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Characterization of the Chemical Composition, Amino Acid, and Fatty Acid Profiles of Underutilized Poultry Feathers

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Abstract
Poultry is one of the leading subsectors of animal husbandry. However, despite its socioeconomic importance, it is considered a significant contributor to environmental problems through its waste production, including feathers. Feathers are protective layers that make up the typical outer wrapping. It can be found on feathery and in some non-feathery winged creatures. In this context, this research was conducted to determine the proximate, mineral, fatty acid, and amino acid profile in poultry feathers. The proximate analysis revealed the values of ash (1.40%), moisture (6.30%), crude fiber (9.20%), protein (67.50%), crude fat (2.90%), and carbohydrate (12.70%). The mineral elements (ppm) indicated sodium (0.04), magnesium (0.03), potassium (0.04), calcium (0.06), phosphorus (0.05), manganese (0.01), iron (0.01), and zinc (0.01). The amino acid profile showed that it contained sixteen amino acids which includes important amino acids most especially all the essential amino acids except lysine. In contrast, the fatty acid profile revealed that it contained twelve fatty acids. Among these, it includes basic saturated fatty acids such as glycine and rich in unsaturated fatty acid contents. The finding indicates that poultry feathers can contribute useful nutrients, mineral elements, fatty acids,

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and amino acids to livestock feed for maximum utilization and rapid development, making it a good potential and sustainable material from waste to wealth.

Keywords: Amino acid, Fatty acid, Poultry, Waste, Feathers

INTRODUCTION

Poultry is a well-recognized sector of animal husbandry. It served as one of the major sources of meat and also met the demand for eggs by human beings for the past decades (Zhang, Ren and Bai, 2023). World egg consumption as well as poultry meat demand has increased tremendously since late 2010 and even surpass the demand for pork meat (Zhang, Ren and Bai, 2023). The poultry industry create jobs, reduce poverty and also reduce malnutrition in the world (Rahman, 2018). However, It constitute a threat to the environment through its massive waste production in spite of its socioeconomic advantages to the society(Agrawal *et. al.*, 2023). Its waste consists of remnant feeds, faecal matter, bedding materials, packing materials, broken eggs, departed chicken, and feathers(Rahman, 2018). Poultry waste especially, chicken feathers are not easily biodegradable and non-cost effective(Ali *et. al.*, 2021).

Feathers are stiff and inflexible complex structures in the epidermis of birds. They are different in size, shape, colour, internal structure and varies from one species of bird to another (Lin *et. al.*, 2022). They are protective layers that make up typical outer wrappings or clusters. They can be seen on plumed and even on some wingless fossils and a few archosaurs. They are said to be the most compound integumentary organization seen in vertebrates(Richard O. Prum, 2002; Pap *et. al.*, 2019). And a remarkable illustration of a sophisticated evolutionary novelty. The characteristic that sets current birds apart from all other living things is their feathers (Li *et. al.*, 2012). Though feathers protect most of the bird's body, they grow only in specific areas of the skin. Feathers are important in a bird's ability to fly, they serve as a temperature regulator and also waterproofing as well. Furthermore, hue aids with protection and connection(Terrill and Shultz, 2023). They have several religious, utilitarian and cultural functions. They are tender and are great for dealing with heat, hence they are frequently utilized in high-end bedding, primarily pillows, mattresses, and blankets.

Additionally, they are utilized in the production of outdoor bedding and winter clothing, like as sleeping bags and winter coats. Feathers of big birds have always been used to manufacture quill pens. Throughout history, killing of birds for beautifying and decoration has endangered the existence of most birds and has caused the extinction of certain birds (Belova, 2023). Feathers are now considered a waste product of poultry, including geese, chickens, ostriches, turkeys, and many more, and are used in fashion and military headgear and clothing. These feathers are coloured and their fashion naturally appear faint compared to the feathers of wild birds. They often protect birds from water and low temperatures. They are also removed to make their nests and serve as insulation for the eggs and young. One feather on the wings and tail is crucial for controlling flight (Wang and Meyers, 2017). Certain groups of birds have a plume of feathers on their heads.

