Effects of different levels of cassava fibre and traditional fibre sources on extrusion, kibble characteristics, and palatability of dog diets

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ABSTRACT

Pet food companies often use fibres in extruded diets as a strategy to improve intestinal functionality and reduce energy density, but studies evaluating the effect of fibres on the extrusion process, kibble characteristics, and palatability of dog diets are scarce. Thus, the objective of this study was to evaluate the effect of cassava fibre (CA) levels and conventional fibre sources on the extrusion process, kibble characteristics, and palatability of diets. Seven diets were evaluated: control diet (CO), without the inclusion of fibre sources; three diets with increasing levels of CA—4, 8, and 12% (totalling 6.1, 7.2, and 8.3% total dietary fibre—TDF, respectively); diet with 3.8% cellulose (CE); diet with 6% beet pulp (BP); and diet with 3.8% lignocellulose (LC). Diets 12% CA, CE, BP, and LC presented approximately 8.0% TDF. Diet palatability was evaluated in 16 adult beagle dogs in a completely randomised design. Seven paired tests were conducted, with two consecutive days per test, totalling 32 repetitions. Diets with fibre sources had lower kibble density than the CO diet ($p = .004$). The inclusion of increasing dietary CA levels resulted in a linear increase in the kibble expansion index ($p = .0001$). Dogs preferred the 12% CA diet to the CO ($p = .032$) or BP diets ($p = .0001$). The evaluated insoluble fibre sources resulted in greater expansion and lower density kibbles than the CO diet. Furthermore, 12% of CA positively affected diet palatability in dogs.

HIGHLIGHTS

- Cassava fibre linearly increased the expansion of kibbles.
- 12% cassava fibre positively affected diet palatability.
- Diets with fibre sources changed the physical characteristics of kibbles.

Introduction

The extrusion process induces structural and chemical changes in ingredients, which affects kibble shape and texture and improves the nutritional value of the final product (Riaz 2007; Tran et al. 2008). Variables, such as humidity, pressure, temperature, time, and ingredients affect extrusion and directly impact kibble quality. Thus, evaluating kibble characteristics is important for the pet food industry because it supports the standardisation and control of the manufacturing processes and the development of new products. Moreover, this assessment allows relating ingredients and processing to chew force and palatability of the final product (Ishizaki et al. 2006).

Fibre sources may affect the extrusion process and kibble characteristics (Donadelli et al. 2021). The use of fibre in extruded diets is a common strategy in most pet food companies to reduce energy density and improve intestinal functionality (Middelbos et al. 2010; Kröger et al. 2017; Sabchuk et al. 2017). However, information on the effects of fibres on extrusion is scarce. Since they are made of a highly polymerised and structured material, fibres are not expandable and have variable water holding capacity. These characteristics interfere with viscosity, cooking, and with mass flow inside the extruder barrel, as well as cell structure formation and kibble expansion rate (Karkle 2012; Monti et al. 2016). Thus, the addition of fibres in dog diet formulations can pose relevant processing challenges, such as increased electrical energy consumption and less expanded, dense, and hard extruded products (Karkle 2012; Robin et al. 2012; Monti et al. 2016). On another hand, studies have also
shown that insoluble fibres with smaller particle sizes may improve kibble expansion due to greater continuity in starch and fibre matrices, reducing premature cell rupture, and thus, improving cell size (Kallu et al. 2017). Considering those potential contradictory effects, it is important to further evaluate the effects of different fibre sources on pet food processing.

The most common fibre sources in dog diets are beet pulp (BP), cellulose (CE), and lignocellulose (LC). However, these sources have a high cost because they are either imported or subjected to expensive production processes. Given that Brazil is one of the largest producers of cassava in the world (FAO 2017), with an annual production volume of 19.4 million tons grown in an area of 1.4 million hectares (IBGE 2019), the use of cassava fibre (CA) is a potential alternative. The CA is a co-product of the processing of cassava starch (Osundahunsi et al. 2012), obtained from the cassava cortex after drying and grinding. It has an average composition of 32.4% insoluble fibre and 2.6% soluble fibre. Despite its interesting nutritional characteristics, no studies evaluating the effects of CA on the processing and palatability of dog diets have been found. Only one study evaluated the effects of CA on digestibility and faecal fermentative metabolites and microbiota of dogs (Souza et al. 2021). Thus, the objective of this study is to evaluate the effects of different inclusion levels of CA and conventional fibre sources on the extrusion process, kibble characteristics, and palatability of dog diets.

