

ORIGINAL RESEARCH

Nutritional and physical properties of organic Beauregard sweet potato [*Ipomoea batatas* (L.)] as influenced by broiler litter application rate

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Abstract

Organic farming has been on an upward trend in recent years. However, the manures used like broiler litter have variable nutrient content, making it important to establish optimal application rate, for maximum crop yield and quality. Additionally, some states like Alabama restricts the amount of broiler litter to control excessive nutrients accumulation which can lead to surface and ground water contamination. The current study evaluated the effect of broiler litter at rates 0, 0.5, 1, 2, and 3 t ha⁻¹ (treatments T₀, T_{0.5}, T₁, T₂, and T₃), on the nutritional and physical properties of Beauregard sweet potato. Analyses were performed to determine moisture, ash, fiber, vitamin C, and β -carotene contents using oven, muffle furnace, dye, and spectrophotometric methods; texture; and color using compressive strength and *L, a, b* system, respectively. Ash content of the samples ranged from 0.9% to 1.4% with a very strong positive linear correlation ($r = 0.9$) to the broiler litter rate. However, vitamin C had a quadratic relationship with the broiler litter rate with a peaking at T_{0.5} (15.5 mg/100 g). The yellow color (*b*-value) also had a strong linear relationship with the broiler litter rate ($r = 0.86$). However, the other measures showed moderate, weak, or negligible correlations to the broiler litter level. T_{0.5} had the highest β -carotene (262.0 μ g/g), dry matter contents and had the most firm (0.040 kN) sweet potatoes with the deepest orange color ($L = 60.7$). Based on the study's findings, 0.5 t ha⁻¹ appeared to be appropriate level of broiler litter, which is consistent with Alabama's law and is also advantageous in terms of low cost of farming practices and water pollution reduction.

Introduction

Organic farming has received a lot of attention in the past few decades. From the 1980s, organic farming has had a steady growth, and has recently increased tremendously worldwide (Stolze and Lampkin 2009). For labeling a product as organic, farmers have to meet some standard practices during the growth process. For example, according to the USDA National Organic Program, one of the standard practice is the use of organic fertilizer, which is a soil amendment derived from natural resources that guarantees at least the minimum percentage of N, P, and K. Hence, the soil is fertilized through tillage/cultivation, crop rotation, cover crop, and use of animal or plant

waste material (USDA/National Organic Program 2013). However, when using animal waste as a fertilizer, it is essential to establish an optimum application rate, for a particular crop. The reason for establishing the manure optimal rate is to avoid underfertilization or overfertilization, which can adversely affect the crop of interest. As reported by Bary et al. (2000), application of too little manure could lead to inadequate growth of crop. On the other hand, applying too much manure may reduce the quality of crop and can also lead to surface and ground water contamination. For example, some mineral nutrients like Cu and Cl are toxic to plants when applied in very high concentration, beyond requirement of a particular crop (O'Sullivan et al. 1997). In addition, excessive

nutrients in the soil can cause degradation of both surface and ground water through surface runoff and leaching, which is a growing environmental concern. For example, Gilfillen et al. (2010) observed that application of broiler litter to meet the N need of orchardgrass in a 4-year study resulted in a three-, seven-, and fivefold soil accumulation of P, Cu, and Zn, respectively. For such reason, Alabama Cooperative Extension Program recommends application of broiler litter at a rate of 4.5 t ha⁻¹ year⁻¹ and emphasizes on residual soil N consideration when applying nutrients in subsequent seasons Mitchell and Donald (1999).

Adequate supply of plant nutrients is important for healthy growth of crops as they are the chemical elements which form the plant tissues (O'Sullivan et al. 1997). For example, N is the key element in protein synthesis. Although the most common plant elements (C, O, and H) come from water and air, the other, macronutrients (N, K, P, Ca, Mg, and S) and micronutrients (Fe, Cl, B, Mn, Zn, Cu, and Mo), come from the soil. When deficient in the soil, these mineral nutrients may be supplemented as inorganic or organic fertilizer to achieve healthy crop growth. However, mineral nutrients like boron, chlorine, manganese, and copper are toxic to plants if applied in high concentrations. In addition, Al and Na, which are not essential to sweet potato, can also cause toxicity to the crop (O'Sullivan et al. 1997). It is, therefore, important to apply the right amount of the soil fertilizing material. Sometimes the optimal amount is not straight forward, especially when dealing with organic manure. Organic manures have slow release and variable nutrients composition depending on the source, as opposed to the chemical fertilizers, which have readily available nutrients and of known concentration.

