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Micro Nutrient Profiles of *Pleurotus tuber regium* Biodegraded Rice Straw and Ground nut Shells

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Abstract

The mineral and vitamin status of rice straw and ground nut shell biodegraded by Pleurotus tuber regium were evaluated in this study. The minerals and vitamins assessed in the untreated (UTRS) and Pleurotus tuber regium treated (PTTRS) rice straw were calcium, phosphorus, magnesium, sodium, sulphur, copper, zinc, molybdenum, cobalt selenium and vitamins A, B_1, B_2, B_6, D, E and K respectively while minerals evaluated in the untreated (UGNS) and Pleurotus tuber regium biodegraded (PTGNS) ground nut shells were calcium, phosphorus, sodium, magnesium, potassium, iron, copper, manganese and zinc. Samples of rice straw and ground nut shell were composted for seven days and thereafter inoculated with spores of Pleurotus tuber regium and kept in the dark room for 30 days. Analysis of the ensuing Pleurotus tuber regium biodegraded rice straw compared to rice straw not biodegraded revealed that the fungal biodegradation significantly ($P < 0.05$) increased the amounts of calcium, phosphorus, sulphur, copper, molybdenum, cobalt and selenium and also significantly decreased ($P < 0.05$) the amounts of magnesium, sodium, and zinc. Fungal biodegradation also significantly ($P < 0.05$) increased vitamins A, B_1, B_2, and C and significantly ($P < 0.05$) decreased vitamins B_6, D, E and K. Evaluation of the ensuing fungal biodegraded ground nut shell, compared to non biodegraded ground nut shell showed significant ($P < 0.05$) increase in the calcium, sodium and potassium levels while the levels of phosphorus, magnesium, iron, copper, manganese and zinc were not significantly ($P > 0.05$) affected by the fungal biodegradation. It was concluded that the fungal biodegradation by Pleurotus tuber regium generally upgraded the quality of the ensuing rice straw and ground nut shells residue as their use in feeding animals would supply to them the synthesised minerals and vitamins while those that were depleted would also be of no consequence since ruminant animals synthesise most of them in their reticulo-rumen.

Keywords: *Fungal Biodegradation; Pleurotus tuber regium; Rice straw; Ground nut shells; Vitamins; Minerals*

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Introduction

Minerals are inorganic elements which furnish structural materials for bones and teeth, are constituents of soft tissues, blood, fluids of the body, certain secretions and regulate many of the vital processes of the body. Vitamins are organic substances required in minute amounts by animals for normal growth, production, reproduction and/or health. History relates that prior to discovery and characterization of vitamins by the Polish scientist, Funk in 1912, most effects of vitamin deficiencies were attributed to superstition or unexplainable factors (Ensminger 1977). Knowledge about vitamins, their names, functions, deficiency symptoms and interaction have grown over the years. Vitamins and minerals are now known to be involved and utilized in very essential metabolic functions in living organisms. While there are many feeds from which farm animals derive vitamins and minerals, biosynthesis by micro-organisms have also been reported. The dynamics of fungal mineral biosynthesis and utility have been reported by many authors (Timothy., *et al*. 1988; Debratta., *et al*. 2004; Mark., *et al*. 2009; Tarafder and Raliya 2012; Amin., *et al*. 2015; Zielonka., *et al*. 2017). Details of fungal biosynthesis and utilization of vitamins have also been reported (Strzelczyk and leniarska, 1988; Solomko and Eliseeva, 1988; Ananya, 2014). According to Brooklyncuny (2018), vitamins and minerals serve as coenzymes and cofactors. Coenzymes include nicotinamide in nicotinamide adenine dinucleotide, flavine as flavine adenine dinucleotide, thiamine as thiamine phosphate, pyridoxal as pyridoxal phosphate and carbamide as carbamide phosphate while enzymes that require metal ions (cofactors) include carbonic anhydrase and alcohol dehydrogenase which require zinc; cytochromes, haemoglobin and ferrdoxin which require iron, cytochrome oxidase which require copper and pyruvate phosphokinase which require potassium and magnesium.