Materials and methods

The experiments with animals in this study were approved by the Ethics Committee on Animal Use (CEUA) of the Sector of Agrarian Sciences of the Federal University of Paraná, Curitiba, Paraná, Brazil (protocol n. 007/2019).

Experimental diets

Seven experimental diets were formulated to meet the nutritional needs of dogs according to the European Pet Food Industry Federation (FEDIAF 2019). The ingredients were grounded on 0.8 mm sieves and extruded in a single-screw extruder (Ferraz, E-130; Ribeirão Preto, SP, Brazil). After the extrusion process, the diets were dried in a horizontal dryer for 20 min at 115°C and coated with oil and palatant.

The evaluated diets were: a control diet containing no added fibre source (CO); three diets containing increasing levels of CA: 4, 8, and 12%—resulting in contents of 6.1, 7.2, and 8.3% of total dietary fibre (TDF), respectively; diet containing 3.8% CE; diet containing 6% BP, and a diet containing 3.8% LC. The last three diets contained the same level of TDF as the 12% CA diet (~8.0% TDF). The CA was obtained from the cassava cortex after the grinding and drying process, resulting in a fibre length of 125 µm. The total cyanide concentration of CA was evaluated according to Cardoso et al. (2005), resulting in a residual concentration of 1.9 mg/kg of CA. This cyanide content is below the maximum accepted concentration of 50 mg/kg for cassava products, according to the Associação Brasileira da Indústria de Produtos para Animais de Companhia (ABINPET 2019).

The experimental diets were ground to 1 mm using a Willey hammer mill (Arthur H. Thomas Co., Philadelphia, PA, United States of America) and analysed for dry matter (DM) at 105°C for 12 h. Nitrogen was analysed (method 954.01) and the crude protein (CP) was calculated as N × 6.25 nitrogen. Additionally, acid-hydrolyzed ether extract (AHEE, method 954.02) and ash (method 942.05) were also analysed according to the Association of Official Analytical Chemists (AOAC 1995). Organic matter (OM) was determined by 100—ash. Total dietary fibre (TDF) content of diets and faeces was determined according to Prosky et al. (1988). Gross energy (GE) was measured using a bomb calorimeter (Parr Instrument Co., Model 1261, Moline, IL, United States of America). The ingredients and chemical composition of the experimental diets are presented in Table 1.

Extrusion parameters and physical characteristics of the kibbles

The preconditioner exit temperature and the extruder barrel amperage, screw speed, and productivity were measured. The temperature was measured with a digital infra-red thermometer (LaserGrip Model GM400, São Paulo, SP, Brazil). The steam and water added to the preconditioner were kept constant among the treatments. No water or steam was injected into the extruder barrel.

Diet density at the extruder exit was calculated in 10 samples from each treatment and determined by the ratio of weight (g) to volume (L). The samples were homogenised, placed in a 1-L burette, and weighed on a digital scale (2,000 g capacity).

Kibble width was measured using a digital calliper (MTX-316119). The expansion index (EI) was calculated as the ratio of the kibble width to the die diameter. In
both analyses, 20 samples were evaluated for each treatment. For hardness analysis, 20 kibbles were selected from each diet. These samples were analysed using a hardness tester (Ethik Technology; 298 DGP), which measures the diametrically applied force required to break a kibble. Force was measured in Newton (N), and converted to and expressed in kgf/cm².

To determine friability, 20 kibbles of each treatment were weighed, introduced into a friability tester (Erweka®; Erweka model TA 20, Langen, HE, Germany), and removed after one hundred rotations made over a 5-min period (20 xg). The kibbles were weighed again after removing any residue. Thus, the friability, as a function of the percentage of powder lost, was represented by the difference between kibble initial weight and final weight, determining their abrasion resistance when submitted to the mechanical action of a specific apparatus.

Scanning electron microscopy was performed on kibbles of each treatment at a magnification of 10× to verify porosity. A longitudinal cut was made in the kibbles to facilitate pore visualisation. Kibble pore area (mm²) was measured using ImageJ® (Wayne Rasband, National Institutes of Health, Bethesda, MD, United States of America). The evaluated variables were: total pore area, number of pores, and average pore area.

