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Potassium content of some Nigerian plant foods and effects of daily consumption on blood pressure and pressor responses in rats

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Abstract

The study set out to assay the potassium content of ten locally eaten plant foods and to determine the possible effects of daily consumption of the foods on blood pressure and pressor responses in rats. The potassium contents of nine fruits and carrot were determined by flame atomic absorption spectrophotometry. The two with the highest amounts of potassium were fed to rats at a dose 5 g/day for 28 days. Tap water (2 ml/day) and potassium citrate (25 mg/kg) for 28 days served as negative and positive controls respectively. Blood pressure and pressor responses to noradrenaline, verapamil and sodium nitroprusside were measured by invasive method. The potassium concentration varied in all the foods with carrot and plantain having the highest amount of potassium (0.42 ± 0.14 and 0.36 ± 0.10 % w/w respectively). Carrot, plantain and potassium citrate did not significantly lower blood pressure. The pressor responses to 10 µg/kg noradrenaline were significantly attenuated in the carrot ($P < 0.02$) and plantain ($P < 0.05$) fed rats compared to controls. Also, carrot significantly ($P < 0.05$) augmented blood pressure decreases to sodium nitroprusside and verapamil. The study shows that carrot and plantain may be helpful in preventing acute blood pressure increases while carrot may augment the antihypertensive effects of some drugs.

Keywords: Fruits; Carrot; Potassium supplementation; Blood pressure; Pressor responses

INTRODUCTION

Non-pharmacologic methods are becoming popular in the treatment and prevention of hypertension (Gu *et al*., 2001; Beilin *et al*., 2001; Savica *et al*., 2010). Among these methods, the use of potassium supplements seems to be very well established. This is because various human and animal studies have shown the usefulness of oral potassium supplementation in the management of hypertension (Suzuki *et al*., 1981; Cappuccio and MacGregor, 1991; Franzoni *et al*., 2005; Haddy *et al*., 2006). There have been contradictory reports as well (Sacks *et al*., 1995; Dickinson *et al*., 2010) but this may have been due to the wide variety of protocols that have been used to effect potassium supplementation. The use of potassium supplement has been found to be more effective in hypertensive than in normotensive human subjects (Cappuccio and MacGregor, 1991). Although, most studies involving potassium supplementation have involved hypertensive animals and humans, some reports have also confirmed that supplementation may be helpful in the non-

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hypertensives (Naismith and Braschi, 2003; Omogbai *et al*., 2005; Haddy *et al*., 2006).

Plants are a natural source of potassium and therefore the consumption of medicinal plants or foods can provide a medium for increased potassium intake which could be helpful in the hypertensive and its cardiovascular sequelae (Bazzano *et al*., 2003; Liu *et al*., 2000). These plant based foods are often eaten by both the rich and the poor and their potassium content may be contributory to the prevention and management of hypertension. However, the potassium content of the locally consumed and popular plant foods/fruits is often a subject of much debate. It is therefore not known if their consumption would influence blood pressure. This study was designed with the objectives of 1): assaying the potassium content of nine selected fruits and carrot and 2): testing the effects of daily feeding on the two with the highest amounts of potassium on the blood pressure and pressor responses of rats.

EXPERIMENTAL

Sourcing, preparation and determination of potassium content of fruits and carrot. Ripe fruits and carrot (*Daucus carota*) were sourced from five different markets located within metropolitan Benin City, Nigeria. The fruits were: banana (*Musa paradisiaca*), plantain (*Musa serpentium*), pommelo (*Citrus grandis*), soursop (*Anona muritica*), sweet orange (*Citrus sinensis*), garden eggs (*Solanum melongena*), bush mango (*Irvingia gabonensis*), pineapple (*Ananas comosus*) and apple (*Malus domestica*). They were rinsed in clean water and dried with a clean piece of cloth after which plantain, banana, bush mango and pineapple were peeled to obtain the edible portion. All fruits and carrot were homogenized with a kitchen blender to obtain a smooth paste. The potassium content of each was determined by flame atomic absorption spectrophotometry according to the method described by Howe *et al* (2005) and expressed as % w/w of the plant food. The two foods with the highest potassium content were used for blood pressure experiments.

