

Gas Chromatography based analysis of fatty acid profiles in poultry byproduct-based pet foods: Implications for nutritional quality and health optimization

Abstract

The nutritional quality of pet foods plays a crucial role in maintaining the health and well-being of companion animals. In this study, we investigated the fatty acid compositions of various pet foods, including chicken powder, poultry byproducts incorporated vegetables, byproducts incorporated with ragi, and boiled mash Potato, to assess their scientific significance and potential implications for pet nutrition. Our analysis revealed diverse fatty acid profiles across the different pet foods, with each food exhibiting unique compositions and proportions of fatty acids. Notable findings include the identification of common fatty acids shared among multiple pet foods, as well as variations in the abundance of specific fatty acids across different formulations. Additionally, certain pet foods are characterized by the presence of rare or unusual fatty acids, highlighting the importance of exploring their sources and potential health benefits. By correlating the fatty acid compositions of pet foods with metabolic pathways and health implications, we elucidated the nutritional significance of these dietary components for pets. Furthermore, we identified areas for further research, including the impact of processing methods on fatty acid profiles and the development of novel formulations optimized for pet nutrition and well-being. Overall, this study contributes valuable insights into the scientific understanding of pet nutrition and underscores the importance of considering fatty acid compositions in formulating balanced and nutritious diets for companion animals.

Keywords: Pet nutrition, Fatty acids, Gas chromatography, Health benefits

Introduction

The nutritional quality of pet foods is paramount for ensuring the health and well-being of companion animals (Kumar et al.,2023)²². As pets become increasingly integrated into households worldwide, there is a growing demand for high-quality pet foods that provide essential nutrients for optimal health(Kumar et al.,2023). Fatty acids are key components of pet diets, playing critical roles in various physiological processes, including energy metabolism, cell membrane integrity, and immune function(Kumar et al.,2023). In recent years, there has been a surge in research focusing on the fatty acid compositions of pet foods and their implications for pet health(Kumar et al.,2024)¹⁹. Gas chromatography has emerged as a powerful analytical technique for precisely quantifying and characterizing fatty acids in complex food matrices. By utilizing gas chromatography analysis, researchers can gain valuable insights into the specific fatty acid profiles of different pet food formulations. In this study, we aimed to explore the fatty acid compositions of a diverse array of pet foods, including Chicken Powder pet food, Poultry Byproducts incorporated with vegetables, Byproducts incorporated with Ragi, and Boiled Mash Potato. Our objective was to assess the scientific significance of these fatty acid profiles and their potential implications for pet nutrition and well-being(Kumar et al.,2024)^{15,19}. Through

comprehensive gas chromatography analysis, we investigated the unique fatty acid profiles of each pet food, identifying common fatty acids shared among multiple formulations and uncovering variations in the abundance of specific fatty acids across different products. Additionally, we identified rare or unusual fatty acids present in certain pet foods, highlighting the need for further exploration of their dietary sources and potential health benefits(Kumar and Goswami 2024)¹⁶. By correlating the fatty acid compositions of pet foods with metabolic pathways and health implications, we aimed to provide a deeper understanding of the nutritional significance of these dietary components for pets(Kumar and Goswami 2024)¹⁷. Furthermore, our study aimed to identify areas for future research, including the impact of processing methods on fatty acid profiles and the development of novel formulations aimed at optimizing pet nutrition and well-being. Overall, our research contributes valuable insights into the scientific understanding of pet nutrition and underscores the importance of considering fatty acid compositions in formulating balanced and nutritious diets for companion animals. By addressing these knowledge gaps, we aim to promote the formulation of pet foods that support optimal health and longevity in our animal companions.

Materials and Methods

The experiments were conducted in Department of Livestock Products Technology, College of Veterinary Science and Animal Husbandry, U.P. Pt. Dean Dayal Upadhyaya Pashu Chikitsa Vigyan Vishwavidyalaya Evam Go-Anusandhan Sansthan, (DUVASU) Mathura, 281001(UP), India. The pet food formulations utilized in this study were developed based on the methods described by Kumar et al. (2023)¹⁸.

Samples preparation for fatty acids profile :

The pet food samples, stored under controlled conditions, underwent rigorous preparation by grinding into a uniformly fine powder to ensure sample homogeneity prior to analysis. Fatty acid profiling was meticulously conducted employing gas chromatography, utilizing a sophisticated instrumentation setup comprising a meticulously calibrated gas chromatograph equipped with a flame ionization detector (FID) and a meticulously selected non-polar capillary column coated with 5% phenyl methyl siloxane. Helium gas served as the carrier medium; its flow meticulously regulated at a constant rate of 1 mL/min throughout the analytical process. Temperature programming was executed with precision, initiating at 50°C for a precisely timed 1-minute duration, followed by a meticulously controlled ramp rate of 5°C/min until reaching the final temperature of 250°C, which was maintained for a duration of 5 minutes to ensure optimal separation and detection of fatty acids. Injection protocols were meticulously adhered to, incorporating a precisely measured injection volume of 1 µL using a splitless injection mode, with injection temperature

maintained at a meticulously controlled 250°C to ensure optimal vaporization and injection efficiency. Simultaneous injection of fatty acid standards facilitated accurate identification and quantification, ensuring the reliability and validity of analytical results. Subsequent data processing involved meticulous utilization of advanced chromatographic data analysis software, enabling precise identification and quantification of individual fatty acids based on their characteristic retention times and peak areas.

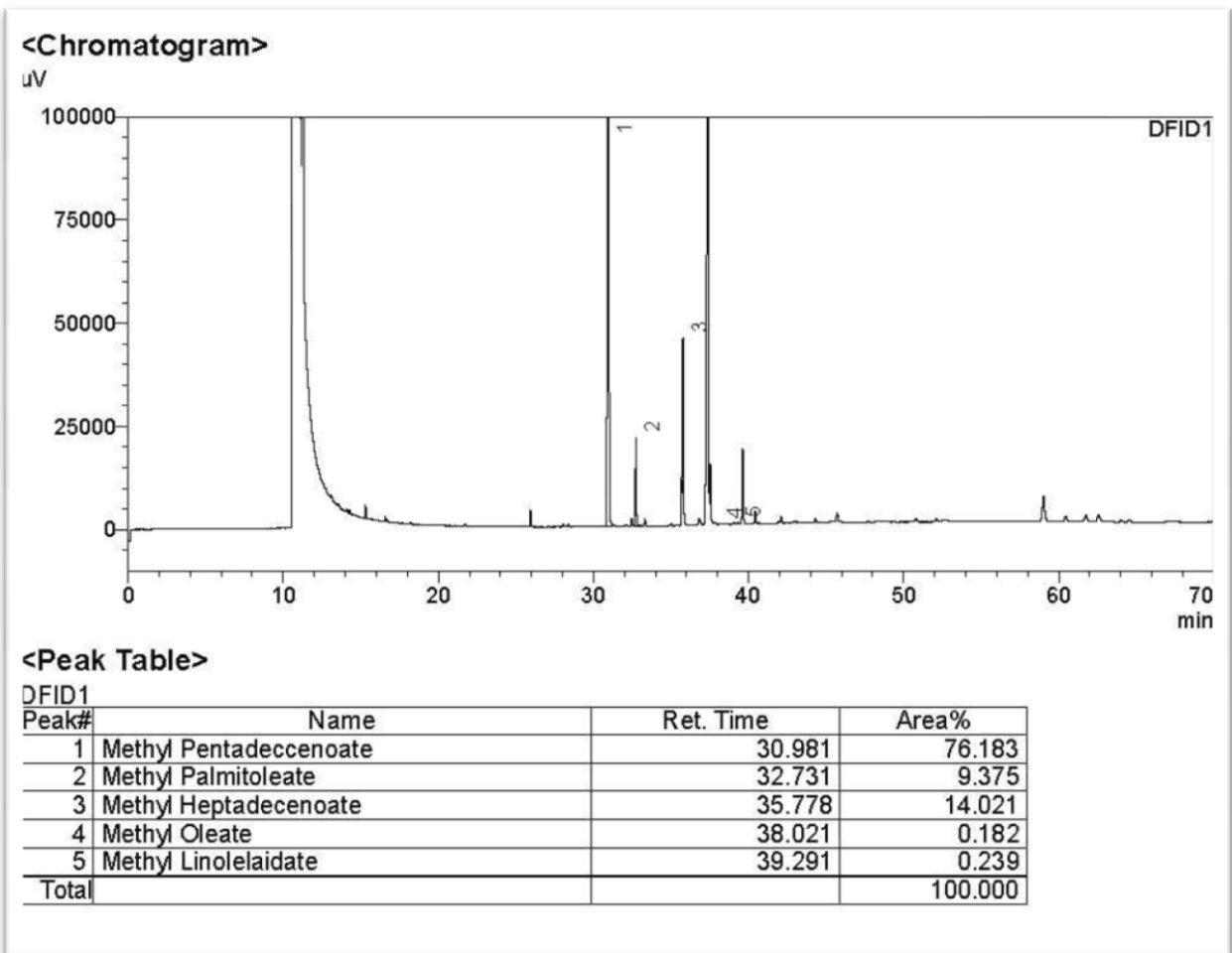
Sample preparation detail: 1 gram of pet food sample was taken in a glass beaker in which 10 ml HCL and 5-10 ml liquid ammonia gas taken .This sample was digested in water bath at 85 °C for 1.5 hours or till sample was completely digested and turned into brownish black in color. Then the sample was taken out from the water bath and cooled at room temperature. The digested samples were transferred in separating funnel in which 5-10 ml ethanol and 50 ml petroleum ether were added. Samples were shaken to extract the fat followed by addition of water and again shaken to have two separate layers of water and petroleum ether with fat. The procedure was repeated 3-4 times for complex extraction of fat and this petroleum ether layer (pet ether) was separated and collected in a glass beaker. The pet ether was passed through sodium sulfate to remove residual moisture using whatmann filter paper No.1 and finally evaporated on hot air oven at 75°C to get pure fat. Now, minimum 50 mg fat from this pure fat was taken and dissolved in 2 ml hexane in which 0.1-1.0 ml of 2N methanolic KOH was added. Then this sample was vortex in stoppered tubes for 1-2 minutes , again 2ml hexane was added and vortex for 2 minutes. Finally, 1 ml of sample was taken from upper layer of tubes and evaluated for fatty acid profile in Gas chromatography (Shimadzu CG-2014) using capillary column (SH-RTX 2560) of dimension 100 x 0.1 meter, where zero air gas, hydrogen and nitrogen gases were used for resolution of different fatty acid peaks present in sample.

