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Effect of Combined Application of NPK Fertilizer and Poultry Manure on the Nutritional and Functional Properties of Aerial Yam (*Dioscorea bulbifera*)

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Authors' contributions

This work was carried out in collaboration between all authors. Author VCE designed the study, managed the literature searches, laboratory analyses and statistical analysis of the study. Authors NRN and LIC advised on the level of NPK fertilizer and poultry manure application. Authors AEO, LIC and ONEO managed the field work. All authors read and approved the final manuscript.

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ABSTRACT

Aims: To investigate the effects of combined application of NPK fertilizer and poultry manure on the nutrient composition and functional properties of flours from aerial yam (*Dioscorea bulbifera)*.
Study Design: The experiment was a single factor trial in a randomized complete block design replicated three times.
Place and Duration of Study: National Root Crops Research Institute, Umudike Research farm in 2012 and 2013 cropping seasons.
Methodology: The treatment combinations consisted of four levels (150, 250, 350 and 450kg/ha) of NPK 15:15:15 fertilizer and four levels (1, 2, 3, 4t/ha) of poultry manure with a control (No fertilizer or manure application). After harvest the bulbils were analysed for starch yield, proximate

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composition (dry matter, crude protein, ash, crude fibre, crude fat), total carotenoid and mineral (phosphorus, calcium and magnesium) contents. The functional properties of the flour were also investigated.

Results: Starch content increased significantly from 8.52% in the control to 14.95% in 450:1 NPK and poultry manure, ash content increased from 3.73% in control to 6.58% in 350:1 and 450:1 NPK and poultry manure. Crude protein increased from 1.35% in control to 4.33% in 350:2NPK and poultry manure. However the dry matter content decreased from 31.06% in the control to 22.28% in 250:1 NPK and poultry manure. Gelatinization temperature increased from 74ºC in the control to 88.50ºC in 450:2 NPK and poultry manure. Bulk density was not significantly affected by NPK and poultry manure, however, swelling index reduced from 200.16 in the control to 80.50 in 350:4 NPK and poultry manure.

Conclusion: Combined application of NPK and poultry manure may increase some nutrients in *Dioscorea bulbifera* however some important functional properties of the flours were adversely affected which may have effect on its utilization.

Keywords: Nutrient; functional properties; NPK fertilizer; Poultry manure; Dioscorea bulbifera.

1. INTRODUCTION

Agricultural Intensification is a viable option in a decreasing arable land scenario due to increasing world population. However this has had negative effects on the soil environment such as declining soil fertility culminating in decreased yield and quality of food crops [1]. In order to increase crop yield, farmers have to add amendment to improve the productivity of their soil. Soil fertility on smallholder farms is almost entirely dependent on locally available resources. Continued use of organic fertilizers results in increased soil organic matter, reduced erosion, moderation of soil acidification, improved soil bulk density, better water infiltration and aeration, higher soil biological activity as the materials decompose in soil, and increased yields after the year of application (residual effects). Chemical fertilizer application is one of the best means of increasing yield per unit area. It is believed that NPK fertilizer improve both yield and quality of the crop [2]. The amount of inorganic fertilizer used in most smallholder farming systems is far below standard recommendations, due to poor purchasing power of farmers and lack of significant returns [3]. Integrated soil fertility management involving the judicious use of combinations of organic and inorganic fertilizers is a feasible approach to overcome soil fertility constraints [4-6]. Combined application of organic and inorganic fertilizers both enhanced Carbon storage in soils, and reduced emissions from N-fertilizer use, while contributing to high crop productivity in agriculture [7].

