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การย่อยได้ของโภชนะไขมันโครงสร้างที่มีกรดสเตียริกและกรดปาล์มมิติกเป็นองค์ประกอบในสุนัข

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บทคัดย่อ: ไขมันโครงสร้างที่มีกรดสเตียริกและกรดปาล์มมิติกเป็นองค์ประกอบน่าจะมีประสิทธิภาพการย่อยได้ต่ำ ซึ่งมีบทบาทเสมือนวัตถุดิบอาหารเพื่อสุขภาพ ที่ให้พลังงานต่ำมากและสามารถใช้ประกอบในอาหารสูตรเพื่อลดน้ำหนักสำหรับสุนัขได้ จากรายงานพบว่าครึ่งหนึ่งของไขมันโครงสร้างนี้ ประกอบด้วย กรดสเตียริกร้อยละ 55 และกรดปาล์มมิติกร้อยละ 44 ในการศึกษาครั้งนี้เป็นการทดสอบอาหารสำหรับสุนัข ดำเนินการโดยวัดค่าสัมประสิทธิ์การย่อยได้ของไขมันโครงสร้างด้วยวิธีผลต่าง (difference method) โดยเปรียบเทียบกับน้ำมันปาล์ม วางแผนงานทดลองแบบ 3 × 3 ละตินสแควร์ โดยใช้สุนัขพันธุ์โกลเดนท์รีทรีฟเวอร์ จำนวน 11 ตัว ซึ่งได้รับอาหารแห้งสำเร็จรูปจากบริษัทที่ไม่เสริมน้ำมันปาล์ม หรือ เสริมน้ำมันปาล์มร้อยละ 10 หรือ เสริมไขมันโครงสร้างร้อยละ 10 ผลการศึกษาพบว่าค่าสัมประสิทธิ์การย่อยได้ของน้ำมันปาล์มและไขมันโครงสร้างเท่ากับร้อยละ 96.6 และ ร้อยละ 68.8 ตามลำดับ ดังนั้นจากการศึกษาครั้งนี้สามารถสรุปได้ว่าค่าสัมประสิทธิ์การย่อยได้ของไขมันโครงสร้างมีค่าการย่อยได้ที่สูงมากเกินไปสำหรับประกอบสูตรอาหารที่ให้พลังงานต่ำมากเพื่อช่วยลดน้ำหนักสุนัข นอกจากนี้การเสริมอาหารด้วยไขมันโครงสร้างทดแทนน้ำมันปาล์มส่งผลให้เพิ่มปริมาณมูลที่ขับออก ซึ่งมีสาเหตุมาจากการลดลงของค่าสัมประสิทธิ์การย่อยได้ของวัตถุแห้ง อันมีผลมาจากการย่อยได้ที่ต่ำของไขมันโครงสร้างและการลดลงของการย่อยได้ของคาร์โบไฮเดรตที่ไม่ใช่โครงสร้าง

คำสำคัญ: ไขมันโครงสร้าง กรดสเตียริก กรดปาล์มมิติก ค่าสัมประสิทธิ์การย่อยได้ของโภชนะ สุนัข

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Digestibility of a Structural Fat Consisting of Stearic and Palmitic Acid in Dogs

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Abstract: It was speculated that a structured fat consisting of stearic and palmitic acid would have sufficiently low digestibility that it could serve as functional ingredient in a very-low energy, weight-reduction diet for dogs. The fatty-acid moiety of the structured fat under study contained 55 % stearic acid and 44 % palmitic acid. In a feeding trial with dogs, the apparent digestibility of the structured fat was determined by the difference method and compared with that of palm oil. In a 3x3 Latin square-design, 11 dogs were fed a commercial dry food without or with 10% added palm oil or structured fat. The digestibility of palm oil was found to be 96.6 % and that of the structured fat was 68.8 %. It is concluded that the digestibility of the structured fat is too high for the formulation of a very-low energy, canine weight-reduction diet. The addition to the diet of the structured fat, instead of palm oil, increased the amount of feces. This was caused by a lower apparent digestibility of dietary dry matter, due to the low digestibility of the structured fat and a decrease in the digestibility of non-structural carbohydrates.

