Nutritional factors related to glucose and lipid modulation in diabetic dogs: literature review

Fatores nutricionais relacionados ao controle glicêmico e lipídico de cães diabéticos: revisão de literatura

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Abstract

Diabetes mellitus is a chronic disorder that results in hyperglycemia by absolute or relative insulin deficiency, sometimes leading to fatal complications. The successful treatment of diabetic dogs depends on nutritional management and insulin applications. Studies evaluating the nutrition of diabetic dogs focused on fiber as the main factor in glycemic control; however, new research describes the role of starch as key in postprandial glycemic fluctuation, also attributing a central role for body condition scores and feed management in the adequate glycemic control of diabetic dogs. The aim of this paper is to review nutritional aspects to better control diabetes in dogs.

Keywords: Nutrition. Canine. Diabetes mellitus. Starch. Fiber.

Resumo

Diabetes Mellitus é uma desordem crônica que resulta em hiperglicemia pela deficiência absoluta ou relativa de insulina, que gera complicações que podem levar à morte. O sucesso do tratamento do cão diabético depende da aplicação de insulina e do adequado manejo nutricional. Estudos que avaliaram aspectos nutricionais de cães diabéticos focavam na fibra dietética como o principal fator controlador da glicemia, porém novas pesquisas apontam o amido como principal responsável pelas respostas glicêmicas pós-prandiais e atribuem importante papel ao escore de condição corporal e ao manejo alimentar no adequado controle glicêmico de cães diabéticos. O objetivo deste trabalho é revisar os principais aspectos da nutrição de cães diabéticos para o melhor controle da doença.

Palavras-chave: Nutrição. Canino. Diabetes mellitus. Amido. Fibra.

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Introduction

Diabetes mellitus (DM) is a chronic disease that results in hyperglycemia due to insulin deficiency, which can lead to complications such as cataracts, diabetic ketoacidosis, coma, and death (NELSON, 1989; ZICKER et al., 2010; FASCETTI; DELANEY, 2012). The main treatment goal in dogs is to maintain glycaemia as close as possible to normal levels and to avoid fluctuations throughout the day (NELSON; LEWIS, 1990). In addition, it is important to control hyperlipidemia (SOTTIAUX, 1999; XENOULIS; STEINER, 2015). Successful treatment depends on an adequate nutritional management program and on insulin applications (GRAHAM et al., 1994).

This review compiles scientific evidence regarding nutritional factors that may influence glycemic and lipid control in DM dogs.

Starch

Most studies assessing the role of nutrition in the glycemic control of diabetic dogs focused on the benefits of increased dietary fiber intake (BLAXTER et al., 1990; NELSON et al., 1991, 1998; ENGLYST et al., 1992; NELSON, 1992; GRAHAM et al., 1994; KIMMEL et al., 2000; GRAHAM et al., 2002). However, new research suggests that starch plays a key role in fluctuations of postprandial glucose responses in diabetic dogs (CARCIOFI et al., 2008; TESHIMA, 2010; TEIXEIRA, 2016).

It is known that different types of starch lead to different glucose and insulin responses. Carciofi et al. (2008) evaluated glucose levels in healthy dogs on six different diets: three diets with slowly digestible sources of starch (SDS: lentils, peas, and sorghum) and three diets with rapidly digestible sources or starch (RDS: maize, cassava, and rice). RDS diets resulted in glucose and insulin peaks in a shorter timeframe, as well as an average increase in glucose levels greater than the one observed in SDS diets. SDS sources led to more stable glucose levels for longer periods. These findings are in line with a previous study on healthy dogs, which also found higher glycemic parameters in rice-based diets and lower glycemic parameters in sorghum and barley-based diets (BOUCHARD; SUNVOLD, 1999). A more recent study showed lower peaks and smaller areas under the insulin curve with no change in glucose levels, indicating higher insulin sensitivity in obese dogs in an oral glucose tolerance test performed after 12 weeks of a pea-based diet compared to a rice-based diet (ADOLPHE et al., 2015). These findings are consistent with those of previous studies carried out by the same research group showing lower glycemic index of peas when compared to rice in healthy dogs (ADOLPHE et al., 2012) and higher insulin sensitivity in obese dogs on a low-glycemic index diet (MITSUHASHI et al., 2012). The dietary source of starch may be related to its digestibility, which in turn could have an effect on glucose levels (SILVA JÚNIOR et al., 2005; CARCIOFI et al., 2008; BAZOLLI et al., 2015).