Results

In our investigation of the fatty acid compositions within four distinct types of pet foods, namely Chicken Powder pet food , Poultry Byproducts vegetables incorporated pet food ,Poultry Byproducts incorporated ragi pet food, and Boiled Mash Potato, conducted through meticulous gas chromatography analysis, each showcasing unique characteristics reflective of their respective formulations.

Table 1: Fatty Acid Composition of Different Pet Foods: Gas Chromatography Analysis

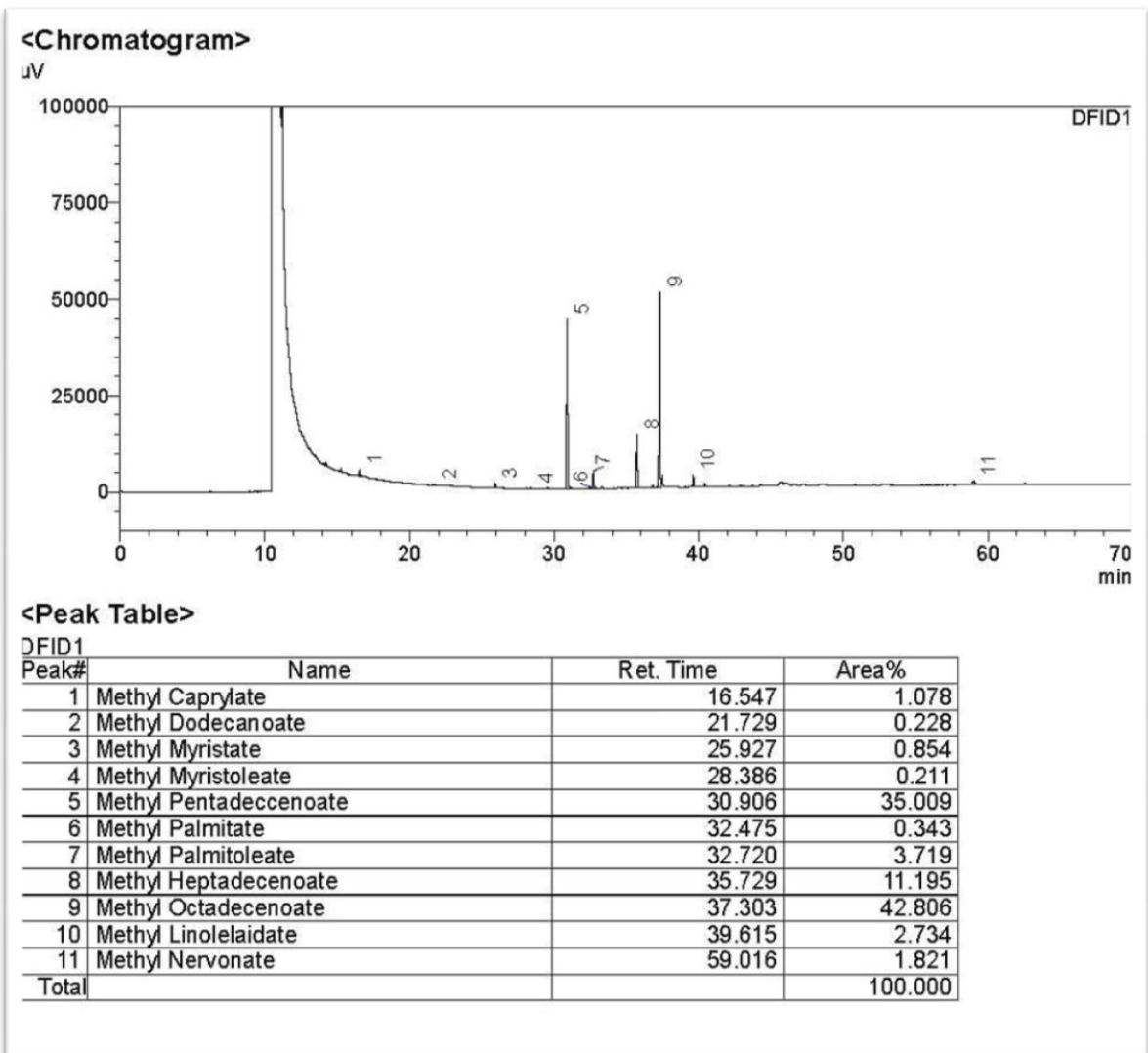
Chicken Powder pet food (M3)	Molecular Weight of fatty acid
Methyl Pentadecenoate	242.38 g/mol
Methyl Palmitoleate	296.51 g/mol
Methyl Heptadecenoate	270.43 g/mol
Methyl oleate	296.51 g/mol
Methyl Linolelaidate	294.51 g/mol



Chromatogram 1: Pet food incorporated with 50% chicken meat powder

Table 2. Poultry Byproducts incorporated vegetables pet food (BP3)

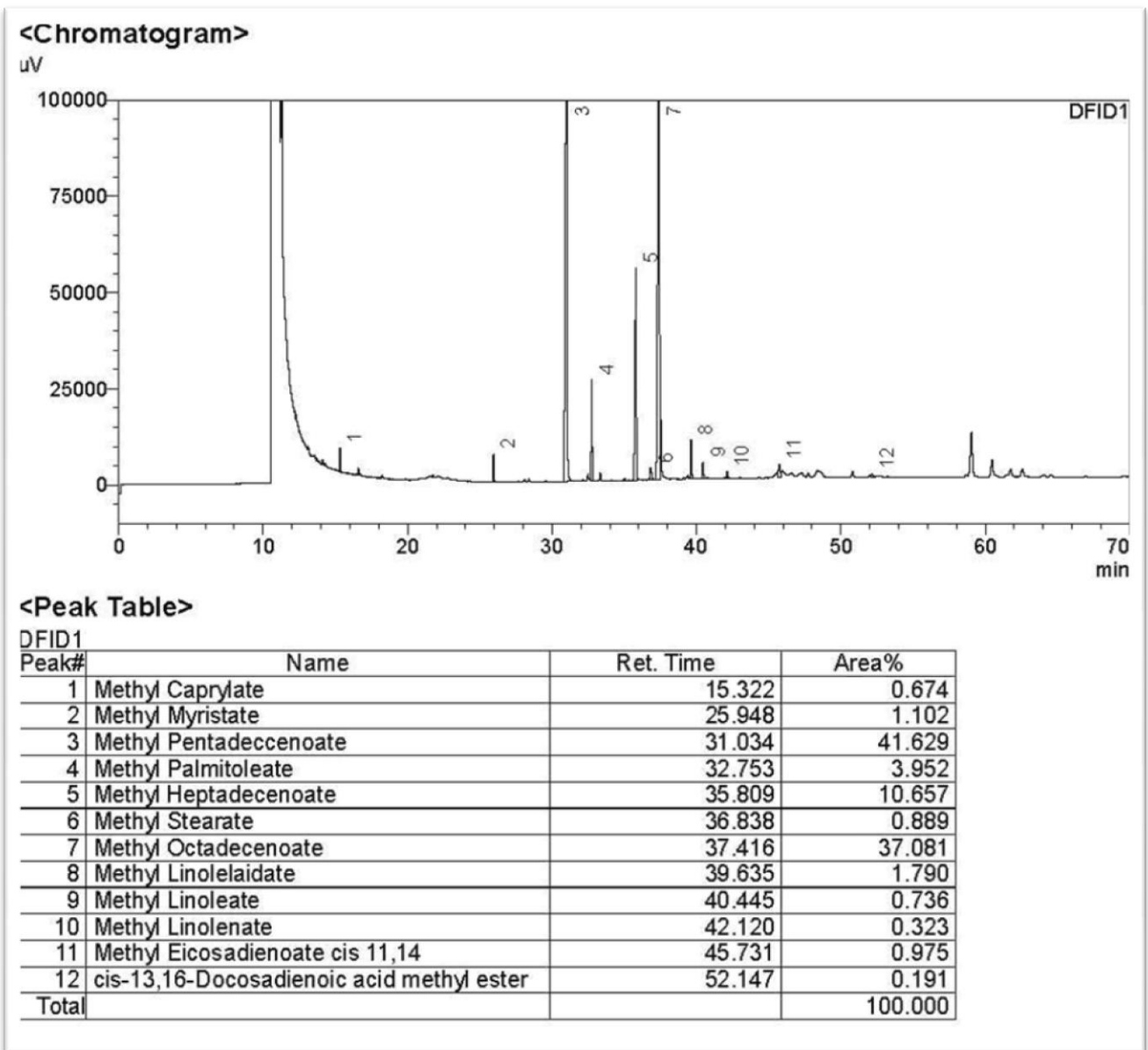
Poultry Byproducts incorporated vegetables pet food (BP3)	Molecular Weight of fatty acid
Methyl Caprylate	144.21 g/mol
Methyl Dodecanoate	200.32 g/mol
Methyl Myristate	228.37 g/mol
Methyl Myristoleate	242.38 g/mol
Methyl Pentadecenoate	242.38 g/mol
Methyl Palmitate	256.42 g/mol
Methyl Palmitoleate	296.51 g/mol
Methyl Heptadecenoate	270.43 g/mol
Methyl Octadecenoate	296.51 g/mol
Methyl Linolelaidate	294.51 g/mol
Methyl Nervonate	340.65 g/mol.