Animals. Male Wistar rats weighing 230 – 250 g were used for the experiments. The animals were obtained from the Animal House Unit, University of Ibadan, Nigeria. The animals had free access to rat chow (Bendel Feeds and Flour Mill Ltd, Ewu, Nigeria) and tap water. The animals were exposed to day/night light cycle and room temperature. They were handled according to international protocols for the use of animals in experiments (National Institute of Health, 2002). The animals were allowed two weeks of acclimatization before they were used for the experiments. The animals were randomly allotted into four groups comprising of: group A (sham-treated controls); group B (potassium citrate); group C (carrot); and group D (plantain). Each rat in the control group was given 2.0 ml of distilled water daily for 28 days while potassium citrate was given as 25 mg/day for 28 days to each rat in group B. Carrot and plantain were each administered at a daily dose of 5 g/rat for 28 days to groups C and D respectively. Feeding was done once daily by use of orogastric tube, after homogenizing the weighed amount (5 g) of each fruit or carrot and mixing it with 2.0 ml of distilled water. Potassium citrate was dissolved in distilled water before oral administration.

Measurement of blood pressure and pressor response. One hour after the 28th -day administration, the animals were used for blood pressure experiments. The mean arterial blood pressure (MAP) of each rat was measured invasively as described by Omogbai *et al* (2005). The rats were anaesthetized with urethane (1.75 g/kg, *i.p*). The right jugular vein and the left common carotid artery were isolated and cannulated. While the jugular served as the route for the administration of drugs, the carotid was connected through the cannula to a physiological pressure transducer (Bentley Trandec, USA), which was in turn connected to an Ugo Basile 2-channel “Gemini” recorder model 7070 (Ugo Basile, Italy). Prior to use, the instrument was switched on for 30 min, adjusted and then calibrated with a standard mercury sphygmomanometer (Aneroid, UK). In order to prevent clotting, the arterial (carotid) cannula was filled with heparinised saline (200 units/ml). Animal body temperature was maintained at 37 ± 0.5^{o}C by means of an overhead lamp to which a thermometer was fitted. Respiration was assisted by endotracheal intubation. BP measurement was begun after 10 min of surgery, with the pre-drug administration values taken as baseline. The volume of the solution of drug injected at any point in time was not in excess of 0.20 ml. After 5 min of baseline recording, drugs were administered according to a protocol such that reading returned to pre-injection level before another bolus injection. Bolus doses of noradrenaline (5, 10 µg/kg), verapamil (2 and 4 µg/kg) and sodium nitroprusside (2, 4 µg/kg) were administered to each rat. Changes (increase or decrease) from baseline MAP occurring after bolus administration was calculated for each rat.

Drugs and chemicals. Noradrenaline (NA), sodium nitroprusside (SNP), and urethane were all purchased from Sigma (UK). Verapamil (VE) was manufactured by Knoll AG (Germany) and heparin was manufactured by Biochemie (Austria). Solutions of the drugs were prepared fresh in distilled water before administration.

Statistics. Blood pressure readings are presented as mean arterial pressure (MAP) in millimeters of mercury (mm Hg). All data are presented as mean ± standard error of the mean (SEM) and *n* represents the number of rats used for each experiment. Comparisons were made using Kruskal Wallis ANOVA with Dunn’s post hoc test (GraphPad Prism Software, UK). Values were considered statistically significant at $P < 0.05$.

RESULTS

Table 1 shows the potassium content (% w/w) of each of the plant foods. The highest concentration of potassium was found in carrot (0.42 ± 0.14 %). Whereas banana which is usually eaten raw contained 0.22 ± 0.04 % potassium, plantain its related species which is often cooked and served as a meal in various forms contained higher amount of potassium (0.36 ± 0.10 %). The table also shows that apple which is least commonly available and often regarded in Nigeria as the fruit for rich contained the least amount of potassium (0.03 ± 0.01).

Figure 1 shows the mean arterial pressure (MAP) after 28 days of feeding two groups of the animals with 5 g/day/rat of either carrot or plantain. Although blood pressure decreased with potassium supplementation (potassium citrate, carrot and plantain), this was not statistically significant when compared to control. Whereas, MAP value for the control group was 114.0 ± 4.6 mm Hg, it was 108.2 ± 2.1 mm Hg for potassium citrate group, 107.2 ± 1.2 mm Hg for carrot group, and 111.5 ± 2.8 mm Hg for plantain group.

