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Research Article

Using of Pelleted and Extruded Foods in Dog Feeding [1] [2]

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Abstract

This study was carried out to determine the effects of pellet and extruded foods on gelatinization, digestibility and faecal quality of dogs. In study 30 adult male dogs of mixed breed, weighing 15-30 kg, neutered and around 1-3 of age were used. The two tested dog-food formulations had the same composition, but one was produced in pellet form, while the other was extruded in a private factory. Feeding experiments were conducted at the Dog Unit of the Veterinary Faculty in Selçuk University. Pelleted and extruded food contained 4.87% and 17.81% gelatinized starch, respectively (P<0.001). Tested dogs preferred extruded food at a rate of 0.66. The digestibility, faecal score, and cost of pelleted, extruded, imported, and domestic dog food were compared. The most common commercial brands were selected for the latter two categories. Based on faecal samples, the dry matter digestibility of the four dog-food types was 81.2%, 84.2%, 83.7%, 83.5% (P<0.05) respectively. The faecal score was 3.48 for dogs that consumed pelleted food and 3.68-3.91 for dogs fed the other three extruded foods. Cost calculations revealed that extruded food is five times more economical than imported food.

Keywords: *Extruded, Dog food, Digestibility, Pellet, Preference*

Pelet ve Ekstrude Mamaların Köpek Beslemede Kullanılması

Özet

Bu çalışma pelet ve ekstrude formda üretilen mamaların jelatinizasyon, köpeklerde sindirilebilirlik ve dışkı kalitesine etkilerinin belirlenmesi amacıyla yapıldı. Çalışmada 15-30 kg ağırlıkta kısırlaştırılmış 30 adet 1-3 yaşlı karışık ırk erkek köpek kullanıldı. Bileşimi aynı olan iki formülün biri pelet şeklinde, diğeri ekstrude formda özel bir tesiste üretildi. Yedirme denemeleri Selçuk Üniversitesi Veteriner Fakültesi Köpekçilik Ünitesinde yürütüldü. Jelatinize nişasta oranı pelet mamada %4.87, ekstrude mamada %17.81 (P<0.001) bulundu. Ekstrude mamanın köpekler tarafından tercih edilme oranı 0.66 olarak tespit edildi. Bu çalışmada üretilen pelet ve ekstrude mamalar, piyasada en çok bilinen biri ithal ve biri yerli olan ticari mamalar ile sindirilebilirlik, dışkı skoru ve maliyet bakımından karşılaştırıldı. Pelet, ekstrude, ithal ve yerli ticari mamaların dışkı toplama yöntemiyle belirlenen kuru madde sindirilebilirlikleri sırasıyla %81.2, 84.2, 83.7, 83.5 (P<0.05) olarak tespit edildi. Dışkı skoru pelet mama tüketenlerde 3.48 bulundu, diğer üç ekstrude mamaları tüketenlerde 3.68-3.91 arasında idi. Maliyet hesaplamasında bu çalışmada üretilen ekstrude mama ile köpek beslemenin ithal mamadan 5 kat daha ekonomik olabileceği belirlendi.

Anahtar sözcükler: *Ekstrude, Köpek maması, Pelet, Sindirilebilirlik, Tercih*

INTRODUCTION

The dog food industry of Turkey has experienced rapid progress in recent years, with a rising number of entrepreneurs interested in producing dog food. At present, dog nutritional needs are largely met with imported food, which can be purchased off the internet and vary greatly in price. Due to inconsistent prices and a desire for natural products, dog owners tend to mix home-grown dog food as an inexpensive, domestic, and higher quality alternative.

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Whether homemade or commercial, dog food formulas contain a considerable amount of cereal, with rice and corn being the most common. Due to high starch content, grains are mainly used as an economical energy source, while also acting as a swelling and bonding agent. However, raw starch has very low digestibility and must be gelatinized or cooked during food production. Homemade recipes tend to boil grains, whereas commercial foods process grains in an extruder.

Gelatinization is a mechanical process that deteriorates starch crystal structure through altering moisture, temperature, and pressure conditions, causing starch granules to swell [1]. Starch gelatinization and the form of the final product are both taken into account when measuring dry food quality [2].