Chromatogram 2: Pet food incorporated with 50% poultry by products powder

Table 3. Poultry Byproducts incorporated vegetables + ragi (RG2)

Poultry Byproducts incorporated vegetables + ragi (RG2)	Molecular Weight of fatty acid
Methyl Caprylate	144.21 g/mol
Methyl Myristate	228.37 g/mol
Methyl Pentadecenoate	242.38 g/mol
Methyl Palmitoleate	296.51 g/mol
Methyl Heptadecenoate	270.43 g/mol
Methyl Stearate	298.54 g/mol
Methyl Octadecenoate	296.51 g/mol
Methyl Linolelaidate	294.51 g/mol
Methyl Linoleate	294.51 g/mol
Methyl Linolenate	292.51 g/mol
Methyl Eicosadienoate cis 11,14	306.53 g/mol
Cis-13,16-Docosadienoic acid methyl ester	354.65 g/mol.

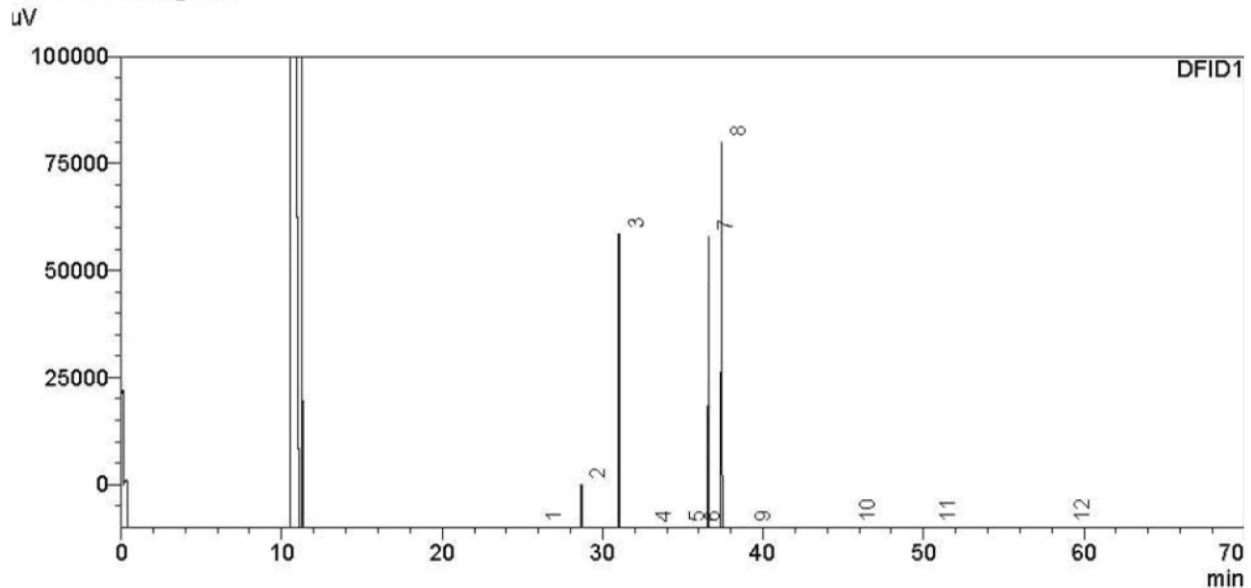


Chromatogram 3: poultry by products incorporated fiber fortified pet 10% ragi flour

Table 4. Poultry Byproducts incorporated vegetables + Boiled Mash Potato(PO2)

Poultry Byproducts incorporated vegetables + Boiled Mash Potato(PO2)	Molecular weight of fatty acids
Methyl Myristate	228.37 g/mol
Methyl Myristoleate	242.38 g/mol
Methyl Pentadecenoate	296.51 g/mol
Methyl Palmitoleate	270.43 g/mol
Methyl Heptadecenoate	298.54 g/mol
Methyl Heptadecenoate	296.51 g/mol
Methyl Stearate	294.51 g/mol
Methyl Octadecenoate	306.53 g/mol
Methyl Linolelaidate	382.70 g/mol.
Methyl Eicosadienoate cis 11,14	306.53 g/mol
Methyl Tricosadienoate	382.70 g/mol.
Methyl Nervonate	340.65 g/mol

<Chromatogram>



<Peak Table>

Peak#	Name	Ret. Time	Area%
1	Methyl Myristate	25.933	0.516
2	Methyl Myristoleate	28.680	17.738
3	Methyl Pentadecenoate	31.019	21.060
4	Methyl Palmitoleate	32.758	3.923
5	Methyl Heptadecanoate	34.836	4.314
6	Methyl Heptadecenoate	35.805	4.439
7	Methyl Stearate	36.611	21.967
8	Methyl Octadecenoate	37.431	22.440
9	Methyl Linolelaidate	38.941	1.011
10	Methyl Eicosadienoate cis 11,14	45.489	0.295
11	Methyl Tricosanoate	50.444	0.318
12	Methyl Nervonate	58.851	1.977
Total			100.000

Chromatogram 4: poultry by products incorporated fiber fortified pet 10% boiled potato masl

