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Assessment of the Food Value of *Trametes elegans* Before and After Fermentation

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ABSTRACT

Background and Objective: Mushrooms are known to be sources of food and bioactive compounds with pharmacological properties. Some mushrooms are edible, while some are not. In this study, the proximate, mineral, and amino acid composition of a wild macrofungus, *Trametes elegans* was investigated. Samples of *T. elegans* were collected from dead wood in the forest around FUTA and separated into three portions. **Materials and Methods:** Two portions were respectively subjected to liquid and solid-state fermentation. The third portion serves as a control. The proximate, mineral, and amino acid composition of the *T. elegans* subjected to the treatments above was assessed using standard methods. Experiments were performed in triplicate, and data were analyzed using one-way ANOVA with mean separation by Duncan's test (SPSS 20.0) at $p \leq 0.05$. **Results:** The results of the proximate composition revealed a decrease in carbohydrates and an increase in protein after fermentation. Moreover, there were significant increases in the magnesium, potassium, and phosphorus content of *T. elegans* subjected to solid and liquid fermentation when compared with the raw. Potassium was the highest mineral found in *T. elegans*. Fermentation also has a profound effect on the amino acid content, with solid-state fermentation having the overall effect of increasing levels of essential and nonessential amino acids. The most predominant essential amino acid is leucine (4.06 g/100 g), and methionine is the least (0.69 g/100 g), while aspartic acid (5.07 g/100 g) and cysteine (0.28 g/100 g) are the most abundant and least abundant nonessential amino acids, respectively. **Conclusion:** In light of high protein, mineral, and amino acids as revealed in this study, *T. elegans* could be considered a good source of food supplement for animals.

KEYWORDS

Evaluation, food, mineral, proximate, amino acids, *Trametes elegans*

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INTRODUCTION

Fungi are made up of yeast, molds, and mushrooms and constitute the second largest group of eukaryotic organisms on earth, with an estimated species ranging from 1.5 to 5.1 million[1]. Mushrooms are higher fungi found all over the world that could be edible, inedible, or poisonous based on their composition. They contain valuable amounts of various nutrients, including organic acids and polysaccharides[2]. The presence of these compounds confers various health-promoting properties, such as antioxidant, anticarcinogenic, antidiabetic, antimicrobial, and immunomodulatory, on mushrooms[3-5]. These physiological properties have made mushrooms a source of food, medicine, and health supplements[2].

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Trametes species is one of the groups of inedible mushrooms. It was officially described as *Trametes* by Fries in 1835[6]. It was formerly known as Lenzites[7]. According to Goyat *et al.*[8], it is a member of the genus Basidiomycota, the family Polyporaceae, and the phylum Basidiomycete[9,10]. This endophytic fungus is typically found on wood, particularly hardwoods woods[11]. *Trametes* spp., are economically important as bioremediators and biodegraders of cellulosic organic waste in the ecosystem[12,13]. Apart from their economic importance in the environment, some species of *Trametes* are important in medicine[14]. *Trametes elegans* is well-known for its industrial and therapeutic uses[8].

Trametes species is also employed in the food production sector[15]. Generally, mushrooms are rich in polyphenolic compounds, polysaccharides, protein, lectins, vitamins, minerals, and steroids are bioactive compounds in the cellular component of wild macrofungi[16]. Fermentation as a method of food processing involves the conversion of complex organic molecules in substrates into simple end products by the action of microorganisms[17]. Fermentation has been reported to significantly 21 of cereal and legumes through the activation of endogenous enzymes[18]. It is therefore imperative that the food value of *Trametes elegans* be investigated to determine its potential food value. The present study is aimed at investigating the effects of fermentation on the proximate, mineral, and amino acid content of *Trametes elegans*.

MATERIALS AND METHODS

Collection of *Trametes elegans*: Fruit bodies of *Trametes elegans* were collected from dead wood in forests around FUTA, Akure, Ondo State, Nigeria, between September and October, 2023. The *T. elegans* were identified by a Taxonomist in the Department of Microbiology, FUTA. The fruit bodies were kept dried in a desiccator until it was needed for use. A voucher of the specimen was kept in the Department of Microbiology, FUTA.

Fermentation of *Trametes elegans*: After the collection of the *T. elegans*, it was divided into three portions. The first portion was separated as a raw sample, and the second and third portions were subjected to solid and submerged state fermentation, respectively, for four days following the method of Akingbesote and Oyetayo[19]. The fermented portions were thereafter dried in an oven (DHG 9053-A, Zenith Lab (Jiangsu) Co. Ltd., Jiangsu, China) at 30°C.