Bolus doses of noradrenaline (NA) resulted in increased blood pressure in all the groups (Figure 2). Among the groups, the administration of 5 µg/kg of NA did not result in significant difference in the change from basal MAP values. The Change from basal MAP following bolus administration of 10 µg/kg of NA was however significantly less in the carrot group (22.3 ± 1.9 mm Hg) compared to control group (37.7 ± 5.8 mm Hg, $P < 0.02$) and potassium citrate group (30.7 ± 3.0 mm Hg, $P < 0.05$) but not significantly less in the plantain group (28. 3 ± 2.5 mm Hg). The difference between the values for plantain and control was statistically significant ($P < 0.05$).

Changes in MAP occurring with bolus administration of verapamil (VE) are shown in Figure 3. The administration of 2 µg/kg of VE resulted in decrease from basal MAP values. This pattern was observed with the administration of 4 µg/kg of the drug. Irrespective of the dose, changes from basal value were significantly lower (P < 0.05) in the carrot group compared to others. For the dose of 4 µg/kg, changes were: -5.8 ± 2.9 mm Hg (control); -6.8 ± 1.1 mm Hg (potassium citrate); -14.4 ± 1.9 mm Hg (carrot); and -9.2 ± 0.9 mm Hg (plantain).

Figure 4 represents the changes in MAP after bolus administration of two doses of sodium nitroprusside (SNP). The pattern is similar to that of Figure 3 with the changes being more significant (P < 0.05) in the carrot group compared to others. For example, the administration of 4 µg/kg of SNP resulted in the following changes from basal values: -6.4 ± 1.6 mm Hg (control); -7.9 ± 1.2 mm Hg (potassium citrate); -14. 6 ± 1.9 mm Hg (carrot); and -7.8 ± 1.3 mm Hg (plantain).

DISCUSSION

Various reviews have shown that plants foods are sources of essential minerals such as potassium which have positive influences on hypertension and other cardiovascular diseases (Kris-Etherton *et al*., 2008; Liu *et al*, 2000; Bazzano *et al*, 2003). The present study has shown that the ten plant foods contained potassium to varying degrees. Although all of them are eaten in Nigeria, the level of their consumption depends mainly on availability. Orange, banana, plantain, garden eggs and pineapple are eaten by most Nigerians regardless of financial status. Bush mango is not very common among city dwellers while soursop and pommelo are not very popular. Apple is an imported fruit and therefore very costly and unaffordable to many Nigerians. While carrot is often used as a component of western diets mainly by the rich, plantain is often a component of main diets. Of all the foods, we chose carrot and plantain which had the highest amount of potassium for daily feeding of rats in order to evaluate how they might influence blood pressure and pressor responses. Supplementation with carrot, plantain or potassium citrate at the doses used in this study does not significantly reduce blood pressure in normotensive rats. Although potassium supplementation in drinking fluid has been reported to reduce blood in normotensive rats (Omogbai *et al*, 2005), the protocol has varied with authors. Therefore, it is not known what the results would be if the doses in the present study were higher. However, the results show that pressor responses to bolus doses of 10 µg/kg of noradrenaline (NA) were significantly attenuated in the carrot or plantain-fed rats compared to their control counterparts.

Table 1. Potassium content in the various plant foods fruits

Fruits	Common Name	Potassium Conc. (% w/w)	Number of samples
Daucus carota	Carrot	0.42 ± 0.14*	8
Musa paradisiaca	Banana	0.22 ± 0.04	5
Musa serpientum	Plantain	0.36 ± 0.10*	7
Citrus grandis	Pommelo	0.14 ± 0.02	8
Anona muricata	Soursop	0.24 ± 0.04	8
Citrus sinensis	Sweet orange	0.08 ± 0.02	8
Solanum melongena	Garden egg	0.08 ± 0.02	7
Irvingia gabonensis	Bush mango	0.12 ± 0.02	5
Ananas comosus	Pineapple	0.08± 0.02	7
Malus domestica	Apple	0.06 ± 0.02	7

* Selected for oral administration to rats at a dose of 5 g/day for 28 days.