Keywords: Structured fat, Stearic acid, Palmitic acid, Nutrients digestibility, Dog

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Introduction

Obesity is common in dogs, the prevalence being as high as 30% in many countries. The condition is associated with an increased incidence of diseases such as osteoarthritis, cardiovascular disorders, diabetes mellitus, hyperlipidemia, cancer and skin problems (German, 2006). The development of overweight has been shown to reduce longevity in dogs (Kealy *et al*., 2002). It is anticipated that weight loss in obese dogs reduces the severity of disease or prevents its development. Indeed, it has been shown that weight loss improves the clinical signs of osteoarthritis in obese dogs (Mlacnik *et al*., 2006). Weight loss can only be achieved by creating a negative energy balance: energy intake must be less than energy expenditure. This implies food restriction, ideally in combination with increased exercise. A specific weight-reduction diet with low energy content may have surplus value in the treatment of canine obesity. A low energy value can be achieved by the combination of a low content of fat and a high level of crude fiber. On a weight basis, fats provide twice as much energy as proteins or carbohydrates. The energy value of crude fiber is considered negligible in canine nutrition. Time-limited feeding of a low-energy, high-fiber diet lowers energy intake (Weber *et al*., 2007). In addition, such a diet may reduce pet owner's pitying because a reasonable amount of food can be supplied while imposing energy restriction. Technically, the energy value of a low-fat, high-fiber, weight-reduction diet can be lowered further by the replacement of carbohydrates by a fat source that is indigestible or poorly digestible. Indigestible fats do not provide energy. For poorly digestible fats to be applicable, they must provide substantially less energy than carbohydrates. Ideally, the indigestible or poorly digestible fat contributes to diet palatability. In rats, digestibilities of different fat sources are negatively correlated with melting points above 30 °C (Clifford *et al*., 1986). It is likely that high-melting point, and thus solid state, impairs the emulsifying capacity of the digestive tract. Higher degree of saturation and longer chain length of the constituent fatty acids of fats are associated with higher melting point. Fats that are rich in stearic and palmitic acid can be structured by enzymatic hydrolysis, fractionation and selective re-esterification of palm oil. It would be anticipated that such fats have low digestibility and might be useful as ingredient of a weight-reduction diet for dogs. Clearly, it should be excluded that the structured fat has any negative impact on health. It is reassuring that the long-term feeding to dogs of a dry diet containing 10 % of an indigestible sorbitol fatty acid polyester did not cause steatorrhea or any other negative effects (Miller *et al*., 1991).

The questions to be addressed in the present experiment with dogs were as follows. 1) What is the apparent digestibility of a structured fat consisting of stearic and palmitic acid? To answer this question the apparent digestibility of the fat preparation was determined by the difference method and compared within the same experiment with that of palm oil. 2) Does inclusion of the structured fat into the diet of dogs affect feed intake, body weight and feces quality? 3) Does the structured fat versus palm oil have an effect on the digestibility of crude protein, non-structural carbohydrates (nitrogen-free extract), crude fiber and minerals?

Materials and Methods

Dogs and housing

Eleven Golden Retrievers, aged 8 months, were used. There were 8 intact males and 3 spayed females. The dogs were housed as a group in a confinement (10 × 10 m) located under a roof, but otherwise with open air. Within the confinement there were 12 cages (1.0 × 0.5 × 0.6 m) with plastic grated floor. The animals could move freely within the confinement, including the open cages. However, during feeding and feces collection intervals, the dogs were locked up in their own cage.

Experimental design

The dogs were subjected to a 3 × 3 Latin square design with three experimental diets and three periods of three weeks each. Per diet order there were 3 or 4 dogs. Table 1 shows the ingredient and analyzed composition of the three experimental diets. The control diet was a commercial diet of one production batch. The extruded diet was homogenized, water was added and the mixture was put through a pelleting machine. The pellets were sundried. The test diets were made in the same manner, but after homogenizing either 10 % palm oil or the structured fat, (Cargill, Schiedam, The Netherlands), was added. According to the manufacturer, the structured fat contained 44% palmitic acid (P) and 55% stearic acid (S). The composition of triacylglycerols (with P or S at the 1, 2 and 3 position of the glycerol molecule) was as follows: PPP, 6.3%; SSS, 6.7%; SPS, 4.8%; PSP, 33.9%; SSP, 35.7% and PPS, 8.1%. The manufacturer declared a slip melting point of 55-60 ^{o}C for the structured fat.

