Impact of poultry manure and harvest season on juice quality of yellow passion fruit (*Passiflora edulis* var. *flavicarpa* Deg.) in the sub-humid zone of Nigeria

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Fruits, 2008, vol. 63, p. 239–247

DOI: 10.1051/fruits:2008017
www.fruits-journal.org

RESUMEN ESPAÑOL, p. 247

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Abstract — **Introduction**. The production of high quality fruit juice involves several cultural inputs. Among other factors, fruit quality attributes are influenced by the cultivar, the climate, the harvesting time and soil fertility. Particularly, the soil fertility has a significant effect on the nutritional characteristics of the juice. Good practice as regards fertilization consists of applying rates adapted to plant optimum growth, yield and fruit quality. **Materials and methods**. Effects of four poultry manure rates [(0, 5, 10 and 15) t·ha^{-1}] on the juice quality of passion fruits (*Passiflora edulis* var. *flavicarpa*) were evaluated for two cropping years (2005 and 2006). The seedlings of passion fruit vine were field-established in a randomized complete block design, and the manure treatments were replicated four times. Juice quality assessment was performed on fruits picked in December 2005, coinciding with the dry season and low soil moisture recharge, and August 2006, during the wet season and high soil moisture recharge. **Results**. The results obtained indicated a significant poultry manure effect on all the juice quality parameters studied; the quality of the juice increased gradually as the manure rate increased. Similarly, the season of fruit-picking had a significant effect on the juice quality. As expected, vines that received no manure produced fruits with the poorest juice quality, suggesting unfavorable nutritive conditions within the vines. The concentrations of anti-nutrient factors (tannin, hydrogen cyanide, phytate and calcium oxalate) were low in ripe yellow passion fruits, and insignificant regarding health hazards for consumers of yellow passion fruit. **Conclusion**. The results obtained showed that the manure rate and the harvest period affected the quality of passion fruit juice. Application of 15 t·ha^{-1} poultry manure generally gave the best juice quality; similarly, fruits harvested in the first cropping season had better juice quality.

Nigeria / *Passiflora edulis* / plant nutrition / organic fertilizers / fruit juices / quality

Impacts du fumier de volailles et de la période de récolte sur la qualité du jus de passiflores jaunes (*Passiflora edulis* var. *flavicarpa* Deg.) en zone subhumide du Nigéria.

Résumé — **Introduction**. La production de jus de fruits de qualité est conditionnée à plusieurs facteurs culturaux. Parmi eux, les critères de qualité du fruit sont influencés par le cultivar, le climat, la période de récolte et la fertilité du sol. En particulier, la fertilité du sol a un impact significatif sur les caractéristiques nutritionnelles du jus. Les bonnes pratiques en matière de fertilisation consistent à appliquer des doses adaptées à la croissance de la plante, son rendement et la qualité optimale de son fruit. **Matériel et méthodes**. Les effets de quatre doses de fumier de volailles [(0, 5, 10, 15) t·ha^{-1}] sur la qualité du jus de passiflores (*P. edulis* var. *flavicarpa*) ont été évalués pendant deux campagnes de production (2005 et 2006). Les plants de *P. edulis* ont été disposés selon un dispositif en blocs complets randomisés, et les traitements d'engrais ont été répliqués quatre fois. La qualité du jus a été évaluée sur des fruits récoltés en décembre 2005, période de saison sèche et de faible réserve en eau du sol, et en août 2006, période de saison humide et de forte réserve en eau du sol. **Résultats**. Les résultats obtenus ont mis en évidence un effet significatif de l'utilisation de fumier de volailles sur tous les critères de qualité de jus étudiés ; la qualité du jus a augmenté progressivement au fur et à mesure que la dose de fumier augmentait. De même, la saison de récolte des fruits a eu un impact significatif sur la qualité du jus. Comme attendu, les plants n'ayant reçu aucun engrais ont produit des jus de fruits de moindre qualité, ce qui suggère que les conditions nutritives ont été alors défavorables à leur production. Dans les passiflores mûres, les teneurs en éléments antinutritionnels (tannin, cyanure d'hydrogène, phytate et oxalate de calcium) ont été faibles, et négligeables quant aux risques sanitaires encourus par les consommateurs de ces fruits. **Conclusion**. Les résultats obtenus ont montré que les doses de fumier et la période de récolte ont affecté la qualité du jus des fruits de la passion. Une application de 15 t de fumier de volaille·ha^{-1} a globalement donné la meilleure qualité de jus ; de même, les fruits récoltés lors de la première saison de production ont présenté des jus de meilleure qualité.

