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Research Application Summary

Nutrient composition and phytochemical content of African nightshade (*Solanum nigrum*) edible berries

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Abstract

African nightshade (*Solanum nigrum*) is a green, indigenous leafy vegetable that grows in many parts of the world and its utilization can deliver significant nutrients and phytochemicals into the diet. It is among the indigenous vegetables popularized in Kenya though it is still underutilized. The vegetable has potential of alleviating the burden of hidden hunger which weighs heavily on the nation. Further, only the leafy part is utilized whereas the plant has edible berries. This study sought to address the problem of underutilization by looking at the benefits that can be derived from the berries. Four varieties of the plant were cultivated at the University of Eldoret research field using a Completely Randomized design (CRD). Harvesting of berries began once the first fruits started ripening and harvesting was done periodically till all the fruits were picked. Chemical analyses of the berries were done to determine the content and changes in macro and micro-nutrients and the phytochemical content of the berries as they ripened. Analysis of Variance (ANOVA) was used to determine the significance of *S. nigrum* varieties at different ripening stages for fruit nutrient and phytochemical composition. Tukey's means separation procedure was used to test for significance of differences. The findings indicate high macro- and micro- nutrient content that is comparable to other berries and fruits. Hence the berries should be incorporated into diets so as to alleviate nutrient deficincies.

Key words: Berries, Kenya, indigenous vegetables, nutrient content, *Solanum nigrum*

Résumé

La morelle africaine (*Solanum nigrum*) est un légume à feuilles, indigène vert qui pousse dans de nombreuses régions du monde et son utilisation peut fournir des nutriments et constituants phytochimiques importants dans l'alimentation. Il fait partie des légumes indigènes popularisés au Kenya bien qu'il soit encore sous-utilisé. Ce légume a un potentiel d'alléger le fardeau de la faim cachée. De plus, seule la partie feuillue est utilisée alors que la plante a des baies comestibles. Cette étude visait à résoudre le problème de la sous-utilisation en examinant les avantages pouvant être tirés des baies. Quatre variétés de la plante ont été cultivées dans le champ de recherche de l'Université d'Eldoret en utilisant un dispositif de bloc complètement aléatoire (BCA). La récolte des baies a commencé une fois que les premiers fruits ont mûri et la récolte a été effectuée périodiquement jusqu'à ce que tous les fruits aient été cueillis. Des analyses chimiques des baies ont été effectuées pour déterminer la teneur et les variations en macro et micronutriments et la teneur phyto-chimique des baies à mesure qu'elles mûrissaient. L'analyse de la variance (ANOVA) a été utilisée pour déterminer l'importance des variétés de *S. nigrum* à différents stades de maturation pour les éléments nutritifs des fruits et la composition phytochimique. La procédure de séparation des moyennes de Tukey a été utilisée pour tester la signification des différences. Les résultats indiquent une teneur élevée en macro et micronutriments comparable à celle des autres baies et fruits. Par conséquent, ces baies doivent être incorporées dans les régimes alimentaires afin d'atténuer les carences en nutriments.

Mots clés: Baies, Kenya, légumes indigènes, teneur en éléments nutritifs, *Solanum nigrum*

Introduction

Hidden hunger or micronutrient malnutrition (MNM) is among the major nutritional challenges in the modern world (Allen and Benoist, 2006). This problem is common in the developed nations but is highly prevalent in the developing nations (Muthayya *et al*., 2013). Though it can affect people in all age groups, women of child-bearing age and young children are at a higher risk (UNICEF, 2013). The most common forms of MNM include vitamin A Deficiency (VAD), iron, and iodine deficiencies. Others include zinc, calcium, vitamin D, folate, and copper deficiencies, among others. The deficiencies can be detected through clinical signs or through biochemical analysis. Allen and Benoist (2006) indicate that MNM can contribute to high morbidity and mortality rates leading to high medical budget.

