Evaluation of Fermented Oat as Food Ingredients

Subjects: Agriculture, Dairy & Animal Science

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This entry describes a study verified the safety of fermented oat (Avena sativa) when used in a dog food as part of the effort toward discovering suitable nutritionally excellent and functional food materials.

pet food oat

1. Background

Amid increasing global concerns over the shortage of future food resources [1][2], the rapid growth of the pet food market is raising concerns regarding whether a stable supply of raw materials for pet food can be maintained. In addition, hypercompetition in the pet food market has led to the indiscriminate use of new ingredients where preliminary verifications of safety and nutritional value are lacking [3]. In this regard, the need for research on the nutritional value, safety, and functionality of novel ingredients that can replace existing ingredients has been emphasized [4].

In the pet food industry, livestock products are mostly used as a protein source, but the demand for novel protein materials is increasing due to the competitively for their use in food for humans, and regarding the sustainability of livestock products. In other words, it is known that livestock products mainly used as protein sources in dog food can cause allergies. Therefore, many efforts, such as towards using hydrolyzed proteins and finding alternative protein ingredients, have been made to reduce the allergic response induced by exposure to protein sources in dogs [5]. Many researchers are paying attention to the potential suitability of edible insects for human food as well as animal feed [6][7][8]. In particular, black soldier fly larva (BSFL; Hermetia illucens L.) has been reported to be a suitable insect species given its nutritional value, safety, and amenability for mass production [9][10]. Several studies have reported that BSFL meal can partially replace major protein sources (e.g., fish and soybean meal) in conventional diets for poultry [11][12], fish [13][14], and pigs [15]. In addition, some recent studies that evaluated the safety and physiological effects of a BSFL diet on companion dogs have reported positive results [16][17][18]. Nonetheless, more research is needed in terms of the safety and feeding effects of using BSFL in pet food.

Recently, the trend in the pet food market is showing a shift toward grain-free, gluten-free, human-grade, natural, and organic pet food. However, scientific evidence that these are nutritionally superior or that they are more beneficial to pet’s health is lacking. Oats, one of the grains, are known to provide nutrients such as proteins, unsaturated fatty acids, vitamins and minerals, as well as arabinoxylan, β-glucan, and phenolic compounds, having multiple functional and bioactive properties [19][20]. Although there are very limited studies on the efficacy of oat feeding in dogs, one study reported that the intake of oat beta-glucan could improve the apparent total tract digestibility of macronutrients, and was effective in reducing serum total cholesterol and low-density lipoproteins in adult dogs [21]. Meanwhile, although not studied in dogs, previous studies have suggested that oats with various biologically active substances help to prevent diseases, such as cardiovascular pathologies, colon cancer, type II diabetes, and obesity in humans [22][23][24][25][26]. Furthermore, attempts have been devoted to developing oat-based fermented foods using lactic acid bacteria to improve the nutritional value and functionality of oats [27][28][29]; some studies have confirmed the potential value of fermented oats as a functional food [30][31][32]. Despite the positive effects of oats or fermented oats (FOs), no study has reported the effects of feeding FOs to dogs.

2. Food Intake, Body Parameters, and Fecal Score

Table 1 shows the daily food intake, BW, and BCS, for which no significant differences were found among the CON and each treatment group. In all groups, the body weight was higher at the end of the experiment than at the beginning, but there was no significant difference among the control dogs and those fed FO and BSFL.

Table 1. Effects of dog food with FO and BSFL on food intake and body parameters in dogs at the beginning (initial) and end (final) of the experiment.

Items	CON [1]	FO	BSFL	FO + BSFL	p-Value
ADFI [2], g/d	98.0 ± 9.2	100.4 ± 12.0	102.3 ± 10.2	100.2 ± 12.0	0.735
Body weight, kg					
Initial	4.13 ± 0.75	4.22 ± 0.67	4.20 ± 0.67	4.17 ± 0.67	0.999
Final	4.49 ± 0.83	4.52 ± 0.76	4.62 ± 0.76	4.51 ± 0.73	0.999
Rate of BWG [3], %	108.7 ± 1.2	106.5 ± 1.2	109.8 ± 2.1	108.0 ± 1.0	0.437
BCS [4]					
Initial	4.20 ± 0.73	4.20 ± 0.58	3.60 ± 0.93	3.40 ± 0.87	0.850
Final	4.60 ± 0.68	4.20 ± 0.49	3.60 ± 0.81	3.40 ± 0.68	0.593

), and the dog food with FO and BSFL did not affect the fecal scores (**Figure 1**a,b).