Determination of mineral content of *Trametes elegans*: The mineral composition (magnesium, zinc, iron, potassium, and lead) of each sample was determined by the ashing method[20]. Triplicates of 1.0 g from each sample were weighed into porcelain crucibles and placed in a muffle furnace. The temperature was raised gradually to 550°C for 6 hrs. After cooling to room temperature, the ash was dissolved in 1 mL of HNO_3 (0.5% v/v). The sample volume was brought to 100 mL with distilled water, and the levels of the minerals present were analyzed by atomic absorption spectrophotometer (201VGP, Buck Scientific Inc., Norwalk, Connecticut, USA). A flame photometer (PFP 7, Jenway, Staffordshire, UK) was used to determine potassium (K) content.

Determination of proximate composition of raw and fermented *Trametes elegans*: The method of Horwitz and Latimer[20] was used to determine the moisture, protein, fat, ash, and fiber content of raw and fermented samples of *T. elegans*. The percentage of carbohydrate was obtained by difference. This was done by subtracting the total organic nitrogen, lipid, ash, and fiber from the total dry matter per Horwitz and Latimer[20] as shown below:

$$\text{Carbohydrates (\%)} = 100-(\text{Moisture}+\text{ash}+\text{protein}+\text{fat}+\text{crude fibre})\ (\%)$$

Determination of amino acid content of raw and fermented *Trametes elegans*: Each of the raw and fermented samples (2.0 g) was weighed into the extraction thimble. The fat was extracted with a chloroform-methanol mixture using a Soxhlet extraction apparatus. The extraction lasted for 6 hrs. The defatted samples (40 mg) were weighed into glass ampoules. Seven milliliters of 6 M HCl were added, and oxygen was expelled by passing nitrogen gas into the ampoule to avoid possible oxidation of amino acids during hydrolysis. Each glass ampoule was then sealed with a Bunsen flame and put into an oven at 105±5°C for 22 hrs. The ampoule was allowed to cool before breaking it open at the tip, and the content was filtered to remove humins. The filtrate was then evaporated to dryness at 40°C under a vacuum in a rotary evaporator. Each residue was dissolved with 5 mL of acetate buffer, stored in a plastic specimen bottle, and kept in a deep freezer.

Loading of hydrolysate into the technicon sequential multisampling (TSM): The amino acids in raw and fermented *Trametes elegans* were determined by ion exchange chromatography using the TSM amino acid analyzer (Technicon Instruments Corporation, New York, New York, USA). The amount of hydrolysate loaded was between 5-10 µL and dispensed into the cartridge of the TSM amino acid analyzer. The TSM separates and analyzes free acidic, neutral, and basic amino acids of the hydrolysate, and the period of the analysis lasted for 76 min at 60°C with a gas flow rate of 0.50 mL/min. The net heights of each ion exchange chromatogram peak produced by the chart recorder of TSM (each representing an amino acid) were measured. The half-height of the peak on the chart and the width of the peak at half-height were accurately measured and recorded. The approximate area of each peak was then obtained by multiplying the height by the width at half-height in cited by Ogidi *et al.*[17] and Spackman *et al.*[21].

Data analysis: Experiments were carried out in triplicate, and data obtained were analyzed by One-way Analysis of Variance (ANOVA) and means separated by Duncan's Multiple Range Test (SPSS 20.0 version). Differences were considered significant at $p \leq 0.05$.

RESULTS

There was an increase in the mineral composition of the solid and liquid fermented *T. elegans* compared to the raw *T. elegans* (Table 1). The phosphorus, potassium, and magnesium content of *Trametes* elegans subjected to solid and liquid fermentation was higher and significantly different from the raw. Generally, there were slight increases in the mineral contents of fermented samples compared with the raw. The mineral composition of Samples A, B, and C varies significantly. Sample B exhibits the highest magnesium (593±1.41 mg/kg) and potassium (2531±2.83 mg/kg) levels, followed by Sample C and A. Zinc content is highest in Sample B (4.55±0.06 mg/kg), while iron levels remain statistically similar across all samples. Phosphorus is most abundant in Sample C (1152±1.41 mg/kg), whereas Sample A has the lowest concentration (1093.5±4.95 mg/kg).

The results of the proximate composition revealed a decrease in carbohydrate and an increase in protein contents of *T. elegans* subjected to liquid and solid-state fermentation when compared to the unfermented *T. elegans* (Table 2). The proximate composition of Samples A, B, and C shows significant variations in moisture, fat, protein, and carbohydrate content. Sample B has the highest moisture (3.22±0.13%) and protein (22.48±0.09%) levels, while Sample C has the highest crude protein content (6.68±0.76%) and ash content (3.60±1.39%). Fat content is significantly higher in Samples B (1.85±0.04%) and C (1.71±0.12%) compared to Sample A (1.18±0.03%). Carbohydrate levels are highest in Samples A (70.24±0.33%), while Samples B and C have comparatively lower values.