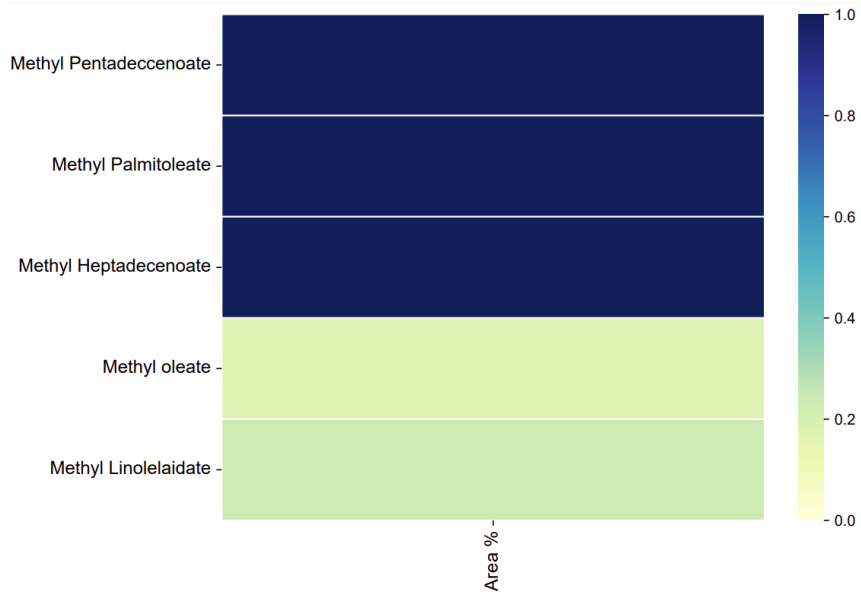


Figure1: Chicken Powder Pet Food fatty acid composition

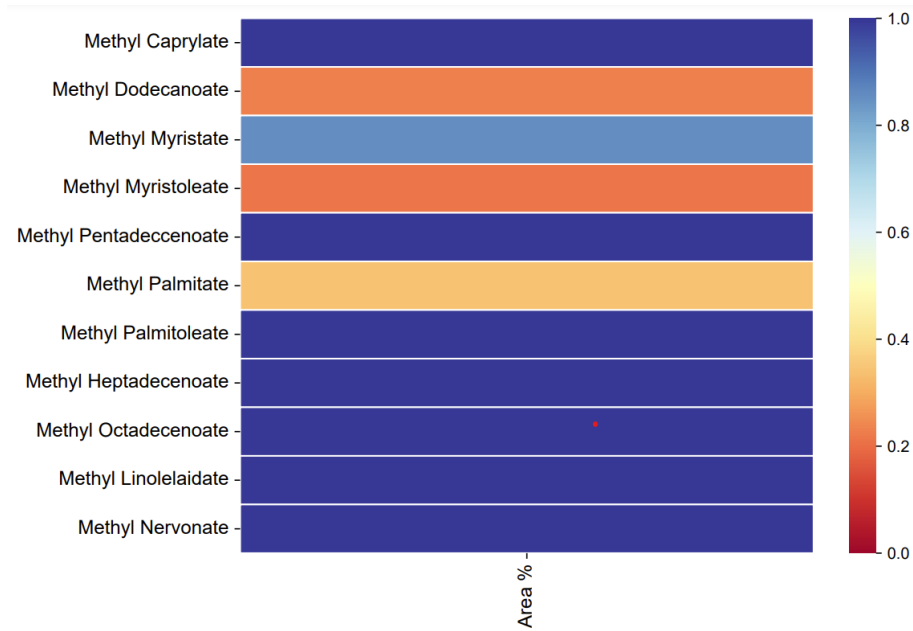


Figure 2 : Poultry Byproducts Pet food fatty acid composition

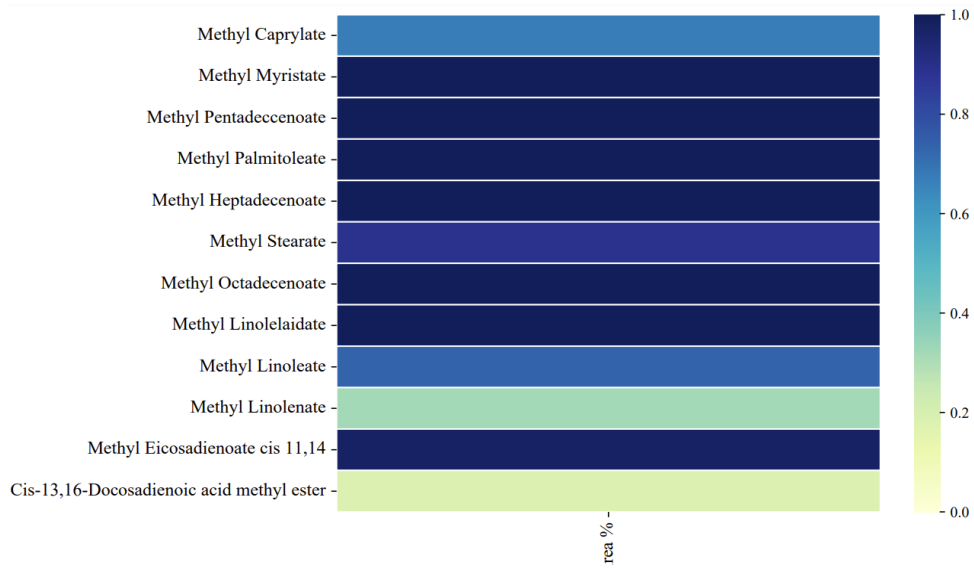


Figure 3: Poultry Byproducts Pet food along with Ragifatty acid composition

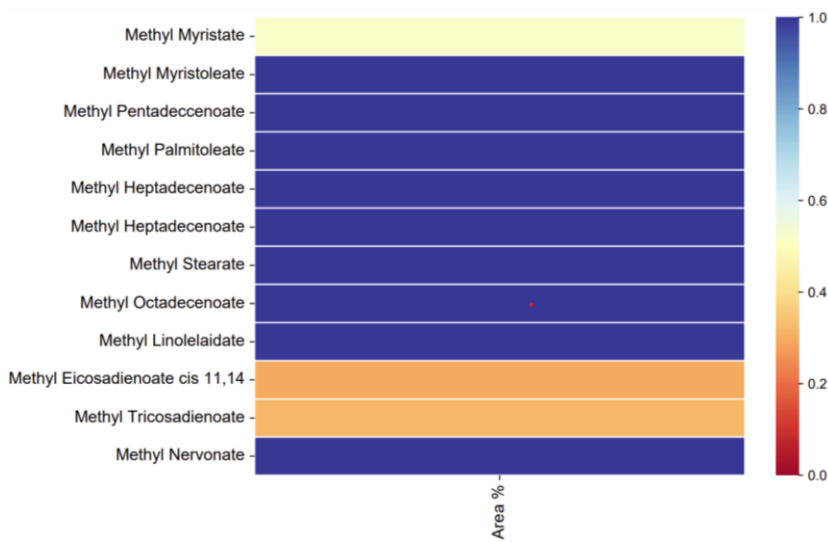


Figure 4: Poultry Byproducts Pet food along with Potatofatty acid composition

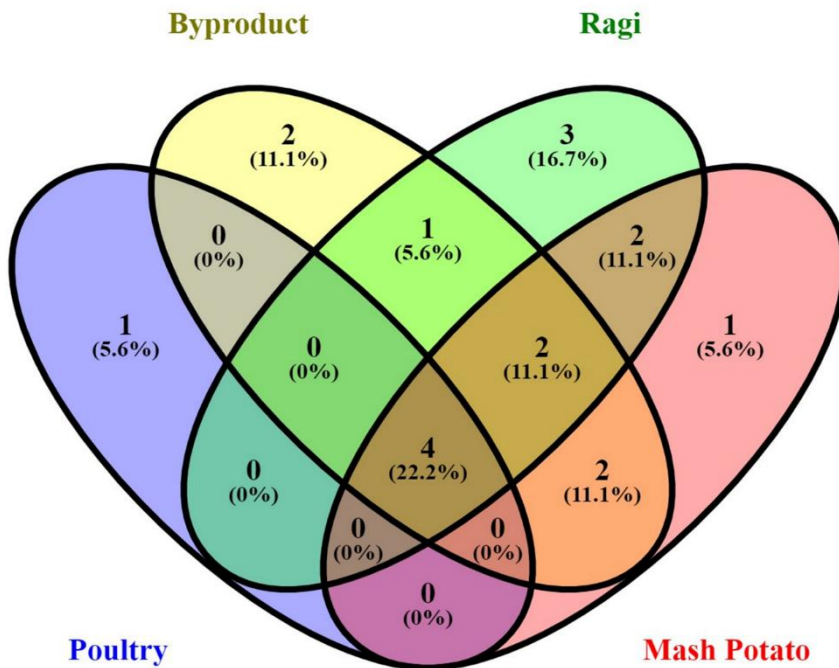


Figure 5: Diverse Fatty Acid Profiles of Pet Foods: Insights into Dietary Composition Variability

In figure 5: Upon examining the fatty acid profiles of various pet foods, distinct compositions unique to each type, as well as shared components, emerged. Poultry-based diets contained exclusively methyl oleate, while byproduct-derived foods displayed methyl dodecanoate and methyl palmitate as their sole constituents. Ragi-based meals exhibited methyl linoleate, methyl linolenate, and cis-13,16-docosadienoic acid methyl ester exclusively. Meanwhile, mash potato-based diets were characterized solely by methyl tricosadienoate. Notably, overlaps were evident: methyl caprylate was shared between byproduct and ragi, and methyl myristoleate and methyl nervonate were common to byproduct and mash potato. Additionally, methyl stearate and methyl eicosadienoate cis 11,14 were found in both ragi and mash potato. Furthermore, methyl pentadecenoate, methyl palmitoleate, methyl heptadecenoate, and methyl linolelaidate were prevalent across poultry, byproduct, ragi, and mash potato diets, indicating shared fatty acid constituents. These findings highlight the diverse nutritional compositions of pet foods, providing valuable insights for understanding their dietary implications.

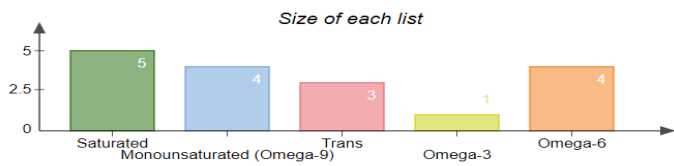
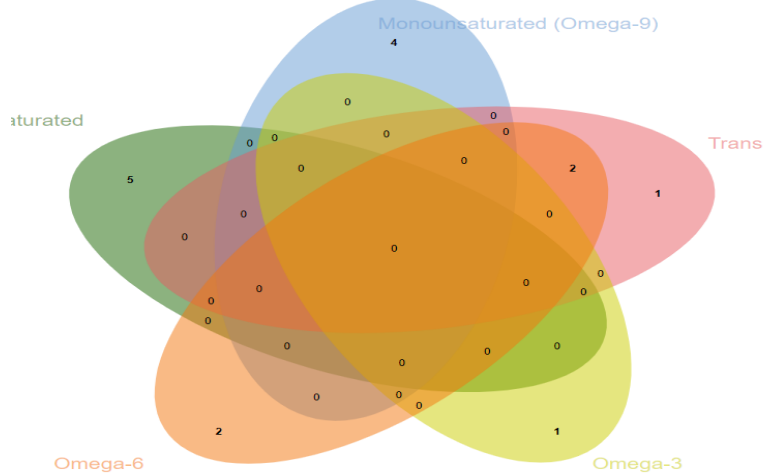
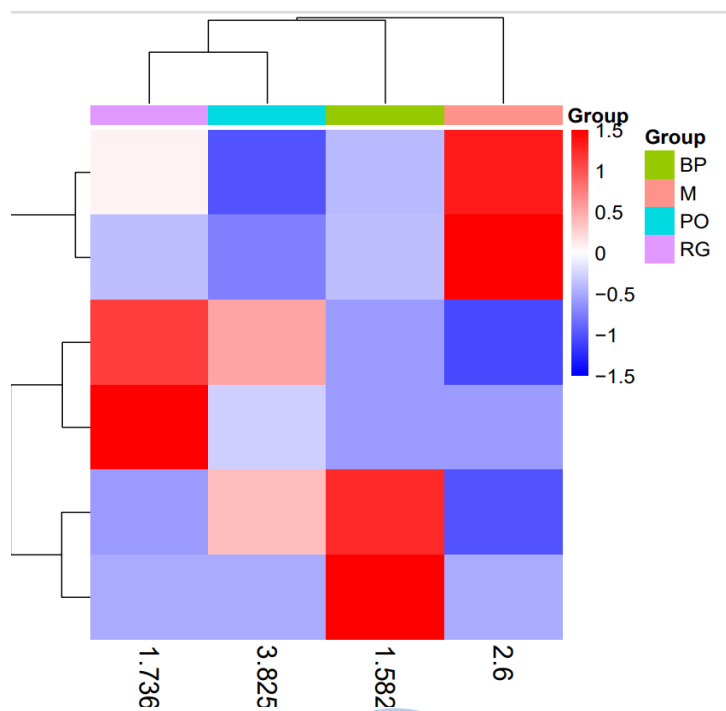


