

Influence of potassium fertilization on the functional components and antioxidant activity of pummelo [*Citrus maxima* (Burm. Ex Rumph.) Merr.] fruit

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ABSTRACT

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This study aimed to determine the influence of potassium (K) fertilization on the functional components and antioxidant activity of 13-year-old 'Magallanes' pummelo [*Citrus maxima* (Burm. Ex Rumph.) Merr.]. The field experiment was conducted at South Davao Corporation (SODACO) farm, Davao City for 12-month duration. Five treatments with increasing K levels were applied per tree: control, no K, 150g K basal, 225g K basal, and 225g K basal + foliar application. The functional components and antioxidant activity were analyzed following harvest at the University of the Philippines, Los Baños.

Application of 225g K rates positively influenced functional components of pummelo. The yield of total phenol, flavonoid, vitamin C and oil per tree increased by 3-10 times with 225g K application.

The effects of basal alone and foliar + basal application of K were only significantly different from each other in terms of flavonoid yield per tree. On the other hand, the application of 225g K basal + foliar resulted to higher total phenol, vitamin C and oil yield per tree in pummelo, implying a higher mobilization of K in the leaves than K uptake by the roots. The results of the study indicated the important role of K in improving the functional components in 'Magallanes' pummelo.

Keywords: Functional Components, Antioxidant Activity, Pummelo, Potassium

INTRODUCTION

Pummelo [*Citrus maxima* (Burm. Ex Rumph.) Merr.; *C. grandis* Osbeck; *C. decumana* L.], locally known as suha or lukban has the largest fruit among all citrus

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species, growing as large as 30cm in diameter and weighing as much as 10kg. The peel is thick such that the fruit has a long shelf life that allows it to be transported to distant markets and resists pests and diseases. For trees over ten years old, the yield of 20t ha⁻¹ is considered economically beneficial (Magat and Mantiquilla 2005).

At present, there is much interest in citrus fruits because they are one of the major sources of antioxidants called flavonoids in the human diet. These antioxidative phytochemicals or functional foods are widely recognized for their role in scavenging free radicals, which are involved in the etiology of many chronic diseases and increased survival rates of elderly. The distinct color of fruits such as in citrus, is especially considered a quality trait that correlates with the fruits' nutritional values and health benefits. Pummelo is one of the most popular species of the Citrus family which is an excellent source of antioxidant flavonoids. Fresh red pummelo juice is an excellent source of antioxidant compounds which exhibited great efficiency in scavenging different forms of free radicals including 2, 2-diphenyl-1-picrylhydrazyl (DPPH), superoxide anion, and hydrogen peroxide radicals (Tsai et al 2007).

The potential biological activities of citrus flavonoids as an antioxidant, anticancer, antiviral, anti-inflammatory, and their effects on capillarity, in lowering cholesterol level, and in inhibiting human platelet aggregation are well documented (Benavente-Garcia et al 1997, Guthrie et al 2000, Middleton and Kandaswami 1994). One or more of the citrus flavonoids may be responsible for the above cited possible beneficial effects, and chemists are now developing new methods for making anti-cancer flavanones. The phenolic compounds found in cell wall structures also play a major role in the growth regulation of plant as an internal physiological regulators or chemical messengers and are used in the fruit growing field which are related with defending system against pathogens and stress. They also increase the success of tissue culture and can be helpful to identification of fruit cultivars, determination of graft compatibility, and identification of vigor of trees. Mostly important because of their contribution to the sensory quality of fruits during the technological processes (Sulusoglu 2014).

