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Valorisation of Poultry Byproducts for Complementary Pet Food Production: A Circular Economy Approach

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ABSTRACT

The pet food market is rapidly expanding as pet owners increasingly seek high-quality diets for their dogs. The pet food industry utilizes approximately 23% of the rendered poultry proteins produced annually. Poultry byproduct meal (PBM) is derived from poultry slaughter waste, including heads, viscera, feathers, and other byproducts. The fat in PBM is rendered and repurposed. For the production of extruded dry pet food for adult dogs, a formulation was developed. This mixture is processed through a twin-screw extruder at 120°C, resulting in extruded dry pet food. The pet food was analysed for various parameters like water activity of 0.41 and *in-vitro* digestibility of 78.24%. The calcium, phosphorus, iron, Zinc, magnesium, and manganese levels were recorded at 0.95%, 0.59%, 610mg, 51mg, 0.0046mg, 20mg/kg, respectively. The proximate composition of the pet food indicated moisture content at 1.54%, protein at 23.8%, crude fat at 8.7%, crude fibre at 2.0%, and total ash at 0.98%. Colour parameters revealed a lightness (L*) of 28.66, redness (a*) of 8.20, and yellowness (b*) of 17.20 and the amino acid profile was analysed.
Keywords: Pet food, Poultry byproducts, Nutrient analysis, Pet nutrition.

Introduction

India's agriculture-based economy relies heavily on the livestock sector, with the meat industry playing a significant role in providing livelihoods and employment, particularly in rural areas. Slaughtering food animals produces not only meat but also valuable byproducts. However, about two-thirds of an animal's weight consists of byproducts and waste that must be properly processed and utilized. According to the research by (Mozhiarasi and Natarajan, 2022), the global broiler chicken production has exceeded 22.85 billion also, further authors predicted that the poultry industry alone generates a significant amount of waste, with poultry abattoirs contributing 32.5–37% of slaughter waste. If not properly processed, these byproducts can lead to environmental pollution and health hazards, making their effective use essential for sustainability.

Pet food, made from meat, byproducts, cereals, and other nutrients, is designed to meet the dietary needs of domesticated animals. With increasing urbanization, the pet food industry in India has been growing rapidly, driven by greater awareness among pet owners about the health and nutrition of pets. Poultry offal's as heads, feet, and inedible viscera, are often used in pet food production, and poultry protein meals are a major source of high-quality protein for pets. According to Credence Research (2024), the pet food market is expected to grow significantly, with projections showing an increase from USD 872.16 million in 2023 to USD 2133.48 million by 2032.

Extrusion cooking, a technique used in making commercial dry pet food, is efficient and versatile, improving the functionality of ingredients by enhancing texture, sterilizing,

and eliminating harmful substances. The use of poultry byproducts in pet food could help improve nutritional value, texture, and palatability, while also reducing the environmental impact of food waste.

This article explores the potential of poultry byproducts in pet food production, the significance presenting a sustainable pathway for the growing pet food industry.

Materials And Methods

Ingredients

The poultry by-products were obtained from different retail meat stores located in and around Chengicherla, Hyderabad, and other ingredients such as maize, rice, de-oiled soya cake, salt, B-complex vitamins, minerals, and antioxidants were purchased from the local market of Hyderabad.

The rendering process was optimized to increase the production of poultry by-product meal. The ingredients, such as maize, rice, and de-oiled soya cake, were procured and pulverized in a hammer mill and kept in containers separately.

Pet food formulation

The pet food was formulated using poultry by-product meal, following the nutrient specifications and recommendations provided by the AAFCO and NRC for an adult dog's maintenance diet.