Nigéria / *Passiflora edulis* / nutrition des plantes / engrais organique / jus de fruits / qualité

1. Introduction

The yellow passion fruit (*Passiflora edulis* var. *flavicarpa*) is a shallow-rooted woody perennial vine, climbing by means of tendrils. The leaves are evergreen with three deep lobes when mature, and are finely tooted. The flower is a single fragrant flower borne at each node in the new growth. Within the fruit is a cavity filled with an aromatic mass of double-walled, membranous sacs filled with orange-colored pulpy juice and small hard-pitted seeds, which can be dark brown or black. The juice flavor is appealing and guava-like [1–3].

Yellow passion fruit, consumed mainly as juice in many parts of the world, is a new crop in Nigeria. It is exploited for its economic importance due to the presence of volatile compounds and a comparatively high acid content, which are responsible for its characteristic exotic flavor and aroma [1–3].

Passion fruit cropping offers a revenue-earning opportunity for developing countries like Nigeria with an emerging economy. Consequently, passion fruit stands a good chance of large-scale cultivation in Nigeria because of the ban on imported fruit drinks into Nigeria, which has stimulated a demand for locally produced juice concentrates by the fruit drink industry for local and export markets [4].

The quality of any agricultural produce is predetermined in the field [5]. Nutrition, among other factors, is a critical determinant of quality of fruits at harvest [6, 7]. Poor quality of fruits before harvesting can never be improved by post-harvest treatments [8]. Hence, sustaining the yield and quality of a new crop in the farmer's field requires appropriate crop management practices, especially soil fertility management.

Currently, there is no adequate production technology package for yellow passion fruit in Nigeria. A production factor, which requires immediate attention, is fertilizer recommendation for optimum fruit yield and high juice quality. Knight and Sauls [9] reported that yellow passion fruit is a shallow-rooted vine and a heavy feeder. Hence, adequate nutrition is essential if production is to remain sustainable in Nigeria. The inorganic fertilizer recommendations for passion fruit based on investigations conducted elsewhere vary widely [4].

According to Nakasone and Paull [2], and Costa Araujo *et al.* [7], fruit quality consists of several attributes, including physico-chemical characteristics, nutritional value, purity, appearance, flavor and consistency. Among other factors, these fruit qualities are associated with the cultivar, the climate, the harvesting time and fertilization [10, 11].

Animal manure is a valuable source of nutrients and organic matter, which can improve the physical characteristics of the soil, and make it more sustainably productive [12, 13]. Poultry manure is the richest of the animal manures and it is essentially a nitrogen-potassium fertilizer [13, 14]. It is often readily available and a cheaper source of nutrient compared with inorganic fertilizers, which are rather expensive for the subsistence farmers and often hard to obtain [14].

One of the best management practices includes applying the correct fertilizer rate for optimum fruit yield. Hence, correct fertilizer rate recommendation is essential for optimum and sustainable productivity. This study was therefore carried out to evaluate the effect of poultry manure rates on the quality of yellow passion fruit, with emphasis on the juice quality.

2. Materials and methods

The experiment was conducted in the research field of the Department of Crop Science, University of Nigeria, Nsukka, Nigeria, between November 2004 and September 2006. Nsukka is in southeastern Nigeria and located on lat. 06° 52' N, long. 07° 24' E, alt. 447 m above sea level. The agro-ecology is sub-humid with a bimodally-distributed annual rainfall of about 1 500 mm. The soil is a sandy loam characterized as an ultisol. Nursery operations commenced in November 2004 with seed sowing; the seeds were broadcast on nursery baskets filled with substrate composted from poultry manure and rice husk (3:1 v/v). The seedlings thereof were transplanted to the field on 10 February 2005, 10 weeks after emergence.