Biodegradation of fibrous feedstuffs have been reported to yield products of enhanced nutritional value. The works have reported improved generation of some nutrients (Akinfemi., *et al*. 2009a; 2009b; Wuanor and Ayoade, 2017) and depletion of others in the ensuing biodegraded materials (Sarklong., *et al*. 2010; Kholif., *et al*. 2011); the explanation being that while some of the nutrients were biosynthesized by the fungi leading to increase of such materials in the ensuing biodegraded products, some nutrients were utilized in the metabolic processes of the fungi during the biodegradation, leading to their reduced quantities. Fungal biodegradation of crop residues also assists in waste cycling (Banjo., *et al*. 2003)

Rice straw has been reported to be produced in copious quantities annually worldwide; its utilization as a feedstuff is hindered by the high fibrous nature and low nitrogen composition (Drake., *et al*. 2002). Ground nut shells have also been reported to abound after harvest and processing of the nuts to get the seeds. Assessment of the micronutrient profiles of biodegraded samples of these two crop residues is needed in the pursuit of transforming them to feedstuffs for ruminant livestock. Many authors have reported on the nutritional value of fungal biodegraded products stating dimensions and patterns of nutrient status of biodegraded materials. These reports, have however, focused mostly on macro nutrients and there is a paucity of information on micronutrients of fungal biodegradation of fibrous feed resources. This work was designed to assess the vitamin and mineral status of two fibrous feed materials, rice straw and ground nut shells biodegraded by the white rot fungus *Pleurotus tuber regium*.

Materials and Methods

Study area

The study was conducted at the University of Agriculture, Makurdi. Makurdi, the capital of Benue State is located between latitude 6° and 8° north and longitude 6° and 10° east. The Federal University of Agriculture, Makurdi is located at latitude 7° 44 N and longitudes 8° 54 E in the southern guinea savannah region of Nigeria. The annual temperature ranges between 21°c in January to 35°c in March. It has annual rainfall of 1105 mm to 1600 mm and relative humidity which is highest between August and September (69%) and lowest between January and February (39%).

Composting and fungal inoculation of rice straw and ground nut shells

Composting of the rice straw as well as fungal inoculation were done using the Procedures described by Wuanor and Ayoade (2017) while composting and fungal inoculation of ground nut shells was done using the procedure of Wuanor., *et al*. (2018)

Analysis for minerals and vitamins

The laboratory analysis for minerals and vitamins in the rice straw and ground nut shell samples was done using atomic absorption Spectrophotometry and chromatography respectively.

Statistical Analysis

Data collected were analyzed statistically using Minitab Statistical Software and Fisher's analysis of the software was used in separating means where significant differences existed

Results

Results of the mineral and vitamin profiles of *Pleurotus tuber regium* biodegraded rice straw and ground nut shells are presented in Tables 1, 2 and 3. Calcium content was significantly ($P < 0.05$) higher in the biodegraded rice straw sample compared to the undegraded sample. This pattern of significant increment in the biodegraded sample was also exhibited in the contents of phosphorus, sulphur, molybdenum, cobalt and selenium. On the contrary, there was a reduction in the magnesium content of the biodegraded rice straw sample leading to a significant ($P < 0.05$) higher value of magnesium in the undegraded material than the biodegraded material. This significant reduction in composition of the biodegraded sample was also reported for sodium and zinc. The vitamin A composition of the biodegraded rice straw sample was significantly ($P < 0.05$) higher than that in the undegraded rice straw, a pattern which was also reported for vitamins B1, B2 and C. *Pleurotus tuber regium* biodegradation however led to a significant ($P < 0.05$) decrease in the amount of Vitamins B6, D, E and K. Fungal biodegradation of ground nut shells resulted in significantly ($P < 0.05$) higher quantity of calcium, a pattern also shown by the sodium and potassium contents. *Pleurotus tuber regium* biodegradation of the ground nut shells however did not exert any significant ($P > 0.05$) on composition of phosphorus, magnesium, iron, copper, manganese and zinc.