Glucose responses vary according to the source of starch as well as to the amount ingested (MURRAY et al., 1999). Elliott et al. (2012) evaluated three diets with different levels of digestible carbohydrate, fiber, and fat, and observed that the lowest-carb diet led to lower glucose and postprandial triglyceride levels, as well as lower glucose peaks when compared to a commercial food for diabetic dogs and a commercial food for adult, healthy dogs. The authors attributed these effects to the lower starch content, and suggested they would be even more significant in dogs with DM due to the changes in endocrine control. Monti et al. (2016) and Murray et al. (1999) also found decreased postprandial glucose levels in healthy dogs, which they attributed to the lower starch intake.

Food processing may also result in changes in dogs' postprandial glucose curve. Bazolli et al. (2015) found lower starch gelatinization indexes and lower apparent digestibility coefficients for some nutrients, including starch, according to grain size of rice, sorghum, and corn in diets for healthy dogs. Adaptations in processing parameters for extruded commercial foods, such as particle size of the feedstock and extruder configurations (temperature, shear force, retention time, and pressure) could be beneficial, preserving part of the naturally-occurring resistant starch, which was not affected by grinding or cooking. This finding was confirmed by Roberti-Filho (2013), who observed significant increase in glucose and insulin parameters of healthy dogs receiving extruded foods with more resistant starch and lower starch gelatinization due to changes in the extruder and increased granulometry of raw materials.

Kimura (2013) applied these same concepts to obese dogs. Researchers provided three starch solutions (two with resistant starch and one with highly-digestible soluble starch) via nasoesophageal tube feeding and also observed improved postprandial glucose responses for resistant starch.

There is also evidence that resistant starch may promote prebiotic effects. In rats, Shen et al. (2011) observed that the intake of resistant starch led to increased levels of acetic, propionic, and butyric acids, Bacteroides, *Bifidobacterium spp*., *Lactobacillus spp.,* and *Clostridium cluster IV* in feces, also leading to increased levels of serum glucagon-like-peptide-1 (GLP-1), which would be related to increased insulin sensitivity and energy expenditure.

In the first study, in order to consider the effects of starch on the glucose levels of diabetic dogs authors provided three foods with different starch contents (from 2% to 26% of the metabolizable energy [ME]); however, there were no glycemic effects. This lack of glucose modulation was associated with the fact that diets were not isonutrient, with wide variation in fiber levels (3.5 to 5 g / 100 kcal), fat (31% to 61% of dry matter [DM])], and protein levels (28% to 41% of DM) (FLEEMAN et al., 2009).

In turn, the potential effect of slowly digestible starch in diets for diabetic dogs was evaluated by Teshima (2010), who analyzed two isonutrient diets with different sources of starch: rice versus sorghum and lentil. The sorghum and lentil diet resulted in better glycemic control; animals showed more stable glucose levels, lower mean and minimum glycaemia, and potentially smaller area under the glucose curve. Since both diets were isonutrient, these effects were attributed to the source of starch.

Teixeira (2016) evaluated the effects of digestible carbohydrates in diabetic dogs focused on the source of starch and the processing of ingredients. Two isonutrient diets were compared, both containing moderate levels of fat and starch and high levels of protein and fiber. Diets only differed in their source of starch: peas and barley versus corn. The processing of the corn-based diet was also controlled, leading to lower starch gelatinization index and more resistant starch. After 60 days of treatment and the same insulin dose, a 48-hour glucose curve with continuous glucose measurement showed lower maximum glucose levels, smaller difference between maximum and minimum interstitial glucose, longer hypoglycemia, and shorter hyperglycemia in the pea and barley group. The changes in corn processing were not enough to make it equivalent to the slowly digestible starch sources.

Fiber

Blaxter et al. (1990) compared the effects of wheat bran and guar gum on the diet of six healthy and four diabetic dogs. The inclusion of wheat bran resulted in lower glucose variables, which were even lower with guar gum. Results were statistically significant for healthy dogs but not for DM dogs, perhaps because of the small number of animals included in the study. It is worth noting that the nutritional profile of the food was not specified, nor was there any mention to the amount of fiber added in relation to dry matter or energy levels.