The treatments comprised four levels, [(0, 5, 10 and 15) $t \cdot ha^{-1}$] of poultry manure, replicated four times. The experimental field was marked out into four blocks, which were further subdivided into sixteen plots. The seedlings were planted in a single row plot of five plants with an intra-row spacing of 1.5 m and an inter-row spacing of 2 m. Each block was separated by an alley measuring 3.5 m. The manure was applied evenly in a localized placement using a ring groove 1 month after transplanting and 3 months after the first application of manure. In the second year of study, no manure was applied.

Post-harvest quality assessment of juice extracted from fruits picked in December 2005 (first season harvest) and in August 2006 (second season harvest) was performed. The juice extracted from the different treatment levels was used immediately after extraction for the chemical analysis. Each of the analyses was replicated three times.

Total soluble solids determined by evaporation, acidity (pH) using a consort digital pH meter and titratable acidity were determined as described earlier [15]. Total moisture was determined according to AOAC methods [16]. Sugar was determined as reducing sugar by the procedure outlined by Lane and Eynon described by Olokodana [15]. The Carr-Price reaction described by Jayaraman [17] was used to determine the vitamin A content. Vitamin C was determined according to the procedure described by Olokodana [15]. Pearson's procedure [18] was used to determine the fat, phytate and calcium oxalate contents; Folin-Denis's spectrophotometric method described by Pearson [18] was used to determine tannin; the macro-Kjeldahl method was used for the determination of protein, and the spectrophotometric method was used to determine total phenol [19], while Wang and Filled's method described by Onwuka [20] was used to determine the hydrogen cyanide content.

Data collected were subjected to analysis of variance using GENSTAT 5.0, release 4.23 DE, Discovery Edition 1 [21], following Complete Randomized Design (CRD). Mean separation to detect the effect of the poultry manure rate was by Least Significant Difference (LSD) at the 5% probability level. In the first season of harvest (2005), the control (no manure) plots did not fruit, therefore data were only obtained for the plots with manure added, and so statistical analysis for the first season was based on data from the plots with manure only. However, in the second season (2006) all the treatment plots had fruited and so data analyses were based on all four manure levels.

3. Results

The pH, organic matter content and essential mineral composition of the poultry manure utilized were expectedly high, contrasting the poor nutritional status of the experimental site (*table I*). Poultry manure rates had a significant ($P < 0.05$) effect on the biochemical composition of yellow passion fruit juice during the first (December 2005) and second (August 2006) years, except in % fat and % total soluble solids, which were non-significant in the first season (*table II*). Juice pH decreased with increasing manure rate in the first season harvest (2005) but, in the second season (2006), there was a gradual increase as the manure rate increased. Titratable acidity, concentration of sugar (as reducing sugar), and vitamin A and C concentrations significantly ($P < 0.05$) increased in both seasons as the manure rate increased; in both seasons, the 15 t manure$\cdot ha^{-1}$ rate gave the highest values. In the second season, there was a pronounced increase in vitamin C in the plots with manure added over the control.

The percentage of the protein in the juice increased significantly as the manure rate increased. The fat content of the juice was not influenced by poultry manure rates in the first season but it varied significantly ($P < 0.05$) across manure rates in the second season. The percent total of soluble solids in the first season was not significantly influenced by poultry manure rates but, in the second season, plots with manure added had significantly higher values over the control. The quantity of moisture, total phenol and the color density of the juice slightly but

Table I.
Physicochemical characteristics of composite soil (the top 15 cm) and poultry manure utilized for studying the effect of this organic fertilizer on yellow passion fruit juice quality (Nigeria). CEC: Cation Exchange Capacity.

Substrate	pH (H_2O)	pH (KCl)	Organic matter	Organic carbon	Nitrogen	Potassium	Calcium	Magnesium	CEC (mEq·100 g^{-1})
			(%)		(mg·kg^{-1})				
Soil substrate	4.90	4.20	1.80	1.40	0.70	114.30	110	176	47200
Poultry manure	7.30	7.20	58.72	34.06	1.26	3000.00	308000	19000	–

Table II.
Impact of poultry manure and harvest season on chemical composition of yellow passion fruit studied in the first (December 2005) and second (August 2006) harvest periods (Nigeria). Values are means of three replicates.