Table 1. Development of pet food formula

Ingredients	Proportion (%)
Maize flour	45
Rice flour	12
De-oiled Soya flour	15.8
Poultry byproduct meal	17
Chicken fat	7
Mineral mixture	0.6
Salt	0.8
Antioxidant	0.001
E–care selenium	0.007
Di-calcium phosphate (DCP)	1.5
Choline chloride	0.28
Vit B complex	0.02
Total	100.00

Preparation of pet food

The premixing of all ingredients was made on the day of pet food preparation. All the dry ingredients were weighed according to the formulation, and mixed in a clean tub, and then transferred into a mixer for uniform mixing of all ingredients. The moisture was adjusted to 26% by adding water preblended with B-complex vitamins, E care-selenium, and Antioxidants. After obtaining desirable moisture, the premix was left in a mixer for 10 minutes for proper conditioning. The second and third heaters of the extruder were switched on, and the temperature was set to 90°C and 120°C, respectively. Following this oil pump was turned on, and the main motor speed was gradually increased to 22 rpm based on product formulation. Then feeding motor speed was set to 12 rpm. Following this, the cutting motor speed was set to 35 rpm. after the successful extrusion of the product, the air conveyor (1.8 RMS) was switched on to shift pellets to a drier. Drier is equipment connected to an air conveyor to receive and dry the pellets so that the desired moisture content can be reached. The temperature of the heaters in the dryer was set to 80^0C, then the conveyor speed was set to 20 rpm and the blower speed was set to 1.4 rpm. Then the pellets were received from the outlet of the dryer into a clean-dry container, which was then transferred to a flavouring unit where rendered chicken oil was added to the pellets as a flavouring agent. After flavouring, the pet food was packed in a vacuum and aerobically in 14.5 x 18.5 cm laminated (metalized polyester and polyethylene) food-grade low-density polyethylene (LDPE) silver pouches and kept for storage studies.

Nutrient composition

The proximate analysis of pet food was determined by the standard procedure of AOAC (1995).

Instrumental colour analysis

The instrumental colour analysis was done by measuring lightness (L), redness (a*), yellowness (b*), hue angle (H), and chroma (c). A white plate was used to calibrate the color equipment (Y = 93.7, x = 0.3132, and y = 0.3192). Five measurements per sample were randomly taken on the surface of pet food by using a digital colourimeter (KONICA MINOLTA, Chroma Meter CR-20, Osaka, Japan) using an illuminate source at a 0° standard observer.

Water activity (a_w)

The water activity of the pet food was measured using a Pawkit water activity meter (Rotronics model no. L1161).

Mineral analysis

Mineral estimation was done by the Di-acid digestion method as per (AOAC 1995), it is the most frequently used procedure for Feed Minerals like Cu, Zn, Fe, Mn, Co, Mg estimations by atomic absorption spectrophotometer by using Air/Acetylene gas.

Amino acid profile

Amino acid analysis of pet food was performed by using the Biocrom amino acid analyser, employing ion exchange chromatography.

In-vitro digestibility

The procedure of *in-vitro* digestibility developed by Biagi et

al. (2016) was employed and slightly modified.

Palatability
A palatability study was conducted over five days, involving ten dogs. During this time, pet owners were provided with pet food to assess and evaluate the dogs' preferences and acceptance of the dog food.

Organoleptic test
The pet food was analysed using sensory evaluation by trained scientists, who assessed the odour, appearance, and colour. The data collected from these evaluations were then compiled for further analysis**.**

Statistical analysis
The data thus obtained were subjected to statistical analysis by using SPSS, Version 27.0.

Results And Discussion

In the present study, the proximate composition of extruded dry pet food indicated that Moisture, crude protein, crude fat, crude fibre, total ash, and carbohydrate were 1.54, 23.8, 8.7, 2.0, 0.98, and 62.98% and ME 3488.4 Kcal/Kg as on a dry matter basis (Table 2). The results obtained were within the standard values recommended by NRC (2006) and AAFCO (2014). The NRC standards (2006) recommended that the dry type of pet food should contain 6-10 percent moisture, 7-20 percent fat, 16-30 percent protein, 41-70 percent carbohydrate, and 2800-4050 kcal/kg ME on a dry matter basis. The AAFCO standards (2014) recommended that the crude protein content of 22.5 percent, Crude fibre 5 percent (maximum), and crude fat 8.5 percent.