According to Muthayya *et al*. (2013), the MNM burden has been increased by the changing economic times. As food prices rise by the day, many people move away from consuming foods that are rich in micronutrients. They, therefore, opt for foods that are cheaper, more starchy and less nutrient dense. Ruel-Bergeron *et al*. (2015) further indicate that MNM is more potent due to the fact that it is not easy to decipher an individual suffering from it, thereby earning the term 'hidden hunger.' As such, an individual could be suffering from the condition yet appears healthy. This is quite unfortunate especially given that in the developing countries, where food security is often a major challenge, individuals could be suffering from more than one micronutrient deficiencies (UNICEF, 2013). This has adverse effects on the individual, economic and social spheres.

Due to the gravity of the MNM burden, different alternatives have been employed in attempts to alienate the adverse effects of the same. Allen and Benoist (2006) recorded that two of the most successful strategies are supplementation and dietary supply of micronutrients. Provision of the micronutrients in the diets has been championed as another successful avenue of dealing with MNM (Burchi *et al*., 2011). This can be achieved through adoption of food and nutrition system regimes which integrate sustainable agriculture that improves dietary diversity and livelihoods. In this regime, vegetables and legumes feature strongly as a viable option to explore. Ojiewo *et al*. (2015) concluded that to save the vulnerable populations from the threat of food insecurity, vegetables and legumes production and consumption not only promotes the economic status of the individuals, but also provides the much-needed nutrients. These include the micronutrients as well as phytochemicals that promote health.

Of the vegetables, the African Indigenous Vegetables (AIVs) have been reported to be key sources of the micronutrients. Mavengahama *et al*. (2013) concluded that the AIVS (also referred to as wild vegetables), are commonly used as accompaniments to the cereal-based staple diets. Although they are consumed in low quantities, they provide the vital micronutrients that supplement the cereal diets. Therefore, they help in improving the food and nutrition security of the poor, vulnerable households. Interestingly, an analysis by Nyadanu and Lowor (2015) concluded that compared to the exotic species, the indigenous leafy and fruit vegetables are nutritionally superior. African nightshade is among these vegetables that have been highly popularized for their nutritional quality.

Despite its documented benefits, only its leaves are used as vegetables. This is because the plant is characterized as a leafy vegetable. Consequently, its berries are not considered as a potential source of the micronutrients despite the fact that the plant fruits after maturity. As such, little has been studied on the nutrient composition and possible dietary applications of the African nightshade berries. This study, therefore, sought to bridge this knowledge gap by looking at the nutrient composition of the berries and ultimately, possible inclusion of the berries in the diet so as to curb the hidden hunger menace in Kenya.

Materials and methods

Selected African nightshade seeds were planted in the experimental field at the University of Eldoret. Field trials were conducted between February – May 2017. The Completely Randomized Design (CRD) was employed during planting on site as described by Bvenura and Afolayan (2016). There were four (4) blocks, each subdivided into three (3) subplots to allow for three replications. Within the main blocks, there were subplots measuring 4 m by 2 m. These were separated by margins of about 1m within the replicate blocks. The distance between blocks was about 1.5 m. Four varieties of African nightshade were planted in the plots. These comprised of Giant Nightshade (Simlaw seeds), Black Nightshade – local variety (Simlaw seeds), Improved variety (JKUAT), and Agriculture variety (KARLO-Kakamega). These were planted with a spacing of about 60 cm and 45 cm. Drip irrigation was installed within the plots so as to ensure that the plants did not suffer from water stress. Appropriate crop husbandry was employed till the berries reached maturity. The berries were harvested on weekly basis.