According to Kingery et al. (1994), extensive use of broiler litter, can cause accumulation of components like organic C, total N, P, K, Ca, Mg, Cu, Zn, and NO₃⁻ and also increase in the soil pH. However, element like Cu is toxic to plant at high concentration and elevated soil pH can reduce the solubility of nutrients like P, Fe, Mn, Zn, and Cu (O'Sullivan et al. 1997). In addition, although NO₃⁻ is one of the major source of N, high concentration in the soil can lead to its accumulation in plants (Nesic et al. 2008), which can cause growth retardation. Chen et al. (2004) observed the effect of application of N in form of KNO₃ in potted vegetables at levels, 0.00, 0.15, 0.30, 0.45, and 0.60 g N per 5 kg soil. The results from the study indicated that the 0.30 g N/5 kg level had the maximum yield and the 0.00 g N/5 kg level had the minimum yield. This means that the 0.30 g N/5 kg was the optimum application rate of the KNO₃ fertilizer. Excessive accumulation of NO₃⁻ in plant can also be harmful when consumed by animals. Plants normally respond to

nutrients imbalance by decrease in growth rate and development. In addition, symptoms of the imbalance may only be visible on the plant when at severe levels, for example chlorosis, the reduction in the green color (O'Sullivan et al. 1997). However, some anomalies may not be visually notable on the crop or harvest if the nutrients aberration is not at a critical level. Therefore, nutritional analysis is important in determining the qualitative status of crop under different treatments. In addition, most nutritional studies compare organic versus the conventional crops, but not the effect of manure application rate in the organic farming. In the current study, the nutritional and physical properties of organically grown Beauregard sweet potato were evaluated to determine the effect of application of broiler litter at rates of 0, 0.5, 1, 2, and 3 tons per hectare (t ha⁻¹) in meeting the application rate recommended by Alabama Cooperative Extension Program.

Materials and Methods

Samples and sample preparation

Beauregard sweet potatoes were organically grown in the Department of Agriculture, Tuskegee University, with broiler litter at rates of 0, 0.5, 1, 2, and 3 t ha⁻¹, reported as treatments T₀, T_{0.5}, T₁, T₂, and T₃, respectively. Selected properties of the broiler litter composition are reported in Table 1. Each treatment was grown in randomly distributed rows with four blocks (6 m × 6 m) each. The rows were 2 m, and the blocks 4 m apart. The maximum broiler litter rate of 3 t ha⁻¹ tested in our study was established from previous field research experiments conducted at Tuskegee University, which showed that sweet potato storage root yield and quality tend to decline above broiler litter rates of 3 t ha⁻¹ when preceded by cover crops (crimson clover or black oat) in organic farming systems (K. Kpombekou-A, pers. comm., 2014). The application rate was also consistent with the recommendation of the Alabama Cooperative Extension Program broiler litter application rate of 4.5 t ha⁻¹ year⁻¹ to prevent the potential of ground and surface water pollution by excess nutrients.

After harvest, the sweet potatoes were delivered to the Department of Food and Nutritional Sciences, Tuskegee

Table 1. Selected properties of the broiler litter used.

pH	Organic C		Inorganic N (g kg ⁻¹)	
	(g kg ⁻¹)	Total N (g kg ⁻¹)	NH ₄ ⁺ -N	NO ₃ ⁻ -N + NO ₂ ⁻ -N
8.5	290	46	3.03	1.57

University, for the nutritional analysis study. Sweet potato from the four different blocks of each treatment were mixed together and then randomly sampled for analysis. The sampled roots were washed, blot dried with paper towel, peeled, and finely diced together for subsequent analyses. All the analyses were done in triplicate.

Moisture analysis

Sweet potato samples (5 g) were weighed into predried, preweighed aluminum pans and heated in a conventional oven overnight at 105°C (Bradley 1998). The pans, plus dry sample, were then cooled in a desiccator and reweighed. Moisture content was calculated as percent weight loss of a sample to the initial weight.

Ash analysis

Samples (5 g) were weighed into predried crucibles, placed in a muffle furnace, and heated at 550°C for 12 h. The crucibles, plus ash, were then cooled in a desiccator and reweighed. Ash content was calculated as the percent of ash weight to the initial sample weight.

Crude fiber analysis

An Ankom2000 Fiber Analyzer (Macedon, NY) was used to determine the fiber content of the sweet potatoes. As per the manufacturer's instructions, samples (1 g) were weighed into preweighed Ankom filter bags and heat sealed. The filter bags were placed on the trays of the bag suspender, inserted into the vessel of the fiber analyzer, and subjected to acid followed by base digestions, with hot water rinses between runs. After the acid/base digestions, the bags were removed from the analyzer, placed in a beaker, and the excess water gently squeezed out. The bags were then soaked in acetone for 5 min, air-dried on a wire screen, and then dried in oven for 2 h at 102°C. The dry bags, with digested samples, were reweighed, placed in preweighed crucibles, and heated in a muffle furnace at 600°C for 2 h, to remove the remaining organic matter (fiber). The crucibles were then cooled in a desiccator and reweighed to determine the ash (crude minerals) proportion, and consequently the fiber content. Percent of the proportion of the fiber to the initial sample weight was calculated to determine its content.