Though feathers possess less weight, mainly because lots of bones are empty and contain air sacs. Colour patterns are used as a disguise against hunters for birds in their natural territory it serves as a disguise for predators hunting for food. Just as it is with fishes, the up and down colours may be distinct, so as to serve as a disguise during flight. Obvious differences in feather outline and colours are parts of the sexual dimorphism of many birds' groups and are essential key in the choosing of a mating partner.

While feathers are a recognized waste product in poultry farming and are primarily used in fashion, military gear, and other industries, their potential in other industrial applications remains underexplored. Existing research has focused on their physical characteristics, such as coloration, flight control, and thermal insulation (Tesfaye *et. al.*, 2017), but there is limited understanding of their chemical composition, amino acid, and fatty acid profiles. This knowledge gap is crucial because feathers may possess valuable biochemical components that could be repurposed for industrial applications, such as bio-based materials, fertilizers, or even pharmaceuticals.

Thus, this research seeks to fill the gap by investigating the chemical composition and biochemical profiles of underutilized poultry feathers. By exploring their amino acid and fatty acid content, this study aims to identify potential applications that could help reduce waste and create new value in industries beyond fashion and traditional uses.

MATERIALS AND METHODS

Sample collection and preparation

The broiler feathers samples used for this research work were collected from a poultry farm at Ikirun, Osun State. The sample was washed using distilled water, sieved and oven dried at 105^0C for about one hour. The dried sample was grounded using a Gasa grinder to form a smooth powder. For subsequent analytical examination, the powdered material was stored in an airtight container.

Minerals analysis

The mineral composition of the sample was analyzed by spectroscopy and spectrometry methods. Sodium and potassium levels were measured using a flame photometer (Jenway model), while the remaining minerals, calcium, magnesium, iron, zinc, manganese, and nitrogen were assessed by Atomic Absorption Spectrophotometer (Perkin-Elmer Model Norwalk CT, USA) following the method reported by Oluduro (2012).

Determination of proximate composition

The broiler's feather sample's proximate composition was measured using the AOAC-described procedure (Horwitz, 2005).

Amino acid analysis.

The procedure outlined by Ajayi and Akomolafe (Ajayi & Akomolafe , 2016) was used to determine the amino acid profile.

Fatty acid profile analysis

The amount of fatty acids was determined using Slover and Lanza's (Slover & Lanza, 1980) approach, with minor adjustments. One milliliter of petroleum ether was used three times to separate the esterified fatty acids. The remaining oily surface was then loaded into gas chromatography to determine the fatty acids after the ether content had evaporated.

RESULTS AND DISCUSSION

The proximate composition of the analyzed sample is shown in Table 1. The ash content of the sample was found to be 1.40 %. It was in the range of value (1.48±0.18 %) reported for maize meal in the analysis of poultry and fish feed(Mishra, Thakur & Khan, 2023).This value was compared with the value obtained for skin goat (01.96±0.01) as reported by Ajayi & Akomolafe (2016).

Table 1: Proximate analysis of broiler's feather (%)

Parameters	Compositions
Ash content	1.40
Moisture content	6.30
Crude fibre	9.20
Protein	67.50
Crude fat	2.90
Carbohydrate	12.70