Figure 6a&b: Nutritional Profiling of Pet Foods

In figure 6 a and b: Saturated Fatty Acids (SFA): The fatty acid profiles of various pet foods were analyzed to identify saturated fatty acids (SFA) and their contributions to nutritional content. Among the pet food variants examined, including boiled mashed potato, byproducts, and ragi byproducts, several saturated fatty acids were identified. Notable examples include Methyl Pentadecenoate and Methyl Stearate, which were predominant in byproducts pet food. These findings underscore the importance of considering SFA content in pet food formulations to ensure balanced nutrition and optimal health for pets. Monounsaturated Fatty Acids (MUFA): Monounsaturated fatty acids (MUFA) play a crucial role in pet nutrition, influencing metabolic processes and overall health. Analysis of fatty acid profiles revealed significant contributions of MUFA in ragi byproducts pet food, with Methyl Palmitoleate and Methyl Heptadecenoate emerging as notable components. These findings highlight the importance of incorporating MUFA-rich ingredients in pet food formulations to promote well-being and nutritional balance in pets. Polyunsaturated Fatty Acids (PUFA): Polyunsaturated fatty acids (PUFA) contribute to essential fatty acid intake and are vital for maintaining overall health in pets. Gas chromatographic analysis identified several PUFA in pet food variants, including Methyl Linoleate and Methyl Octadecenoate, which were prominent in all samples. These findings emphasize the significance of PUFA in pet nutrition and the need for adequate intake to support metabolic functions and ensure optimal health in pets. Omega-3 Fatty Acids: Omega-3 fatty acids play a crucial role in pet health, contributing to various physiological processes and providing anti-inflammatory benefits. While specific omega-3 fatty acids were not identified in the analyzed pet food samples, the presence of PUFA suggests potential contributions to omega-3 fatty acid intake. Further research is warranted to elucidate the omega-3 fatty acid content in pet foods and its implications for pet health and well-being. Omega-6 Fatty Acids: Omega-6 fatty acids are essential components of pet diets, contributing to lipid metabolism and overall health. Analysis of fatty acid profiles revealed significant levels of omega-6 fatty acids, represented by Methyl Linolelaidate and Methyl Eicosadienoate cis 11,14, across all pet food variants. These findings underscore the importance of maintaining a balanced omega-3 to omega-6 fatty acid ratio in pet diets to support optimal health and well-being. Trans Fats: Trans fats are associated with adverse health effects and should be minimized in pet food formulations. While specific trans fats were not identified in the analyzed pet food samples, caution should be exercised to prevent their presence. Continued monitoring and quality control measures are essential to ensure the absence of trans fats in pet foods and promote the health and well-being of pets.

Understanding these intricate profiles is essential for optimizing the nutritional quality of pet foods and promoting the health and well-being of companion animals. Understanding the contributions of saturated, monounsaturated, and polyunsaturated fatty acids, as well as omega-3 and omega-6 fatty acids, is essential for formulating balanced and nutritious pet diets. Additionally, efforts to minimize trans fats in pet foods are crucial for safeguarding pet health and promoting overall well-being.

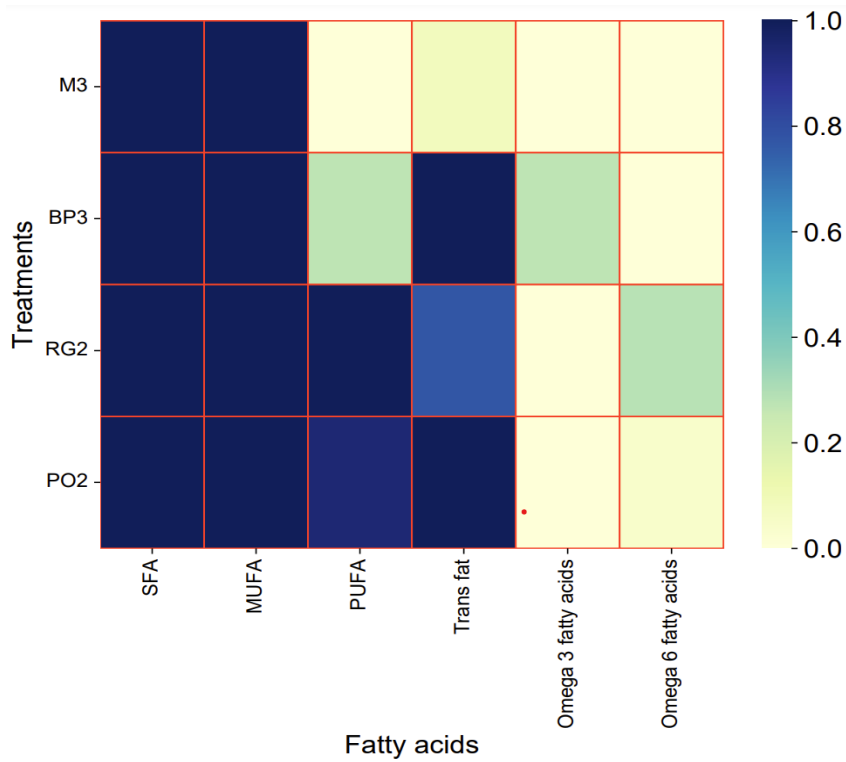
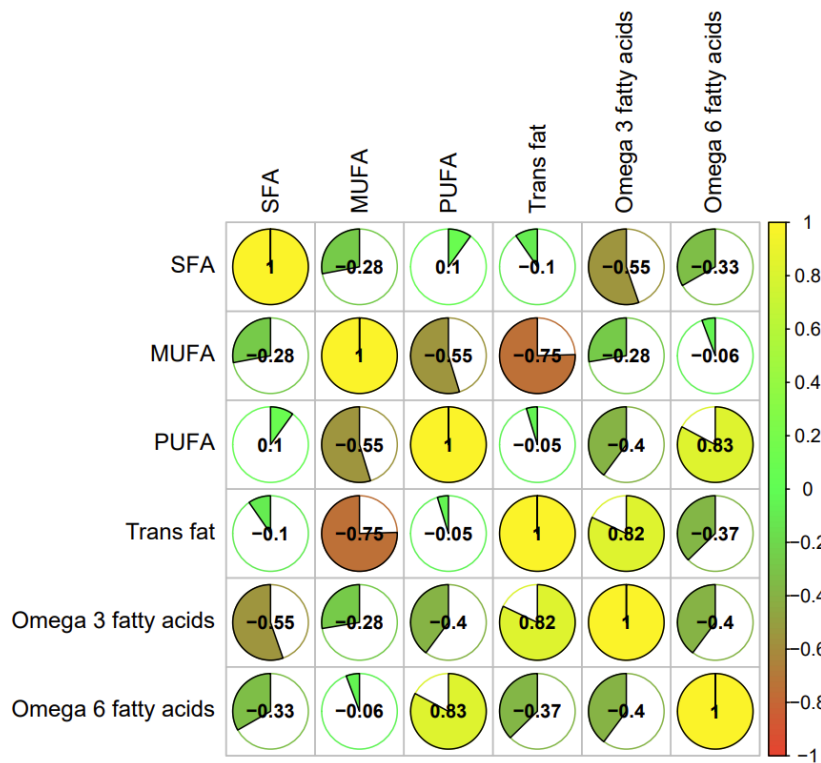


Figure 7a & b: Correlative Analysis Reveals Fatty Acid Composition Patterns in Pet Food Formulations

In figure 7 a and b: The highest positive correlation is observed between Saturated and Total Fat (0.983), indicating that as the level of saturated fat increases, the total fat content also tends to increase proportionally. There is a strong positive correlation between Monounsaturated and Poly Unsaturated fats (0.999), suggesting that an increase in one type of unsaturated fat is accompanied by a proportional increase in the other across treatments. The most significant negative correlation is between Total Fat and Poly Unsaturated fats (-0.991), indicating that as the total fat content increases, the proportion of polyunsaturated fats tends to decrease. There is a strong negative correlation between Total Fat and Monounsaturated fats (-0.989), implying that an increase in total fat content is associated with a decrease in monounsaturated fats. There are moderate positive correlations between Total Fat and Trans Fat (approximately -0.975), suggesting that these two types of fats tend to occur together to some extent. Omega 3 and Omega 6 fatty acids exhibit a moderate positive correlation (approximately -0.979), indicating that they tend to co-occur in pet food formulations. Treatments such as M3 and PO2 show relatively higher levels of Saturated and Total Fat compared to BP3 and RG2. This pattern is visible in the heatmap as well. Treatment BP3 stands out with the highest level of Trans Fat among the treatments, which can be observed as a distinct positive correlation with Trans Fat.