Vitamin C analysis

Vitamin C (ascorbic acid) was determined using the 2,6-dichlorophenol indophenol titration method (Eitenmiller *et al.* 1998). Samples (2 g) were ground with mortar/

pestle and homogenized with 10 mL of metaphosphoric/ acetic acid solution. For each sample, the extract was vacuum filtered using a Buchner funnel and the residue reextracted two more times. The residue was then poured on the Buchner funnel and rinsed with about 15 mL of the extraction solution, until the filtrate was clear. The filtrates were pooled into a 50 mL volumetric flask and filled to the mark with the extraction solution. Three aliquots (10 mL) of the extract were pipetted into Erlenmeyer flasks and titrated with the indophenol dye to a faint pink endpoint. Vitamin C content was determined by comparing the volume of the dye used to titrate a sample to the volume of the dye used to titrate ascorbic acid standard of known concentration.

β -Carotene analysis

Hexane:acetone (7:3) mixture was used to extract β -carotene from the sweet potato samples. Each sample (1 g) was extracted with 25 mL of the hexane–acetone mixture and then vacuum filtered, rinsing the sample residue with 15 mL of extraction solvent until the filtrate was clear. The filtrate was then transferred into a separating funnel, washed with 50 mL of distilled water, allowed to settle and the water portion discarded. The extract was then dried with 10 g of anhydrous Na₂SO₄, transferred into a 50-mL volumetric flask and filled up to the mark with the extraction mixture. The extract was then transferred into cuvettes and absorbance read at 450 nm using a Shamadzu U-1201 UV-Vis spectrophotometer (Shamadzu, Jiangsu, China). A calibration curve generated using β -carotene standard was used to determine the total β -carotene content.

Texture analysis

Sweet potato samples were prepared for texture analysis by cutting cylindrical pieces, longitudinally through the roots, using a cork borer with diameter 6.5 mm. Texture was then determined using a Mini 44 Instron Machine (Instron, Canton, MA). The maximum force (kN) required to break a cylindrical piece of sweet potato with the crosshead from a height of 30 mm at a speed of 10 mm/min was determined as the firmness of the sweet potato.

Color analysis

The peeled, finely diced sweet potato samples were filled into petri dishes (plastic plates) and covered. Color was then measured from three different positions on the plate cover, using a handheld Minolta Chroma Meter (Minolta, Osaka, Japan) and the measurements reported using the *L*, *a*, *b* color system.

Statistical analysis

The triplicates among treatments were analyzed using the Analysis of variance (ANOVA) to determine whether there were differences among the means and Fisher's LSD at $P < 0.05$ to determine where the differences lied. Pearson's correlation was used to measure the strength of the relationships between broiler litter and the nutrition/physical measures.

Results and Discussion

Moisture content

The moisture content of the sweet potatoes in the current study ranged from 77.0% for $T_{0.5}$ to 78.6% for T_2 (Table 1). This range translates to dry matter content of about 21.4–23.0%, which is within the range of findings in some past studies. In a study of nine orange-fleshed and three cream-fleshed sweet potatoes grown in four agrogeographical sites, Laurie et al. (2012) found the dry matter content range to be 15.5–34.9%. Specifically, the Beauregard variety had dry matter content ranging from 17.3% to 25.1%. In another study which involved 49 sweet potato varieties, Oboh et al. (1989) found the dry matter content of the roots to be between 17.82% and 38.18%. In the current study, the broiler litter application rate did not seem to have much effect on the moisture content of the sweet potatoes, although the $T_{0.5}$ sweet potatoes had slightly less moisture than the control, T_0 (Table 2). The other three treatments had moisture contents which were not statistically ($P < 0.05$) different to the control. The moisture contents of the different sweet potato treatments showed a moderate positive linear relationship ($r = 0.42$) with the level of the broiler litter applied (Table 4). However, Nedunchezhiyan et al. (2010) observed that sweet potato grown without fertilizer had less dry matter content than the ones grown with fertilizer and Jarvan and Edesi (2009) also observed that potato

dry matter content increased with addition of manure or mineral fertilizer. These past studies may have shown contrasting results to the current study possibly because of large difference in application rates. For instance, Jarvan and Edesi (2009) compared zero and 60 t ha^{-1} of cattle manure unlike in the current study which had a narrow range of $0\text{--}3 \text{ t ha}^{-1}$ broiler litter.

Ash content

Ash content of the sweet potato ranged from 0.91% for T_0 to 1.37% for T_3 . Ash content of the sweet potatoes grown without broiler litter was significantly ($P < 0.05$) lower than that of the sweet potatoes grown with 1, 2, or 3 t ha^{-1} of broiler litter (Fig. 1). Generally, the ash content of the sweet potatoes increased as the broiler litter rate increased, with a high linear correlation ($r = 0.90$) (Table 4). Although treatment T_2 sweet potatoes had slightly less ash content than T_1 , the difference was not statistically significant. The increase in ash content of the sweet potatoes as the broiler litter rate increased may have been due to the higher availability of the mineral nutrients in the soil and hence, higher absorption. Sistani et al. (2008) found that higher application of broiler litter resulted in higher accumulation of P, K, Mg, and Ca in the soil. Agbede and Adekiya (2011) also observed that the leaf N, P, and K in sweet potato gradually increased as the level of poultry manure applied was increased from 0, 5, 10 to 15 t ha^{-1} . In addition, Demir et al. (2010) found that the P concentration of tomato leaves and fruits significantly increased with increase in poultry manure application rate. Agbede (2010) also found that addition of poultry manure significantly increased the nutrient (N, P, K, Ca, and Mg) concentration in the sweet potatoes leaves. The current findings were consistent with these past studies as it showed that higher rate of application of the broiler litter resulted in higher amounts of ash content.