Furthermore, pummelo is a very nutritious fruit, which is an excellent source of vitamin C. Each serving of pummelo provides about twice the daily recommended amount of vitamin C (Smith 2009.) It also contains vitamins A, B₁, B₂, B₆ and B₁₂, protein, Ca, fiber, folate, K, and Fe. Therefore, functional foods, such as pummelos are a potent dietary option for preventing diseases such as cancer, heart disease, hypertension, cholesterol, diabetes, asthma, common colds, inflammation, and diverticular diseases. Pummelo peel also contains essential oils which have applications in the food and flavor industries. The oils are used for the synthesis of fine chemicals and new fragrances for the cosmetics industry, and for medicinal purposes in Oriental cultures (Njoroge et al 2005, Lis-Balchin and Hart 1999, Reische et al 1998).

As a health food with industrial use, there is a big demand for pummelo in both domestic and export market considering that Malaysia and Thailand are actively selling pummelo to Singapore, Hongkong, Japan, and other countries (The National RDE Network For Fruit Crops 2002). However, production of pummelo is limited by problems like instability of fruit quality, nutritional disorders, and some pest and disease infections. Based on the Bureau of Agricultural Statistics data, the area

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devoted to pummelo production in the Philippines as of 2008 has increased to 5,306ha from 4,592ha in 1997. However, the production volume decreased from 49,763metric tons in 1997 to 36,686metric tons in 2008 (Bureau of Agricultural Statistic 2009).

Hence, there is a need to assess and improve the functional components of pummelo to cater to the increasing demands of health conscious consumers for both local and export markets. To increase functional components, it is important to provide an efficient fertilizer program. Potassium (K) is a macronutrient in plants that has multiple enzymatic and catalytic functions used in many photosynthetic and metabolic processes in plants. Among the important elements in plant nutrition, K is the most abundant element found in fruits and the highest nutrient removed in the soil. Thus, K is considered a key element in fruit production and quality worldwide (Erner et al 2005).

Studies on different rates of K fertilizers have been shown to increase growth, yield, and quality of several plants such as orange, grapefruit, lemon, papaya, avocado, watermelon, plum, pummelo, and peach (Magbalot-Fernandez and De Guzman 2021, 2019, Fernandez and De Guzman 2013, Fernandez and Tipay 2013, Mimoun 2009, Kumar 2006, Erner et al 2005, Alva et al 2001, Patil 2002, Perkins-Veazie and Roberts 2002, Lahav et al 1976, Calvert 1973, Embleton and Jones 1964, Koo 1963, Sites and Deszyck 1952). Some experimental evidence have also been demonstrated to affect functional components such as vitamin C, carotenoid, K levels, and isoflavone content of tomatoes, grapefruit, orange, grapes, strawberries, and soybean (Patil 2002, Perkins-Veazie and Roberts 2002, Hale 1977, Reese and Koo 1975, Calvert 1973, Choureidah and Bünemann 1972, Hobson and Davis 1971, Sites and Deszyck 1952). The potential effect of K on the functional components of pummelo has not been investigated yet; hence, this particular study was conducted.

MATERIALS AND METHODS

Field Experiment

A field experiment was conducted at South Davao Corporation (SODACO), Calinan, Davao City for a 12-month duration to evaluate the effect of application of K on the functional components and antioxidant activity of 'Magallanes' pummelo fruits. The area is located 7° latitudes and 125° longitudes with an elevation of 700m Mean Sea Level (msl). Based on modified Coronas classification, Davao city belongs to the Type IV climate where rainfall is more or less evenly distributed throughout the year. Meteorological data of the area were taken within the duration of the study at the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) weather station at Sasa, Davao City. Temperature, amount of sunshine, relative humidity, rainfall, and wind speed were favorable for the growth and development of pummelo.

The experiment was carried out in Randomized Complete Block Design (RCBD) with five treatments replicated three times. There were three sample trees per replication per treatment for a total of 45 pummelo trees with a planting distance of 7m x 8m in a rectangular planting system. Soil and leaf tissue analyses were done to determine the nutrient requirement of the trees based on the standard procedures of the Department of Agriculture-Bureau of Soils Laboratory, Davao City. Soil

sample at 30cm deep was air-dried, pulverized, and placed in bags for analysis. Samples of 4-6 month-old leaves from non-fruiting terminals in the mid-region of the tree were collected and placed in bags for analysis. The result of the soil and leaf tissue analysis before and after the experiment is shown in Table 1.

