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Influence of dietary fiber on macrostructure and processing traits of extruded dog foods

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ABSTRACT

Fiber is currently used in dog food formulations due to its nutritional properties. However, few studies have evaluated the influence of fiber on the extrusion traits and kibble formation. The present study evaluated the effect of fiber type and particle size on extrusion processing parameters and kibble macrostructure of dog foods. In treatment 1, guava fiber was added to a control formula (CO) at different inclusion levels: 3% (GF3), 6% (GF6), and 12% (GF12). In treatment 2, two fiber types (sugarcane and wheat bran) and two fiber particle sizes were compared to a control (CO) product. Foods were manufactured using a single screw extruder. Each food was processed on two separate days and samples were collected four times per run, for a total of eight replications per diet. The processing conditions were not changed for any treatment. Data were analyzed via analysis of variance, and compared by polynomial contrasts for treatment 1, and by defined orthogonal contrasts for treatment 2 ($P < 0.05$). Guava fiber inclusion resulted in a linear increase in temperature, pressure, and specific mechanical energy (SME) input ($P < 0.001$) during extrusion, whereas starch cooking (assessed by the amyloglucosidase method) and radial expansion decreased linearly ($P < 0.001$). Kibble density and cutting force increased linearly ($P < 0.001$) with guava fiber inclusion. In treatment 2, fiber addition also increased SME ($P < 0.001$) and decreased radial expansion ($P = 0.008$). However the latter was compensated by an increase in longitudinal expansion in the case of sugarcane fiber, resulting in no change in kibble density. Cutting force was higher ($P < 0.001$) for fiber supplemented foods, similar to treatment 1, but sugarcane fiber had a higher impact on hardness than wheat bran ($P < 0.001$). The finely ground fibers led to higher starch gelatinization ($P < 0.05$) and kibbles with lower piece density ($P = 0.018$). To summarize, insoluble fibers such as guava fiber, sugarcane and wheat bran at high inclusion rate increase the electric energy required to extrude, may reduce starch cooking and result in the production of less expanded, denser and harder kibbles. However, kibble characteristics are also significant impacted by fiber type and particle size.

Abbreviations: CO, control diet without added fiber source; CP, crude protein; DM, dry matter; GF3, diet with the addition of 3% guava fiber; GF6, diet with the addition of 6% guava fiber; GF12, diet with the addition of 12% guava fiber; OM, organic matter; SAS, Statistical Analysis Systems; SF_L, diet with sugarcane fiber large particles; SF_S, diet with sugarcane fiber small particles; SME, specific mechanical energy; STE, specific thermal energy; TSE, total specific energy; WB_L, diet with wheat bran large particles; WB_S, diet with wheat bran small particles.

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Table 1
Chemical composition of the fiber sources used in the experiment. Values in g/kg on as-fed basis.[b]

Item	Fiber sources[a]		
	Guava fiber	Sugarcane fiber	Wheat bran
Moisture	93.1	57.0	71.1
Protein	32.4	29.4	163.8
Starch	68.1	6.5	249.3
Fat	22.8	11.2	47.1
Total dietary fiber	702.6	869.9	395.2
Insoluble fiber	689.0	869.9	378.0
Soluble fiber	13.6	0.0	17.2
Cellulose	361.0	458.1	71.8
Hemicellulose	173.3	281.9	290.3
Lignin	113.4	93.0	46.7

[a] All fiber sources were provided by Dilumix, Leme, SP, Brazil.
[b] Analyzed in duplicate.

1. Introduction

During extrusion to make dog food, a combination of moisture, shear, temperature, and pressure are applied, in a continuous and short process that ends with forcing the material through a specifically designed opening (Riaz, 2000). The process induces changes in food ingredients, resulting in extensive cooking and a plasticized food dough (Altan et al., 2008; Yağci and Göğüş, 2008). These modifications are directly linked to and depend on the total energy transferred to the dough, composed of mechanical and thermal energy as measured by the specific mechanical energy (SME) and specific thermal energy (STE) input, respectively. The combination of these two types of energy promotes starch gelatinization, protein denaturation, lipid modification, enzyme inactivation, and reduction of microbial viability. At the end of the extruder barrel, the plasticized dough expands in contact with atmosphere, creating a particular kibble macrostructure that affects shape and texture (Griffin, 2003; Challacombe et al., 2011).

Fiber supplemented extruded foods are produced nowadays by most pet food companies. Fiber is used to dilute energy density promoting specific benefits related to gut and general health (Kawauchi et al., 2011; Fischer et al., 2012). Inclusion of fiber sources, however, influences the processing parameters, SME and possibly STE as well, potentially altering the final product characteristics (Mendonça et al., 2000). Dietary fiber is a highly structured and unexpandable material with variable water absorption capacity; that can affect viscosity, mass flow inside the barrel, and formation of cellular structure in the extrudates (Karkle et al., 2012a). Due to this, kibble expansion and important textural characteristics such as hardness and crispness may be altered by fiber (Karkle et al., 2012a), thus changing the sensory attributes and palatability (Koppel et al., 2015).

Detailed information about the impact of fiber on extrusion traits and kibble macrostructure is only available for human foods (Brennan et al., 2008; Baik et al., 2004; Karkle et al., 2012b). Characteristics of the specific fibrous material included in the formula also have an impact on extrusion traits, and thus fiber effects cannot be generalized. Fruit and vegetable processing by-products have been studied in extruded foods for humans (Upadhyay et al., 2010; Karkle et al., 2012a), as a way to add value and to minimize the environmental impact of these residues (Altan et al., 2008). Besides fiber type, its particle size is also important. It is possible to change dynamics of the extrusion process and kibble structure formation by changing the fiber particle length. Understanding these effects could be important to achieve better cooking, reduce extrusion cost, and overcome some negative effects of fiber on extrudate macrostructure. Palatability and digestibility issues are concerns when fiber is added to dog foods; it is possible that some of these possible negative effects could be related to reduced efficiency of the extrusion process. However, there is no data regarding the effect of fiber particle size on the extrusion of dog foods.

The present study aimed to evaluate the influence of increasing amounts of guava fiber (treatment 1) and sugarcane and wheat bran fiber of two different particle sizes (treatment 2) on the extrusion traits and kibble macrostructure of dog foods.

2. Material and methods

2.1. Fiber ingredients and diet formulation

Two separate treatments were conducted, the first treatment was designed to study the inclusion level of guava fiber (*Psidium guajava*) and the second one to assess the impact of sugarcane fiber and wheat bran particle sizes. Guava fiver is a by-product of guava juice extraction, produced from drying and grinding the solid residues after removal of all solubles. Its composition includes the insoluble material of the pericarp and the seeds. Sugarcane fiber is obtained from sugarcane bagasse, which is washed and centrifuged to remove residual sugars and minerals, and afterwards dried and micronized. The company Dilumix (Leme, Sao Paulo, Brazil) provided the fiber ingredients used in the study. The chemical composition of the fibers is provided in Table 1.