Yam is a crop that belongs to the genus *Dioscorea* and family Dioscoreaceae. *Dioscorea bulbifera*is distinguished from all other *Dioscorea* species by having specialized aerial bulbils on the base of petioles [8]. The yam *Dioscorea bulbifera*is used as food and is a good source of calories, apart from starch, bulbils contain other chemical elements such as protein, fats, fibres and minerals such as iron, phosphorous and calcium [9-11]. They are usually eaten boiled, charcoal roasted and rarely pounded as '*fufu*'. Leaves and bulbils of *Dioscorea bulbifera* are used for traditional medicine in some areas [12]. Low soil fertility is a constraint for enhancing yam productivity because yams are high nutrient demanding crops [13]. Diby et al. [14] attributed the low yam yield in infertile soils to a decrease in leaf area index for *D. alata* and to a decrease in radiation use efficiency for *D. rotundata*. Despite the enormous potential of *D. bulbifera*, information is still scanty on the fertilizer requirement that will bring about proper functional and nutritional quality of the plant. This study looks at the effect of combined use of poultry manure and NPK fertilizer on the nutrient and functional properties of *D. bulbifera.*

2. MATERIALS AND METHODS

Dioscorea bulbifera was planted on a sandy loam soil in the 2012 and 2013 cropping seasons at National Root Crops Research farm. The plot size was $8m^2$ with a planting space of 50cm x 1m. The experiment was a single factor trial in a randomized complete block design replicated three times. The treatment combinations consisted off our levels (150, 250, 350 and 450 kg/ha) of NPK 15:15:15 fertilizer and four levels (1, 2, 3, 4t/ha) of poultry manure with a control (No fertilizer or manure application). This combination gave a total of seventeen treatments. Planting and weeding were done

manually; harvesting was done six months after planting. Samples were collected at harvest, peeled, chipped, oven dried at 60ºC, ground and used for laboratory analysis.

The proximate composition of samples: moisture, ash, crude protein, fat, fibre and carbohydrate contents of *D. bulbifera* were estimated according to the standard methods of A. O. A. C. [15]. Minerals were analyzed by the method reported by Oshodi [16].

The water and oil absorption capacity were determined using the method of Sathe et al. [17]. Bulk density was determined with the method of Narayana and Narasinga [18] and swelling index was determined using the method of Lin *et al*. [19].

2.1 Statistical Analysis

Each analysis was replicated three times and data were subjected to analysis of variance (ANOVA) using the SAS statistical package version 9.0. Means were separated using Fischer's LSD at 5% level of probability.

3. RESULTS AND DISCUSSION

3.1 Nutrient Contents

Starch content is the main quality factor in yams. Highest starch yields were observed in plants (bulbils) that received 450 kg/ha &1t/ha (14.95%) and 350 kg/ha &3t/ha (14.85%) combination rates of NPK fertilizer and poultry manure while the lowest starch yield was observed in the control (8.52%) and ata combination of 150 kg/ha: 2 t/ha rates of NPK fertilizer and poultry manure (9.19%) as shown in Table 1. Starch yield was significantly increased (P<.05) by the combined application of NPK fertilizer and poultry manure especially in treatments with high NPK fertilizer. Oliveira et al. [20] reported an increase in starch content of *D. cayennensis* with addition of mineral fertilizers of N, P and K. This could be through their effect on chlorophyll formation, photosynthesis and leaf formation which translates to starch formation in the bulbils.

Dry matter content of the samples ranged from 22.28% (in 250 kg NPK/ha &1t poultry manure/ha) to 31.89% (in 250 kg/ha & 4 t/ha NPK fertilizer and poultry manure combinations respectively). The dry matter content of the bulbils treated with NPK and poultry manure were low relative to the control except at combination levels of 150 kg/ha & 2 t/ha (31.25%); 150 kg/ha & 3 t/ha (31.37%); 250 kg/ha & 3 t/ha (31.17%); 250 kg/ha & 4 t/ha (31.89%) and 450 kg/ha:1t/ha (31.75%) NPK and Poultry manure respectively (Table 1). The observed reduction in dry matter content could be due to excess N in treatments with high NPK fertilizer and poultry manure which has been reported to reduce dry matter content [21]. This shows that combined application of NPK fertilizer and poultry manure increases the moisture content of *D. bulbifera*.

Crude fibre was significantly (P<0.05) affected by the different levels of combined application: Application of 250 kg/ha & 3 t/ha level NPK and poultry manure respectively had the highest crude fibre content (7.7%) while 450 kg/ha &4t/ha NPK and poultry manure had the lowest content. Fiber provides bulk to the food, thereby enhancing the digestibility of food inside the body.