Extrusion has been used in the food industry and animal-feed production since the 1950s. The aqueous food mixture undergoes heat treatment and is forced through the die with a spiral screw, resulting in a product of a particular shape, such as strips that are then cut and then dried. To enhance flavour, the product is typically sprayed with oil or similar compounds. During extrusion, products experience up to 200°C in as little as 270 s, causing major chemical and physical changes that result in swelling (similar to making popcorn). For optimal protein quality in dog food production, extrusion conditions were found to be 110-150°C, with a 300 g/kg moisture content, and 120-160°C drying temperature [3,4]. During this process, undesired enzymes are denatured, anti-nutritional factors are destroyed, and food is sterilised, all without impairing the natural odour and taste [5-8]. Extrusion also significantly increases digestible starch [9], but may also cause undesirable effects, such as vitamin (A, E, thiamine) deficiencies, lipid oxidation, and a reduction in amino acid content through the Maillard reaction [6].

An important method for assessing dog health involves examining stool amount and consistency. High digestibility is a desirable quality for dog food [10], and stool characteristics act as a useful indicator of digestion levels.

In addition to digestibility, dog foods must also be palatable. Various methods are available for determining dog preferences, with the two-pan palatability test being widely used. This test involves presenting two foods simultaneously before the animal and observing consumption. After a set duration, the remaining food is measured and the preference rate is calculated [11,12].

This study had three objectives. First, we determined the suitability of pelleted dog foods commonly used in temporary care and rehabilitation centres. Second, we aimed to demonstrate that domestic extruded foods can be produced commercially. Finally, we evaluated the quality of several manufactured foods via feeding experiments in dogs.

MATERIAL and METHODS

Animals and Management

Experimental procedures were approved by the local ethics committee (No: 2014/53) at the Dog Unit of Selçuk University's Veterinary Faculty. Dogs were housed in individual cells with concrete floors, each containing a 190 × 190-cm enclosure and a 510 × 230-cm open area.

Subjects were 30 neutered, adult male dogs, of mixed breed and around 1-3 of age. Exposure of the dogs to general health conditions and internal and external parasitic practices were routinely performed. Dogs weighed around 15-30 kg.

Dogs were fed daily at the same time. Food and water were provided in 90-oz metal pans and ceramic bowls, respectively. The containers and housing were washed weekly with pressurised water.

Dog Food Production

Tested dog food formulations contained the same raw material and nutrient composition *(Table 1)*. One was pelleted and the other was processed with an extruder. Both were produced at Bil-Yem Facilities.

Food ingredients were first weighed and then milled to pass through a 0.4 mm sieve. Water was added to

Table 1. *Composition of pellet and extrude dog foods*

Ingredients	**%**
Poultry meal	15.00
Barley	10.00
Corn	27.00
Corn gluten meal	13.00
Corn starch	10.78
Rice	15.00
Whey	2.00
Sunflower oil	3.00
Beef tallow	3.00
Vitamin-mineral*	1.22
Calculated nutrients/100 g DM	
Crude protein, g	23.50
Energy, kcal	445
Crude fibre, g	2.27
Ash, g	4.25
Carbohydrate, g	62.53
Calcium, g	0.64
Phosphorus, g	0.61
Fat, g	10.80
Linoleic acid, g	2.02

** Aminovit, minesol, K chloride, Zn proteinate, Ca iodate, Na bicarbonate* the ingredients to maintain moisture at around 25%, processed in a mixer for 20-30 min, and then added to a double-screw extruder. Extruder internal temperature was raised from 90°C to 135°C in four steps; the contents were cooked for a maximum of 4 min. Dog food was then moved to a conveyer-belt dryer and subjected to temperatures peaking at 148°C for 30-45 min. The resulting product was sprayed with oil, vitamins, and mineral additives in the lubricating unit before being cooled, then stored in 15-kg bags. The same formulation was passed through the pelletizing unit (70-80°C, 18% moisture) to obtain a 6 mm pellets.

Nutrient Analyses

Dog foods were ground in a Retsch SM100 laboratory mill and passed through 0.5 mm sieves. Analyses of dry matter (DM), ash, crude protein (CP), ether extract (EE), crude fibre (CF), and starch were performed following AOAC methods [13]. The resultant data were used to calculate the metabolic energy in both products [14]:

$$\text{ME-NRC, kcal/kg} = ((5.7 \times CP \times 10) + (9.4 \times EE \times 10) + (4.1 \times (NFE \times 10 + CF \times 10))) \times (91.2 - (1.43 \times CF))/100 - (1.04 \times CP \times 10),$$

where CP is crude protein, EE is ether extract, NFE is nitrogen-free extract, and CF is crude fibre.