Table 1a. Soil analysis before and after the conduct of the study from the Bureau of Soils, Department of Agriculture, Davao City

Treatments	Class	pH	OM (%)	OC (%)	N (%)	P (ppm)	K (ppm)
Initial	Clay	5.1	2.82	1.64	1.4	27	228
Control	Clay	4.7	4.75	2.76	2.5	52	300
no K	Clay	5.2	2.86	1.66	1.7	13	295
150g K basal	Clay	5.4	3.54	2.06	2.3	8	388
225g K basal	Clay	5.5	3.32	1.93	1.7	27	355
225g K basal + foliar	Clay	6.0	3.47	2.02	2.1	16	325

All treatments were applied with recommended rate of NP except for the control (no fertilization).

Table 1b. Soil Analysis Legend based on the Soil Analysis of the Bureau of Soils, Davao City.

Soil Analysis Legend:	Very low	Low	Medium	High	Very high
pH	<4.4	4.4-5.5	6.1-6.6 5.6-6.0	7.3-7.8 6.7-7.2	>9.0 8.5-9.0 7.9-8.4
Organic Matter (OM) Walkey Black (%)	<3.44	3.44-6.88	6.88-17.20	17.20-34.40	>34.40
Organic Carbon (%)	<2	2-4	4-10	10-20	>20
Nitrogen (%)		Low	Medium		Adequate
OM (Wilde's Method)		<1.5	1.6-3.0		>3.0
Olsen Phosphorus (ppm)	Very low <10	Low 10-20	Medium 20-30	High 30-50	Very high >50
Extractable Potassium (ppm)	Very deficient <250	Deficient 260-500	Possibly deficient 510-750	Adequate >750	

Five treatments with increasing K levels were applied per tree: control, no K, 150g K basal, 225g K basal, and 225g K basal + foliar application. The area was applied with basal and foliar fertilizers following the recommendations of soil and leaf tissue analysis as practiced by the farm. The different rates of fertilizers were applied in installments: at flushing or flower bud initiation and at 30 and 60 days after flowering (DAF). All treatments were applied with recommended rate of fertilizers except for the control (no fertilization) at the rate of 400g N, 100g P, and 150g K per tree except for no K. Urea (46-0-0), Complete (14-14-14) fertilizer, Solophos (0-18-0) and Muriate of Potash (0-0-60) were the sources of NPK fertilizers. Fertilizers were applied basally at 1.5m radius around the canopy. K foliar fertilizers were prepared by mixing the required amount of K fertilizer in water at the rate of 10g L⁻¹ and applied at 30 and 60 days after fruit set (DAFS) on target fruits and

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leaves. Adjuvant concentrate containing Poly (oxy-1,2-ethanediyl), alpha-(4-nonylphenyl)-omega-hydroxy, branched was also added to improve performance of the K foliar fertilizer. The pummelo trees were maintained by irrigating, weeding, pruning, and applying pesticide and fungicide whenever necessary.

The pummelo fruits were harvested after 156 days from fruit set. Fruit samples were sent after harvest to the Analytical Chemistry Laboratory of the University of the Philippines for analysis. Data were analyzed using analysis of variance (ANOVA) and means were compared using Honest Significant Difference Test (HSD).