**Palatability test**

In this study, 16 adult beagles (8 males and 8 females) with an average age of 3.4 ± 0.1 years and an average weight of 10.3 ± 1.07 kg were used. All dogs underwent clinical and physical examination, and were vaccinated and dewormed. They were housed in concrete stalls covered with a solarium (5 m long x 2 m wide), and water was provided ad libitum. The facilities had sidewall grates allowing visual and limited interaction with neighbouring dogs. The ambient temperature ranged from 16 to 28°C with a 12 h light-dark cycle (light from 6 a.m. to 6 p.m.). Dogs were kept individually closed in the kennels only during the palatability test (for about 30 min).

Each palatability test was performed on two consecutive days in which the diets were offered in two different feeders once a day at 8:30 a.m. for 30 min. Each diet was fed at amounts 30% higher than the recommended metabolisable energy (ME) requirement according to the following equation (NRC 2006): ME (kcal/day) = 130 × Body weight⁰.⁷⁵.

### Table 1. Ingredients (%) and chemical composition (% of dry matter) of the experimental diets.

| Item               | CO  | 4    | 8    | 12   | CE  | BP  | LC    |
|--------------------|-----|------|------|------|-----|-----|-------|
| Ingredients        |     |      |      |      |     |     |       |
| Corn               | 51.45 | 46.72 | 42.61 | 38.50 | 47.18 | 44.88 | 47.18 |
| Poultry offal meal | 25.00 | 25.31 | 25.59 | 25.88 | 25.45 | 25.44 | 25.45 |
| Corn gluten meal 60% | 6.68 | 6.68 | 6.68 | 6.68 | 6.68 | 6.68 | 6.68 |
| Poultry fat        | 6.00 | 6.08 | 6.15 | 6.22 | 6.05 | 6.11 | 6.05 |
| Soy protein concentrate | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 |
| Fibre source       | 0.00 | 4.35 | 8.11 | 11.87 | 3.79 | 6.04 | 3.79 |
| Palatant®          | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| Calcitic lime      | 1.16 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 |
| Premix®h           | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Potassium chloride | 0.54 | 0.54 | 0.54 | 0.54 | 0.54 | 0.54 | 0.54 |
| Common salt        | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 |
| Choline chloride   | 0.27 | 0.27 | 0.27 | 0.27 | 0.27 | 0.27 | 0.27 |
| L-taurine          | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 |
| Antifungals®c      | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 |
| Antioxidant®d      | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| Chemical composition |    |      |      |      |     |     |       |
| Dry matter         | 92.34 | 91.29 | 92.50 | 91.38 | 93.40 | 91.50 | 93.30 |
| Crude protein      | 30.22 | 31.11 | 30.84 | 30.75 | 31.22 | 28.92 | 30.64 |
| Acid-hydrolyzed ether extract | 13.93 | 14.53 | 14.37 | 14.57 | 14.03 | 13.93 | 14.14 |
| Ash                | 5.85 | 5.74 | 5.98 | 5.79 | 6.15 | 5.72 | 6.12 |
| Total dietary fibre (TDF) | 4.31 | 6.10 | 7.22 | 8.32 | 8.06 | 8.08 | 8.21 |
| Insoluble fibre (IF) | 3.66 | 5.18 | 6.21 | 7.15 | 7.50 | 6.46 | 7.63 |
| Soluble fibre (SF) | 0.64 | 0.91 | 1.01 | 1.16 | 0.56 | 1.61 | 0.57 |
| Calcium            | 1.32 | 1.13 | 1.18 | 1.14 | 1.19 | 1.15 | 1.26 |
| Phosphorus         | 0.76 | 0.72 | 0.75 | 0.71 | 0.76 | 0.73 | 0.80 |
| Gross energy (kcal/kg) | 4629 | 4820 | 4727 | 4589 | 4700 | 4656 | 4706 |