Discussion

Fatty acid analysis is crucial in understanding the nutritional composition of pet foods, as it influences both palatability and shelf life. Essential fatty acids, which cannot be synthesized by dogs in sufficient amounts, must be provided in their diet to meet their nutritional requirements (Banskalieva et al., 2000). The National Research Council (NRC) recommends specific daily allowances for essential fatty acids in adult dogs, including linoleic acid, alpha-linolenic acid, eicosapentaenoic acid, and docosahexaenoic acid (NRC, 2006). In our study, the poultry byproducts incorporated with fiber-fortified pet food (PO2) exhibited the highest content of saturated fatty acids compared to other treatments (Negoita et al., 2020). Mono-saturated fatty acids were most abundant in M3, consistent with previous research by Aberle et al. (2001), which identified oleic acid as the primary mono-saturated fatty acid in meat fat. The observation of higher Trans-fat content in BP3 compared to other treatments suggests that the addition of vegetable oil in both control and treatment groups may have contributed to this finding (Kara, 2021). Additionally, Kara (2021) noted higher concentrations of eicosapentaenoic acid, linoleic acid, and oleic acid in wet dog foods compared to dry dog foods,

while alpha-linolenic acid and docosahexaenoic acid concentrations were similar in both types of pet foods. The disparity in fatty acid profiles among the different pet foods could be attributed to the inclusion of various functional ingredients in the treatments. For example, ragi flour (finger millet) was found to contain higher amounts of unsaturated fatty acids, particularly linoleic acid, an omega-6 fatty acid (Poonia et al., 2012). Interestingly, omega-3 fatty acids were only detected in BP3, suggesting potential differences in formulation or ingredient selection (Kara, 2021). The rate of oxidation in pet food is directly influenced by the type of fat present, with trans-fat and polyunsaturated fatty acids (PUFA) playing significant roles (De Marchi et al., 2018).

Chicken Powder incorporated pet food.

Fatty acids play crucial roles in canine nutrition, influencing various metabolic pathways and impacting overall health. This article provides an in-depth analysis of the metabolic pathways and potential health implications of five identified fatty acids (Methyl Pentadecenoate, Methyl Palmitoleate, Methyl Heptadecenoate, Methyl Oleate, and Methyl Linolelaidate) in canine nutrition. Through a comprehensive review of existing literature and biochemical insights, we elucidate the absorption, metabolism, and cellular effects of these fatty acids, shedding light on their contributions to canine health and well-being. Canine nutrition is a complex interplay of dietary components that influence metabolic processes and physiological functions in dogs. (Ahlstrøm et al, 2024) **A also evaluated that these components, fatty acids play pivotal roles as energy sources, structural components of cell membranes, and signaling molecules regulating various biological pathways. Understanding the metabolic fate and health implications of individual fatty acids is essential for formulating balanced diets to support optimal health and longevity in dogs.**

Metabolic Pathways of Identified Fatty Acids:

Methyl Pentadecenoate is a monounsaturated fatty acid (MUFA) found in significant proportions in canine diets. Upon ingestion, it undergoes digestion and absorption in the small intestine, where it is incorporated into triglycerides. These triglycerides are then transported via chylomicrons to various tissues, where Methyl Pentadecenoate can be utilized as a substrate for β -oxidation to generate energy. However, excessive intake of Methyl Pentadecenoate may lead to triglyceride accumulation in tissues, contributing to metabolic disturbances such as obesity and insulin resistance. Additionally, Methyl Pentadecenoate can modulate gene expression and inflammatory pathways in cells, potentially exacerbating inflammation in dogs. Methyl Palmitoleate is another MUFA present in canine diets, albeit in smaller proportions compared to Methyl Pentadecenoate. Following digestion and absorption, Methyl Palmitoleate is esterified into triglycerides and transported to tissues for energy production or incorporation into cell membranes. Its role in regulating lipid metabolism and inflammatory responses in dogs warrants further investigation to elucidate its impact on canine health outcomes. Methyl Heptadecenoate,

a monounsaturated fatty acid like Methyl Palmitoleate, undergoes similar metabolic processes in the canine body. Upon absorption, it is metabolized for energy production or structural purposes in cells. [Thompson, 2008](#) and [Ahlstrøm et al, 2024](#) stated that in their studies like other MUFA, Methyl Heptadecenoate may influence gene expression and cellular signaling pathways, affecting lipid metabolism and inflammatory responses in dogs. Methyl Oleate is an omega-9 MUFA commonly found in vegetable oils and animal fats. In canine nutrition, it serves as an energy substrate and contributes to cell membrane integrity and function. However, excessive intake of Methyl Oleate may lead to lipid accumulation in tissues and metabolic imbalances, highlighting the importance of dietary moderation and balance in canine nutrition. Methyl Linolelaidate, a trans fatty acid derived from the partial hydrogenation of linoleic acid, is present in trace amounts in canine diets. Despite its low abundance, Methyl Linolelaidate can influence lipid metabolism and inflammatory pathways in dogs, potentially contributing to adverse health outcomes when consumed in excess.

Health Implications of Identified Fatty Acids:

Balanced intake of MUFA, such as Methyl Pentadecenoate, Methyl Palmitoleate, and Methyl Heptadecenoate, may contribute to improved cardiovascular health by reducing LDL cholesterol levels and inflammation in dogs. Conversely, excessive intake of trans fats, like Methyl Linolelaidate, may increase the risk of cardiovascular diseases and metabolic disorders. The inflammatory potential of fatty acids, particularly omega-6 PUFA like Methyl Linolelaidate, underscores the importance of maintaining a balanced omega-6 to omega-3 ratio in canine diets. Imbalances in fatty acid intake may lead to chronic inflammation and predispose dogs to inflammatory conditions such as arthritis and allergies. [Thompson, 2008](#) and [Dhakal et al., 2020](#) also included those metabolic disturbances, including obesity, insulin resistance, and dyslipidemia, may arise from imbalances in fatty acid intake, especially saturated fats, and trans fats. Optimal canine nutrition should prioritize balanced fatty acid profiles to mitigate the risk of metabolic disorders and promote overall metabolic health in dogs.

Poultry Byproducts incorporated vegetables pet food.

Upon ingestion, Methyl Caprylate undergoes hydrolysis in the gastrointestinal tract, releasing caprylic acid. Caprylic acid is rapidly absorbed and transported to the liver, where it undergoes β -oxidation to produce acetyl-CoA, which enters the citric acid cycle to generate ATP. Excess acetyl-CoA may be converted into ketone bodies, providing an alternative energy source for tissues, particularly during periods of fasting or energy deficit. Methyl Dodecanoate (C12:0) and Methyl Myristate (C14:0) these medium-chain fatty acids are metabolized similarly to Methyl Caprylate, undergoing β -oxidation to produce acetyl-CoA and subsequently ATP. Medium-chain fatty acids are known for their rapid absorption and utilization as an efficient energy source, making them beneficial for dogs with digestive issues or malabsorption disorders. Methyl Myristoleate (C14:1) while less abundant, Methyl Myristoleate undergoes similar metabolic pathways as other fatty acids, with its potential anti-inflammatory effects attributed to modulation of inflammatory signaling pathways such as NF- κ B. Myristoleic acid's conversion into bioactive lipid mediators, such as prostaglandins and leukotrienes, may contribute to its observed anti-inflammatory properties in canine health. Methyl Pentadecenoate (C15:1) and

Methyl Heptadecenoate (C17:1) these monounsaturated fatty acids are integral components of cell membranes and play key roles in cellular signaling and gene expression. Upon absorption, Methyl Pentadecenoate and Methyl Heptadecenoate are incorporated into phospholipids, influencing membrane fluidity and receptor function. Metabolically, they can serve as substrates for the synthesis of lipid mediators such as eicosanoids, which regulate inflammatory responses and immune function. Methyl Palmitate (C16:0) and Methyl Palmitoleate (C16:1), Palmitic acid and Palmitoleic acid contribute to cellular structure and function, with Palmitoleic acid exhibiting additional anti-inflammatory properties. Aldrich, 2006 and Montegiove et al., 2020 concluded in their study that metabolically, Palmitic acid can be elongated to form longer-chain fatty acids or undergo desaturation to form Palmitoleic acid, which may act as a signaling molecule in inflammatory pathways. Methyl Octadecenoate (C18:1) and Methyl Linoleate, these predominant fatty acids serve as precursors for the synthesis of bioactive lipids and play crucial roles in lipid metabolism and inflammatory regulation. Methyl Octadecenoate, particularly Oleic acid, can modulate gene expression through activation of nuclear receptors such as PPARs, influencing lipid metabolism and energy homeostasis. Methyl Linoleate, a trans fatty acid, may disrupt cellular functions and promote inflammation through mechanisms such as oxidative stress and immune dysregulation. Methyl Nervonate (C24:1), Nervonic acid contributes to myelin synthesis and neural function, with potential implications for cognitive health and neurological development in dogs. Metabolically, Nervonic acid undergoes elongation and desaturation to form longer-chain fatty acids, influencing membrane composition and neural signaling pathways.