Functional Component Analysis

To evaluate the influence of different rates of K on functional components of 'Magallanes' pummelo, three fruits were sampled per treatment from the fertilizer rate treatments. Fruits were sampled from middle trees to minimize the border effects. After harvest, the fruit juice was used for analysis of vitamin C using titration, total phenolic content using modified Folin-Ciocalteu, flavonoid content using spectrophotometry, and antioxidant activity using 2,2-diphenyl-1-picrylhydrazyl (DPPH) method. The essential oil of the fruit peel was extracted using the Clevenger apparatus and analyzed for antioxidant activity using DPPH method. The standards used: ascorbic acid for Vit. C, catechin for total phenolics, gallic acid for flavonoid, butylated hydroxytoluene and Vit. E for antioxidant content, Folin-Ciocalteu reagent, and 2,2-diphenyl-1-picrylhydrazyl (DPPH) were purchased from commercial source. Fruits were washed and fruit peel (flavedo and albedo) was removed with a knife. The remaining parts (juice sacs and pulp) were blended for 3min and filtered using cheese cloth. Filtered samples were collected in 1000mL Erlenmeyer flask and stored in -80°C until analyzed for vitamin C content, total phenolic content, total flavonoid content and antioxidant activity. The results were then converted to content per tree by multiplying the amount with the average weight of fruit yield per tree.

Oil extraction. The peel of fresh fully matured ripe fruits were washed and removed. The fruit albedo layers were peeled off carefully and discarded. The fruit flavedo were blended for 3min before oil was extracted. The peel essential oils were collected by hydro-distillation for 1h in Clevenger's apparatus (Sharma and Tripathi 2006). The yield of oil was recorded (amount in mL 100g^{-1} peel) and stored in air-tight sealed glass vials covered with aluminum foil at 4°C for antioxidant activity analysis.

Vitamin C content. Ascorbic acid (AA) was determined using redox titration with iodine. About 5mL of ascorbic acid solution was placed into a 250mL Erlenmeyer flask and added with 50mL distilled water and 5mL 0.5% starch solution. About 5mL of the extracted fruit juice sample was added with 50mL distilled water and 5mL 0.5% starch solution in a 250mL Erlenmeyer flask. The samples and standards were titrated with the freshly prepared iodine solution up to the first permanent blue-black end point. Ascorbic acid content of the sample and percent (%) recovery was calculated using the formula (Lees 1975):

$$\text{Titer} = (\text{mg. Std. AA} \times \text{dilution factor}) / (\text{mL } I_2 - \text{blank ave.})$$

$$\text{Vit. C (mg } 100\text{mL}^{-1}\text{)} = \frac{\text{Titer} \times \text{total mL } I_2 \text{ used for sample}}{\text{mL of sample} \times \text{df}} \times 100$$

$$\% \text{ recovery Vit. C} = \frac{\text{Titer} \times \text{total mL } I_2 \text{ used for sample}}{\text{mL of sample} \times \text{df}} \times 100$$

Total phenolic assay. Total phenolic compounds were measured using the modified Folin-Ciocalteu method (Singleton et al 1999). This procedure involves the addition of 0.2mL Folin-Ciocalteu reagent to samples or standards and allowing them to react for 15min. Each juice sample and the catechin standard (0.10mg mL^{-1}) were dissolved in 5.0mL absolute methanol and shaken for 30min in an evaporator. Standard solutions were prepared with known concentrations of 0, 0.20, 0.40, 0.60, 0.80 and 1.00mL catechin in methanol. The mixture was centrifuged at 3000rpm for 5min. and 0.2mL of supernate was added with 2.8mL dH_2O and mixed thoroughly. One mL 0.2M Na_2CO_3 and 0.2mL of Folin Ciocalteu Phenol reagent was added to the mixture and mixed thoroughly and placed in boiling water bath for 15min. It was cooled to room temperature and the absorbance was measured at 710nm using spectrophotometer. The content of phenolic compounds was reported as mg catechin equivalent (CE) mL^{-1} .