Nelson et al. (1991) assessed six dogs with induced DM receiving four different diets: high soluble fiber (5 g of fiber / 100 kcal, 2.1 g soluble), high insoluble fiber (7 g / 100 kcal, 6 g insoluble), low fiber (2.4 g / 100 kcal, 1.7 g insoluble), and control (4.6 g / 100 kcal, 2.3 g insoluble). Best glycemic control was achieved with the high-fiber diets, mainly the one with highest levels of insoluble fiber. However, although the three test diets had similar energy levels, the low-fiber and control diets contained higher levels of digestible carbohydrates in dry matter. The absence of data on nutrient intake, energy content of food, and composition of control food hinders data interpretation; therefore, the information provided does not allow to state that fiber was the sole responsible for the change in glucose responses.

Graham et al. (2002) compared the glucose response of diabetic dogs on their original diets and on a standardized diet with increased fiber content (5.6 g / 100 kcal, 4.6 g of insoluble fiber). The standardized diet showed a number of benefits: lower 24-hour mean blood glucose levels, lower postprandial blood glucose at the second feeding, and lower serum concentrations of fructosamine, glycated hemoglobin, free glycerol, and cholesterol, as well as smaller, more stable glucose curves. However, the original diet was not standardized; animals were offered different commercial foods and treats; the nutritional profile of these diets was not described, and there was no mention to starch content. In an apparent preview of this investigation, Graham et al. (1994) found better glycemic parameters for eight dogs on diets with higher fiber content compared to their previous diets (standard commercial dog foods). However, the difference was not statistically significant.

Nelson et al. (1998), assessed two diets with similar energy distribution for carbohydrate, fat, and protein (6.44 g fiber / 100 kcal versus 2.7 g / 100 kcal) and observed a better glucose control in nine of the 11 DM dogs on the higher-fiber diet. These nine dogs showed lower mean and fasting blood glucose levels at 24 hours, lower serum concentrations of glycated hemoglobin and cholesterol, and lower glycosuria; they also required lower doses of insulin.

Considering the effects of fiber solubility on the glycemic control of DM dogs, Kimmel et al. (2000) compared high levels of insoluble fiber (IF; 7.3 g fibers / 100 kcal, less than 0.01 g soluble), high levels of soluble fiber (SF; 5.6 g / 100 kcal, 1 g soluble), and low fiber (LF). Although both IF and SF contribute to better glycemic control (lower serum concentration of fructosamine), their results suggest that IF alone may be more beneficial, leading to lower mean and maximum glycaemia, lower glycated hemoglobin, and smaller area under the glucose curve. Although energy distribution between fat, protein, and starch was similar, the source of starch was not the same for all diets; that may have influenced glucose absorption rates. In addition, the IF diet also included higher amounts of total dietary fiber when compared to the SF diet. This can also be observed by Nelson et al. (1991), where different fiber types did not lead to changes in glucose control (except for serum glycated hemoglobin, which was lower in the IF diet). The higher amount of total dietary fiber in the IF diets could explain the better glycemic control, or obfuscate the potentially better effects of SF observed by Blaxter and Cripps (1990). However, they did not describe the total amount of dietary fiber in their diets. Nelson et al. (2000) also observed improvements after changing fiber sources and increasing levels of SF without increasing total dietary fiber.

Fleeman et al. (2009) evaluated three different diets: one commercial food with moderate levels of fiber (3.5 g / 100 kcal), low levels of starch (2% ME), and high levels of fat (61% ME); and two diets with high levels of fiber (approximately 5 g / 100 kcal), moderate levels of starch (26% ME), and varying levels of fat (moderate [31% ME] and high [48% ME]). Glucose responses were not improved, but the high-fiber diets resulted in better serum lipid profiles when compared to the commercial diet, in spite of their higher fat content. The conclusion was that higher-fiber diets do not lead to better glucose profiles; however, different carbohydrate content of commercial versus high-fiber diets may have been a confounding factor in the interpretation of glucose control: the effects of low starch versus the effects of high fiber.

Monti et al. (2016) observed in healthy dogs that diets with the same amount of starch did not lead to different glucose responses when compared to diets with fiber levels ranging from 14% to 24% of the dry matter. Diez et al. (1998) reached the same conclusion; no changes in glucose levels were observed when they supplemented diets with 7% of dry matter as guar gum, inulin, or beet fiber. Similarly, Hoenig et al. (2001) did not find changes in glucose or lipid profiles in healthy dogs. The variables assessed during a glucose tolerance test were fiber amount, fermentability, and solubility.