Values are expressed as mean ± SE. [1] CON, control group; FO, group with 10% fermented oat added to food; BSFL, group with 5% black soldier fly larva added to food; FO + BSFL, group with 10% fermented oat and 5% black soldier fly larva added to food. [2] ADFI, average daily food intake; [3] BWG, body weight gain; [4] BCS, body condition score.

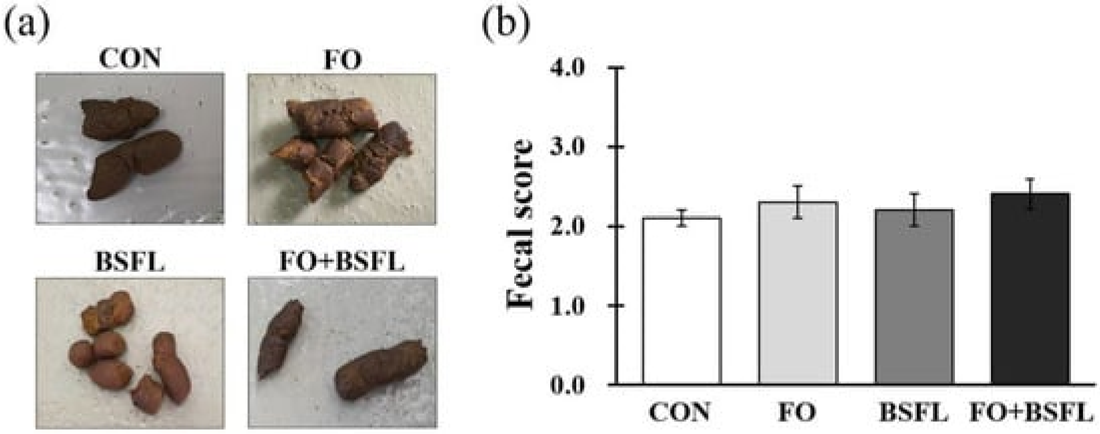

Figure 1. Effects of dog food with FO and BSFL on fecal scores of dogs: (**a**) photographs of the feces; (**b**) scores based on the following 5-point fecal score scale (1 = hard and dry feces to 5 = liquid diarrhea). The results are expressed as mean ± SE. CON, control group; FO, group with 10% fermented oat added to food; BSFL, group with 5% black soldier fly larva added to food; FO + BSFL, group with 10% fermented oat and 5% black soldier fly larva added to food. The p-value on fecal score was 0.666.

3. Skin Status

Figure 2 shows the effects of the feeding of FO and BSFL on skin status. At the end of the experiment, the TEWL, moisture, and oil levels of the groin, armpits, back, and ears were measured, and the measured value is expressed as the average of values determined at the four sites. The TEWL, moisture, and oil levels of each treatment group did not show significant differences compared to the control group (**Figure 2**a–c).