Gelatinized Starch Ratio

To determine the effect of pelleting and extrusion on starch degradation, three repetitive gelatinized starch measurements were made with a spectrophotometer, using a starch damage assay kit (Megazyme International Ireland 2014). This procedure has been adopted by the American Association of Cereal Chemists (AACC Method 76-31.01) and the International Association for Cereal Science and Technology (ICC Method No. 164). In the procedure, damaged starch granules are hydrated and hydrolysed to maltosaccharides plus α-limit dextrins by controlled treatment with purified fungal α-amylase. The fungal α-amylase treatment is designed to give near complete solubilisation of damaged granules with minimum breakdown of undamaged granules. This reaction is terminated on addition of dilute sulphuric acid, and aliquots are treated with excess levels of purified amyloglucosidase to give complete degradation of starch-derived dextrins to glucose. The glucose is specifically measured with a high purity glucose oxidase/peroxidase reagent mixture. Determined values are presented as starch (damaged) as a percentage of flour weight on an "as is" basis (Megazyme International Ireland 2014).

Preference Test

To determine whether dogs preferred pelleted or extruded foods, dogs were fed 500 g of each in two identical feeding pans, once per day (at the same time). The food pans were positioned at the same distance away from the subjects, so that they could reach either equally easily. Dogs were kept in the outer area of their compartments while the pans were being placed in the enclosure.

The dogs were given clean water ad libitum during the experiment. At the end of 1 h, both food pans were removed and weighed to determine how much was consumed. Potential directional preferences were eliminated by switching the pans' left/right positions daily until the end of the test (4 days). Food preference was calculated with the following equations [12,15]:

$$\text{Extruded food preference ratio, \%} = A/(A + B),$$

$$\text{Pellet food preference ratio, \%} = B/(A + B),$$

where A is the amount of consumed extruded food (g) and B is the amount of consumed pellet food (g).

Determination of Digestibility

The total collection method [10,16] was used to determine the digestibility of organic matter (OM), CP, EE, and CF in two commercial diets (one imported, one domestic). Four groups (seven dogs each) were separated using sensitive sorting [17], based on weight, body condition scores, and their location in the Dog Research Unit. Each group was fed a different type of food for 14 days. Subjects were given the same amount of food daily, around 3-8% of their maintenance requirements (according to their consumption levels during a nine-day acclimatisation period). Any remaining food was collected and weighed on the next day. Water was provided ad libitum. Twice a day during the last five days, faeces were collected with plastic scrapers, placed in nylon bags, weighed, and stored at -20°C. At the end of the trial, stool samples were dissolved, homogenised, and then weighed in aluminium containers to determine dry matter content. Next, samples were oven-dried (70°C) for 60 h, then ground for the analysis of ash, crude protein, ether extract, and crude fibre content. Nutrient digestibility was calculated using the following formulas:

$$\text{Dry matter digestibility, \%} = (\text{dry matter of food} - \text{dry matter of faeces})/\text{dry matter of food} \times 100,$$

$$\text{Nutrient digestibility, \%} = (\text{nutrient in food} - \text{nutrient in faeces})/\text{nutrient in food} \times 100.$$

Faecal Consistency

During the last 4 days of the digestibility trial, faecal consistency was scored as follows: 1. soft and unshaped stool; 2. soft and vaguely shaped stool; 3. soft, moist, and spotted stool with definite shape; 4. well-formed, undistorted, and non-marking stool; 5. well-formed, solid, and dry stool [18]. Scoring was conducted by three independent observers and a final average was taken.

Determination of Cost

Potential retail sale prices of the pelleted and extruded foods if offered as a commercial product were calculated to estimate costs. Ingredients prices and their value-added taxes were determined using the diet formulation. Potential operating expenses, packing costs, production wastages, post-shipment waste, depreciation, and profitability expenses were added to the price. Calculated prices were then compared to the retail prices of commercial imported and domestic foods.

Statistical Analyses

Differences in nutrient digestibility and faecal scores across the dog food types were examined using ANOVA. Differences in the ratio of damaged starch were analysed with the Student's t-test. Means were separated with Duncan's multiple range tests. Significance was set at P<0.05. All analyses were performed in IBM SPSS Statistics (version 22, IBM Corp., Chicago, IL).