Ash content was significantly affected by the different combination levels of fertilizer application. Application of 350 kg/ha & 1 t/ha and 450 kg/ha & 1 t/ha NPK and Poultry manure combinations gave bulbils with the highest ash content. It was generally observed that bulbils from treatments with higher NPK levels had relatively higher ash content (Table 1). This could be attributed to ease of availability of the composite minerals in NPK fertilizer. A similar observation was made by Makhinde et al. [22] on *Amaranthus cruentus*.

The crude protein content of the bulbils ranged from 1.18% to 4.33% and was significantly increased (P<0.05) by the various rates of treatment combinations (Table 1). The observed increase in crude protein and ash content of the bulbils with application of NPK fertilizer and poultry manure relative to the control could be due to the fact that nutrients released from NPK fertilizer and poultry manure (N, P and K) are formation blocks for protein (N), nucleoprotein(P) and ash (K) [23].

The effect of the different treatment combinations on the total carotenoid content was not significant (P<0.05) (Table 1).

Table 1. Effect of combination of poultry manure and NPK fertilizer on the nutrient composition of *D. bulbifera*

NPK & poultry manure combinations	Starch (%)	DM (%)	MC (%)	Fat(%)	CF (%)	Ash (%)	CP (%)	TC (µg/g)	P (ppm)	Ca (%)	Mg(%)
NPK(kg/ha): PM(t/ha)											
0:0	8.52	31.06	68.94	0.37	2.52	3.73	1.35	4.56	5.21	1.40	0.24
150:1	9.63	30.86	69.14	0.54	2.94	3.83	1.88	4.55	5.42	1.40	0.12
150:2	9.19	31.25	68.75	0.21	5.27	5.34	1.36	5.63	5.26	1.00	0.25
150:3	10.34	31.37	68.64	0.14	2.46	5.58	1.37	3.90	5.49	1.40	0.12
150:4	12.76	28.46	71.54	0.12	2.47	6.33	1.53	4.68	5.51	1.20	0.12
250:1	13.65	22.28	77.72	0.16	2.59	4.40	1.18	4.57	5.45	1.40	0.12
250:2	13.29	30.56	69.45	0.05	2.48	3.43	1.71	5.58	5.44	0.80	0.49
250:3	12.43	31.17	68.83	0.08	7.70	3.42	3.19	4.10	5.44	1.00	0.49
250:4	12.12	31.89	68.13	0.16	6.79	3.63	1.50	4.36	5.55	1.40	0.45
350:1	10.57	26.47	73.54	0.12	2.28	6.58	4.21	4.14	5.41	1.00	0.36
350:2	11.65	30.03	69.97	0.07	2.20	5.74	4.33	3.66	5.42	1.80	0.12
350:3	14.85	29.50	70.50	0.14	3.67	4.08	1.56	4.36	5.47	1.80	0.24
350:4	13.42	30.14	69.86	0.13	2.07	3.88	1.71	4.68	5.22	1.00	0.12
450:1	14.95	31.75	68.25	0.15	6.63	6.58	1.97	5.03	5.21	0.60	0.49
450:2	10.99	27.59	72.42	0.24	3.00	2.25	1.71	5.57	5.38	1.40	0.24
450:3	12.05	26.79	73.21	0.02	3.77	4.74	4.31	4.42	5.43	1.20	0.12
450:4	11.74	26.78	68.08	0.34	2.02	1.13	3.11	5.19	5.31	1.00	0.24
$LSD_{0.05}$	3.525	5.661	5.644	0.274	0.099	0.183	0.006	0.883	0.018	0.004	0.002

Where PM = poultry manure, DM = dry matter, MC = moisture content, CF = crude fiber, CP = crude protein and TC = total carotenoid

Mineral contents such as calcium, magnesium and phosphorus were significantly (P<0.05) affected by the different treatment combinations. However, the phosphorus content was highly significant (P<0.05). Bulbils with 250kg/ha&4t/ha NPK fertilizer and poultry manure application showed the highest phosphorus content.