Fiber content

The crude fiber contents of the sweet potato treatments had a very narrow range from 0.89% for $T_{0.5}$ to 0.99% for the T_3 (Table 1). Considering the moisture content of the sweet potatoes (Table 1), the fiber content range was equivalent to 3.9–4.5%, on dry weight basis, which was consistent with findings from some previous studies. Mullin et al. (1994) found the insoluble fiber content of fresh, cured, and stored Beauregard sweet potatoes to be 4.70%, 4.60%, and 5.02%, respectively, on dry weight basis. This observation was consistent with the findings in the present study, because crude fiber mainly accounts for the insoluble fiber (Knudsen 2001). Oboh et al. (1989) also

Table 2. Moisture, fiber, and β -carotene contents of the sweet potato under the different treatments.

Treatment	Moisture (%)	Fiber (%)	p-Carotene ($\mu\text{g/g}$)
T_0	$77.92 \pm 0.14^{\text{ab}}$	$0.95 \pm 0.02^{\text{ab}}$	$178.0 \pm 28.5^{\text{c}}$
$T_{0.5}$	$76.98 \pm 0.34^{\text{c}}$	$0.89 \pm 0.06^{\text{b}}$	$263.0 \pm 18.7^{\text{a}}$
T_1	$77.19 \pm 1.01^{\text{bc}}$	$0.95 \pm 0.05^{\text{ab}}$	$139.0 \pm 40.0^{\text{c}}$
T_2	$78.58 \pm 0.15^{\text{a}}$	$0.91 \pm 0.02^{\text{ab}}$	$191.2 \pm 9.9^{\text{bc}}$
T_3	$77.84 \pm 0.25^{\text{ab}}$	$0.99 \pm 0.05^{\text{a}}$	$238.3 \pm 25.3^{\text{ab}}$

Values on the same column with similar letters are not significantly different ($P < 0.05$). T_0 , $T_{0.5}$, T_1 , T_2 , T_3 refer to treatments and the subscripts represent tons of broiler litter applied.

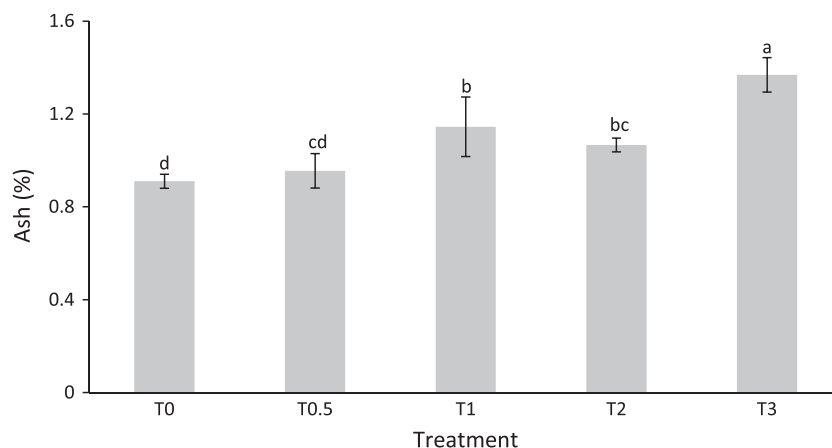


Figure 1. Ash content of the sweet potatoes growth with different amount of broiler litter.

found that the crude fiber content of 49 sweet potato varieties ranged between 3.45% and 6.36% on dry basis. In fact, the two light orange-fleshed sweet potatoes among the 49 varieties had crude fiber contents of 4.00% and 4.42%. In the current study, the broiler litter application rate did not show much effect on the crude fiber content of the Beauregard sweet potato. The fiber contents of all the treatments were not significantly different from that of the control. Only T_{0.5} had statistically slightly lower fiber content than the T₃ sweet potatoes. However, the fiber content had a moderate positive linear correlation ($r = 0.47$) with the rate of broiler litter application (Table 4).