RESULTS

Table 2 shows the results of nutrient analysis, and *Table 3* shows the damaged starch ratios. Extruded food contained four times more gelatinized starch than pelleted food.

Table 4 shows the nutrient digestibility of four tested foods. Pelleted food contained the lowest DM and CP digestibility. Extruded food and the two commercial foods did not differ in their DM, OM, and CF digestibility. *Table 5* shows subject preferences for pelleted versus extruded food. On average, subject dogs consumed 199.85 g of pelleted and 380.33 g of extruded food daily, preferring extruded food by 66% and pelleted food by 34% (P<0.001). Finally, *Table 6* shows the faecal scores. The lowest faecal score (3.48) was obtained from animals consuming pellet food.

The retail price per kg of pelleted and extruded food was determined. *Table 7* compares the costs of the daily amount necessary to meet a 25-kg dog's energy requirements across the four tested foods. Because the foods differ in nutrient content, we calculated how much it would cost to meet the daily energy requirement of an adult dog of average weight. We found that the daily feeding cost was 1.13 TRY, 0.87 TRY, 5.78 TRY, and 1.33 TRY for extruded, pelleted, commercial imported, and commercial domestic food, respectively.

DISCUSSION

Although the pelleted and extruded foods were produced with the same formulation, the latter contained slightly less ash, CF, and EE than the former. The low ash and EE content may be due to a lack of precision in adjusting the amount of oil used when applying minerals during preparation. Regardless of the lower EE, dogs preferred extruded food over pelleted food. Furthermore, we observed that measured EE, CP, and energy levels were lower than the expected values based on the ingredients used in the formula, an outcome that could be attributed supplier overestimation of protein and fat content in the poultry meal and corn gluten meal used.

The gelatinized starch ratio in dog food varies between by 10-35% [19]. This study found a gelatinized starch content

Table 2. *Analysis results of foods, DM%*

Food	DM	Ash	EE	CF	CP	Starch	ME, kcal
Pelleted	92.81	4.88	9.23	2.66	22.76	51.72	393
Extruded	92.57	4.29	8.66	2.25	22.98	50.84	395
Commercial, imported	94.02	4.92	12.59	3.12	22.26	45.14	405
Commercial, native	94.34	5.97	9.39	3.12	26.52	42.28	388

DM: *Dry Matter*

Table 3. *Gelatinized starch in foods, %*

Food	X	Sx
Pellet	4.87	0.04
Extrude	17.81	0.18
P	<0.001	

Table 4. *Nutrient digestibility of foods, % (n=7)*

Food	DM	OM	EE	CF	CP
Pelleted	81.17 ± 1.12^{b}	84.13 ± 1.11^{b}	94.98 ± 0.30^{ab}	26.77 ± 3.60	76.05 ± 1.60^{c}
Extruded	84.20 ± 0.45^{a}	87.87 ± 0.36^{a}	95.72 ± 0.40^{a}	19.96 ± 5.12	79.63 ± 1.12^{b}
Commercial, imported	83.66 ± 0.66^{a}	85.96 ± 0.63^{ab}	95.29 ± 0.26^{ab}	29.23 ± 2.61	79.94 ± 0.97^{b}
Commercial, native	83.47 ± 0.52^{a}	87.7 ± 0.39^{a}	94.16 ± 0.38^{b}	19.79 ± 2.90	85.62 ± 0.59^{a}
P	0.039	0.003	0.029	0.235	<0.001

^{a,b} Means within a row with no common letter differ significantly (P<0.05); ***DM:*** *Dry Matter,* ***OM:*** *Organic Matter* ***EE:*** *Ether Extract,* ***CF:*** *Crude Fibre,* ***CP:*** *Crude Protein*

Table 5. *Results of two-pan preference test (n=30)*

Preference Test	Pellet	Extrude
Daily consumption, g	199.85	380.33
Preference rate, %	34	66

Table 6. *Faecal scores of foods (n=7)*

Food	Faecal Score	
	X	Sx
Pelleted	3.48	0.15
Extruded	3.68	0.21
Commercial, imported	3.91	0.15
Commercial, native	3.78	0.15
P	0.349	

Table 7. *Daily food costs for a 25 kg adult dog*

Food	Daily Intake, kg	Cost, TRY	Rate, %
Pelleted	0.368	0.87	77
Extruded	0.366	1.13	100
Commercial, imported	0.351	5.78	510
Commercial, native	0.383	1.33	118

of 17.81% and 4.87% in extruded and pelleted food, respectively. The degree of gelatinization in extruded food reached the desired limit, indicating greater starch digestibility. Digestion trial results corroborate this conclusion. In sum, an increase in starch gelatinization shows that the dry and organic matter in extruded food has higher digestibility. Furthermore, pelleted food was less digestible because it was not sufficiently gelatinized.