3.2 Functional Properties

The effect of different levels of combination of poultry manure and NPK fertilizer on the functional properties of *D. bulbifera*is shown in Table 2. Bulk density is an indication of the load the flour samples can carry, if allowed to rest directly on one another. The bulk density of the *D. bulbifera* samples ranged from 0.97-1.05 g/cm^3 which was higher than the range (0.49-0.63 g/cm^3) reported for yam [24]. However, it is similar to the range (0.71-1.05 g/cm^3) reported by Ezeocha et al. [25] for *D. rotundata* landraces. The combined application of NPK fertilizer and poultry manure did not have a major effect on the bulk density of *D. bulbifera* flour.

The water absorption capacity of the flours ranged from 1.75-2.15% while the oil absorption capacity ranged from 1.00-2.20% (Table 2). A similar result was obtained by Ukpabi, [26] for lesser yam. The combinations of NPK fertilizer and poultry manure significantly (P<0.05) affected the water absorption capacity. Treatments with high poultry manure combination tended to have higher water absorption capacity relative to the control. Water absorption capacity is the ability of a substance to associate with water under a limited water condition [27]. The variations in water and oil absorption capacity may be due to different protein contents, their degree of interaction with water and oil as well as their conformational characteristics [28].

The gelatinization temperature increased significantly (P<0.05) with the application of combined NPK fertilizer and poultry manure relative to the control. This has important implication on the energy and time required to gelatinize the starch of *D. bulbifera*.

The swelling index of the flour from bulbils treated with fertilizer and poultry manure were significantly (P<0.05) lower than the control. High swelling index is an important criterion for good quality flour, *D. bulbifera* flour grown without application of fertilizer and poultry manure had the best swelling index (Table 2).

Table 2. Effect of combination of poultry manure and NPK fertilizer on the functional properties of *Dioscorea bulbifera*

NPK & poultry manure combination	WAC (%)	OAC (%)	GTT (ºC)	SI	BD (g/cm^3)
NPK(kg/ha): PM(t/ha)					
0 : 0	1.95	1.92	74.00	200.16	0.99
150: 1	1.95	2.09	84.00	133.33	1.00
150: 2	1.95	1.65	85.00	181.82	0.98
150: 3	2.00	2.05	86.00	117.41	1.01
150: 4	2.10	2.00	86.50	124.20	1.02
250: 1	1.95	1.90	88.00	103.50	1.03
250: 2	1.75	1.85	87.00	137.50	1.02
250: 3	1.90	1.80	86.00	112.92	1.04
250: 4	2.10	2.45	81.00	111.67	1.02
350: 1	2.00	2.13	88.00	107.14	1.02
350: 2	1.90	1.90	88.00	127.50	1.05
350: 3	2.15	1.00	84.00	119.91	1.01
350: 4	1.85	1.25	80.50	158.33	1.00
450: 1	1.75	1.95	87.00	107.14	0.97
450: 2	1.90	1.90	88.50	121.96	1.01
450: 3	2.15	2.20	86.00	112.50	1.02
450: 4	2.05	1.90	83.00	170.08	1.04
$LSD_{0.05}$	0.140	0.631	1.765	17.789	0.056

Where PM = Poultry Manure, WAC = Water absorption capacity, OAC = oil absorption capacity, GTT = Gelatinization temperature, SI = Swelling Index, BD = Bulk Densit

4. CONCLUSION

The results showed that combined application of NPK fertilizer and poultry manure increased the starch yield, ash, crude protein and phosphorus content while crude fibre content reduced with increased rate of NPK fertilizer and poultry manure. Gelatinization temperature of *D. bulbifera* flour increased with application of combined NPK and poultry manure. The bulk density was not seriously affected however, the swelling index reduced with the application of NPK fertilizer and poultry manure. The result of this study is important for better integrated soil nutrient management for improved nutrition and utilization of *D. bulbifera.*

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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