Vitamin C content

Treatment T₀ (6.43 mg/100 g) sweet potatoes had the least ascorbic acid content, whereas T_{0.5} (15.51 mg/100 g) had the highest amount (Fig. 2), a range close to the

findings of some past studies. Using Voltammetric and titrimetric methods, Ogunlesi et al. (2010) found the vitamin C of sweet potato to be 6.15 and 4.28 mg/100 g, respectively, and in another study, Watada and Tran (1987) found the content to be 27.7 mg/100 g, on fresh weight basis. In the current study, vitamin C content of the sweet potatoes peaked at T_{0.5} and then gradually declined as the broiler litter rate increased (Fig. 2). In fact, vitamin C content of treatment T₃ (7.57 mg/100 g) was not statistically different from that of T₀. The vitamin C content showed no linear correlation with the rate of broiler litter applied (Table 4); however, the two parameters portrayed a fairly strong, concave down, quadratic relationship ($R^2 = 0.62$) (Fig. 3). Some past studies have also shown that the level/type/method of soil fertilization do affect the vitamin C content with similar trend as observed in the current study. Using five levels of poultry manure (0, 5, 10, 15, 20 t ha⁻¹), Ademoyegun et al. (2011) found that the vitamin C content of pepper

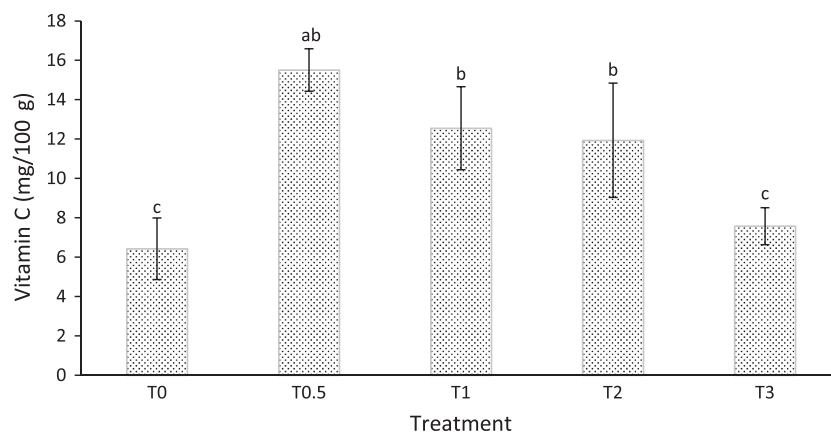


Figure 2. Vitamin C content of the sweet potatoes growth with different amounts of broiler litter.

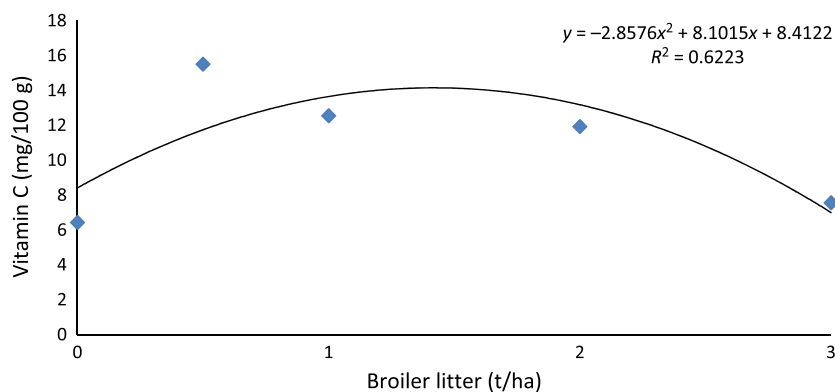


Figure 3. Quadratic relationship between the vitamin C content of the sweet potato and the rate of broiler litter ($t\ ha^{-1}$) applied.

Table 3. Texture of the sweet potatoes grown with the different amount of broiler litter manure.

	Treatment				
	T ₀	T _{0.5}	T ₁	T ₂	T ₃
Firmness (kN)	0.033 ± 0.006 ^b	0.040 ± 0.004 ^a	0.037 ± 0.004 ^{ab}	0.034 ± 0.001 ^{ab}	0.035 ± 0.003 ^{ab}

Values on the same row with similar letters are not significantly different ($P < 0.05$). T₀, T_{0.5}, T₁, T₂, T₃ refer to treatments and the subscripts represent tons of broiler litter applied.

Table 4. Linear correlation between sweet potato measure and the rate ($t\ ha^{-1}$).

Analysis	Moisture	Ash	Fiber	Texture	Vitamin C	β -Carotene	Color		
							L-value	a-value	b-value
Correlation coefficient (<i>r</i>)	0.4230	0.9019	0.4686	-0.2020	-0.1833	0.2338	0.0637	0.1579	0.8563

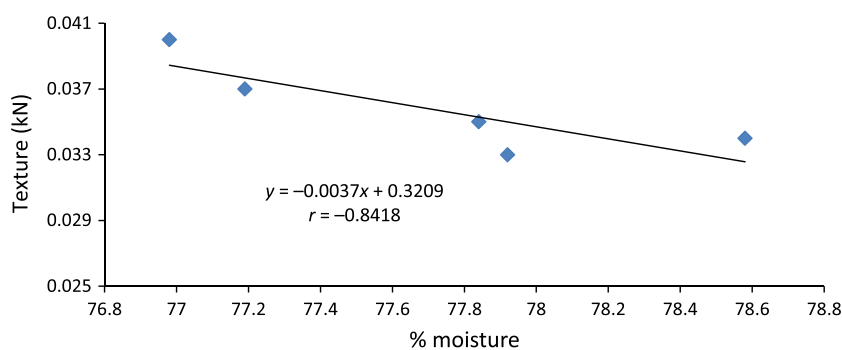


Figure 4. Linear correlation between firmness and moisture content of the sweet potatoes.