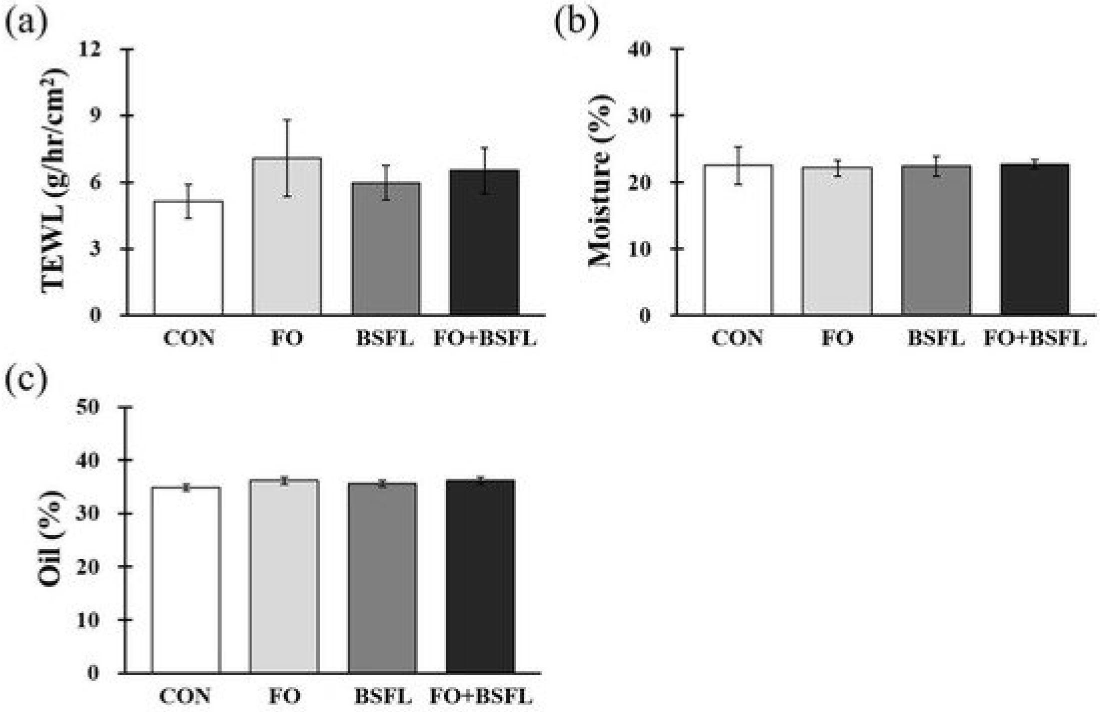

Figure 2. Effects of dog food with FO and BSFL on skin barrier status in dogs. (**a**) TEWL, (**b**) moisture, and (**c**) oil concentration were measured from four different areas (groin skin, armpit skin, back skin, and ear skin) at the end of the experiment. The results are expressed as mean ± SE. TEWL, transepidermal water loss. CON, control group; FO, group with 10% fermented oat added to food; BSFL, group with 5% black soldier fly larva added to food; FO + BSFL, group with 10% fermented oat and 5% black soldier fly larva added to food. p-value: (**a**) 0.486, (**b**) 0.565, (**c**) 0.639.

4. Hematological and Biochemical Parameters

The results of hematological parameters are presented in **Table 3**. All hematological parameters analyzed in this study were within the normal reference range, and no significant differences in these parameters were observed by the single or combined feeding of BSFL and FO among all experimental groups, except for white blood cells (WBCs) in the BSFL group. At the end of the experiment, the BSFL group had a significantly higher WBC value than the CON group ($p < 0.05$). Basophils (BASO) were not affected by the feeding FO or BSFL, but BASO in the BSFL group was significantly increased at the end of experiment compared to the beginning ($p < 0.05$). All the experimental groups showed no significant effects of FO and BSFL on neutrophils (NEU), lymphocytes (LYM), monocytes (MONO), red blood cells (RBC), hemoglobin (HGB), or hematocrit (HCT) during the study period.

Table 2. Effects of dog food with FO and BSFL on CBCs in dogs.

Items	CON	FO	BSFL	FO + BSFL	p-Value
WBC, ×10^6/mL (Ref. range: 5.05–16.76)					
Initial	8.08 ± 0.80	8.10 ± 1.89	10.26 ± 2.15	6.28 ± 1.00	0.385
Final	7.48 ± 0.81	9.48 ± 2.88	12.24 ± 1.10 *	7.65 ± 1.08	0.194
NEU, ×10^6/mL (Ref. range: 2.95–11.64)					
Initial	5.42 ± 0.53	4.97 ± 1.23	7.23 ± 1.71	4.11 ± 0.86	0.321
Final	5.58 ± 0.54	6.56 ± 2.21	8.38 ± 1.16	5.57 ± 0.64	0.415
LYM, ×10^6/mL (Ref. range: 1.05–5.10)					
Initial	1.69 ± 0.28	2.15 ± 0.38	1.82 ± 0.29	1.40 ± 0.16	0.362
Final	1.48 ± 0.26	2.06 ± 0.39	2.74 ± 0.79	1.34 ± 0.30	0.200
MONO, ×10^6/mL (Ref. range: 0.16–1.12)					
Initial	0.55 ± 0.24	0.65 ± 0.25	0.65 ± 0.25	0.46 ± 0.13	0.919
Final	0.19 ± 0.12	0.55 ± 0.29	0.74 ± 0.20	0.53 ± 0.18	0.324