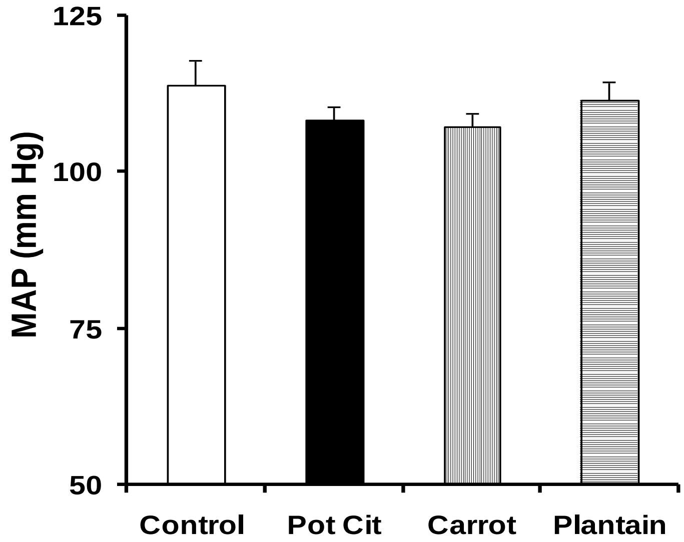

Figure 1. Mean arterial blood pressure (MAP) following daily administration of 5 g/day of carrot and plantain and 25 mg/day of potassium citrate to groups of rats, for 28 days. Values are not significantly different. n = 5 per group.

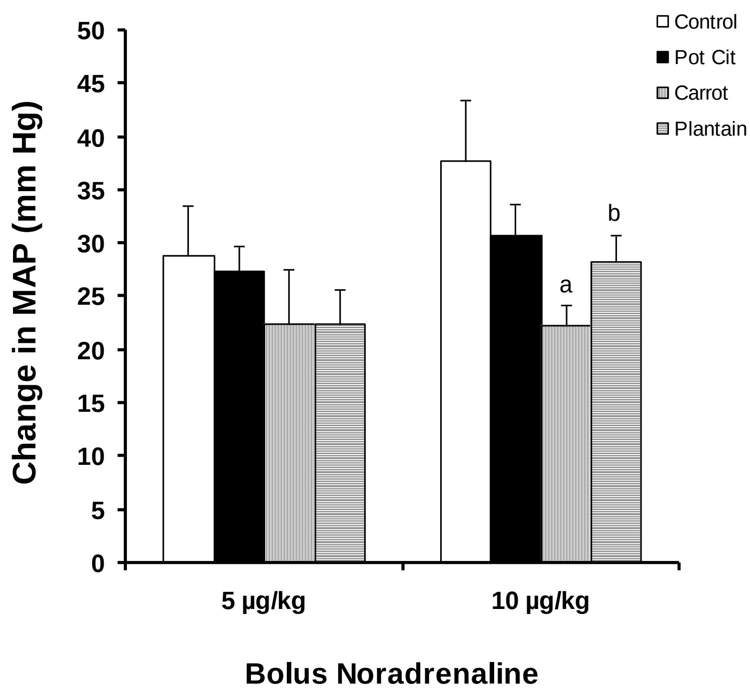

Figure 2. Changes from basal mean arterial pressure (MAP) values after bolus administration of 5 µg/kg and 10 µg/kg noradrenaline to groups of rats given 5 g/day of carrot or plantain or 25 mg/day of potassium citrate for 28 days. [a] $P < 0.02$ compared to control; [b] $P < 0.05$ compared to control, n = 5 per group.