All the chemical analyses were carried out in triplicates, using standard AOAC methods. Protein analysis was carried out using the Kjeldahl method as outlined by AOAC Method 984.13, 1995 (Codex Alimentarius Commission, 1999). Crude fibre was analyzed using the AOAC Method 978.10, 1995 was used. Ash determination was done using AOAC Method 923.03, 1995. Carbohydrate content was analyzed by the difference method. The concentration of Zinc (Zn), Calcium (Ca), Magnesium (Mg), Phosphorus (P), Iron (Fe), Sodium (Na) and potassium (K) was determined using the Atomic absorption spectrophotometry (AAS), AOAC (1995) method 985.35. Vitamin C was determined using the HPLC approach, AOAC Method 967.22. The phytochemicals that were analyzed included flavanoids, Total phenols, oxalates, Total carotenoids, phytates and tannins. These were analyzed by UV-VIS spectrophotometry as described by Jeyasree *et al*. (2014). About 100 g of the ground berries was extracted using continuous hot percolation by use of soxhlet apparatus. The extraction was carried out using ethanol at temperature range 60 – 700 C. The extract was filtered and kept in an oven at 500 C for 24 hours. Ultimately, the greenish black waxy residue that was obtained was used for phytochemical analysis.

Results and discussion

Analysis of variance showed that both varietal and maturity stage of the fruits significantly influenced the phytochemical content of nightshade fruits. Changes in phytochemical content of the ripening berries are shown in Table 1. Oxalates ranged from 22.64 to 155.59 mg/g. The highest amount of oxalates was recorded from green JKUAT while the least was recorded from ripe Black N.S. Generally, oxalates decreased as fruits matured. Total phenols were highest (9.083 mg/g) in green Giant N. S. and lowest (3.212 mg/g) in KARLO Agric. The amounts of flavonoids, phytates, tannins, vitamin C, TTA and total carotenoids are shown in Table 1. As with oxalates, total phenols, flavonoids and phytates decreased as the fruits ripened. This was also observed by Skrovankova *et al*. (2015). On the other hand, the content of Vitamin C, Tannins and total carotenoids increased with ripening. Since the berries are consumed ripe, it is evident that ripening reduces the anti-nutritional factors while enhancing the much needed vitamin C. Black nightshade, which is the local variety grown in Kenya, had significantly higher beta-carotene content compared to the other varieties. This higher content gave the berries an orange-yellow color while all other varieties were purple-black. It also had lower percentage of titrable acidity.

Calcium content decreased as the fruits ripened while iron, potassium and phosphorus all increased through the ripening stages (Table 2). Magnesium and Sodium decreased as the fruits ripened but as they reached senescence, the content increased. Proximate composition did not vary a lot during the first three stages but it was observed that during senescence, most varieties had increased fibre, ash and protein content but decreased carbohydrate content. These changes affirm the observation by Skrovankova *et al*. (2015) that nutrients in berries from different varieties vary as the berries ripen. As such, berries should be picked at a particular stage depending on the nutrient that is required.

Conclusions

Though different amongst different varieties, berries of the African Nightshade showed macro and micro-nutrient content comparable to other berries and fruits. They have anti-nutrient factors at the earlier maturity stages but these reduce at the ripe stage which is the point at which the fruits are eaten. Given their nutritional value, the berries should be incorporated in the diet as an avenue of diet diversification and optimal utilization of a popular indigenous plant.

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Table 1. Changes in phytochemical content of the ripening berries