⁶Palasant® (Kemin Industries, Indaiatuba, SP, Brazil).
⁷Enrichment per kg product: vitamin A (retinol) = 20.000 IU; vitamin D₃ = 2000 IU; vitamin E (alpha-tocopherol α) = 48 mg; vitamin K₃ = 48 mg; vitamin B₁ = 4 mg; vitamin B₂ = 32 mg; pantothenic acid = 16 mg; = 56 mg niacin; choline = 800 mg; Zn as zinc oxide = 150 mg; Fe as ferrous sulfate = 100 mg; Cu as copper sulfate = 15 mg; I as potassium iodide = 1.5 mg; Mn as manganese oxide = 30 mg; Se as sodium selenite = 0.2 mg; antioxidant = 240 mg.
⁸Myco Curb® (Kemin Industries, Indaiatuba, SP, Brazil).
⁹Pet-Ox® (Kemin Industries, Indaiatuba, SP, Brazil).
CO: Control; CA: Cassava fiber; CE: Cellulose; BP: Beet pulp; LC: Lignocellul.
The diets were compared in pairs resulting in seven trials (A vs. B): Control diet (CO) vs. 12% CA; CO vs. CE; CO vs. BP; CO vs. LC; 12% CA vs. CE; 12% CA vs. BP; 12% CA vs. LC. Palatability was determined by measuring the intake ratio (IR) and the first choice between the diets offered to the dogs. The first choice was defined by recording the first bowl that the dog approached during simultaneous feeding. The quantities supplied and the leftovers were quantified to determine the IR, calculated by the following equation: $\text{IR} = \frac{\text{g ingested of diet A or B}}{\text{total g consumed (A + B)}}$.

**Statistical analysis**

Kibble density, size, hardness, friability, and expansion index were tested for normality using the Shapiro-Wilk test ($p < .05$). After checking for orthogonality, the following orthogonal contrasts were evaluated ($p < .05$): CO vs. diets with the same concentration of TDF (12% CA, CE, BP, and LC); 12% CA diet vs. CE; 12% CA diet vs. BP; and 12% CA diet vs. LC. Subsequently, the results obtained with the increasing dietary levels of CA (0, 4, 8, and 12%) were subjected to regression analysis, considering $p < .05$. Data were analysed using the SAS Institute Inc (version 9.2, SAS Institute Inc., Cary, NC, United States of America, 2011) statistical package. The variables of the extrusion process and porosity were presented descriptively.

Palatability data were submitted to the Shapiro-Wilk test. The IR data were analysed using the paired Student’s t-test and the first choice using the Chi-square test, considering $p \leq .05$ as statistically significant and with 32 repetitions per test.

**Results**

The inclusion of 12% CA in the diet resulted in higher preconditioner temperature in relation to diets without CA (Table 2). The extruder screw speed decreased during the production of CO and LC but remained constant for the other diets. The amperage was higher for the BP diet (Table 2).

The density of CO kibbles was higher ($p = .0042$) than that of diets with the same TDF level (12% CA, CE, BP, and LC). The same was observed when comparing 12% CA to CE ($p = .0241$; Table 2).

The EI ($p = .004$), kibble size ($p = .004$), and friability (of diets with the same TDF level (12% CA, CE, BP, and LC)) were higher in relation to the ($p = .0001$) CO diet (Table 2). When compared to the BP diet, the 12% CA diet resulted in higher EI ($p = .016$), size ($p = .016$), and friability ($p = .0001$). The 12% CA diet also showed higher friability ($p = .0001$) when compared to the diets with the same TDF level (CE, BP, and LC).

In addition, the inclusion of increasing levels of CA (0, 4, 8, and 12%) showed a linear effect on EI ($p = .0001$) and kibble size ($p = .0001$), as well as a quadratic effect on friability ($p < .0001$; Table 2). There was no difference between diets concerning hardness ($p = .653$).

The 12% CA diet had apparently the highest number of pores, but with smaller pore size, compared to the other diets. While the CO diet presented the

**Table 2. Extrusion parameters and kibble physical characteristics for the control diet (CO) and diets containing cassava fibre (CA), cellulose (CE), beet pulp (BP), and lignocellulose (LC).**