Mean values of triplicate analysis

The ash content primarily indicates the mineral composition of a food sample, with minerals encompassing both essential macro and trace nutrients. They are required for bone formation, blood clotting, and enzyme activation (Igwemmar *et. al.*, 2022). The moisture content was found to be 6.30 %. It was lower than the value reported for dogs (13.83±0.71) and cane rats (12.44±0.05) in the comparative study of nutritional composition from the hides of four distinct animals (Ajayi and Akomolafe, 2016). It was also lower when compared with the value obtained for Peebly fish (*Alestes baremoze*) (72.54 ±0.11) as reported by Kasozi & Degu (2014). The moisture content of feed influences its appearance, taste, texture, shape, and weight. It is also an essential barometer for monitoring feed quality(Uyeh *et. al.*, 2021). The longevity of food products is associated with their moisture content. It should be noted that high content favors microbial proliferation and a downward trajectory in shelf life. The crude fibre was found to be 9.20 % which is lower than the South Darfur seeds (14.95 ± 0.12 %) as reported by Mohammed *et. al.* (2023). Food high in fibre may assist in lessening the instance of non-transferable ailments such as gastrointestinal problems, obesity, hypertension, colorectal cancer, diabetes, and coronary artery disease (Mohammed *et. al.* (2023). The protein in the sample was found to be 67.50 % this was far higher than the value of pig skin (25.36± 0.01%) as reported by Ajayi & Komolafe (2016). It was also higher than 56.06±0.06 % reported for protein-supplemented fish feed ingredients in Madhya Pradesh and Chhattisgarh states (Mishra, Thakur & Khan, 2023). Protein is an essential muscle component that consists of myofibrilla sarcoplasmic and other connective tissues (Ajayi & Akomolafe, 2016). It is one of the essential components of feeds and it is the major growth factor in the meals. The fat in the sample was 2.90 % which was higher than the value reported for pebbles fish (0.21± 0.60 %) by Kasozi & Degu (2014). Fats serve an essential role in transporting compounds that are very important in the growth and development of vitellogenin precursors in vertebrates and invertebrates Ajayi and Komolafe, (Ajayi & Akomolafe, 2016). The carbohydrate in the sample was found to be 12.70 %, this was higher when compared to the value reported for pebbly fish (0.27± 0.01%) by Kasozi & Degu (2014). Carbohydrate in glycogen is a part of chemical constituents in nucleotides Kasozi & Degu (2014). Table 2 shows the mineral compositions of the Broiler's feathers (ppm).

Table 2: Mineral analysis of broiler's feather (ppm)

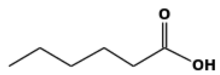
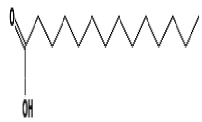
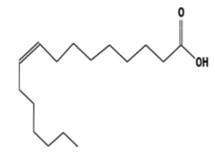
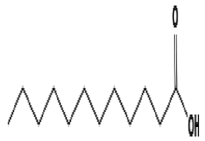
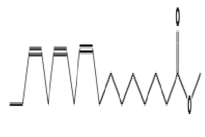
Parameters	Compositions
Sodium	0.04
Magnesium	0.03
Potassium	0.04
Calcium	0.06
Phosphorus	0.05
Manganese	0.01
Iron	0.01
Zinc	0.01

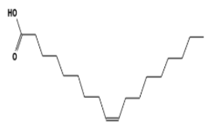
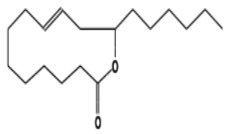
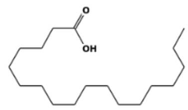
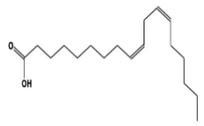
Mean values of triplicate analysis

The results indicated sodium (0.04), magnesium (0.03), potassium (0.04), calcium (0.06), phosphorus (0.05), manganese (0.01), iron (0.01) and zinc (0.01). Table 2 shows the comparison of the mineral compositions indicating calcium has the highest value followed by phosphorus followed by sodium and potassium with the same value. Followed by magnesium while manganese, iron, and zinc were of the lowest values. Minerals are essential in human and animal nutrition. Potassium, sodium, magnesium as well as zinc are important enzymatic activities for the electrolytic balance of the body blood fluid and osmotic equilibrium Ajayi & Akomolafe (2016). Trace level of all the important elements were present in the poultry Broiler's feathers. Zinc deficiency can lead to loss of immunological abnormities, skin changes, growth retardation, and loss of appetite (Kasozi & Degu, 2014).