Minerals	UTRS	PTTRS	LOS
Calcium (%)	$0.12^b \pm 0.03$	$0.26^a \pm 0.20$	*
Phosphorus (%)	$0.21^b \pm 0.10$	$0.32^a \pm 0.02$	*
Magnesium (%)	$0.25^a \pm 0.10$	$0.08^b \pm 0.03$	*
Sodium (%)	$0.48^a \pm 0.10$	$0.04^b \pm 0.03$	*
Sulphur (%)	$0.12^b \pm 0.03$	$0.26^a \pm 0.02$	*
Copper (ppm)	$0.43^b \pm 0.02$	$0.89^a \pm 0.02$	*
Zinc (ppm)	$0.85^a \pm 0.02$	$0.15^b \pm 0.06$	*
Molybdenum (ppm)	$0.05^b \pm 0.02$	$0.18^a \pm 0.01$	*
Cobalt (ppm)	$0.06^b \pm 0.02$	$0.13^a \pm 0.01$	*
Selenium (ppm)	$0.13^b \pm 0.02$	$0.28^a \pm 0.02$	*

Table 1: *Mineral Content of Untreated and Fungal Treated Rice Straw (means ± SD).*

UTRS = Rice straw

*PTTRS = *Pleurotus tuberregium* treated rice straw

SD = standard deviation

Each means is average of three replicates

Vitamins	UTRS	PTTRS	LOS
A (iu/100 g)	$109.57^b \pm 0.43$	$156.31^a \pm 0.69$	*
B1(iu/100 g)	$180.30^b \pm 0.16$	$196.81^a \pm 133.5$	*
B2(mg/100 g)	$175.11^b \pm 1.09$	$230.42^a \pm 10.56$	*
B6(mg/100 g)	$40.15^a \pm 0.34$	$25.09^b \pm 0.97$	*
C(mg/100 g)	$1.67^b \pm 0.03$	$3.50^a \pm 0.44$	*
D(iu/100 g)	$17.6^a \pm 0.02$	$10.50^b \pm 0.36$	*

E(iu/100 g)	$360.12^a \pm 0.18$	$215.61^b \pm 0.93$b	*
K(iu/100 g)	$142.50^a \pm 0.50$	$98.73^b \pm 0.64$	*

Table 2: *Vitamin Composition of Untreated and Fungal Treated Rice Straw (means ± SD).*

UTRS = Untreated rice straw; PTTRS = *Pleurotus tuber regium* treated rice straw
LOS = level of significance; * = significantly different (P < 0.05)
SD = standard deviation; each means is average of three replicates

Minerals	UGNS	PTGNS	LOS
Calcium (%)	0.12b ± 0.03	0.89a ± 0.03	*
Phosphorus (%)	0.15 ± 0.70	0.08 ± 0.02	NS
Sodium (%)	0.15b ± 0.06	0.45a ± 0.05	*
Magnesium (%)	0.10 ± 0.01	0.09 ± 0.01	NS
Potassium (%)	0.12b ± 0.03	0.22a ± 0.03	*
Iron (ppm)	1.13 ± 0.04	1.11 ± 0.14	NS
Copper (ppm)	0.03 ± 0.03	0.26 ± 0.38	NS
Manganese (ppm)	0.03 ± 0.01	0.01 ± 0.00	NS
Zinc (ppm)	0.04 ± 0.03	0.07 ± 0.02	NS

Table 3: *Effect of fungal treatment on mineral content of groundnut shells (means ± SD).*

Ppm = part per million; UGNS = Untreated ground nut shells; PTGNS = *Pleurotus tuber regium* treated ground nut shells; LOS = level of significance *= significantly different (P < 0.05); NS = not significantly different; SD = standard deviation; each means is average of three replicates