Variety	Maturity stage	Phytochemicals							
		Oxalates (Mg/g)	Total phenols (Mg/g)	Flavanoids (Mg/g)	Phytates (Mg/g)	Tannins (Mg/100g)	Vit. C (Mg/100g)	TTA (%)	Total Carotenoids (Mg/100g)
Black N.S	Green	51.22 ^{bcde}	3.99 ^{abcd}	37.44^{h}	20.34^{de}	23.01^{abc}	20.34^{abcd}	3.521^{b}	1.187^{ab}
Giant N.S.		128.83^{g}	9.083^{i}	27.27^{g}	58.09^{g}	48.87^{cd}	38.63^{bcde}	9.246^{e}	1.707^{bc}
JKUAT		155.59^{h}	5.365^{efg}	16.23^{de}	54.6^{g}	91.63^{ef}	41.59^{de}	9.246^{e}	1.116^{ab}
KARLO Agric.		84.62^{f}	8.71^{i}	22.74^{f}	50.85^{g}	75.41^{de}	14.26^{ab}	11.737^{f}	1.808^{cd}
Black N.S.	Colour break	39.86^{bc}	5.062^{def}	5.5^{a}	4.65^{ab}	70.46^{de}	29.57^{abcde}	3.762^{b}	0.895^{a}
Giant N.S.		92.48^{f}	3.546^{ab}	19.72^{ef}	28.47^{f}	74.07^{de}	48.62^{ef}	5.303^{c}	4.428^{h}
JKUAT		81.79^{f}	4.529^{bcde}	20^{ef}	26.47^{ef}	105.55^{f}	40.32^{cde}	9.757^{e}	3.442^{g}
KARLO Agric.		60.23^{e}	3.212^{a}	22.27^{f}	22.09^{def}	40.92^{bc}	14.88^{abc}	15.92^{g}	1.942^{cde}
Black N.S.	Ripe	22.64^{a}	4.786^{cde}	2.8^{a}	3.18^{ab}	8.95^{a}	42.98^{def}	3.072^{ab}	8.314^{i}
Giant N.S.		36.54^{ab}	4.696^{cde}	28.61^{g}	8.94^{bc}	36.5^{bc}	7.83^{a}	6.625^{d}	2.364^{def}
JKUAT		58.77^{de}	6.117^{fgh}	37.58^{h}	6.42^{ab}	169.84^{g}	19.11^{abcd}	6.625^{d}	2.578^{f}
KARLO Agric.		52.52^{cde}	3.785^{abc}	10.46^{bc}	6.22^{ab}	149.17^{g}	28.97^{abcde}	9.685^{e}	2.006^{cdef}
Black N.S.	Senescense	23.68^{a}	3.672^{abc}	4.39^{a}	1.08^{a}	21.59^{ab}	68.14^{f}	2.162^{a}	4.612^{h}
Giant N.S.		51.23^{bcde}	5.663^{efg}	14.84^{cd}	15.14^{cd}	74.24^{de}	182.3^{g}	5.288^{c}	2.231^{cdef}
JKUAT		43.47^{bcd}	6.845^{h}	12.42^{bcd}	3.62^{ab}	35.61^{abc}	39.88^{bcde}	5.288^{c}	2.524^{ef}
KARLO Agric.		50.37^{bcde}	6.321^{gh}	10.01^{b}	3.55^{ab}	80.11^{ef}	37.65^{bcde}	7.583^{d}	3.77^{g}

Values with different superscript letters along the same column are significantly difference at P=0.05 as assessed by Tukey's significant difference