Table 2. Proximate composition of extruded dry pet food (Mean ±SE)

Parameters	Value
Moisture (%)	1.54 ± 0.01
Crude protein (%)	23.8 ±0.12
Crude fat (%)	8.7 ±0.11
Crude fibre (%)	2.0 ±0.08
Total ash (%)	0.98 ±0.02
Carbohydrates (%)	62.98 ±0.13
Calories (kcal/100g)	425.42 ±0.11

N= 6

Table 3. Instrumental colour analysis of pet food

Parameter	(Mean±SE)
L* (Lightness)	28.66 ± 0.09
a* (Redness)	8.20 ± 0.05
b* (Yellowness)	17.20 ± 0.03

N= 6

The colour of pet food can significantly influence their appeal to pet owners, even though it might not have a direct connection to their nutritional value or the pets' willingness to accept them. The colour analysis of pet food revealed for lightness, Redness, and yellowness were 28.66, 8.20, 17.20, respectively. Similarly, (Pame et al. 2018) evaluated colour properties of the control and shelf stable pet kibbles by incorporating 20% meat cum bone meal, 5% rendered fat and were assessed objectively in terms of L*, a*, and b* values are 31.60, 6.08, 20.42, respectively. The inclusion of meat cum bone meal, and rendered fat resulted in a substantial drop in redness value (a*). This might be attributed to dilution of meat pigment concentration and lower dispersion of cereal flour mix in the products. The Instrumental colour analysis of pet food is given in Table 3.

Table 4. *In-Vitro* digestibility and water activity of pet food

Parameter	(Mean±SE)
In-Vitro - digestibility (%)	78.24 ± 0.09
Water activity	0.4 ± 0.02

N= 6

The *in-vitro* digestibility of extruded dry pet food was analysed on Day 1 and was 78.24 percent. The results are in accordance with (Castrillo et al. 2001), who studied to evaluate the apparent digestibility of nutrients and energy in 38 different dry commercial extruded dog foods and observed that the apparent digestibility of energy varied from 77.3% to 91.6%. similarly, (Penazzi et al. 2021) studied the *in-vitro* digestibility of extruded pet food containing black soldier fly (BSF). The water activity of pet food was found to be 0.40. These findings are similar to (Baser and Yalcin, 2017) observed mean water activities of 0.41 and 0.44, for dry extruded cat and dog foods. (Scott, 1957) observed that foods with a water activity below 0.65 are unlikely to spoil for as long as one and a half to two years. The In-vitro digestibility and water activity of pet food are given in Table 4.

Table 5. Mineral analysis of pet food (Mean±SE)

Mineral	(Mean ± SE)
Calcium (%)	0.954±0.04
Phosphorus (%)	0.590±0.05
Sodium (%)	0.319±0.01
Potassium (%)	0.242±0.06
Iron(mg/kg)	610±0.04
Zinc(mg/kg)	51±0.0002
Magnesium (%)	0.0046±0.0001
Manganese (mg/kg)	20 ±0.0003

N=6

The mineral analysis of pet food revealed that the calcium, phosphorus, sodium, and potassium were 0.954, 0.590, 0.319,

and 0.242 % respectively. The results of mineral analysis obtained were within the standard values recommended by AAFCO (2014). The AAFCO (2014) recommended that calcium be 0.5 percent, Phosphorus 0.4 percent, sodium 0.3 percent, manganese 7.2 (mg/kg), and iron 88 (mg/kg). The minerals like calcium, phosphorus, zinc, and potassium, all of which are crucial for pets' overall health and well-being. Iron is a crucial mineral for dogs, supporting red blood cell production, preventing anaemia, boosting immune function, enhancing cognitive abilities, promoting muscle health, and aiding energy production. It ensures proper oxygen transport, vitality, and overall well-being. The mineral analysis of pet food is given in Table 5.