| Item                  | CO    | 4     | 8     | 12    | CE    | BP    | LC    | SEM  |
|-----------------------|-------|-------|-------|-------|-------|-------|-------|------|
| Preconditioner        |       |       |       |       |       |       |       |      |
| Temperature (°C)      | 91.40 | 91.70 | 90.10 | 95.90 | 92.80 | 88.60 | 89.50 | –    |
| Exuder                |       |       |       |       |       |       |       |      |
| Amperage (A)          | 20.00 | 25.00 | 20.00 | 28.00 | 22.00 | 30.00 | 20.00 | –    |
| Screw speed (Hz)      | 34.00 | 45.00 | 45.00 | 45.00 | 45.00 | 45.00 | 45.00 | 40.20|
| Productivity (kg/h)   | 95.67 | 93.00 | 88.68 | 93.36 | 92.76 | 99.24 | 82.20 | –    |
| Kibble characteristics|       |       |       |       |       |       |       |      |
| Density (g/l)$^{a,b}$ | 383.50| 341.30| 349.10| 364.50| 323.80| 369.50| 371.60| 4.479|
| Expansion index$^{a,d,f}$ | 1.51  | 1.58  | 1.59  | 1.60  | 1.62  | 1.51  | 1.62  | 0.025|
| Size (mm)$^{a,d,f}$   | 6.78  | 7.12  | 7.18  | 7.18  | 7.33  | 6.79  | 7.32  | 0.115|
| Hardness (kgf/cm²)    | 6.39  | 7.02  | 6.25  | 7.16  | 7.15  | 6.36  | 7.41  | 0.303|
| Friability (g)$^{a,b,c,d,e,g}$ | 0.060 | 0.030 | 0.109 | 0.104 | 0.069 | 0.050 | 0.099 | 8.65 E-04|

Contrasts:
- $p > .05$ for variables without superscript letters for contrasts.
- CO diet vs. diets with the same TDF level (12% CA, CE, BP, and LC) ($p < .05$).
- 12% CA diet vs. diets with the same TDF level (CE, BP, and LC) ($p < .05$).
- 12% CA diet vs. CE diet ($p < .05$).
- 12% CA diet vs. BP diet ($p < .05$).
- 12% CA diet vs. LC diet ($p < .05$).
- Linear effect for 0 (CO), 4, 8, and 12% CA diets ($p < .05$).
- Quadratic effect for 0 (CO), 4, 8, and 12% CA diets ($p < .05$).
lowest pore area when compared to the other diets (Figure 1 and Table 3). These results need further confirmation considering that they are only descriptive.

All dogs remained healthy and normally consumed all the diets. No episodes of vomiting, diarrhoea, or coprophagia were observed. The 12% CA diet was the dogs’ first choice when compared to the BP diet \( (p = .050, \text{Table 4}) \). Regarding the IR, dogs ingested less of the CO diet when compared to the 12% CA \( (p = .032) \), CE \( (p = .0001) \), and LC diets \( (p = .0001) \).

Dogs also showed a higher IR of the 12% CA diet when compared to the BP diet \( (p = .0001, \text{Table 4}) \).

Discussion

A previous study observed that CA has positive effects on faecal characteristics and modulation of the intestinal microbiota of dogs, similar to some conventional fibre sources, such as BP (Sousa et al. 2021). However, no studies evaluating the effects of CA on the physical characteristics of kibbles and diet palatability in dogs have been found.

The lower water holding capacity of some insoluble fibres (Karkle et al. 2012) may explain the higher temperature observed in the preconditioner with the 12% CA diet in the present study. Similarly, when evaluating diets with CE, Donadelli et al. (2021) observed a higher steam addition compared to a diet containing a soluble fibre source (BP). The increased resistance to mass flow that was observed can be attributed mainly to the rigid, stiff nature of some insoluble fibres (Hill 2003). Moreover, it was identified that increased screw speed and amperage during the production of diets containing fibre sources, which corroborates the study of Monti et al. (2016) on the dietary inclusion of guava fibre (3, 6, and 12%, \( \sim 13.1\% \) of TDF). This effect can lead to higher energy consumption, since some fibres may increase the resistance of the dough, hindering the flow inside the extruder, and thus require higher
temperatures and more severe processing conditions (Koppel et al. 2015). In addition to a high processing cost, the increase in shear usually intensifies the wear on the equipment.

Regarding kibble density, other studies also observed a lower kibble density in extruded diets containing fibre sources, like sugarcane fibre (Monti et al. 2016) and CE (Chinnaswamy and Hanna 1991). Conversely, Donadelli et al. (2021) found a higher kibble density in a BP diet in relation to a CE diet (0.400 vs. 0.351 g/cm³, respectively). According to the authors, this opposite effect of fibres on kibble characteristics is probably related to specific physical characteristics of some fibres and their effect on the dynamic flow of the dough inside the extruder.

Fibres with greater particle size, like BP, may restrict the air cells’ development by disrupting them and increasing the rupture of cell walls, thus reducing kibble expansion (Alam et al. 2014; Kallu et al. 2017). On another hand, smaller particle size fibres, like CA, may act as a nucleating agent, improving the continuity in starch and fibre matrices by reducing premature cell rupture. This contributes to starch integrity and more air cells, resulting in lower density and greater expansion of kibbles (Kallu et al. 2017). Furthermore, the higher mechanical energy, observed by the higher amperage, used for processing the diets containing fibre sources can also result in lower kibble density (Sá et al. 2013; Pacheco et al. 2018).