Table 3 reveal the fatty acid profile. Twelve fatty acids were identified in this study. Out of these, seven were saturated fatty acids such as hexanoic acid, tetradecanoic acid, dodecanoic acid, heptadecanoic acid, n-Hexadecanoic acid, Octadecanoic acid and Eicosanoic acid while four were monounsaturated (Palmitoleic acid, 9-Octadecenoic acid, (E)- , Oleic Acid and 13-Hexyloxacyclotridec-10-en-2-one) and we have one poly unsaturated which was 9,12-Octadecadienoic acid (Z,Z)-. It was observed that n-hexanedecanoic acid has the highest percentage composition followed by dodecanoic acid, then, 9,12-octadecadienoic acid (Z, Z). while oleic acid has the lowest percentage composition.

Table 3: Fatty acid profile

	RT	Compound Detected	Mol. Formula	M	Peak Area %	Comp (%wt)	m/z	Structures
1	2.75	Hexanoic acid	$C_6H_{12}O_2$	278	1.49	2.52	41, 60, 116	
2	6.50	Tetradecanoic acid	$C_{14}H_{28}O_2$	228	2.23	6.08	43, 73, 228	
3	8.96	Palmitoleic acid *	$C_{16}H_{30}O_2$	254	2.99	3.15	41, 67, 254	
4	9.75	Dodecanoic acid	$C_{12}H_{24}O_2$	200	24.85	15.65	43, 73, 200	
5	16.50	Heptadecanoic acid	$C_{17}H_{34}O_2$	292	1.79	2.54	41, 79, 292	
6	23.98	9-Octadecenoic acid, (E)- *	$C_{18}H_{34}O_2$	282	2.39	3.62	41, 55, 282	

7	25.62	Oleic Acid *	$C_{18}H_{34}O_2$	282	3.13	.61	41, 55, 282	
8	28.19	13-Hexyloxacyclotridec-10-en-2-one *	$C_{18}H_{32}O_2$	280	1.64	2.93	41, 73, 280	
9	30.48	n-Hexadecanoic acid	$C_{16}H_{32}O_2$	256	36.57	27.81	43, 73, 256	
10	34.75	Octadecanoic acid	$C_{18}H_{36}O_2$	284	3.28	8.54	43, 73, 284	
11	38.50	9,12-Octadecadienoic acid (Z,Z)- **	$C_{18}H_{32}O_2$	280	8.96	12.98	41, 55, 280	
12	40.57	Eicosanoic acid	$C_{20}H_{40}O_2$	312	10.67	6.52	43, 73, 312	

* Indicated monounsaturated, **indicated polyunsaturated

Results also revealed an abundance of Dodecanoic acid (Lauric acid) which is a non-toxic saturated fatty acid with strong bactericidal properties; It has a role as a plant metabolite, an antibacterial agent, and an algal metabolite (Casillas-Vargas *et al.*, 2021) It can thus be employed as antimicrobial agent. The presence of eicosanoic acid also indicates its use as a component in organic thin film in the production of liquid crystals for a wide variety of technical applications and phase change materials(Mjallal *et al.*, 2021). The feather is also a rich source of unsaturated fatty acids (9,12-Octadecadienoic acid and 9-Octadecenoic acid) more importantly is 9,12-Octadecadienoic acid which is an essential fatty acid (Whelan and Fritsche, 2013) Oleic acid, a monounsaturated fatty acid, is an omega -9 fatty acid and has a characteristic effect as an antioxidant. It might also improve heart conditions by lowering cholesterol and reducing inflammation. The most intricate skin appendage on vertebrates, particularly birds, is their feathers. Even though feathers are frequently regarded as a waste product and a byproduct of raising poultry, some manufacturers grow chickens expressly for their feathers. It was previously stated that feathers had an average protein content of 87%. However, this protein is present in an indigestible keratin helix, which requires special processing to break apart the disulfide-bonded helices. Table 4 presents the amino acid profile observed in this research work, sixteen amino acids were detected. Eight were essential amino acids while we also have eight non-essential amino acids. It should be noted that only lysine is not found among the nine essential amino acids. the broiler feathers contain essential amino acids that the body cannot manufacture but are required for growth and development. The most predominant amino acid in Broiler's feathers is a non-essential amino acid; glycine. Other non-essential amino acids observed in this study include Aspartic Acid, Serine, Proline, Tyrosine, Glutamic Acid, Arginine, and Alanine. Essential amino acids in the sample were. Threonine, Valine, Phenylalanine, Leucine, Methionine, Isoleucine, Tryptophan and Histidine. However, the lowest quantity of essential amino acids is isoleucine. Numerous significant metabolites, including glutathione, haem, creatine, porphyrins, and purines, are precursors to glycine. In addition to its multiple functions as an antioxidant, anti-inflammatory, cryoprotective, and immunomodulatory in peripheral and neurological tissues, glycine functions as a neurotransmitter in the central nervous system(Razak *et al.*, 2017). Small amounts of glycine deficit are not hazardous to health, but severe shortages can cause low growth, aberrant nutrition metabolism, immune system failure, and other negative effects(Soh *et al.*, 2024). One of the branched-chain amino acids, isoleucine is also essential for the body's physiological processes, including growth, immunity, protein metabolism, fatty acid metabolism, and glucose transport. The immune system, which includes immunological organs, cells, and reactive substances, can be strengthened by isoleucine.