Table 6. Amino acid profile of pet food (g/100gm)

Amino acid	(Mean ± SE)
Lysine	0.895 ±0.04
Proline	0.405 ±0.1
Alanine	1.295±0.07
Threonine	0.765±0.04
Glutamic acid	3.455±0.18
Aspartic acid	1.745±0.09
Glycine	1.345±0.08
Tryptophan	0.16±0.009
Methionine	0.17±0.009
phenylalanine	0.91±0.02
Arginine	1.15±0.08
leucine	1.82±0.08
Isoleucine	0.76±0.02
Tyrosine	0.73±0.005

N= 3

The amino acid profile of the pet food contains Lysine, Proline, Alanine, Threonine, Glutamic acid, Aspartic acid, Glycine, Tryptophan, Methionine, Phenylalanine, Arginine, Leucine, Isoleucine, and tyrosine values are 0.895, 0.405, 1.295, 0.765, 3.455, 1.745, 1.345, 0.16, 0.17, 0.91, 1.15, 1.82, 0.76, 0.73 gm/100gm. The results are in accordance with the recommended nutritional requirements for dogs as established by the AAFCO (2014). According to AAFCO, the amino acid requirements, such as Lysine, Threonine, tryptophan, phenylalanine, Arginine, leucine, and isoleucine, were 0.63, 0.48, 0.16, 0.45, 0.51, 0.68, and 0.63 g/100 g for dogs. Phenylalanine and tyrosine offer several key benefits for dogs. These amino acids play a crucial role in the production of pigments like pheomelanins and eumelanin, which contribute to the colour of a dog's hair coat, helping to maintain its natural appearance. Additionally, phenylalanine and tyrosine serve as precursors to neurotransmitters such as dopamine, noradrenaline, and adrenaline, which are essential for cognitive function, mood regulation, and alertness. They also support thyroid function by aiding in the production of thyroid hormones, which regulate metabolism and energy levels, promoting overall health. Furthermore, these amino acids help dogs cope with stress and physical exertion by contributing to the synthesis of norepinephrine and adrenaline, improving their ability to respond to challenges. Glycine is essential for maintaining your dog's physical and mental health, supporting joint function, muscle growth, digestion, and detoxification, while promoting a healthy coat and skin. The amino acid profile of pet food (g/100gm) is given in Table 6.

Table 7. Sensory evaluation and dog palatability of extruded dry pet food (Mean ± SE)

Attribute	Score
General appearance	4.3 ± 0.14
Colour	4.1 ± 0.10
Meat odour intensity	4.3 ± 0.14
Crispness	3.8 ± 0.20
Overall acceptability	4.2 ±0.10
Palatability (dog)	4.0 ±0.24

N = 21

It was observed that the attributes preferred by the owners (colour, odour, crispness) and the palatability of the pet food were well accepted by the dogs. According to (Dust et al. 2005), incorporating animal protein and fat in pet foods enhanced their palatability, improved physical characteristics, and increased owners' preferences. (Trivedi and Benning, 2003) The palatability of dry pet food can be increased with an appropriate preconditioning procedure. The palatability of a product can be enhanced by heating a feed mixture to 95°C before feeding it into an extruder. Similarly, (Karthik et al. 2010) prepared pet food by incorporating dry rendered spent hen meal (SHM) at 10% and 20% levels, and a feeding trial was conducted on different breeds of dogs found that dogs are accepting well. Sensory evaluation and dog palatability of extruded pet food is given in Table 7.

Conclusion

The utilization of poultry byproducts in pet food is a sustainable approach to waste management, promoting a circular economy and significant environmental, economic, and industrial potential. The pet food was well accepted by pet dogs. The findings of the study are important for sustainable pet food production, circular economy and employment generation. The limitation of the present study is the lack of feeding trial data. Future studies are required to evaluate the feeding trials with pet food to assess its nutritional quality.

Competing Interests

The authors do not have any competing interests among themselves, or others related to this research work.

Ethics Statement

Not applicable

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