Year	Manure rate (t·ha^{-1})	Juice pH	Titratable acidity	Sugar	Vitamin A	Vitamin C	Total phenol	Crude protein	Fat	Total soluble solids	Moisture
			(%)		(mg·100 mL^{-1})			(%)			
1st year of harvest (December 2005)	5	3.11	3.75	6.91	5.30	15.60	0.777	2.19	1.00	78.55	21.45
	10	3.09	3.95	7.96	5.33	16.40	0.781	2.77	0.50	77.73	22.24
	15	2.93	4.35	8.93	5.70	17.40	0.747	3.36	1.00	79.04	20.88
LSD (0.05)		0.08	0.10	1.27	0.18	0.54	0.410	0.027	Non significant	Non significant	0.62
2nd year of harvest (August 2006)	0	2.72	1.90	5.47	8.53	14.41	0.600	1.65	1.74	21.17	85.57
	5	2.74	2.07	5.91	8.50	24.53	0.300	2.31	3.75	20.30	86.33
	10	2.75	2.33	6.44	9.67	25.63	0.400	2.54	5.75	20.43	86.10
	15	2.77	2.63	7.78	12.67	30.95	0.467	3.50	6.63	20.63	86.30
LSD (0.05)		0.01	0.13	0.33	1.85	0.70	0.02	0.054	0.13	0.21	0.57

significantly varied across the treatments; nevertheless, there was no consistent trend in the variation.

The study of the poultry manure rate effect on the anti-nutrient components of fruit juice of yellow passion fruit showed that poultry manure rates had a significant ($P < 0.05$) effect on the concentration of calcium oxalate in the juice in the first season. In the first season, the 10 t manure·ha^{-1} rate supported a higher quantity of calcium oxalate but, during the second season, the effect of poultry manure was non-significant.

In both seasons, the addition of manure significantly influenced the concentration of hydrogen cyanide. In the first season, there was a linear increase in the concentration of hydrogen cyanide as the manure rate increased but, in the second year of harvest, there was a downward trend in the concentration. Similarly, the concentration of phytate varied with the manure rates in both seasons. In the first season, there was an increase in concentration as the manure rate increased but, in the second season, a reversed trend was obtained. For both seasons, the concentration of tannin in the juice was influenced by the highest manure treatment. In the first season, there was an increase in the tannin concentration as the manure rate increased but, during the second season, there was no tannin in fruits harvested from the plots with manure added.

Table III.
The effect of poultry manure rates on the anti-nutrient components of fruit juice of yellow passion fruit in the first and second harvest periods of the study (Nigeria). Values are means of three replicates.

Year	Manure rate ($t \cdot ha^{-1}$)	Calcium oxalate	Hydrogen cyanide	Phytate	Tannin
		($mg \cdot 100\ g^{-1}$)			
1st year of harvest (December 2005)	5	1.407	0.0029	0.673	0.240
	10	2.110	0.0031	0.723	0.310
	15	1.485	0.0035	0.830	0.700
LSD (0.05)		0.221	0.0003	0.001	0.099
2nd year of harvest (August 2006)	0	1.250	0.0009	0.625	0.293
	5	1.250	0.0007	0.343	0.000
	10	1.250	0.0004	0.286	0.000
	15	1.250	0.0000	0.200	0.000
LSD (0.05)		Non-significant	0.0001	0.035	0.217

4. Discussion

The quality traits of juice in the first season of harvest were in most cases distinctly different from the corresponding traits in the second season; this could be due to variability in the soil moisture regimes during the two seasons. The first year of harvest (December 2005) was during the low soil moisture recharge in Nigeria, in contrast to the second year of harvest (August 2006), which coincided with high soil moisture recharge. Baiyeri and Tenkouano [22], working in the same local environment, reported significant variability in proximate qualities of ten *Musa* genotypes across two cropping seasons.