Table 4: Amino acids profile

Peak #	RT	Compound Detected	Peak Area %	Comp (mg/100g) Mean values of triplicate analysis
1	4.00	Aspartic Acid	1.72	4.85
2	6.25	Threonine*	14.22	2.61
3	7.82	Serine	1.81	3.16
4	10.00	Glycine	15.99	2.78
5	10.41	Valine*	12.07	5.02
6	12.07	Phenylalanine*	3.02	4.03
7	13.42	Proline	4.31	5.95
8	15.62	Leucine*	3.45	10.21
9	16.25	Methionine*	12.93	0.58
10	18.50	Isoleucine*	0.86	0.80
11	20.00	Tyrosine	2.59	3.34
12	24.99	Tryptophan*	1.29	0.28
13	27.49	Glutamic Acid	1.64	8.35
14	30.15	Histidine*	14.66	2.09
15	36.50	Arginine	0.95	1.05
16	42.00	Alanine	9.70	3.94

** Essential amino acids*

CONCLUSION

Broiler's feathers are low-cost and abundantly available, making them a renewable and sustainable raw material for various applications. From this research work, the proximate analysis revealed that it contained a high content of protein, a profound amount of fibre, and low moisture content. It was also revealed that it contained an appreciable quantity of mineral elements and a significant amount of carbohydrates. The amino acid profile showed that it contained sixteen amino acids which includes important amino acids most especially eight out of nine essential amino acids. In contrast, the Fatty acid profile revealed that it contained twelve fatty acids. Among these, It include basic saturated fatty acids such as glycine and also riches in unsaturated fatty acid contents. Given this, Feathers can serve as a source of protein for farm animals acting as complementary feed composition. It could be used to produce fish meals, poultry meals, dog meals, pig meals, and feeds for other animals at a relatively cheap and affordable price, making it a good potential material from waste to wealth.