Although the greater expansion and lower density of diets containing fibre sources, in relation to the CO diet, no differences were observed in kibble hardness, which demonstrates the lack of significant difference in physical breakage of the kibbles. However, other studies evaluating diets with sugarcane fibre and CE observed greater hardness compared to diets without fibre sources (Monti et al. 2016; Donadelli et al. 2021). This may possibly be explained due to smaller cells with thicker walls and the reinforcing effect of fibre particles that prevent the rupture of the molten starch mass (Koppel et al. 2015), as previously commented.

The findings of the present and other studies (Pacheco et al., 2021) indicated a positive effect of fibre sources on diet palatability. However, other studies on dogs observed a negative effect of fibre in the IR of diets (Koppel et al. 2015). Palatability is a complex process and may be influenced by several factors, such as ingredients, food processing, kibble macrostructure, food chemical composition, and palatants, and how they all relate to sensory properties, such as aroma, texture, shape, and taste (Aldrich and Koppel 2015). Thus, it is possible that the alterations in the physical characteristics of kibbles due to the fibre sources were the main factors that affected the palatability of the diets in the present study.

The texture of the kibbles affects the crunchiness and chewiness, and thus diet palatability for dogs. Besides, well-extruded diets, with lower kibble density and with greater pore area improve the homogeneity of fat absorption and palatant covering, contributing to diet palatability (Vieira 2010). In the current study, diets containing fibre sources presented lower kibble density and possibly greater pore area, resulting in greater IR than the CO diet. However, as only a qualitative evaluation of kibble images was performed, further studies must evaluate the effects of fibre sources on pores formation of extruded diets for dogs to better understand its influence on diet palatability.

Conclusion

In conclusion, increasing dietary levels of CA results in a linear increase in kibble expansion. The fibres evaluated in this study resulted in kibbles more expanded and with lower density when compared to diets without fibre sources. In addition, the 12% CA diet shows a positive effect on diet palatability for dogs.

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Disclosure statement

Marcelino Bortolo is employed by Kemin (Indaiatuba, SP, Brazil). Kemin sells the cassava fibre evaluated in this study and provided financial support for the analysis. The other authors state that no conflicts of interest exist.

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Data availability statement

The data that support the findings of this study are available from the corresponding author (CMM Souza), upon reasonable request.

References

ABINPET. 2019. Manual pet food Brasil. 10th ed. São Paulo (SP): Associação Brasileira da Indústria de Produtos para Animais de Estimação.

Alam SA, Jarvinen J, Kirjoranta S, Jouppila K, Poutanen K, Sozer N. 2014. Influence of particle size reduction on structural and mechanical properties of extruded rye bran. Food Bioprocess Technol. 7(7):2121–2133.

Aldrich GC, Koppel K. 2015. Pet food palatability evaluation: a review of standard assay techniques and interpretation of results with a primary focus on limitations. Animals. 5(1):43–55.

AOAC. 1995. Official methods of analysis. 16th ed. Arlington (VA): AOAC International.

Cardoso AP, Mirione E, Ernesto M, Massaza F, Cliff J, Rezaul Haque M, Bradbury JH. 2005. Processing of cassava roots to remove cyanogens. J. Food Compos. Anal. 18(5):451–460.

Chinnaswamy R, Hanna MA. 1991. Physicochemical and macromolecular properties of starch-cellulose fiber extrudates. Food Struct. 10:6.

Donadelli RA, Dogan H, Aldrich G. 2021. The effects of fiber source on extrusion parameters and kibble structure of dry dog foods. Anim Feed Sci Technol. 274:114884.

FAO. 2017. Quebec, Canadá. Acess in: abr. 09, 2020. Available from: www.fao.org/publications.

FEDIAF. 2019. Nutritional guidelines for complete and complementary pet food for cats and dogs. Brussels: The European Pet Food Industry Federation.

Hill DA. 2003. Fiber, texturized protein and extrusion. Mount Morris (IL): Watt publishing.