Passion fruit juice is typically acidic: the juice pH range of 2.72–3.11 obtained for both studied seasons was normal and it agreed with the earlier reports by Morton [3] and Araujo *et al*. [7], who found that yellow passion fruit juice pH ranged from 2.06 to 3.00. It was notable that titratable acidity revealed a progressive increase (1.9–4.35) as the manure rate increased in both seasons, similar to what was reported by Nakasone and Paull [2], who showed a range of 2.5–4.0%, although Beal and Farlow [23] reported 3.0–4.0%. The variation in these values may probably be attributed to seasons and/or location. Citric acid is the predominant organic acid in yellow passion fruit, accounting for about 83% [3, 7]. Pretty [24] observed that in many species there is a relationship between total acidity and potassium in soil. Poultry manure is an important source of potassium and so increasing the quantity of application will increase the quantity of available potassium; this could explain the increase in the acidity as the manure rate increased in this study.

Brownleader *et al*. [25] reported that citric acid has an important role in the metabolism of carbohydrate. Higher acidity may therefore be a precursor for high sugar in the juice, as obtained in this study. It was interesting to note as well that increasing the rate of applied poultry manure similarly increased the quantity of vitamin A and vitamin C (ascorbic acid) in both seasons of harvest. However, values obtained in the second season (2006) were higher than those obtained in the first season (2005). The work of Oloyede and Adeboye [26] on snake tomato revealed a similar trend in the concentration of vitamin C.

Reports by Lavon and Goldschmidt [27] and Mengel [28] showed that potassium activates biochemical processes in the plant, particularly its ability to make proteins. The increase in the concentration of protein as the manure rate increased may probably be due to an increase in potassium concentration. This is because the increase in poultry manure rate increased the concentration of potassium, which is an important mineral in fruit quality [7].

The percentage soluble solids were higher in the first season and declined in the second season. The trend may probably be attributed to the moisture stored in the fruit juice in both seasons. The smaller quantity of juice obtained in the first year of study (2005) may probably explain why the total soluble solids was higher but, in the second year of study (2006), there was abundant water in the fruit juice, which probably brought about dilution per a given volume of juice. The percentage moisture showed an opposite trend to what was observed in the soluble solids. In the first year of study (2005), percentage moisture was low compared with the abundant water obtained in the second year of study (2006). The difference probably may be due to the water available in the soil during the fruit maturity in the two years of study. The juice color rating slightly increased with the addition of manure but, on the contrary, the quantity of phenol in the juice decreased with the increase in the rate of manure applied.

Only in the first year of study, addition of manure significantly influenced the concentration of calcium oxalate. In the second year, there was no variation between the control and the manure rates. Oxalate forms a strong complex with dietary calcium, magnesium and iron at certain concentrations [20], leading to formation of insoluble oxalate salts and resulting in oxalate stones [29]. It exerts a negative effect on the bioavailability of nutrients [30], interfering with the utilization of these minerals in the body. The threshold of oxalate toxicity in man is said to be 2–5 g·100 g^{-1} of the sample [31]. The oxalate content in the passion fruit is low. Thus, it has no health hazard tendency. In the first year of study, the hydrogen cyanide concentration increased slightly as the manure rate increased, whereas, in the second year, a downward trend was observed, with 15 t manure·ha^{-1} showing zero percentage cyanide. The anti-nutrient characteristic of hydrogen cyanide is its ability to inhibit the respiratory chain at the cytochrome oxidase level [32, 33]. Our result (0.00–0.035%) indicated that the concentration was much less than that which could result in toxicity. People that consume passion fruit even in large quantity are unlikely to experience cyanide toxicity. The decline in the concentration as the manure rate increased may probably be because of adequate nutrition. Mohammed [34] reported that adequate nutrient results in the production of high quality and better nutritious plants. The concentration of phytate increased with the manure rate in the first season but the reverse was obtained in the second season. The result obtained by Okon and Akpanyung [35], while working on Nigerian brands of malt, was in the range 9.22–5.72 mg phytate·L^{-1} and was rated as a low level that cannot result in a toxicity problem. The result obtained in passion fruit (0.20–0.83 mg·100 mL^{-1}) was lower than the result they obtained, indicating that juice of passion fruit is safe for consumption.