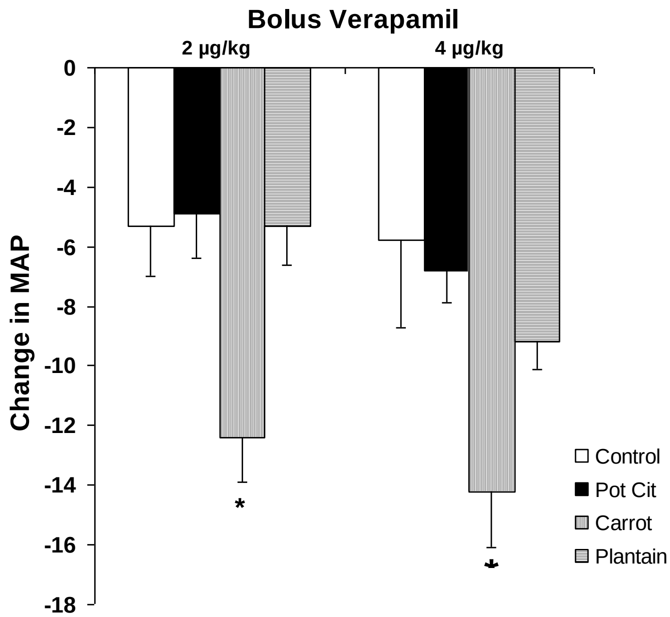

Figure 3. Changes from basal mean arterial pressure (MAP) values after bolus administration of 2 µg/kg and 4 µg/kg verapamil to groups of rats given 5 g/day of carrot or plantain or 25 mg/day of potassium citrate for 28 days. *$P < 0.05$ compared to other groups, n = 5 per group.

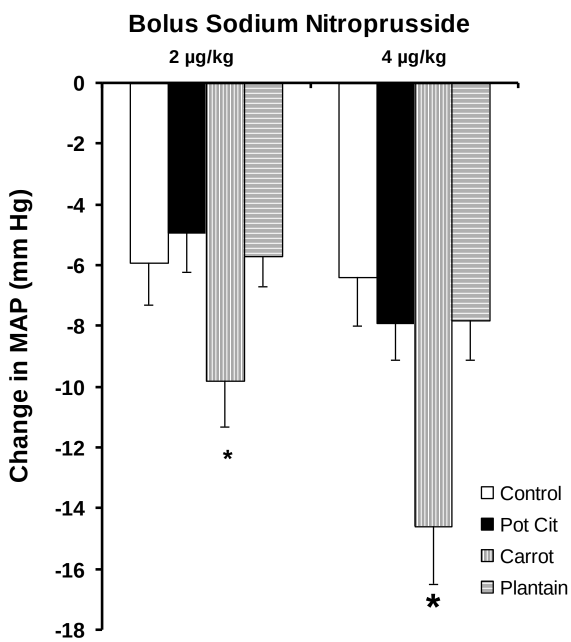

Figure 4. Changes from basal mean arterial pressure (MAP) values after bolus administration of 2 µg/kg and 4 µg/kg sodium nitroprusside to groups of rats given 5 g/day of carrot or plantain or 25 mg/day of potassium citrate for 28 days. *$P < 0.05$ compared to other groups, n = 5 per group.

Noradrenaline, a sympathetic neurotransmitter increases systemic blood pressure and is a factor in the pathophysiology of hypertension (Grassi, 2010; Grassi *et al*., 2010). The release of noradrenaline and its hormone congener adrenaline occurs following stressful conditions (Floras, 1992; Esler, 2001). This may suggest that consumption of these foods in sufficient quantities may be protective against acute increases in blood pressure.

Of all the fruits only carrot significantly augmented the depressor effects of the antihypertensives verapamil and sodium nitroprusside. This may be related to the potassium content of carrot which is higher than that of plantain and what was available by potassium citrate. The implication of this finding is the possibility of hypotensive responses accompanying antihypertensive therapy when carrot is concomitantly consumed. Carrot has been used in traditional medicine for the treatment of hypertension (Gilani *et al*., 2000). This effect has been ascribed to the inhibitory effect of coumarin glycoside constituents on blood vessels and atrial contractility (Gilani *et al*., 2000). The additive effect of the potassium and coumarin constituents may have been responsible for the superior beneficial effects of carrot on blood pressure in this study.

Several mechanisms have been suggested for the blood pressure reducing effect of potassium supplementation. These include: enhancement of endothelium relaxation (Raij *et al*., 1988; Tolvanen *et al*., 1998), increased vascular Na^+, K^+-ATPase and superoxide dismutase enzymes (Dolson *et al*., 1995; Ozolua *et al*., 2003), and reduced vascular reactivity to pressor agents (Campbell and Schmitz, 1978). One or more of these mechanisms may be responsible for the observations in the present study.

In conclusion, this study has shown the levels of potassium in some fruits and carrot. Consumption of carrot or plantain has potential for reducing acute increases in blood pressure while carrot has the potential of augmenting the fall in blood pressure that follows the use of antihypertensive drugs.

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