The results of amino acid analysis revealed a general increase in all amino acids analyzed in fermented samples compared with the unfermented *T. elegans*. Leucine (4.06 g/100 g) was the most predominant essential amino acid, and methionine (0.69 g/100 g) was the least (Table 3). Aspartic acid (5.07 g/100 g) was the most predominant non-essential amino acid, and cystine (0.28 g/100 g) was the least (Table 4).

Table 1: Mineral composition of raw and fermented *T. elegans* extracts (mg/100 g)

Sample	Magnesium	Iron	Zinc	Potassium	Phosphorus
A	465.5±2.12^{a}	17.47±0.66^{a}	4.02±0.16^{a}	2391.5±2.12^{a}	1093.5±4.95^{a}
B	593.0±1.41^{c}	18.56±0.01^{a}	4.55±0.06^{b}	2531.0±2.83^{c}	1131.0±2.83^{b}
C	582.0±4.24^{b}	18.30±0.08^{a}	4.17±0.07^{a}	2412.0±1.41^{b}	1152.0±1.41^{c}

*Values with the same superscript along the column are not significantly different ($p \geq 0.05$). A: Raw *T. elegans*, B: *T. elegans* subjected to solid fermentation and C: *T. elegans* subjected to liquid fermentation

Table 2: Proximate composition of raw and fermented *T. elegans* extracts (g/100 g)

Sample	Moisture	Fat	Crude	Ash	Protein	Carbohydrate
A	2.64±0.02^{a}	1.18±0.03^{a}	5.96±0.42^{a}	3.11±0.47^{a}	16.88±0.32^{a}	70.24±0.33^{b}
B	3.22±0.13^{b}	1.85±0.04^{b}	5.77±0.08^{a}	3.38±0.08^{a}	22.48±0.09^{c}	63.30±0.43^{a}
C	2.56±0.06^{a}	1.71±0.12^{b}	6.68±0.76^{a}	3.60±1.39^{a}	21.54±0.36^{b}	63.92±2.56^{a}

*Values with the same superscript along the column are not significantly different ($p \geq 0.05$). A: Raw *T. elegans*, B: *T. elegans* subjected to solid fermentation and C: *T. elegans* subjected to liquid fermentation

Table 3: Essential amino acid composition of raw and fermented *T. elegans*

Amino acid	A (g/100 g)*	B (g/100 g)*	C (g/100 g)*
Histidine	1.11±0.01^{a}	1.36±0.01^{c}	1.18±0.01^{b}
Isoleucine	2.35±0.03^{a}	3.03±0.03^{c}	2.46±0.05^{b}
Leucine	3.34±0.05^{a}	4.06±0.04^{c}	3.44±0.04^{b}
Lysine	2.20±0.05^{a}	2.59±0.03^{c}	2.34±0.04^{b}
Methionine	0.69±0.04^{a}	0.98±0.01^{c}	0.83±0.04^{b}
Phenylalanine	2.62±0.06^{b}	2.90±0.05^{c}	2.52±0.06^{a}
Threonine	2.06±0.08^{a}	2.89±0.08^{c}	2.39±0.02^{b}
Tryptophan	0.72±0.03^{a}	1.09±0.01^{c}	0.91±0.02^{b}
Valine	2.86±0.13^{a}	3.38±0.03^{c}	3.13±0.04^{b}

*Values with the same superscript along a row are not significantly different ($p \geq 0.05$). A: Raw *T. elegans*, B: *T. elegans* subjected to solid fermentation and C: *T. elegans* subjected to liquid fermentation

Table 4: Non-essential amino acid composition of raw and fermented *T. elegans*

Amino acid	A (g/100 g)	B (g/100 g)	C (g/100 g)
Alanine	2.56±0.09^{a}	3.10±0.01^{c}	2.79±0.03^{b}
Arginine	4.25±0.08^{a}	5.04±0.18^{c}	4.95±0.06^{b}
Aspartic acid	4.35±0.09^{a}	5.07±0.06^{c}	4.65±0.04^{b}
Cystine	0.28±0.03^{a}	0.53±0.04^{c}	0.40±0.04^{b}
Glutamic acid	8.68±0.04^{a}	11.07±0.09^{c}	9.64±0.04^{b}
Glycine	1.42±0.05^{a}	2.34±0.11^{c}	1.87±0.05^{b}
Proline	1.82±0.02^{a}	2.38±0.06^{c}	2.07±0.06^{b}
Serine	1.92±0.06^{a}	2.51±0.03^{c}	2.25±0.06^{b}
Tyrosine	1.39±0.01^{a}	2.08±0.01^{c}	1.59±0.06^{b}