A restricted amount of each diet was fed in two equal portions per day. During feeding, the dogs were confined in their own cage for a period of 15 min. The daily amount of food provided was equivalent to 5,752 kJ (1,375 kcal) and 4,314 kJ (1,031 kcal) of metabolizable energy for the males and females, respectively. The amounts of energy were equivalent to those fed prior to the experiment. To calculate the energy value of the experimental diets, the energy values for protein, fat and non-structural carbohydrates were taken to be 17 (4.06), 37 (8.84) and 16 (3.82) kJ (kcal) metabolizable energy per gram. It was assumed that crude fiber and the structured fat would not provide energy. The calculated energy value of the control diet was 1,612 kJ (385 kcal)/100 g. For the test diets with palm oil or structured fat the calculated energy densities were 1,821 (435) and 1,451 (347 kcal) kJ/100 g. The energy density of the control diet was based on the guaranteed analysis panel on the packaging: crude protein, 27 %; crude fat, 13 %; crude fiber, 3 %; ash, 6 %; moisture, 9 %. During the last 5 days of each period, the dogs were locked up in their own cage. From each dog the feces were collected quantitatively.

Measurements

At the beginning of each period, body weights of the dogs were determined. Throughout the experiment, the feces quality was scored on a 1-5 scale (Waltham Faecal Grading System). Feed and feces samples were processed for the proximate analysis of macronutrients (dry matter, crude fat, crude protein, crude fiber, ash) and minerals (calcium, phosphorus) as described (Vasupen *et al*., 2008). Nitrogen-free extract was calculated as residual fraction.

Statistical analysis

The data were evaluated for diet effects with the use of ANOVA. If there were statistically significant diet effects, the three diet groups were compared with the Tukey test. The paired Student’s t test was used to evaluate the digestibilities of the two fat sources. ***P***<0.05 was taken as criterion of statistical significance.

Results

Table 1 shows the analyzed composition of the experimental diets. The protein content of the control diet was lower than that declared by the manufacturer. As would be expected the addition of palm oil and structured fat raised the amount of crude fat in the diet, the increase being somewhat smaller than that calculated. The addition of extra fat lowered the concentrations of crude pr***S***otein and minerals.

It was detected that the feces collected during the first period of the Latin-square design was not pooled properly. The feces samples were discarded and the experiment was extended by repetition of the first period. Throughout the experiment there were no food refusals: each dog ate its ration within 15 min after administration. Within each feeding period, there was no significant change in body weight. Initial

Table 1 Ingredient and analysed composition of the experimental diets

	Control	**Palm oil**	**Structured fat**
Ingredient, g			
Commercial diet	1,000	900	900
Palm oil	-	100	-
Structured fat	-	-	100
Chemical analysis, % of dry matter			
Dry matter*	92.8	94.4	92.6
Crude fat	13.3	20.0	20.7
Crude protein	22.8	21.3	21.7
Crude fiber	3.6	3.3	3.9
Nitrogen-free extract	53.5	49.3	47.6
Ash	6.8	6.1	6.1
Calcium	1.12	0.98	1.04
Phosphorus	0.74	0.68	0.66

*Expressed on product basis.

body weights were 26.8 ± 0.4 kg (mean ± SEM) for the males and 20.9 ± 0.5 kg for the females. The final body weights were 31.5 ± 0.5 and 25.3 ± 0.7 kg.

The inclusion of structured fat versus palm oil in the diet significantly elevated the amount of fresh and dry feces (Table 2). The diet containing structured fat significantly increased the percentage of dry matter in feces. The mean values were 30.9 % for both the control and palm-oil diet. After feeding the structured-fat diet, the feces contained 34.1 % dry matter. The SEM was 0.34 %. The feces score was slightly, but significantly, lowered by the addition of either palm oil or structured fat to the diet (Table 2). A feces score of 2.5 is equivalent to well formed stools with a slightly moist surface.

Apparent digestibility of dry matter was reduced by 2.7 % units after feeding the diet with structured fat (Table 3). The intake of palm oil did not influence dry-matter digestibility. Structured fat versus palm oil in the diet significantly reduced apparent, total-fat digestibility. The digestibility of crude protein was not differently influenced by the experimental diets. The addition of fat to the diet markedly raised the apparent digestibility of crude fiber, irrespective of the type of fat. Group mean apparent digestibility of the nitrogen-free extract was lowered by the addition of palm oil to the diet, but more so, and significantly, by the addition of structured fat. The three diets did not differently influence the apparent digestibility of ash. Calcium absorption was not clearly affected by diet, but phosphorus absorption was significantly lowered by high fat intake (Table 3).