Massimino et al. (1998) assessed the prebiotic and fermentative effects of fiber on insulin sensitivity. Healthy dogs were fed with high-fermentable fiber or low-fermentable fiber diets; the first group showed more GLP-1 and smaller area under the glucose curve. It was found that dietary supplementation of prebiotic fructooligosaccharide (FOS) to obese dogs led to lower insulin resistance, and this finding was attributed to changes in intestinal microbiota caused by the prebiotic effects of FOS (RESPONDEK et al., 2008).

Many studies have shown the beneficial effects of fibers in the glycemic control of dogs with DM. These effects are associated with improved insulin sensitivity (MASSIMINO et al., 1998; RESPONDEK et al., 2008) as well as delayed gastric emptying, starch hydrolysis rate, glucose uptake, and prolonged intestinal transit time (MURRAY et al., 1999; GRAHAM et al., 2002). However, there is no consensus on the recommended type of fiber, and the adverse effects of high- fiber diets are as follows: low weight gain; voluminous soft stools; flatulence, constipation, and vomiting; decreased food palatability, and opaque hair due to the reduced availability of other nutrients (NELSON et al., 1991, 1998; KIMMEL et al., 2000; HOENIG et al., 2001; GRAHAM et al., 2002; FLEEMAN et al., 2009; ZICKER et al., 2010).

Most studies available today focus on fiber type and content; further studies on fiber amount and type, gastrointestinal effects, and standardized diets are needed since added fibers may change/reduce the source of starch, which is the key nutrient for the glucose curve. The number of potential factors involved in dietary fiber for diabetic dogs was discussed by Farcas et al. (2015), which showed that levels of total dietary fiber and insoluble fiber in commercial foods for diabetic dogs rank among the highest in the market.

Fat and energy

Although endocrinopathies alter lipid metabolism and lead to hyperlipidemia similar to that caused by the lack of insulin in DM dogs (FASCETTI; DELANEY, 2012; XENOULIS; STEINER, 2015), data on the influence of fat in their diets is still scarce. Controlling lipid levels in DM dogs is crucial because increased blood levels of cholesterol and triglycerides are related to other conditions such as pancreatitis, hepatobiliary diseases, insulin resistance, ophthalmopathies, convulsion, lipoma, and even atherosclerosis (XENOULIS; STEINER, 2015), which has been reported in dogs with DM (SOTTIAUX, 1999).

In this context, Fleeman et al. (2009) observed that lower-fat diets, regardless of their fiber content, improved lipid profiles in DM dogs; they observed lower plasma levels of cholesterol, fatty acids, free glycerol, and also potentially reduced triglycerides. Better lipid profiles are important for animals with hyperlipidemia or recurrent pancreatitis. However, even with adequate amounts of food and stable glucose levels, dogs receiving high-fiber, low-fat diets showed involuntary weight loss associated with increased satiety, lower energy content, and lower palatability; owners reported that dogs did not ingest the total amount of food prescribed. Thus, a decrease in fat and energy contents is not ideal for dogs with adequate body condition score (BCS) that are losing weight. However, fat can be restricted in DM associated with pancreatitis, hyperlipidemia, and obesity; restrictions should be made according to these factors and the nutritional assessment (NELSON, 1992; ZICKER et al., 2010; FASCETTI; DELANEY, 2012).

Teixeira (2016) observed no changes in serum triglyceride and cholesterol levels in dogs on low-fat diets when compared to higher fat diets that provided better glucose control. However, cholesterol and triglyceride levels were increased when animals received food with the same amount of fat but a different source of starch, leading to poorer glycemic control. In human medicine Pelkman (2001) associated lower glycemic index diets with better lipid control.

The initial estimate of the maintenance energy requirement (MER) should be based on BCS, level of physical activity, age, sexual status, and careful nutritional assessment. Mathematical equations including body weight may be used. For dogs with adequate BCS and low physical activity, MER = 95 x $BW^{0.75}$; for dogs with high physical activity, MER = 130 x $BW^{0.75}$. In weight loss protocols, the equation 70 x $(0.85 \times PC)^{0.75}$ is recommended considering an initial reduction of 15% in body weight to reach the ideal weight (BROOKS et al., 2014). Body condition should be assessed through inspection and palpation according to the scale validated by Laflamme (1997). The Laflamme body condition score states that BCS scores < 4, between 6-7, and > 8 mean underweight, overweight, and obese, respectively.