peaked at $5\ t\ ha^{-1}$, and then declined as the manure application rate increased. Mathur et al. (2010) also observed that tomato fruits grown with the higher rate of $8\ m^3/20\ m^2$ of chicken manure had less vitamin C con-

tent than fruits fertilized with the lower rate of $4\ m^3/20\ m^2$ of the manure. Xu et al. (2001) observed that soil fertilization method/type do influence vitamin C content of crop. Possibly, elevation of N at higher broiler litter

Table 5. Color values of the sweet potatoes grown with the different amounts of broiler litter.

Treatment	L-value	a-value	b-value
T ₀	61.71 ± 0.18 ^{bc}	20.24 ± 0.20 ^a	23.33 ± 0.34 ^b
T _{0.5}	60.73 ± 0.32 ^c	19.85 ± 0.25 ^a	22.12 ± 0.47 ^c
T ₁	63.37 ± 0.44 ^a	20.67 ± 0.23 ^a	24.73 ± 0.57 ^a
T ₂	62.19 ± 0.049 ^b	20.34 ± 0.56 ^a	23.32 ± 0.65 ^b
T ₃	61.52 ± 1.09 ^{bc}	20.1 ± 0.77 ^a	24.71 ± 0.43 ^a

Values on the same column with similar letters are not significantly different ($P < 0.05$). T₀, T_{0.5}, T₁, T₂, T₃ refer to treatments and the subscripts represent tons of broiler litter applied.

rate is the reason for the quadratic relationship as high concentration have been shown to cause drop in vitamin C content (Lee and Kader 2000).

β-Carotene content

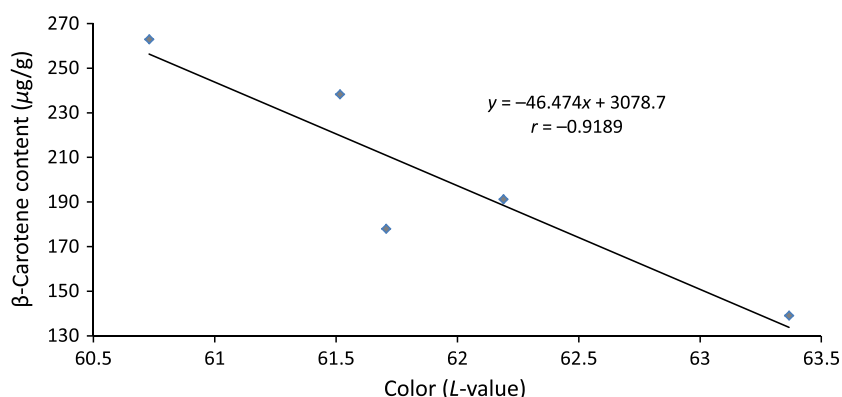
Treatment T_{0.5} sweet potatoes had the highest (263 μg/g) β-carotene content, which was significantly higher than all the other treatments, except T₃ (Table 1). T₁ (139 μg/g) sweet potatoes had the least β-carotene content. However, there was a gradual increase in the β-carotene content from T₁ to T₃ (238 μg/g) (Table 1). Nedunchezhiyan et al. (2010) found that application of farm yard manure increased β-carotene content in sweet potato, compared to the roots which were grown without soil fertilization. Rattler et al. (2005) also observed that β-carotene content of lettuce increased significantly with increase in the rate of soil fertilization. In addition, Kipkosgei et al. (2003) working with black nightshade and Naikwade et al. (2011) with spinach also observed that β-carotene content was significantly increased depending on the type and the level of fertilizer applied. However, in the current study, there was weak linear relationship ($r = 0.23$) between the β-carotene content and the broiler litter (Table 4).

Texture

The firmness of the sweet potatoes ranged from 0.033 to 0.040 kN, for treatments T₀ and T_{0.5}, respectively (Table 3). Only treatment T_{0.5} had significantly firmer sweet potatoes than the control. Although the firmness of the treatments (T₁, T₂, and T₃) appeared slightly higher than that of the control, they were not significant different (Table 3). T_{0.5} sweet potatoes appeared firmer possibly because they had the least moisture content (Table 1) compared to all the other treatments. The firmness of the sweet potatoes had a very strong negative correlation ($r = -0.84$) to the moisture content (Fig. 4); however, the linear relationship ($r = -0.20$) with the broiler litter rate was very weak (Table 4).