IBGE. 2019. Levantamento sistemático da produção agrícola: Mandioca. Rio de Janeiro, Brazil. Acess in: abr. 09, 2020. Available from: www.ftp.ibge.gov.br/producao_agricola/fasciculo/lspa_201701.

Ishizaki MH, Visconte LLY, Furtado CRG, Leite MCAM, Leblanc JL. 2006. [Mechanical and morphological characterization of polypropylene composites and green coconut fibers: influence of fiber content and mixing conditions]. ABPol. 16:182–186.

Kallu S, Kowalski RJ, Ganjyal GM. 2017. Impacts of cellulose fiber particle size and starch type on expansion during extrusion processing. J Food Sci. 82(7):1647–1656.

Karkle EL, Alavi S, Dogan H. 2012. Cellular architecture and its relationship with mechanical properties in expanded extrudates containing apple pomace. Food Res Int. 46(1):10–21.

Koppel K, Monti M, Gibson M, Alavi S, Don Francesco BDi, Carciofi AC. 2015. The effects of fiber inclusion on pet food sensory characteristics and palatability. Animals. 5(1):110–125.

Kröger S, Vahjen W, Zentek J. 2017. Influence of lignocellulose and low or high levels of sugar beet pulp on nutrient digestibility and the fecal microbiota in dogs. J Anim Sci. 95(4):1598–1605.

Middelbos IS, Vester Boler BM, Qu A, White BA, Swanson KS, Fahey GC. 2010. Phylogenetic characterization of fecal microbial communities of dogs fed diets with or without supplemental dietary fiber using 454 pyrosequencing. PLOS One. 5(3):e9768.

Monti M, Gibson M, Loureiro BA, Sá FC, Putarov TC, Villaverde C, Alavi S, Carciofi AC. 2016. Influence of dietary on macrostructure and processing traits of extruded dog foods. Anim Feed Sci Technol. 220:93–102.

NRC. 2006. Nutrient requirements of dogs and cats. Washington (DC): National Academies Press.

Osundahunsi OF, Williams AO, Oluwala IB. 2012. Prebiotic effects of cassava fibre as an ingredient in cracker-like products. Food Funct. 3(2):159–163.

Pacheco PDG, Baller MA, Peres FM, Ribeiro ÉdM, Putarov TC, Carciofi AC, 2021. Citrus pulp and orange fiber as dietary fiber sources for dogs. Anim. Feed Sci. Technol. 282:115123 doi:10.1016/j.anifeedsci.2021.115123.

Pacheco PDG, Putarov TC, Baller MA, Peres FM, Loureiro BA, Carciofi AC. 2018. Thermal energy application on extrusion and nutritional characteristics of dog foods. Anim Feed Sci Technol. 243:52–63.

Prosky L, Asp NG, Schweizer TF, DeVries JW, Furda I. 1988. Determination of insoluble, soluble, and total dietary fiber in foods and food products: interlaboratory study. J Assoc Anal Chem. 71(5):1017–1023.

Riaz MN. 2007. Extruders and expanders in pet food, aquatic and livestock feeds. Clenze: AgriMedia GmbH.

Robin F, Schuchmann HP, Palzer S. 2012. Dietary fiber in extruded cereals: limitations and opportunities. Trends Food Sci Technol. 28(1):23–32.

Sá FC, Vasconcellos RS, Brunetto MA, Filho FOR, Gomes MOS, Carciofi AC. 2013. Enzyme use in kibble diets formulated with wheat bran for dogs: effects on processing and digestibility. J Anim Physiol Anim Nutr. 97:51–59.

Sabolchuk TT, Lowndes FG, Scheraiber M, Silva LP, Félix AP, Maiorina A, Oliveira SG. 2017. Effect of soya hulls on diet digestibility, palatability, and intestinal gas production in dogs. Anim Feed Sci Technol. 225:134–142.

Souza CMM, Bastos TS, Kaelle GCB, Bortolo M, Vasconcellos RS, De Oliveira SG, Félix AP. 2021. Comparison of cassava fiber with conventional fiber sources on diet digestibility, fecal characteristics, intestinal fermentation products, and fecal microbiota of dogs. Anim Feed Sci Technol. 281:115092.

Taran QD, Hendriks WH, Van Der Poel AF. 2008. Effects of extrusion processing on nutrients in dry pet food. J Sci Food Agric. 88(9):1487–1493.

Vieira SL. 2010. [Food consumption and preference of domestic animals]. 1st ed. Londrina: Phytobiotics Brasil.