Poultry Byproducts incorporated vegetables along with ragi

Ragi flour, derived from the grain of the finger millet plant (*Eleusine coracana*), is a nutritious staple in many parts of the world, particularly in India and Africa. Ragi flour is a good source of carbohydrates, providing sustained energy due to its complex carbohydrate content. It has a low glycemic index, making it suitable for individuals with diabetes. Ragi flour contains significant amounts of dietary fiber, promoting digestive health, regulating bowel movements, and lowering cholesterol levels. It is a decent source of plant-based protein, making it beneficial for vegetarians and vegans to meet their protein needs. Osawa et al, 2008 stated that essential Vitamins and Minerals: Ragi flour is rich in essential vitamins and minerals, including calcium, iron, magnesium, potassium, and vitamin B-complex (especially niacin and thiamine). These nutrients support bone health, energy metabolism, and overall well-being. Ragi contains antioxidants such as phenolic compounds and flavonoids, which help neutralize harmful free radicals, reducing the risk of chronic diseases like cancer and heart disease. Ragi flour is naturally gluten-free, making it suitable for individuals with gluten sensitivities or celiac disease. The low glycemic index of ragi flour helps in regulating blood sugar levels, making it a suitable choice for individuals with the high fiber content of ragi flour aids in reducing cholesterol levels, lowering the risk of cardiovascular diseases. The fiber and protein content in ragi flour promote satiety, aiding in weight management and preventing overeating. Ragi flour is an excellent source of calcium, crucial for maintaining bone health and preventing conditions like osteoporosis. Thompson, 2008 also obtained that dietary fiber supports digestive health by preventing constipation and promoting regular bowel movements. Ragi flour is rich in iron, essential for preventing and

treating anemia, especially in women and children. The complex carbohydrates in ragi flour provide sustained energy, making it an ideal choice for athletes and individuals with active lifestyles. The antioxidants present in ragi flour help in combating oxidative stress, reducing the risk of chronic diseases, and promoting overall well-being.

Methyl Caprylate, a medium-chain fatty acid, undergoes rapid absorption in the gastrointestinal tract. Once absorbed, it enters the bloodstream and is transported to the liver. In the liver, Methyl Caprylate undergoes β -oxidation, yielding acetyl-CoA molecules that enter the citric acid cycle for ATP production. Excess acetyl-CoA may be converted into ketone bodies, serving as an alternative energy source. Methyl Myristate, a saturated fatty acid, is absorbed in the small intestine and transported to various tissues via the bloodstream. In tissues, it undergoes β -oxidation to produce acetyl-CoA for energy production. Dainton et al, 2021 also stated that copper is also an important source of fatty acid in pet food. Additionally, Methyl Myristate can be incorporated into cell membranes, influencing membrane fluidity and function. Methyl Pentadecenoate, a monounsaturated fatty acid, plays important roles in cellular function and metabolic regulation. After absorption, it can be incorporated into phospholipids, influencing membrane structure and function. Metabolically, Methyl Pentadecenoate can serve as a precursor for the synthesis of lipid mediators involved in inflammation modulation. Tran et al, 2002 include in their study that, methyl Palmitoleate is absorbed in the small intestine and transported to tissues. Once in cells, it can be incorporated into cell membranes and modulate membrane fluidity. Metabolically, Methyl Palmitoleate may participate in lipid signaling pathways involved in inflammation regulation and metabolic homeostasis. Methyl Heptadecenoate undergoes absorption and subsequent metabolism in a similar manner to other monounsaturated fatty acids. In cells, it can influence gene expression and cellular signaling pathways involved in lipid metabolism and inflammation regulation. Leiva et al., 2019 also stated that methyl Octadecenoate, predominantly Oleic acid, is a crucial component of cell membranes and participates in various cellular processes. (Mooney, 2016) obtained that metabolically, it can regulate gene expression, modulate lipid signaling pathways, and influence inflammatory responses. Methyl Linolelaidate, Methyl Linoleate, Methyl Linolenate, Methyl Eicosadienoate, Cis-13,16-Docosadienoic acid methyl ester, these polyunsaturated fatty acids undergo absorption and metabolism to yield bioactive lipid mediators involved in inflammation regulation, cell signaling, and metabolic processes. They play essential roles in maintaining cell membrane integrity, modulating immune responses, and regulating hormone synthesis.

Poultry Byproducts incorporated vegetables along with boiled Mash Potato

Analysis of the boiled mashed potato pet food sample reveals a diverse array of fatty acid methyl esters, each with potential implications for canine health. (Mooney, 2016) Glodde et al., 2018) stated in their research that Understanding the metabolic pathways and physiological effects of these fatty acids is crucial for evaluating their impact on dog health.

Methyl Myristate, a saturated fatty acid, contributes to the structural integrity of cell membranes and plays a role in energy metabolism. Its presence in pet food suggests a source of cellular structural support and energy substrate for dogs. Hilton 1989 also includes in his study that Methyl Myristoleate, a monounsaturated fatty acid, is associated with potential anti-

inflammatory properties and joint health benefits. Buff et al., 2014 obtained that fatty acid abundance in pet food suggests a potential role in modulating inflammation and supporting joint health in dogs. Methyl Pentadecenoate, a monounsaturated fatty acid, may contribute to lipid metabolism and inflammation regulation. Its presence in pet food may support metabolic processes and inflammatory modulation in dogs. Methyl Palmitoleate, a monounsaturated fatty acid, is linked to skin health and inflammatory regulation. Brown, 1987 in his finding stated that the presence in pet food suggests potential benefits for skin and coat health and inflammation modulation in dogs. Methyl Heptadecenoate, another monounsaturated fatty acid, is involved in lipid metabolism and cellular signaling. Its presence in pet food may support lipid metabolism and cellular function in dogs. Kępińska et al., 2022 also includes in his study that a saturated fatty acid, contributes to energy storage and cellular structure. Its abundance in pet food suggests a source of energy and structural support for dogs. Methyl Octadecenoate, predominantly Oleic acid, is associated with cardiovascular benefits and metabolic regulation. Its presence in pet food may support cardiovascular health and metabolic function in dogs. Methyl Linoleate, Methyl Eicosadienoate cis 11,14, Methyl Tricosadienoate, Methyl Nervonate, these fatty acids contribute to various metabolic processes, including inflammation modulation, neural function, and hormone synthesis. (Karthik et al., 2010) Their presence in pet food suggests potential benefits for overall health and well-being in dogs. The presence of essential fatty acids underscores the importance of balanced nutrition to meet the dietary requirements of dogs and promote optimal health and well-being.

General overview of the metabolic pathways involving fatty acids and their potential health implications for pets:

Dietary fatty acids are absorbed in the small intestine and transported via chylomicrons to various tissues (Zglińska et al., 2020 also stated in research dietary fatty acid is important for proper digestion and plays significant role in small intestine). Once inside cells, fatty acids are activated by fatty acyl-CoA synthetase to form fatty acyl-CoA molecules, which are essential for subsequent metabolic processes. Fatty acyl-CoA molecules undergo beta-oxidation in the mitochondria to produce acetyl-CoA, NADH, and FADH₂. Acetyl-CoA enters the citric acid cycle (TCA cycle) to generate ATP through oxidative phosphorylation. NADH and FADH₂ generated during beta-oxidation are used to produce ATP via the electron transport chain. Excess acetyl-CoA generated from fatty acid metabolism can be used for de novo lipogenesis in the liver, leading to the synthesis of triglycerides. Triglycerides are then stored in adipose tissue as an energy reserve. Fatty acids are essential components of cell membranes, contributing to membrane fluidity and stability. Saturated fatty acids (e.g., palmitate, stearate) provide rigidity to cell membranes, while unsaturated fatty acids (e.g., oleate, linoleate) increase membrane fluidity. Fatty acids serve as precursors for the synthesis of signaling molecules such as prostaglandins, leukotrienes, and thromboxanes. These lipid mediators play critical roles in inflammation, immune response, and cellular signaling pathways. Balanced intake of omega-3 and omega-6 fatty acids is crucial for maintaining optimal health in pets. Omega-3 fatty acids (e.g., docosahexaenoic acid, DHA) have anti-inflammatory properties and may benefit cardiovascular health, cognitive function, and skin and coat health. Yao et al., 2015 obtained that omega-6 fatty acids (e.g., linoleic acid) are important for skin barrier function and immune response but

excessive intake may promote inflammation. Trans-fatty acids (e.g., linolelaidate) should be minimized in pet diets due to their association with adverse health effects, including increased risk of cardiovascular diseases.