Total flavonoid. The juice samples and gallic acid standard (0.10mg mL^{-1}) were diluted to about 5mL in absolute methanol and shaken for 30min in a vortex mixer. Standard solutions were prepared with known concentrations of 0, 0.20, 0.40, 0.60, 0.80, and 1.00mL gallic acid in methanol. Each sample and standard in methanol was centrifuged at 3000rpm for 5min., and 0.5mL of supernate was added with 2mL dH_2O and mixed thoroughly. A 0.30mL of 5% M Na_2NO_2 was mixed and stood for 5min. A 0.30mL 10% AlCl_3 reagent was added to the mixture and stood for 1min. It was added with 1.0mL 1.0N NaOH and mixed well. The absorbance of the solutions was read at 510nm using spectrophotometer and the flavonoid concentrations were expressed as mg gallic acid equivalent (GAE) mL^{-1} (Luximon-Ramma et al 2002).

Total antioxidant activity. A simple method that has been developed to determine the total antioxidant activity of foods using the stable 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical was used (Leong and Shui 2002). A 0.25 μL methanolic extract was added with 75 μL distilled water and 2.9mL DPPH and mixed using a vortex. The mixture was incubated in the dark at 30°C for 30min. The absorbance of the mixture and DPPH solution was measured at 517nm using spectrophotometer. Standards were prepared using butylated hydroxytoluene treated as sample. Percent lipid peroxidation was computed by subtracting the absorbance readings of the sample from the absorbance reading of DPPH. The difference was divided with the absorbance of DPPH and multiplied by 100. The result was subtracted by 100 and reported as % lipid peroxidation. The higher the percent lipid peroxidation, the lower is the antioxidant activity.

RESULTS AND DISCUSSION

Pummelo Juice Functional Component

The total phenol, flavonoid, and vitamin C contents of the juice extract are desirable attributes that are of central interest due to their antioxidative properties. These metabolites have significant role as well on the overall qualities and development of fruits and tree as a whole. Among the many reported functions of phenolic compounds found in cell wall structures play a major role in the growth regulation of plant as an internal physiological regulators or chemical messengers. They are used in the fruit growing field. They are related with defending system

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against pathogens and stress. They increase the success of tissue culture; can be helpful to identification of fruit cultivars, determination of graft compatibility and identification of vigor of trees. They are also important because of their contribution to the sensory quality of fruits during the technological processes (Sulusoglu 2014).

Analysis of variance showed that the fertilizer treatments did not affect the total phenol, flavonoid, and vitamin C contents of pummelo juice extract per fruit; significant effects, however, were obtained in terms of functional component content per tree.

Soil analysis (Table 1a) revealed rather different characteristics among initial soil result, control and no potassium applications. Results showed that control or without application have lower pH but higher OM, OC, N, P, and K levels than initial result and without potassium applications. This is apparent as the soil initially has lower nutrient contents before bearing fruit and expectedly has lower yields without any applications, hence without much fruit have not utilized accumulated natural deposits. It is also noted that the no K applications were able to bear considerable amounts of fruits and have utilized some of its deposits including NP applications and showed comparable levels with initial soil test.

Application of 225g K rates increased the yield of total phenol per tree by 3-10 times relative to the no K treatment and control (Table 2). The no K treatment had the same effect as that of the control and the 150g K application. Increasing levels of K also increased the yield of total flavonoid per tree. The yield of total flavonoid increased by 85-231g per tree as K rates increased from 150g to 225g. Total flavonoid yield per tree of basal + foliar application of 225g K was higher by 85g than the basal application alone. This indicates the important function for NPK with foliar supplement of K in increasing the total flavonoid contents of the whole tree by enhancing its production through metabolic processing. There was no significant difference in the results between the no K and the control (Table 3).

Highest vitamin C yield per tree was also obtained in 225g K rates which were 4-10 times higher than the no K and control. Vitamin C yield did not vary among 150g K basal, no K and control treatments (Table 4). The different K levels did not significantly affect the total phenols, flavonoids, and vitamin C contents per fruit. Nevertheless, increase in yield per tree of these parameters was observed with higher K rates. This was due to the increase in fruit yield with higher K rates compared with no K treatment and control as shown on previous data.