Table 2. Minerals and proximate composition of the berries

Variety	Maturity stage	Minerals (Mg/100g)								Proximate composition (%)			
		Ca	Fe	K	Mg	Na	P	Zn	Ash	Crude fibre	Fat	CHO	Protein
Black N.S.	Green	404^{de}	6.906^{abc}	131^{ab}	936.8^{bcd}	404^{ef}	211.7^{a}	5.743^{bcde}	5.863^{abc}	18.23^{abc}	3.434^{abcd}	71.42^{efg}	9.16^{abc}
Giant N.S.		507.9^{f}	8.362^{abcd}	131.2^{ab}	918^{bcd}	507.9^{g}	242.9^{ab}	4.346^{bc}	7.532^{cdefg}	19.25^{c}	3.745^{abcde}	61.87^{cdefg}	13.21^{cd}
JKUAT		545.7^{f}	8.242^{abcd}	105.1^{a}	936.1^{bcd}	545.7^{g}	222^{ab}	9.246^{f}	7.71^{defg}	10.62^{a}	3.283^{abcd}	65.31^{defg}	11.81^{bcd}
KARLO Agric.		391.4^{de}	9.431^{bcde}	124.8^{ab}	841.4^{abcd}	23.4^{a}	304.4^{abc}	8.097^{ef}	7.013^{bcdef}	17.25^{abc}	3.643^{abcde}	61.54^{cdef}	11.98^{bcd}
Black N.S.	Colour break	231.4^{ab}	5.787^{a}	128.8^{ab}	943.1^{bcd}	231.4^{b}	256.3^{ab}	4.987^{bcd}	6.414^{bcd}	18.77^{bc}	1.549^{a}	72.02^{fg}	9.01^{ab}
Giant N.S.		415.4^{e}	12.05^{ef}	243^{de}	827.3^{abcd}	415.4f	834.1^{g}	5.682^{bcd}	7.637^{defg}	17.61^{abc}	5.409^{def}	54.59^{abcd}	14.82^{d}
JKUAT		531.5^{f}	7.129^{abcd}	221.2^{de}	888.4^{bcd}	531.5^{g}	291.7^{ab}	6.113^{cde}	8.568^{efgh}	20.15^{c}	4.179^{cdef}	55.94^{abcde}	10.44^{abc}
KARLO Agric.		320.4^{bcd}	7.946^{abcd}	156.9^{abc}	775^{abc}	26.4^{a}	417.9^{cd}	6.279^{cde}	6.895^{bcde}	16.89^{abc}	1.896^{abc}	60.23^{cdef}	12.67^{bcd}
Black N.S.	Ripe	209.9^{a}	6.053^{ab}	164.2^{bc}	629.5^{a}	209.9^{b}	305.9^{abc}	4.236^{bc}	4.602^{a}	20.38^{c}	1.723^{ab}	77.25^{g}	7.1a
Giant N.S.		243.7^{ab}	12.252^{ef}	197.9^{cd}	646.7^{a}	245.5^{b}	339.9^{bc}	4.319^{bc}	5.446^{ab}	19.9^{c}	5.784^{ef}	57.54^{abcdef}	15.01^{d}
JKUAT		318.7^{bcd}	$7.219a^{bcd}$	264.1^{ef}	812.6^{abc}	318.7^{cd}	568.7^{ef}	5.455^{bcd}	6.562^{bcd}	14.22^{abc}	2.09^{abc}	59.1^{bcdef}	15.71^{d}
KARLO Agric.		345.7^{cde}	9.987cde	231.1^{de}	901.7^{bcd}	31.4^{a}	555^{e}	6.948^{def}	5.771^{ab}	15.47^{abc}	1.666^{a}	59.87^{cdef}	15.26^{d}
Black N.S.	Senescense	260.8^{abc}	10.39^{de}	264.7^{ef}	1053.9^{d}	260.8^{bc}	273.2^{ab}	3.493^{b}	5.839^{ab}	11.18^{ab}	2.374^{abc}	64.7^{defg}	15.17^{d}
Giant N.S.		340.3^{cde}	16.266^{g}	316.1^{f}	842.5^{abcd}	340.3de	561.5e	12.781^{g}	10.048^{h}	11.04^{a}	3.992^{bcde}	48.72^{abc}	25.75^{e}
JKUAT		278.4^{abc}	9.426^{bcde}	505.5^{h}	725.8^{ab}	278.4^{bcd}	686.4^{f}	0.535^{a}	8.609^{fgh}	16.39^{abc}	6.456^{f}	43.01^{a}	22.83^{e}
KARLO Agric.		319^{bcd}	14.271^{fg}	394.2^{g}	969.3^{cd}	57^{a}	468.5^{de}	13.253^{g}	9.027^{gh}	15.92^{abc}	$5.521d^{ef}$	44.16^{ab}	21.99^{e}

Values with different superscript letters along the same column are significantly difference at p=0.05 as assessed by Tukey's significant difference

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