The apparent digestibilities of palm oil and structured fat were calculated by the difference method. The mean digestibility of palm oil was found to be 96.6 ± 2.61 % and that of structured fat was 68.8 ± 18.71%

Table 2. Feces production and score for dogs (n=11) fed the experimental diets

	Control	Palm oil	Structured fat	SEM	P value
Feces					
g/day	225[a,b]	204[b]	255[a]	7.3	0.027
g dry matter/day	69[b]	63[b]	87[a]	2.3	<0.001
Score	2.6[a]	2.5[b]	2.5[b]	0.02	0.028

[a,b] Means not sharing the same superscript letter are significantly different (*P*<0.05)

Table 3. Apparent digestibility of nutrients in dogs (n =11) fed the experimental diets

	Control	Palm oil	Structured fat	SEM	*P* value
Apparent digestibility, % of intake					
Dry matter	79.0	79.0	76.3	0.62	0.079
Crude fat	93.9[b]	95.1[b]	83.8[a]	1.40	<0.001
Crude protein	79.2	79.1	79.9	2.05	0.959
Crude fiber	33.7[a]	43.1[b]	44.1[b]	1.65	0.004
Nitrogen-free extract	83.0[b]	81.4[b]	77.8[a]	1.27	0.028
Ash	33.0	30.9	37.1	2.12	0.578
Calcium	49.0	47.0	50.3	2.57	0.670
Phosphorus	64.0[b]	57.5[a]	58.6[a]	1.77	0.033

[a,b] Means not sharing the same superscript letter are significantly different (*P*<0.05)

(means ± SD). The difference was statistically significant (*P*<0.001).

Discussion

This study shows that the apparent digestibility of palm oil in dogs is 96.6 %. For comparison, an earlier experiment with dogs documents that the apparent digestibility of soybean oil, lard and beef tallow is 98 % for all three fat sources (Gröner and Pfeffer, 1997). The observed digestibility for palm oil can be considered accurate.

The slip melting point of the structured fat was 55 - 60 ^{O}C and the apparent digestibility in the dogs was 68.8 %. In rats, there is a strong, negative correlation between fat digestibility and melting point above 30 ^{o}C (Clifford *et al*., 1986). The rats in the study of Clifford *et al*. (1986) were fed diets containing 0.82 % safflower oil and 8% of either trimyristin, tripalmitin or tristearin.

For safflower oil a digestibility of 95 % was assumed and the digestibilities of the variable fats were calculated. Trimyristin, tripalmitin and tristearin were found to have an apparent digestibility of 86, 31 and 13%, respectively. The melting points were reported to be 57, 64 and 73 ^{o}C (Clifford *et al*., 1986). Thus, the observed digestibility of the structured fat in dogs corroborates the negative relationship between melting point and digestibility in rats.

The nutritional energy value of fat in dog food is commonly set at 37 kJ (8.84 kcal) metabolizable energy per gram. According to this study, the energy value of the structured fat would be equivalent to (68.8/96.6) x 37 = 26 kJ (6.21 kcal). For dietary non-structural carbohydrates (nitrogen-free extract), the assumed energy value is 16 kJ (3.82 kcal)/g. The energy value of the structured fat is much higher than that of non-structural carbohydrates. Clearly, the structured fat cannot serve as substitute for carbohydrates to lower the energy value of dog food. Consequently, the structured fat cannot be used for the formulation of a very-low energy, weight-reduction diet.

The addition of the structured fat to the diet instead of palm oil increased the amount of feces. This is explained by the lower average digestibility of dry matter seen after feeding the diet with structured fat. The lower digestibility of dry matter in turn is explained by the significantly lower digestibility of fat and nitrogen-free extract. Possibly, the presence of the structured fat in the digesta interferes with the enzymatic digestion and/or absorption of carbohydrates. The structured fat versus palm oil did not significantly influence the apparent digestibility of crude protein, crude fiber and ash.

The two high-fat diets versus the control diet significantly increased the apparent digestibility of crude fiber and decreased that of phosphorus. These observations are difficult to explain. High fat intake would be expected to lead to higher contents of fatty acids in the hindgut. This would inhibit microbial fermentation of fiber and thus induce lower apparent digestibility of crude fiber. High fat intake would be expected to cause the formation of calcium soaps in the small intestinal lumen. The resulting decrease in calcium availability for the formation of calcium phosphate precipitate would raise apparent phosphorus absorption. We are not aware of other studies in dogs fed a high-fat diet and describing the effect on fiber and phosphorus digestibility. In cats, the addition of beef tallow to the diet, at the expense of an isoenergetic amount of carbohydrates, did not influence phosphorus absorption (Beynen and Opitz, 1994).

In conclusion, in this study with dogs the structured fat consisting of stearic and palmitic acid was found to have a low digestibility, when compared with regular fat sources. However, the digestibility was not low enough to make the structured fat under study a candidate ingredient for the formulation of very-low energy, weight-reduction diets. The structured fat significantly reduced the digestibility of non-structural carbohydrates, thereby lowering the energy value of this diet constituent, but with little impact on the energy content of the whole diet.

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