We expected that the high-heat treatment would increase gelatinized starch, and therefore the digestibility of dry and organic matter. In a comparison with commercial foods, dry matter digestibility was highest in extruded food and lowest in pelleted food, with commercial foods in between. The higher dry matter digestibility was likely due to the fact that commercial foods are also extruded and have higher starch digestibility. Overall, obtained digestibility values are within previously reported limits [20-25].

Organic matter digestibility was higher in extruded food than pelleted food. Also, it was higher in commercial domestic food than pellet food. These are generally in line with previous work using poultry by-product meal and poultry meal as the source of animal protein in dog foods, resulting in an OM digestibility of 87.0-88.8% [20]. In other studies [20,22,23,25], OM digestibility ranged widely between 86.3% and 92.8%. We also found that EE digestibility ranged from 94.16% to 95.72%, with the lowest values in commercial foods. This outcome is probably due to the use of animal fat, which is difficult to digest. Generally, the fat digestibility of dog food varies between 91.7% and 95.5% [20,22,23,25].

The ability of dogs to digest crude fibre is fairly low. Indeed, CF digestibility was reported to be 38.3% on average (across 259 dog foods) in one study [26]. Greater CF digestibility increases stool consistency in dogs. In this study, CF digestibility was varied between 19.79% and 29.23%.

Observed protein digestibility was between 76.05% and 85.62%. The protein digestibility were significantly greater in commercial domestic food than in the other three foods, with pelleted food exhibiting the lowest values. It is known that the processing of extrusion increases protein digestibility [3,6]. In this study, CP digestibility of 76.05% in pellet food increased to 79.63% in extruded food with the same formula, which means an increase of 4.71%. The level of protein in commercial domestic extruded food is higher than other foods. However, a high protein level in the food does not necessarily mean increased digestibility, as proteins with low digestibility (e.g. vegetable sources) can also be elevated. A previous study found that the ability of dogs to digest protein did not differ when fed with foods containing 25% and 35% (dry matter basis) crude protein [27]. On the contrary, there are studies reporting that protein digestibility increases as the protein level increases in the diet [28]. It may be that the high digestibility of CP in the commercial native food contains fish meal as well as poultry meal as an animal protein source. Poultry meal has been used in other foods, but there is no fish meal. In various studies, CP digestibility in dog food ranges between 77.7-91.2% [20,22,23,25].

Dogs exhibited a clear preference for extruded food. One possible explanation for this difference could lie in the fact that pellets tended to crumble, forming flour that settles to the bottom of the container. Dogs were likely unable to consume this dusty residue, which remained in food pans. Moreover, the high heat in extruder processing increased flavour due to the Maillard reaction [3,6]. The enhanced taste and the uniform structure of extruded food appeared to facilitate increased feeding.

The faeces of dogs that consumed pellet food had a slightly softer consistency, probably due to the lower heat treatment during pelleting, which results in less starch gelatinization and decreased dry matter digestibility. However, faecal scores did not significantly differ across dog foods after controlling for the variation in consumption levels. Our observed values are within normal limits and similar to those reported by previous researchers [24,25,29].

In calculating the cost, it was determined that extruded food produced in this study could be 5 times more economical than imported food. According to the results of feeding experiments, extruded food can be easily recommended instead of imported food to dog owners.

We demonstrated that considerable variation exists in the protein, fat, ash, and energy content of animal and vegetable protein sources used to produce dog food. Thus, to ensure consistency in the nutritional value of dog food, raw feedstuffs should be analysed carefully before use.

Furthermore, although pelleted food is inexpensive, it is harder to digest than extruded food, while also being less preferred by dogs. Finally, the pellet form appears to be less efficient, given its propensity to be crumbled and leave behind powder that the animal cannot consume. This characteristic likely also causes nutrients to be lost from the diet.

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