Discussion

Fungal biodegradation leading to increases in calcium, phosphorus, sodium, sulphur, copper, molybdenum, cobalt and selenium contents of rice straw as well as the calcium, sodium and potassium of the ground nut shells is reasoned to be caused by biosynthesis of these mineral elements by the fungus during the biodegradation process. Fungal syntheses of minerals have been reported by other authors too. Debrata., *et al*. (2004) reported extracellular synthesis of calcium carbonate by the fungus *Verticullum* Spp and Amin., *et al*. (2015) reported that fungi made nanoparticles of calcium, gold and silicon. Increased quantity of phosphorus in the fungal biodegraded rice straw is in consonance with the report of Tarafdar and Raliya (2012) who reported biosynthesis of phosphorus nanoparticles from fungi. The significantly higher sodium content in the biodegraded ground nut shells is in conformity with the result of Zielonka., *et al*. (2017) who reported fungal synthesis of sodium sulphate. Significant decreases in contents of magnesium, sodium and zinc were attributed to the fungus using them in its metabolic activities. According to McPherson., *et al*. (2006), zinc is required for proper functioning of a large number of proteins including enzymes. Most zinc containing proteins are transcriptional factors capable of binding DNA and are named zinc finger proteins, they form one of the largest families of transcriptional regulators; members of the family are exclusively fungal. Higher amount of molybdenum in the biodegraded rice straw was also attributed to fungal synthesis. The in vitro synthesis of iron-molybdenum cofactor of nitrogenase was reported by Timothy., *et al*. (1988). According to Yan., *et al*. (2008), molybdenum is a key component in several enzymes in nitrogen, sulphur and carbon metabolism; it is bound in proteins to a pterin, thus forming the molybdenum cofactor (mono) at the catalytic sites of molybdenum enzymes. Higher selenium content of biodegraded rice straw is in line with the result of Mark., *et al*. (2009) who reported fungal synthesis selenium.

That the potassium content was significantly higher in the biodegraded ground nut shell is at variance with the result of the work of Ling., *et al*. (2004) who reported *ectomycorrhizal* fungi depletion of extractable potassium fractions in vitro and by the fungus root association. Note is however taken of the differences in substrate used and also the possible variation in nutrient requirement and metabolism of different fungal species. Higher content of cobalt in the biodegraded rice straw is in line with the work of Raj. (2018) who reported suitability of the fungus *Aspergillus nidulans* for synthesis of cobalt oxide nanophores. Manganese was reported not to be significantly affected by fungal biodegradation of ground nut shells and the result is attributed to its utility by the fungus. Kubicek and Rohr (1977) reported that manganese strongly influences idiophase metabolism in fungi; in the presence of manganese, cell growth increases, sugar consumption is diminished and acidogenesis decreases drastically. The lack of significance in contents of iron in both the undegraged and *Pleurotus tuber regium* biodegraded ground nut shells is consistent with the work of Vishru (2016) who reported that silica, iron and aluminium are "hard" elements (not essential to animals); consequently plant species having a minimum of these are most desirable. The lack of significant effect of fungal biodegradation on contents of phosphorus, magnesium, iron, copper, manganese and zinc in the ground nut shells is reasoned to be caused by a comparably similar rate of synthesis and utilization of the mineral elements in its metabolic activities.

Significant increases in vitamins A, B1, B2 and C were suspected to be caused by synthesis of the vitamins. Strzelczyk and Leniarska (1985) studying vitamin production by fungi reported that the vitamin produced in large amounts by fungi was thiamine. Additionally, Solomka and Eliseeva (1988) reported that Pleurotus tuber regium was autotrophic in respect of thiamin (B_1), riboflavin (B_2), niacin (B_5), pyridoxine (B_6) and biotin (B_7) but failed to synthesize cyanocobalamin (B_{12}) and concluded that the oyster mushroom and other edible mushrooms can be put at one of the top places among foodstuffs by the content of niacin. According to Jose., *et al*. (2016), vitamin and vitamin-like compounds that are produced (exclusively) by microbial fermentation with fungi are vitamins B_2, B_{12}, and C and. The significant reduction in amounts of vitamins B_6, D, E and K were also suspected to be caused by their utilization by the fungus. Ananya (2014) reported that vitamin K is used to inhibit the growth of fungi.

In general the synthesis of minerals and vitamins by the fungus Pleurotus tuber regium was not seen as a surprise because fungi secrete extracellular enzymes in their mode of feeding and these enzymes which are proteins require the use of coenzymes and cofactors which are minerals and vitamins.

Conclusion

It was concluded that fungal biodegradation of the rice straw and ground nut shell led to mineral and vitamin enrichment of the materials.

Recommendation

It was recommended, based on the results obtained that, rice straw and ground nut shells should be biodegraded using *Pleurotus tuber regium* before using them as feed inputs.

Conflict of Interest

The authors hereby state that there does not exist any conflict of interest as far as this article is concerned.

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