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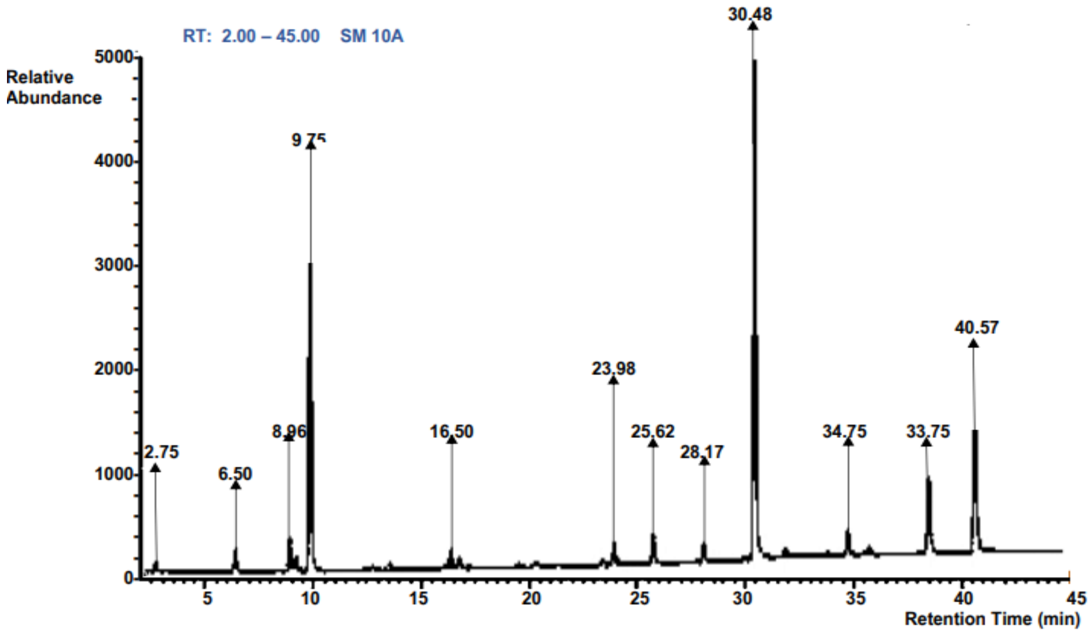
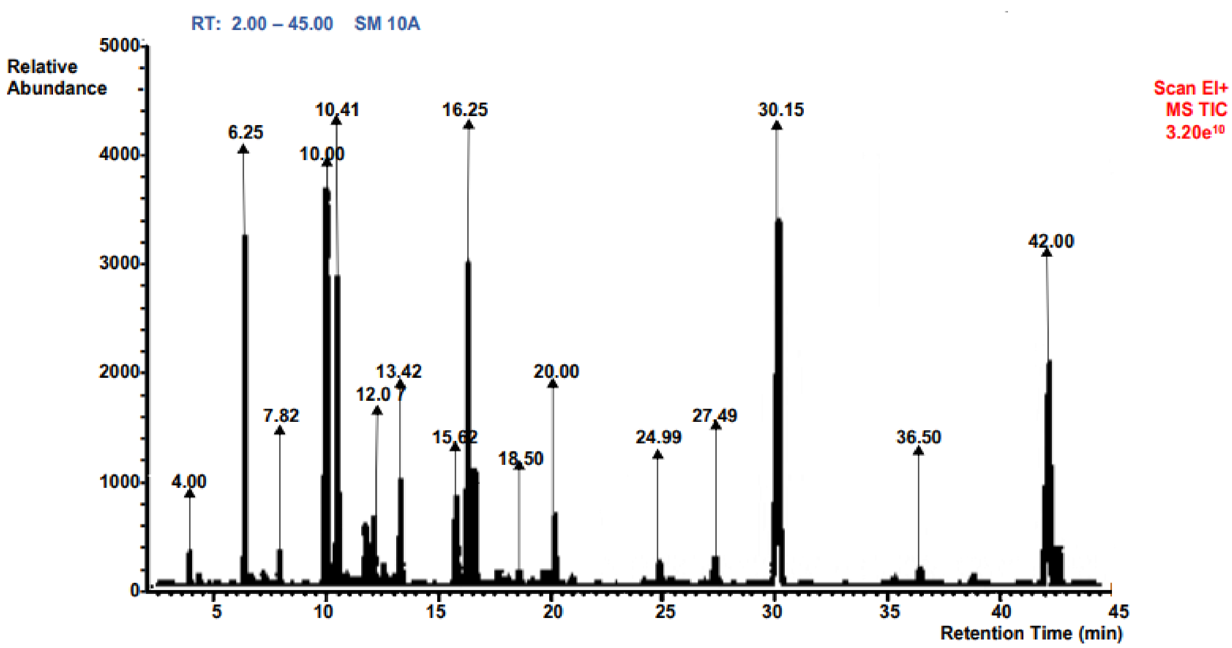
APPENDICES



Fatty acid profile of the poultry feathers samples



Amino acid profile of the poultry feathers samples