The concentration of tannin in the juice was negligible, especially in the fruits picked in the second season: tannin was only detected in the control. Chang *et al.* [36], while working with banana in the subtropical environment of Taiwan, found that tannin concentration decreased as the fruit aged on the plant, and there was a profound difference between seasons. In summer, the tannin concentration in the banana pulp was 0.8% dry weight but, in the winter, it rose to 5% at an equivalent stage of maturity. Chang *et al.* [36] associated the differences in tannin concentration with differences in the rate of ripening of fruits harvested in the different seasons. The significant differences in the concentration of tannin in the first (2005) and second years of study (2006) may probably be as the result of the climatic conditions prevalent in the different years of study and nutrient release in the seasons. The concentration of tannin in passion fruit (0.000–0.070 mg·100 mL^{-1}) is very low compared with what was stated by Wang *et al.* [37, 38].

Inferences derivable from this study are that manure rates and seasons of harvest had significant effects on the quality of passion fruit juice in Nigeria. Seasonal differences in the biochemical properties evaluated could be due to available soil moisture, which consequently affected the juice moisture content. The dilution effect of high juice moisture was reflected in lower values for some of the biochemical traits. Nevertheless, more importantly, our study revealed that irrespective of season, increasing manure rates increased passion fruit juice quality. It was notable that increasing availability of essential nutrients to the plants via addition of increased rates of manure increased the juice quality. The results obtained revealed that 15 t poultry manure·ha^{-1} gave the best juice quality indices, hence it is recommended for growing passion fruit in the sub-humid zone of Nigeria.

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Impactos del excremento de aves y del periodo de cosecha en la calidad del jugo de pasifloras amarillas (*Passiflora edulis* var. *flavicarpa* Deg.) en zona subhúmeda de Nigeria.

Resumen — **Introducción**. La producción de zumo de frutas de calidad está condicionada a sendos factores culturales. Entre estos, los atributos de calidad del fruto se influencian por el cultivar, el clima, el periodo de cosecha y la fertilidad del suelo. En concreto se debe subrayar el impacto significativo de la fertilidad del suelo sobre las características nutricionales del jugo. Las buenas prácticas en materia de fertilización consisten en aplicar dosis correctas para el crecimiento de la planta, su rendimiento y la calidad óptima de su fruto. **Material y métodos**. Se evaluaron los efectos de cuatro dosis de excremento de aves [(0, 5, 10, 15) t·ha^{-1}] sobre la calidad del jugo de pasifloras (*P. edulis* var. *flavicarpa*) durante dos campañas de producción (2005 y 2006). Las plantas de *P. edulis* se establecieron en campo de acuerdo con dispositivo en bloques completos randomizados y los tratamientos de abonos se replicaron cuatro veces. La evaluación de calidad del jugo se realizó en frutos cosechados en diciembre de 2005, periodo de estación seca y de escasa reserva de agua en el suelo, y en agosto de 2006, periodo de estación húmeda y con fuerte reserva de agua en el suelo. **Resultados**. Los resultados obtenidos pusieron de manifiesto un efecto significativo de luso de excremento de aves sobre todos los parámetros estudiados de la calidad del jugo, hubo un aumento progresivo de la calidad del jugo a medida que aumentaba la dosis de abono. Asimismo la estación de cosecha de los frutos tuvo un impacto significativo en la calidad del zumo. Como se esperaba las plantas que no recibieron ningún abono produjeron jugos de frutas de menor calidad, lo que sugiere que las condiciones nutritivas fueron desfavorables en la producción de las lianas. Los contenidos en factores de antinutricionales (tanino, cianuro de hidrógeno, fitato y oxalato cálcico) fueron escasos en las pasifloras maduras, y ignorables en cuanto a los riesgos saludables corridos por los consumidores de estos frutos. **Conclusión**. Los resultados obtenidos mostraron que las dosis de abono y el periodo de cosecha afectan a la calidad del zumo de las frutas de la pasión. Una aplicación de 15 t de excremento de aves·ha^{-1} ofreció globalmente la mejor calidad del jugo, asimismo, los frutos cosechados en el momento de la primera temporada de producción presentaron un zumo de mejor calidad.

Nigeria / *Passiflora edulis* / nutrición de las plantas / abonos orgánicos / jugo de frutas / calidad