Experimental Medicine e Biology**, v. 434, n. 1, p.109-121, 1998. Available at <http://www.ncbi.nlm.nih.gov/pubmed/9598195> Accessed on: April 16, 2013.

CARCIOFI, A. C. et al. Comparison of micronized whole soybeans to common protein sources in dry dog and cat diets. **Animal Feed Science and Technology**, v. 151, n. 3-4, p. 251–260, 2009.

CHIANG, B.Y.; JOHNSON, J.A. Measurement of total and gelatinized starch by glucoamylase and o-toluidine reagent. **Cereal Chemistry**, v.54, p.429-435, 1977.

HARPER, J.M. Extrusion of foods. In: SCHWARTZBERG, H.G.; RAO, M.A. **Biotechnology and Food Process Engineering**. Hardcover. 1° Edition, 493p. Published, 295-308p. 1990.

HOLAY, S. H.; HARPER, J. M. Influence of extrusion shear environment on plant texturization. **Journal of Food Science**, v. 47, n. 6, p. 1869-1874, 1982. Available at <http://onlinelibrary.wiley.com/doi/10.1111/j.1365-621.1982.tb12902.x/abstract> Accessed on: April 16, 2013.

KRABBE, E.L. Controle da atividade de água e produção de alimentos secos e semi-úmidos. In: I Congresso Internacional e VIII Simpósio sobre nutrição de animais de estimação, 2009. Campinas. **Anais...** Campinas: Colégio Brasileiro de Nutrição Animal, 2009.

LIN, S.; HSIEH, F.; HUFF, H. E. Effects of lipids and processing conditions on degree starch gelatinization of extruded dry pet food. **Lebensmittel-Wissenschaft and Technologie**, v. 30, n. 7, p. 754-761, 1997. Available at < http://www.sciencedirect.com/science/article/pii/ S0023643897902711> Accessed on: April 16, 2013.

LIN, S.; HUFF, H. E.; HSIEH, F. Extrusion process parameters, sensory characteristics and structural properties of a high moisture soy protein meat analog. **Journal of Food Science**. v. 67, n. 3, p. 1066-1072, 2002.

LOUREIRO, B. A.; FILHO, F. O. R.; GAVASSO, P. D.; PEIXOTO, M. C.; SÁ, F.C.; MONTI, M.; PEDREIRA, R. S.;

CARCIOFI, A. C. Gelatinização do amido e digestibilidade dos nutrientes de rações extrusadas para cães. In: VI Congresso Internacional e XIII Simpósio sobre Nutrição de Animais de Estimação, 2014. **Anais...** Valinhos, São Paulo. Available at: http://www.cbna.com.br/site/Documentos/VI-Congresso-XIII-Simposio-PET/TRABALHO-09-GELATINIZACAO-DO-AMIDO-Bruna-A-Loureiro.pdf. Accessed on: March 03, 2015.

MURRAY, S. M., FLICKINGER, A. E., PATIL, A. R., MERCHEN, N. R., BRENT JR., J.L., FAHEY JR., G.C. In vitro fermentation characteristics of native and processed cereal gains and potato starch using ileal chyme from dogs. **Journal Animal Science**, v. 79, n. 2, p. 435-444, 2001. Available at <http://www.journalofanimalscience.org/content/79/2/435.full.pdf> Accessed on: April 16, 2013.

NATIONAL RESEARCH COUNCIL - NRC. In: **Nutrient Requirements of Dogs**. National Academy Press. Washington, p.428, 2006.

ROKEY, G. J.; PLATTNER, B.; SOUZA, E. M. de. Feed extrusion process description. **Revista Brasileira de Zootecnia**, v.39, p.510-518, 2010 (supl. especial). Available at <http://www.scielo.br/pdf/rbz/v39sspe/55.pdf> Accessed on: April 16, 2013

STATISTICAL ANALYSIS SYSTEM, 2001. User's Guide: Statistics, version 8.2, **SAS** Institute, Cary, NC, USA.

THYMI, M. K.; KROKIDA, M. K.; PAPPA, A.; MAROULIS, Z. B. Structural properties of extruded corn starch. **Jounal of Food Engineering**, v. 68, n. 4, p.519-526, 2005. Available at <http://www.sciencedirect.com/science/article/pii/S0260877404003140> Accessed on: April 16, 2013.

TIWARI, A; JHA S.K. Extrusion Cooking Technology: Principal Mechanism and Effect on Direct Expanded Snacks - An Overview. **International Journal of Food Studies.** v. 6, p. 113-128, 2017. Available at < https://www.iseki-food-ejournal.com/ojs/index.php/e-journal/article/view/345/187 >. Accessed on: August 21, 2018.

YOVCHEV, A., STONE, A., HOOD-NIEFER, S., & NICKERSON, M. (2017). Influence of the extrusion parameters on the physical properties of chickpea and barley extrudates. **Food Science and Biotechnology**, 26(2), 393–399. doi:10.1007/s10068-017-0054-x

ZHU, L.; JONES, C.; GUO, Q.; LEWIS, L.; STARK, C.R.; ALAVI S. An evaluation of total starch and starch gelatinization methodologies in pelleted animal feed. **Journal of Animal Science.** 2016. v. 94, n.4, p.1501–1507, 2016. Available at < https://academic.oup.com/jas/article/94/4/1501/4704061 >. Accessed on: August 11, 2018. doi:10.2527/jas2015-9822.