Items	CON	FO	BSFL	FO + BSFL	p-Value
		EOS, ×10^6/mL (Ref. range: 0.06–1.23)			
Initial	0.43 ± 0.07	0.33 ± 0.10	0.56 ± 0.22	0.31 ± 0.08	0.542
Final	0.06 ± 0.01	0.16 ± 0.05	0.27 ± 0.15	0.14 ± 0.06	0.406
		BASO, ×10^6/mL (Ref. range: 0–0.1)			
Initial	0.00 ± 0.00	0.002 ± 0.00	0.004 ± 0.00	0.00 ± 0.00	0.547
Final	0.05 ± 0.02	0.11 ± 0.05	0.10 ± 0.03 $^{\#}$	0.07 ± 0.03	0.516
		RBC, ×10^9/mL (Ref. range: 5.65–8.87)			
Initial	5.85 ± 0.26	5.84 ± 0.17	6.11 ± 0.09	5.88 ± 0.27	0.783
Final	6.27 ± 0.31	6.01 ± 0.11	6.33 ± 0.18	6.02 ± 0.31	0.702
		HGB, g/dL (Ref. range: 13.1–20.5)			
Initial	14.26 ± 0.61	13.94 ± 0.47	14.32 ± 0.44	14.16 ± 0.64	0.963
Final	14.40 ± 0.69	13.82 ± 0.54	14.14 ± 0.41	14.18 ± 0.99	0.947
		HCT, % (Ref. range: 37.3–61.7)			
Initial	41.28 ± 1.65	40.36 ± 1.03	42.24 ± 1.06	40.52 ± 1.76	0.777
Final	44.51 ± 1.98	42.27 ± 0.88	43.89 ± 0.93	43.16 ± 2.25	0.790

Values are expressed as mean ± SE. WBC, white blood cell; NEU, neutrophils; LYM, lymphocytes; MONO, monocytes; EOS, eosinophils; BASO, basophils; RBC, red blood cells; HGB, hemoglobin; HCT, hematocrit. *, significant differences from the control in the same row ($p < 0.05$); #, significant differences between the initial and final values in the same column ($p < 0.05$). CON, control group; FO, group with 10% fermented oat added to food; BSFL, group with 5% black soldier fly larva added to food; FO + BSFL, group with 10% fermented oat and 5% black soldier fly larva added to food.

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GGT), or albumin/globulin (A/G) ratio values among all experimental groups. However, the FO and FO + BSFL groups showed significantly lower alkaline phosphatase (ALKP) than the control group at the end of the experiment ($p < 0.05$). For the FO + BSFL group, we recorded significantly lower GLOB compared to the control group at the end of the experiment ($p < 0.05$). For the BSFL group, we recorded significantly lower phosphorous (PHOS) compared to the control group ($p < 0.05$). In addition, the BSFL group showed significantly less total protein (T-PRO) and total cholesterol (T-CHO) at the end compared to the beginning of the experiment ($p < 0.05$).

Table 3. Effects of dog food with FO and BSFL on serum biochemical parameters in dogs.

Items	CON	FO	BSFL	FO + BSFL	p-Value
		GLU, mg/dL (Ref. range: 70–138)			
Initial	97.2 ± 8	98.6 ± 4.34	103.6 ± 6.45	95.8 ± 6.07	0.835
Final	94.6 ± 4.58	95.6 ± 4.34	91.8 ± 3.12	97 ± 3.51	0.816
		CREA, mg/dL (Ref. range: 0.5–1.6)			
Initial	0.64 ± 0.09	0.64 ± 0.07	0.68 ± 0.05	0.6 ± 0.05	0.883