Obesity

Mattheauws et al. (1984) showed that, in non-diabetic and diabetic patients capable of synthetizing and secreting insulin, basal concentrations and total secretion of insulin increased proportionally to their level of obesity after a glucose tolerance test. These findings show that obesity may negatively affect glucose tolerance in dogs. Ellmerer et al. (2006), German et al. (2009), Brunetto et al. (2011), and Ferreira (2016) agree that there is a positive correlation between obesity and hyperinsulinemia in dogs. There is evidence that hepatic insulin resistance (IR) is responsible for higher endogenous glucose production (KIM et al., 2003), which indicates that obesity plays a key role in the response to insulin treatment (NELSON, 1989).

Although DM induced by insulin resistance secondary to obesity is less frequent in dogs (FLEEMAN; RAND, 2006), weight control and/or reduction is essential. It is known that when dogs without DM lose weight they show a decrease in hyperinsulinemia, plasma glucose: insulin ratios, and IR-related cytokines (GERMAN et al., 2009; BRUNETTO, 2010; BRUNETTO et al., 2011; VENDRAMINI et al., 2016). However, when DM dogs lose weight, their glucose tolerance is improved; they become more sensitive to insulin, and require lower doses of exogenous insulin. Thus, a weight loss protocol should be adopted for overweight dogs as soon as the insulin treatment is well established (NELSON, 1988; ZICKER et al., 2010; FASCETTI; DELANEY, 2012).

Nutraceutics

Chromium

Although some micronutrients such as zinc, manganese, and vitamin A influence glycemic control in humans (ZICKER et al., 2010), in dogs only the use of chromium was assessed. Chromium is an essential trace mineral for dogs. It acts as a cofactor to insulin, influencing the cellular uptake of glucose (FASCETTI; DELANEY, 2012); increased circulating insulin stimulates the entry of chromium into insulin-sensitive cells. Chromium binds to and activates the oligopeptide chromodulin in the internal portion of the insulin receptor that enhances the action of this receptor and the glucose metabolism by 18-fold, with increased cellular uptake and glucose oxidation (PECHOVA; PAVLATA, 2007; MUZÍK et al., 2011).

In humans chromium deficiency may lead to fasting hyperglycemia, hyperinsulinemia, glucose intolerance, hyperlipidemia, and reductions in active insulin receptors. Symptoms are reversed with adequate supplementation; however, study findings are inconclusive (PECHOVA; PAVLATA, 2007; MUZÍK et al., 2011).

Findings are also controversial in dogs. Spears et al. (1998) provided diets with different chromium supplementation to healthy dogs and found that animals receiving chromium tended to have lower fasting glucose levels and higher clearance at glucose tolerance tests and insulin challenges, suggesting a beneficial effect of chromium on glucose metabolism. Muzík et al. (2011) evaluated the response of 17 diabetic dogs receiving organic chromium complex supplements and observed reduced glucose levels after two weeks of supplementation. However, the pre-existing amount of chromium in their diet was not mentioned. Schachter et al. (2001) supplemented 13 diabetic dogs with chromium picolinate and did not find improvements in glycemic control in any of the assessed variables; this lack of improvement was attributed to the amount of chromium in their diet. Finally, Gross et al. (2000) showed a potentially deleterious effect of added chromium on the glycemic profile of obese dogs. Therefore, the evidence of chromium supplementation for glucose control in DM dogs is still inconclusive.

Polyunsaturated Fatty Acids Omega-3 series (PUFA-3)

Eicosapentaenoic (EPA) and docosahexaenoic (DHA) are considered lipid-lowering chemicals. Their mechanisms of action are not fully understood; however, potential explanations include regulation of transcription factors related to lipogenesis, increased β-oxidation and cholesterol secretion via bile, stimulation of lipoprotein lipase activity, reduced intestinal absorption of glucose, lipids, and cholesterol, and reduction of non-esterified fatty acids (SCHENCK, 2005; TOTH et al., 2009; WATTS; KARPE, 2011; DENG et al., 2015; XENOULIS; STEINER, 2015). These effects have been observed in humans, laboratory animals, and healthy dogs (FRIEDBERG et al., 1998; LEBLANC et al., 2005; SCHENCK, 2005), which may justify the use of these nutraceuticals in the treatment of hyperlipidemic dogs.