Color

Treatment T_{0.5} sweet potatoes had the darkest ($L = 60.7$) orange color (Table 5), which may have been due to the high β-carotene content as reflected in Table 2. On the other hand, sweet potatoes grown with 1 t ha⁻¹ of broiler litter which were lightest ($L = 63.4$) in color, had the least amount of β-carotene. Generally, deeper orange sweet potatoes had higher β-carotene content than the lighter ones as reflected in the correlation between β-carotene content and the color L-values (Fig. 5). The two characteristics had a negative correlation with $r = -0.9189$. Kidmose et al. (2007) observed that sweet potato with darker orange flesh had higher β-carotene content than the yellow-fleshed variety. Ameny and Wilson (1997) also found that the color L-value of sweet potatoes analyzed had a negative correlation ($r = -0.74$) to the β-carotene content. However, the color b-value which is the measure of yellowness, increased as the broiler litter rate increased, with a strong linear correlation of $r = 0.8563$.

**Figure 5.** Correlation between the β-carotene content and color L-value of the sweet potato treatments.

Conclusion

Addition/increase in broiler litter affected some of the nutritional properties of the Beauregard sweet potatoes. Ash content of the sweet potatoes increased as the broiler litter application rate was increased, probably due to the accumulation of mineral nutrients, like P, K, Mg, Ca, in the roots. Application of broiler litter at the lowest rate significantly enhanced the vitamin C content in the sweet potatoes. However, the vitamin C content gradual decreased as the broiler litter rate was further increased. Also, the least broiler litter application rate yielded sweet potatoes with the highest β -carotene. Although T1 had the least amount of β -carotene, the content gradually rose with further increase in broiler litter rate. Moisture, fiber, and texture of the sweet potatoes were not significantly influenced by the broiler litter application. Overall, the sweet potatoes grown with 0.5 t ha⁻¹ of broiler litter had higher dry matter, vitamin C, and β -carotene contents, and also were firmer with darker orange color than the control. These results show that qualitative Beauregard sweet potatoes can be grown organically using broiler litter application rate as recommended by the Alabama Cooperative Extension Program, minimizing the cost of production and the potential of surface and ground water contamination.

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Conflict of Interest

None declared.

References

- Ademoyegun, O. T., T. A. Fariyike, and R. B. Aminu-Taiwo. 2011. Effect of poultry dropping on the biologically active compounds in capsicum annum (var. Nsukka yellow). *Agric. Biol. J. North Am.* 2:665–672.
- Agbede, T. M. 2010. Tillage and fertilizer effects on some soil properties, leaf nutrient concentrations, growth and sweet potato yield on an Alfisol in southwest Nigeria. *Soil Tillage Res.* 110:25–32.
- Agbede, T. M., and A. O. Adekiya. 2011. Evaluation of sweet potato (*Ipomoea batatas* L.) performance and soil properties under tillage methods and poultry manure levels. *Emir. J. Food Agric.* 23:164–177.
- Ameny, M. A., and P. W. Wilson. 1997. Relationship between Hunter color values and β -carotene contents in white-fleshed African sweetpotatoes (*Ipomoea batatas* Lam.). *J. Sci. Food Agric.* 73:301–306.
- Bary, A., C. Cogger, and D. M. Sullivan. 2000. Fertilizing with manure, *Farming West of the Cascades Series*. Pacific Northwest Extension Publications, Washington State University, Pullman, WA. PNW0533.
- Bradley, R. L., Jr. 1998. Moisture and total solids analysis. Pp. 119–139. in S. S. Nielsen, ed. *Food analysis*, 2nd ed. Aspen Publishers Inc., Gaithersburg, MD.
- Chen, B.-M., Z.-H. Wang, S.-X. Li, G.-X. Wang, H.-X. Song, and X.-N. Wang. 2004. Effect of nitrate supply on plant growth, nitrate accumulation, metabolic nitrate concentration and nitrate reductase activity in three leafy vegetable. *Plant Sci.* 167:635–643.
- Demir, K., O. Sahin, Y. K. Kadioglu, D. J. Pilbeam, and A. Gunes. 2010. Essential and non-essential element composition of tomato plants fertilized with poultry manure. *Sci. Hortic.* 127:16–22.
- Eitenmiller, R. R., Jr., W. O. Landen Jr., and J. Augustin. 1998. Vitamin analysis. Pp. 281–292 in S. S. Nielsen, ed. *Food analysis*, 2nd ed. Aspen Publishers Inc., Gaithersburg, MD.
- Gilfillen, R. A., N. S. Rowland, W. T. Willian, B. B. Sleugh, M. Z. Tekeste, and K. R. Sistani. 2010. Effect of broiler litter application on nutrient accumulation in soil, *Plant Management Network International*. Online Forage and Grazinglands doi: 10.1094/FG-2010-1105-01-RS.
- Jarvan, M., L. Edesi, Edesi L. 2009. The effect of cultivation methods on the yield and biological quality of potato, *Agron. Res.* 7:289–299.
- Kidmose, U., L. P. Christensen, S. M. Agili, and S. H. Thilsted. 2007. Effect of home preparation practices on the content of provitamin A carotenoids in coloured sweet potato varieties (*Ipomoea batatas* Lam.) from Kenya. *Innovative Food Sci. Emerg. Technol.* 8:399–406.
- Kingery, W. L., C. W. Wood, D. P. Delaney, J. C. Williams, and G. L. Mullins. 1994. Impact of long-term application of broiler litter on environmentally related soil properties. *J. Environ. Qual.* 23:139–147.
- Kipkosgei, L. K., L. S. M. Akundabweni, and M. J. Hutchinson. 2003. The effect of farmyard manure and nitrogen fertilizer on vegetative growth, leaf yield and quality attributes of *Solanum villosum* (Black nightshade) in Keiyo district, Rift Valley. *Afr. Crop Sci. Conf. Proc.* 6:514–518.
- Knudsen, K. E. B. 2001. The nutritional significance of “dietary fibre” analysis. *Anim. Feed Sci. Technol.* 90: 3–20.
- Laurie, S. M., P. J. van Jaarsveld, M. Faber, M. F. Philpott, and M. T. Lanuschagne. 2012. *Trans*- β -carotene, selected mineral content and potential nutritional contribution of 12 sweet potato varieties. *J. Food Compos. Anal.* 27:151–159.
- Lee, S. K., and A. A. Kader. 2000. Preharvest and postharvest factors influencing vitamin C content of horticultural crops. *Postharvest Biol. Technol.* 20:207–220.