Items	CON	FO	BSFL	FO + BSFL	p-Value
Final	0.72 ± 0.12	0.72 ± 0.09	0.72 ± 0.07	0.68 ± 0.07	0.984
BUN, mg/dL (Ref. range: 6.0–31)					
Initial	13.6 ± 0.93	14.4 ± 1.63	16.4 ± 1.47	15 ± 1.38	0.545
Final	14.6 ± 1.25	15 ± 1.22	15.8 ± 1.2	14 ± 1.41	0.789
PHOS, mg/dL (Ref. range: 2.5–6.0)					
Initial	4.74 ± 0.35	4.62 ± 0.37	4.22 ± 0.29	4.32 ± 0.32	0.655
Final	4.54 ± 0.26	4.54 ± 0.47	3.52 ± 0.31 *	3.72 ± 0.25	0.049
CA, mg/dL (Ref. range: 8.9–11.4)					
Initial	9.18 ± 0.41	9.34 ± 0.29	9.64 ± 0.48	9.64 ± 0.21	0.295
Final	9.08 ± 0.36	9.38 ± 0.16	8.96 ± 0.32	8.9 ± 0.23	0.628
T-Pro, g/dL (Ref. range: 5.0–7.4)					
Initial	6.98 ± 0.37	6.76 ± 0.27	7.24 ± 0.17	6.24 ± 0.2	0.089
Final	7.34 ± 0.26	6.66 ± 0.25	6.62 ± 0.19 $^{\#}$	6.56 ± 0.22	0.100
ALB, g/dL (Ref. range: 2.7–4.4)					
Initial	3.16 ± 0.12	3.22 ± 0.08	3.44 ± 0.11	2.94 ± 0.14	0.087
Final	3.22 ± 0.09	3.2 ± 0.09	3.14 ± 0.12	3.14 ± 0.13	0.935
GLOB, g/dL (Ref. range: 1.6–3.6)					
Initial	3.82 ± 0.28	3.54 ± 0.22	3.8 ± 0.17	3.3 ± 0.13	0.271
Final	4.12 ± 0.23	3.46 ± 0.29	3.48 ± 0.19	3.42 ± 0.12 *	0.048
A/G ratio (Ref. range: 0.8–2.0)					
Initial	0.84 ± 0.05	0.92 ± 0.05	0.92 ± 0.07	0.88 ± 0.06	0.715
Final	0.78 ± 0.06	0.98 ± 0.09	0.92 ± 0.07	0.9 ± 0.03	0.221
ALT, U/L (Ref. range: 12–118)					
Initial	111.4 ± 48.17	58.8 ± 13.75	135.5 ± 43.56	41.2 ± 6.18	0.164
Final	87 ± 31.58	38.4 ± 9.9	97.5 ± 35.26	35.4 ± 8.07	0.246

Items	CON	FO	BSFL	FO + BSFL	p-Value
ALKP, U/L (Ref. range: 5.0–131)					
Initial	60.6 ± 19.94	24.6 ± 3.61	62 ± 17.52	20.6 ± 4.55	0.079
Final	58.4 ± 7.93	36.4 ± 4.17 *	70 ± 24.03	29 ± 5.39 *	0.043
GGT, U/L (Ref. range: 0–12)					
Initial	0 ± 0	0 ± 0	3 ± 3	0 ± 0	0.418
Final	0 ± 0	0 ± 0	2.8 ± 2.8	0 ± 0	0.418
T-BIL, mg/dL (Ref. range: 0.1–0.3)					
Initial	0.28 ± 0.04	0.22 ± 0.04	0.4 ± 0.03 *	0.3 ± 0.03	0.004
Final	0.28 ± 0.04	0.2 ± 0.04	0.3 ± 0.05	0.2 ± 0.03	0.254
CHOL, mg/dL (Ref. range: 29–291)					
Initial	131.4 ± 15.16	136.4 ± 8.89	177.6 ± 8.95 *	132.8 ± 6.58	0.017
Final	143.2 ± 18.99	141.8 ± 10.94	159.4 ± 9.89	153 ± 10.29	0.749

Values are expressed as mean ± SE. GLU, glucose; CREA, creatinine; BUN, blood urea nitrogen; PHOS, phosphorous; CA, calcium; T-Pro, total protein; ALB, albumin; GLOB, globulin; A/G, albumin/globulin ratio; ALT, alanine aminotransferase; ALKP, alkaline phosphatase; GGT, gamma glutamyltransferase; T-BIL, total bilirubin; T-CHO, total cholesterol. *, significant difference from the control in the same row ($p < 0.05$); #, significant differences between initial and final values in the same column ($p < 0.05$). CON, control group; FO, group with 10% fermented oat added to food; BSFL, group with 5% black soldier fly larva added to food; FO + BSFL, group with 10% fermented oat and 5% black soldier fly larva added to food.