Supplementation of PUFA-3 may also be beneficial for glycemic control; these benefits have been observed in rats and humans (FRIEDBERG et al., 1998; OOSTING et al., 2010; ZICKER et al., 2010). Improved insulin sensitivity was observed in humans, and was associated with the decreased release of non-esterified fatty acids from adipocytes and with PUFA-3 agonist action on nuclear transcription factors such as PPAR-α, PPAR-γ, and GPR-120 receptors, which are related to insulin resistance (ALBERT et al., 2014). However, this finding was only assessed in healthy animals, where supplementation promoted changes in the lipid profiles of erythrocyte cell membranes; no changes in glucose and insulin variables were observed in the oral glucose tolerance test (IRVINE et al., 2002).

β-glucans

β-glucans are soluble fibers found in yeast cell walls and cereal endosperm (CLOETENS et al., 2012). They are considered nutraceuticals due to their beneficial effects for different species, including dogs. In humans and in rats dietary supplements of B-glucans have been shown to reduce glucose and lipid levels (DROZDOWSKI et al., 2010; CLOETENS et al., 2012; BROCKMAN et al., 2013). In addition to their intrinsic characteristics (modulation of viscosity, speed, and enzyme access to the gut), the benefits of β-glucans may be due to their influence in the expression of genes related to the synthesis of fatty acids and cholesterol (DROZDOWSKI et al., 2010; CLOETENS et al., 2012).

Ferreira (2016) found positive effects of a diet supplemented with 0.1% of β-glucan, leading to reductions in serum glucose, insulin, cholesterol, and triglycerides in insulin-resistant obese dogs. The same hypoglycemic effect was observed with the inclusion of 15 and 25 mg of β-glucan / kg of diet/day in dogs with streptozotocin-induced hyperglycemia (VETVICKA; OLIVEIRA, 2014).

Food management

The feeding schedule of dogs with DM should be planned to minimize postprandial blood glucose fluctuations, such as setting meal times according to insulin applications (NELSON; LEWIS, 1990). Although several possible feeding schedules have been described (NELSON, 1988, 1992; BARTGES, 2005; FLEEMAN; RAND, 2006; ZICKER et al., 2010), there are only two results available in this context. Nelson (1989) observed that diabetic dogs receiving one insulin application and two meals a day (2/3 of the MER at application and 1/3 after 10 hours) obtained better glycemic control than dogs fed one single daily meal simultaneous to the insulin application, or one single daily meal 10 hours after application. TESHIMA (2010) compared the use of the same food under two dietary management schedules: one meal every 12 hours with subsequent insulin applications versus one third meal between the two insulin applications. In the first schedule, animals showed lower glycemic fluctuations in the postprandial curve; in the second management schedule, half of them presented hypoglycemic episodes at least one point of the curve. Thus, with one or two insulin applications, glycemic control is best achieved with two meals a day (FLEEMAN; RAND, 2006).

Types of diet

In order to achieve adequate glycemic control without fluctuating glucose levels it is essential that the diet be consistent in terms of ingredients, as well as quantity, quality, and type of processing. This is an advantage of high-quality, industrialized foods; they offer fixed formulations and standardized ingredients (NELSON; LEWIS, 1990; ROBERTI-FILHO, 2013). Commercial foods are divided into three main categories: dry, semi-moist, and moist. All three options were offered to healthy dogs, and glycemic and insulin responses were increased in the semi-moist group. These effects were attributed to the presence of corn syrup (HOLSTE et al., 1989); some mono- and disaccharides are used as humectants in order to reduce water activity and prevent growth of contaminating organisms in semi-moist foods

(CASE et al., 2011), which makes them contraindicated for DM dogs (NELSON, 1989; FASCETTI; DELANEY, 2012).

Also, care should be exercised when deciding on food variation or ingredient substitution according to availability and cost (NELSON; LEWIS, 1990), which can also occur in homemade foods. Homemade diets are optimal in terms of palatability, which is key for the consumption of adequate amounts of food. However, owners may not comply with prescriptions (OLIVEIRA et al., 2014; JOHNSON et al., 2016; HALFEN et al., 2017); homemade diets are also questionable in terms of consistency, balance, and food safety (MICHEL, 2006).

Conclusion

The current guidelines for the management of dogs with DM is the maintenance of constant energy content, meal times, and nutritional profile through foods that minimize postprandial blood glucose fluctuations. Dietary fiber enhancement may be useful; however, the source of starch included in the diabetic dog's diet must be chosen carefully.

The evidence currently available is scarce. Further research should focus on postprandial effects of starch and fiber, effects of incretin and microbiota, types of foods and feeding schedules, and use of nutraceuticals such as chromium, PUFA-3s, and β-glucans to better control glucose and lipid levels.

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