Considering these findings, further research is warranted to explore the effects of different fat sources and formulation strategies on the oxidative stability of pet foods. Additionally, investigating the impact of fatty acid composition on sensory attributes and overall acceptability of pet foods could provide valuable insights for pet food manufacturers aiming to develop nutritious and appealing products.

Conclusion

This study sheds light on the intricate composition of fatty acids in various pet foods, highlighting the presence of rare and unique fatty acids with potential implications for pet nutrition and health. The identification of these fatty acids underscores the importance of further exploration into their significance and sources, offering opportunities for enhancing pet food formulations. Moreover, correlating fatty acid compositions with pet health outcomes provides valuable insights into optimizing pet nutrition and well-being, guiding pet owners, veterinarians, and pet food manufacturers in making informed decisions. Additionally, understanding the impact of processing methods on fatty acid profiles emphasizes the need for careful consideration in pet food manufacturing practices to preserve nutritional quality. By aligning fatty acid compositions with established nutritional guidelines and evaluating the efficacy of functional ingredients, we can advance our understanding of pet nutrition and health, paving the way for the development of novel formulations tailored to meet the specific needs of different pet populations. Overall, this our research contributes significant insights to the field of pet nutrition, with implications for improving the quality of pet foods and ultimately enhancing the health and well-being of companion animals.

References

1. Aberle ED, Forrest JC, Gerrard DE, Mills EW. 2001. Principles of Meat Science. 4thedn. Knedall and Hunt Publishing Co., Iowa, USA.
2. Ahlstrøm , Krogdahl, A., Vhile, S. G., & Skrede, A. (2004). Fatty acid composition in commercial dog foods. *The Journal of nutrition*, 134(8), 2145S-2147S.
3. Aldrich, G. (2006). Rendered products in pet food. *Essential rendering*, 159-178.
4. Banskaliyeva V, Shalu T, Goetsch AL. 2000. Fatty acid composition of goat muscles and fat depots: a review. *Small Ruminant Research*, 37: 255-268.
5. Brown, R. G. (1997). A comparison of certified and noncertified pet foods. *The Canadian Veterinary Journal*, 38(11), 707.
6. Buff, P. R., Carter, R. A., Bauer, J. E., & Kersey, J. H. (2014). Natural pet food: A review of natural diets and their impact on canine and feline physiology. *Journal of animal science*, 92(9), 3781-3791.

7. Dainton, A. N., Pezzali, J. G., Tomlinson, D. J., & Aldrich, C. G. (2021). Effects of copper source and supplementation level on degradation products, color, and fatty acid profile in canned pet food. *Animal Feed Science and Technology*, 282, 115114.
8. De Marchi M, Righi F, Meneghesso M, Manfrin D, Ricci R. 2018. Prediction of chemical composition and peroxide value in unground pet foods by near-infrared spectroscopy. *Journal of animal physiology and animal nutrition*, 102(1):337-342.
9. Dhakal, J., & Aldrich, C. G. (2020). Use of medium chain fatty acids to mitigate *Salmonella typhimurium* (ATCC 14028) on dry pet food kibbles. *Journal of Food Protection*, 83(9), 1505-1511.
10. Glodde, F., Günal, M., Kinsel, M. E., & AbuGhazaleh, A. (2018). Effects of natural antioxidants on the stability of omega-3 fatty acids in dog food. *Journal of veterinary research*, 62(1), 103-108.
11. Hilton, J. W. (1989). Antioxidants: function, types and necessity of inclusion in pet foods. *The Canadian Veterinary Journal*, 30(8), 682.
12. Kara K. 2021. Effect of stocking conditions on fatty acid composition and oxidation capacities of different class and type dog food. *Italian Journal of Animal Science*, 20(1):1042-1053.
13. Karthik, P., Kulkarni, V. V., & Sivakumar, K. (2010). Preparation, storage stability and palatability of spent hen meal-based pet food. *Journal of food Science and Technology*, 47, 330-334.
14. Kępińska-Pacelik, J., & Biel, W. (2022). Insects in pet food industry—Hope or threat?. *Animals*, 12(12), 1515.
15. Kumar, R., Goswami, M., & Pathak, V. (2024). Innovations in pet nutrition: investigating diverse formulations and varieties of pet food: mini review. *MOJ Food Process Technol*, 12(1), 86-89. DOI: 10.15406/mojfpt.2024.12.00302
16. Kumar, R., & Goswami, M. (2024). Feathered nutrition: unlocking the potential of poultry byproducts for healthier pet foods. *Acta Scientific Veterinary Sciences*. (ISSN: 2582-3183), 6(4).
17. Kumar, R., & Goswami, M. (2024). Optimizing Pet Food Formulations with Alternative Ingredients and Byproducts. *Acta Scientific Veterinary Sciences* (ISSN: 2582-3183), 6(4).
18. Kumar, R., Goswami, M. and Pathak, V. (2023). Enhancing Microbiota Analysis, Shelf-life, and Palatability Profile in Affordable Poultry Byproduct Pet Food Enriched with Diverse Fibers and Binders. *J. Anim. Res.*, 13(05): 815-831. DOI: 10.30954/2277-940X.05.2023.24
19. Kumar, R., Goswami, M., Pathak, V., & Singh, A. (2024). Effect of binder inclusion on poultry slaughterhouse byproducts incorporated pet food characteristics and palatability. *Animal Nutrition and Feed Technology*, 24(1), 177-191. DOI: 10.5958/0974-181X.2024.00013.1
20. Kumar, R., Goswami, M., Pathak, V., Bharti, S.K., Verma, A.K., Rajkumar, V. and Patel, P. 2023. Utilization of poultry slaughter byproducts to develop cost effective dried pet food. *Anim. Nutr. Technol.*, 23: 165-174. DOI: 10.5958/0974-181X.2023.00015.X

21. Kumar, R., Goswami, M., Pathak, V., Verma, A.K. and Rajkumar, V. 2023. Quality improvement of poultry slaughterhouse byproducts-based pet food with incorporation of fiber-rich vegetable powder. *Explor. Anim. Med. Res.*, 13(1): 54-61. DOI : 10.52635/eamr/13.1.54-61
22. Kumar, R., Thakur, A., & Sharma, A. (2023). Comparative prevalence assessment of subclinical mastitis in two crossbred dairy cow herds using the California mastitis test. *J Dairy Vet Anim Res*, 12(2), 98-102 <http://dx.doi.org/10.15406/jdvar.2023.12.00331>
23. Leiva, A., Molina, A., Redondo-Solano, M., Artavia, G., Rojas-Bogantes, L., & Granados-Chinchilla, F. (2019). Pet food quality assurance and safety and quality assurance survey within the Costa Rican pet food industry. *Animals*, 9(11), 980.
24. Montegiove, N., Calzoni, E., Cesaretti, A., Alabed, H., Pellegrino, R. M., Emiliani, C., ... & Leonardi, L. (2020). Comprehensive evaluation of lipidic content in dry pet food raw materials: comparison between fresh meats and meat meals. *Scientific Bulletin Series F. Biotechnologies*, 24.
25. Mooney, A. (2016). Stability of essential nutrients in pet food manufacturing and storage (Doctoral dissertation, Kansas State University).
26. Negotta M, Mihai AL, Iorga E, Belc E. 2020. Fatty acid and trans fatty acid profile of potato chips and french fries marketed in Romania. *Revista de Chimie*, 70(1):456-464.
27. NRC. 2006. In *Nutrient Requirements of Dogs and Cats*. Animal Nutrition Series. National Research Council of the National Academies; National Academy Press: Washington, DC, USA.
28. Osawa, C. C., Gonçalves, L. A. G., & Ragazzi, S. (2008). Evaluation of the quality of pet foods using fast-paced techniques and official methods. *Food Science and Technology*, 28, 223-230.
29. Poonia K, Chavan S, Daniel M. 2012. Fixed Oil Composition, Polyphenols and Phospholipids of Finger Millet [Eleusine Coracana (L.) Gaertn]. In *Biological Forum*, 4(1):45-47.
30. Thompson, A. (2008). Ingredients: where pet food starts. *Topics in companion animal medicine*, 23(3), 127-132.
31. Tran, Q. D., Hendriks, W. H., & van der Poel, A. F. (2008). Effects of extrusion processing on nutrients in dry pet food. *Journal of the Science of Food and Agriculture*, 88(9), 1487-1493.
32. Yao, L., & Schaich, K. M. (2015). Accelerated solvent extraction improves efficiency of lipid removal from dry pet food while limiting lipid oxidation. *Journal of the American Oil Chemists' Society*, 92, 141-151.
33. Zglińska, K., Niemiec, T., Bryś, J., Bryś, A., Łozicki, A., Kosieradzka, I., & Koczoń, P. (2020). The combined use of GC, PDSC and FT-IR techniques to characterize fat extracted from commercial complete dry pet food for adult cats. *Open Chemistry*, 18(1), 1136-1147.