3. IgG and Cytokines

Figure 3 shows the effects of feeding FO and BSFL on changes in canine immunoglobulin G (IgG), interleukin 10 (IL-10), and tumor necrosis factor alpha (TNF-α) levels. Canine IgG ranged between 1.68 and 8.10 mg/mL, the IL-10 ranged between 140.24 and 415.58 pg/mL, and the TNF-α between 1.20 and 6.12 pg/mL, and no statistically significant differences were found in any of the experimental groups compared to the control group. In addition, no significant changes were observed in the levels of IgG, IL-10, or TNF-α in any experimental group for 12 weeks (initial vs. final; **Figure 3**).

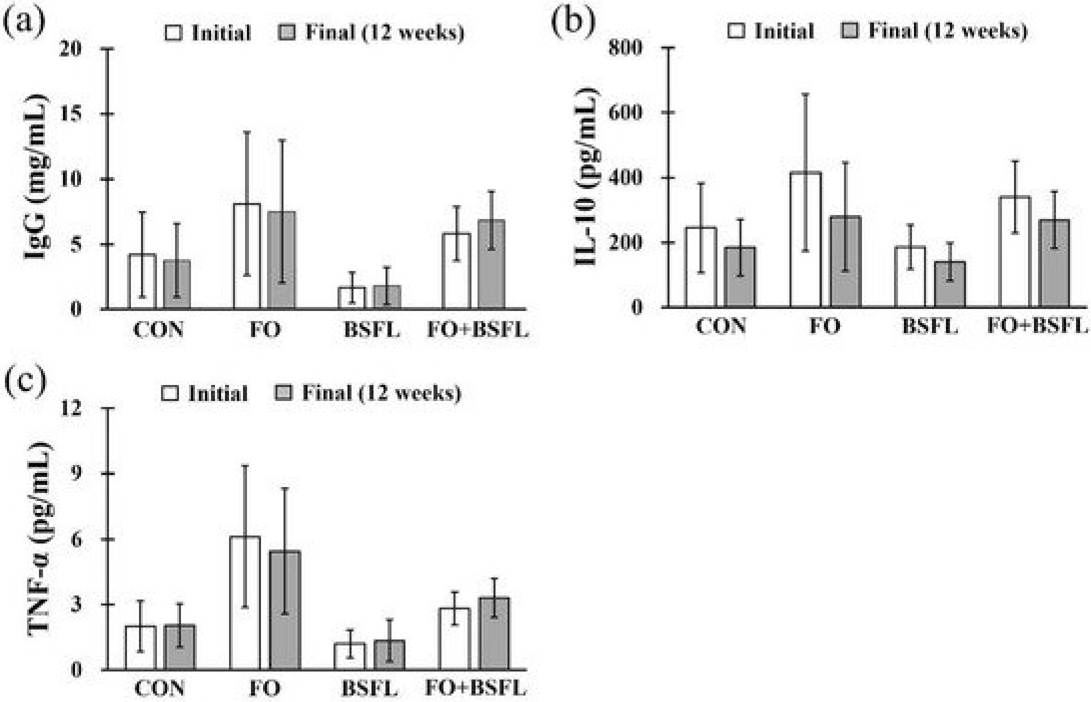

Figure 3. Effect of dog food with FO and BSFL on the IgG and inflammatory cytokines in dogs: (**a**) IgG, (**b**) IL-10, and (**c**) TNF-α. The results are expressed as mean ± SE. IgG, immunoglobulin G; IL-10, interleukin 10; TNF-α, tumor necrosis factor alpha. CON, control group; FO, group with 10% fermented oat added to food; BSFL, group with 5% black soldier fly larva added to food; FO + BSFL, group with 10% fermented oat and 5% black soldier fly larva added to food.

Comprehensively, the feeding of 10% FO and 5% BSFL for 12 weeks did not affect food intake, body weight, or BCS, and did not have a negative effect on physiological and biochemical responses in dogs. Furthermore, the findings suggest that BSFL may have the ability to reduce serum total cholesterol in dogs. Further studies of the effects of BSFL on serum total cholesterol in dogs are required. The results demonstrate the safety and potential functionality of FO and BSFL, and verify their suitability as food ingredients for dogs.

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