*Values with the same superscript along a row are not significantly different ($p \geq 0.05$). A: Raw *T. elegans*, B: *T. elegans* subjected to solid fermentation and C: *T. elegans* subjected to liquid fermentation

Table 5: Percentage of essential and non-essential amino acids in raw and fermented *T. elegans*

Amino acid	A	B	C
TAA	44.63	56.40	49.41
TEAA	17.95	22.28	19.20
TNEAA	26.67	34.12	30.21
TEAA (%)	40.21	39.50	38.86
TNEAA (%)	59.76	60.50	61.14

TAA: Total amino acids, TNEAA: Total non-essential amino acids, TEAA: Total essential amino acids, A: Raw *T. elegans*, B: *T. elegans* subjected to solid fermentation and C: *T. elegans* subjected to liquid fermentation

Table 5 shows the percentage of total essential amino acids (TEAA) and total non-essential amino acids (TNEAA) in fermented and unfermented *Trametes elegans*. The TEAA were higher in *Trametes elegans* subjected to solid state (22.20) and liquid state (19.20) fermentation when compared to the unfermented sample (17.95). The same trend was also observed in the distribution of TNEAA, which was higher in fermented samples of *Trametes elegans* compared with the unfermented.

DISCUSSION

Mushroom, a non-timber forest product, has been used for food, medicine, enzymes, and as a major source of income for people all around the world[22]. Some mushrooms are edible while some are not. *Trametes elegans* is an example of a non-edible mushroom. However, recent research shows that some of these non-edible mushrooms are rich in food values[17,23]. In the present report, *Trametes elegans* was found to be rich in minerals such as phosphorus, potassium, zinc, magnesium, and iron. These elements are involved in biochemical processes such as haemoglobin synthesis and catalysis of metabolic growth[24]. Fermentation increased the levels of these minerals when compared with the unfermented *Trametes elegans.* In a recent study, fermentation was found to increase the bioavailability of mineral elements of plant food[25]. In another study, there was a significant difference observed in the elements' content in fermented mung bean compared to the product before processing[26].

There was a significant increase in the protein content and a concomitant decrease in the carbohydrate content of fermented *T. elegans* when compared with the unfermented *T. elegans*. Previous report shows that fermentation increases *in vitro* protein and starch digestibility of sorghum flours[27]. The increase in protein content of the mushroom during fermentation could have been a result of microbial biomass generated during fermentation[28,29]. Moreover, the dissociation of protein bound with polysaccharides in fungal cell walls could increase the protein content of fermented mushrooms[17]. The fermented and unfermented *T. elegans* were also found to be rich in crude fiber. Much of the insoluble dietary fiber found in higher basidiomycetes is attached to chitin, hemicellulose, mannans, glucans, glycogen, and trehalose in their cell walls[17]. This can be used to increase the nutritional value of some low-fiber diets. Dietary fiber has several health benefits, such as reducing the risk of colon disease, hemorrhoids, and constipation[30]. It also increases the viscosity of the food matrix, slows down digestion, lowers blood sugar, and boosts immunity with antitumor activity[17].

Another significant observation in this study was the increase in amino acids of fermented *T. elegans* samples compared to the unfermented *T. elegans*. Amino acids, which are primary products of metabolism, are produced during the growth of mushrooms and are essential for growth[31]. They are valuable components of functional foods and are an important component of every cell in the body[32]. Both the total essential and nonessential amino acids were higher in fermented *T. elegans* samples compared to the unfermented *T. elegans*. Generally, *T. elegans* is rich in essential amino acids such as histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine. These amino acids are termed essential amino acids because they cannot be synthesized by humans or other mammalian cells and must be supplied from an exogenous diet[33].

CONCLUSION

Fermentation significantly enhanced the nutritional profile of *Trametes elegans*, particularly by increasing its protein, mineral, and amino acid contents. Solid-state fermentation showed the greatest improvement, especially in essential and nonessential amino acids. Notably, potassium was the most abundant mineral, while leucine and aspartic acid were the dominant essential and nonessential amino acids, respectively. A decrease in carbohydrate content was also observed post-fermentation. These findings suggest that fermented *T. elegans* holds strong potential as a protein-rich food supplement for animal feed, with future safety studies in animal models recommended.

SIGNIFICANCE STATEMENT

The data gathered in this study revealed that *T. elegans*, a hitherto inedible mushroom, contains appreciable food value, and when subjected to both solid and liquid fermentation, the food value in terms of proximate and amino acid composition significantly increases. Further research and development could result in the use of *T. elegans* as a supplement in animal feed and subsequently human food.

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