Increasing the K level also increased the fruit yield and functional components of 'Magallanes' pummelo. This is evident on the results of total phenol, flavonoid, and vitamin C contents of pummelo juice extract per total fruits per tree. The total phenolic content of red pummelo juice extracted by methanol was 8.3mg mL^{-1} and the contents of vitamin C and α -tocopherol in red pummelo juice were 472 and 0.35 g mL^{-1} , respectively (Tsai et al 2007) which were lower than the results obtained in this study. In some studies, K also increased the vitamin C content of citrus crops such as grapefruit (Patil 2002), Valencia and Hamlin oranges (Sites and Deszyck 1952), and other crops like tomatoes (Perkins-Veazie and Roberts 2002).

Potassium increased the vitamin C content of pummelo juice by probably enhancing the synthesis of carbohydrates, eg, glucose, which are required for the biosynthesis of vitamin C (Bánhegyi and Mandl 2001). Potassium also takes part in photosynthesis and in the production of galactose and mannose which are efficient precursors of vitamin C in higher plants. Potassium may have also enhanced the synthesis of phenolic compounds and flavonoids by assisting the synthesis of amino

acids like phenylalanine, which are required for the synthesis of flavonoids through the shikimic acid pathway (Herrmann and Weaver 1999).

Table 2. Total phenolic content and yield of 'Magallanes' pummelo as influenced by K fertilization

Treatments	Total Phenol Content of Juice ^{ns}		Yield of Total Phenol	
	(mg mL ⁻¹)	g/fruit ^{ns}	g/tree	
Control	91.02	26.58	64.08d	
no K	85.62	26.79	160.44cd	
150g K basal	84.64	32.58	323.19bc	
225g K basal	87.24	26.59	515.58ab	
225g K basal + foliar	88.03	35.22	716.91a	

Values with a common letter in a column are not significantly different at 0.05 level using HSD. All treatments were applied with recommended rate of NP except for the control (no fertilization).
ns – no significant difference

Table 3. Flavonoid content and yield of 'Magallanes' pummelo as influenced by K fertilization

Treatments	Total Flavonoid Content of Juice ^{ns}		Yield of Total of Flavonoid	
	(mg mL ⁻¹)	g/fruit ^{ns}	g/tree	
Control	32.51	9.36	23.23d	
no K	30.53	9.52	58.31d	
150g K basal	30.11	11.63	112.64c	
225g K basal	29.02	8.73	169.54b	
225g K basal + foliar	31.44	12.63	254.35a	

Values with a common letter in a column are not significantly different at 0.05 level using HSD. All treatments were applied with recommended rate of NP except for the control (no fertilization).
ns – no significant difference

Table 4. Vitamin C content and yield of 'Magallanes' pummelo as influenced by K fertilization

Treatments	Total Vitamin C Content of Juice ^{ns}		Yield of Total Vitamin C	
	(mg 100 mL ⁻¹)	mg/fruit ^{ns}	g/tree	
Control	72.46	208.55	0.518c	
no K	59.83	186.99	1.141c	
150g K basal	66.86	259.70	2.469bc	
225g K basal	71.36	216.70	4.171ab	
225g K basal + foliar	68.83	274.51	5.747a	

Values with a common letter in a column are not significantly different at 0.05 level using HSD. All treatments were applied with recommended rate of NP except for the control (no fertilization).
ns – no significant difference

Essential Oil Content

The essential oil of 'Magallanes' pummelo peel is another desirable functional component which is studied for the first time due to its potential benefits in health and medicine. The different treatments did not significantly affect the oil content of pummelo peel per fruit, but a significant effect was observed in terms of oil yield per tree.