- Mathur, N., J. Singh, S. Bohra, A. Bohra, and A. Vyas. 2010. Growth and productivity of tomato (*Lycopersicon esculentum* Miller) grown in greenhouse as affected by organic, mineral and Bio-N-Fertilizers. *Sci. Cult.* 76:128–131.
- Mitchell, C. C., and J. O. Donald. 1999. The value of use of poultry manures as fertilizer, Alabama Cooperative Extension System (Alabama A&M and Auburn University), ANR-244. Auburn University, Auburn, AL.
- Mullin, W. J., N. Rosa, and L. B. Reynolds. 1994. Dietary fibre in sweet potato. *Food Res. Int.* 27:563–565.
- Naikwade, P., U. Mogle, and B. Jadhav. 2011. Improving total chlorophyll, ascorbic acid and β carotene in spinach by applying weed manures. *Biosci. Discov.* 2:251–255.
- Nedunchezhiyan, M., G. Byju, and S. N. Dash. 2010. Effect of organic production of orange fleshed sweet potato (*Ipomoea batatas* L.) on root yield, quality and soil biological health, *Int. Res. J. Plant Sci.* 1:136–143.
- Nesic, Z., Z. Tomic, V. Krnjaja, and D. Tomasevic. 2008. Nitrate in plants and soil after fertilization of grass-legume mixtures. *Biotechnol. Anim. Husbandry* 23:95–104.
- Oboh, S., A. Ologhobo, and O. Tewe. 1989. Some aspects of the biochemistry and nutritional value of the sweet potato (*Ipomea batatas*). *Food Chem.* 31:9–18.
- Ogunlesi, M., W. Okiei, L. Azeez, V. Obakachi, M. Osunsanmi, and G. Nkenchor. 2010. Vitamin C contents of tropical vegetables and foods determined by voltammetric and titrimetric methods and their relevance to the medical uses of the plants. *Int. J. Electrochem. Sci.* 5:105–115.
- O'Sullivan, J. N., C. J. Asher, and F. P. C. Blamey. 1997. Nutrient disorder of sweet potato, *Aciar Monograph Series*. Australian Center for International Agricultural Research, Canberra.
- Rattler, S., K. Briviba, B. Birzele, and U. Köpke. 2005. Effect of agronomic management practices on lettuce. Pp. 188–191 in U. Köpke, U. Niggli, D. Neuhoff, P. Cornish, W. Lockeretz, and H. Willer, eds. *Researching sustainable systems. Proceedings of the First Scientific Conference of the International Society of Organic Agriculture Research (ISO FAR)*, Adelaide, South Australia, 21–23 September 2005, ISBN 3-906081-76-1.
- Sistani, K. R., F. J. Sikora, and M. Rasnake. 2008. Poultry litter and tillage influences on corn production and soil nutrients in a Kentucky silt loam soil. *Soil Tillage Res.* 98:130–139.
- Stolze, M., and N. Lampkin. 2009. Policy of organic farming: rationale and concepts, *Food Policy* 34:237–244.
- USDA/National Organic Program. 2013. Soil fertility and crop nutrient management practice standard. 7 CFR Section 205.203 Available at www.ams.usda.gov/nop (accessed April 25, 2013).
- Watada, A. E., T. T. Tran. 1987. Vitamin C, B1, and B2 contents of stored fruits and vegetables as determined by high performance liquid chromatography. *J. Am. Soc. Hortic. Sci.* 112:794–797.
- Xu, H. L., R. Wang, M. A. U. Mridha, S. Kato, K. Katase, and H. Umemura. 2001. Effects of organic fertilization and EM inoculation on leaf photosynthesis, fruit yield and quality of tomato plants. *J. Crop Prod.* 3:173–182.