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Increasing K rates did not affect the essential oil content of pummelo peel per fruit despite the fact that increasing K fertilization reduced peel thickness of 'Magallanes' pummelo as shown on previous data. In terms of oil yield per tree, highest oil produced was observed in those applied with 225g K rates, which were 30-47mL higher than 150g K basal, no K and control (Table 5). Basal alone and basal + foliar applications were significantly the same for this variable. The oil yield per tree of the control, on the other hand, was just the same as that for the 150g K basal and no K treatments.

The different treatments did not significantly affect the oil content of pummelo peel per fruit, but a significant effect was observed in terms of oil yield per tree. Similar response was also observed in the oil analyses made with uniformly sized fruit of the Ettinger and Fuerte avocado cultivars which showed that K fertilization did not influence the percentage of oil in the fruit (Lahav et al 1976).

The positive effect of higher levels of K fertilizers on the oil yield per tree of 'Magallanes' pummelo may be accounted for by the observation that K assists in the synthesis of carbohydrates, which is required in the synthesis of terpenes from acetyl coA via the mevalonic acid pathway (Lichtenthaler 1999). Terpenes are the essential oils found in pummelo with monoterpenes (limonene, α -terpene and α -pinene) predominating by 97.5% of the constituents (Njoroge et al 2005). However, in terms of oil content per fruit, did not vary in this case as the distribution of the synthesis of terpenes is accounted in the whole tree plant level. Thus, the content of oil per fruit is not variable but the total production of percent oil per tree is highly affected by higher potassium rates.

Table 5. Essential oil content and yield of 'Magallanes' pummelo peel as influenced by K fertilization

Treatments	% Oil ^{ns}	Oil Yield	
	(v/wt)	mL/fruit ^{ns}	mL/tree
Control	2.4	4.2	12.7c
no K	3.1	3.7	22.1c
150g K basal	2.1	3.0	30.1bc
225g K basal	1.8	2.7	52.2ab
225g K basal + foliar	2.0	2.9	59.7a

Values with a common letter in a column are not significantly different at 0.05 level using HSD. All treatments were applied with recommended rate of NP except for the control (no fertilization).

ns – no significant difference

The effects of basal alone and foliar + basal application of K were only significantly different from each other in terms of flavonoid yield per tree. On the other hand, the application of 225g K basal + foliar resulted to higher total phenol, vitamin C, and oil yield per tree in pummelo, implying a higher mobilization of K in the leaves than K uptake by the roots.

Antioxidant Activity

Both juice and oil extracts of 'Magallanes' pummelo were assessed for their potential antioxidative properties. The antioxidant activity was reported as % lipid peroxidation: the higher the % lipid peroxidation, the lower is the antioxidant activity.

There were significant differences between treatments and standards (Vitamin E and BHT) in terms of % lipid peroxidation of both juice and oil extracts. However, the same effects were observed in the % lipid peroxidation of juice and oil peel extracts among all treatments.

The pummelo juice extract had lower % lipid peroxidation compared with oil peel extract. Lowest % lipid peroxidation of the juice extract was obtained in Vitamin E which was 3 times lower than higher K rates followed by BHT which was 78% lower than the higher K rates (Figure 1). Vitamin E also had the highest antioxidant activity followed by BHT with % lipid peroxidation up to 6 times lower than the oil peel extract of the different treatments.

The antioxidant activity of 'Magallanes' pummelo juice and oil peel extracts were not affected by the different treatments. The ability of methanol extracts of freeze-dried peel and flesh from red pummelo to scavenge radicals was 20-40% that of BHA and vitamin C effects (Tsai et al 2007).

CONCLUSION

Application of K level enhanced the functional components of pummelo. The yield of total phenol, flavonoid, vitamin C and oil per tree were increased by 3-10 times on trees applied with 225g K rates. The total phenols, flavonoids and vitamin C contents per fruit as well as their antioxidant activities were not significantly influenced by the different rates of K. This result accounted to the overall production of functional components per tree as it is negligible in terms of total fruit content. Foliar application of potassium increased total phenol, total flavonoid, vitamin C, and oil yield per tree in pummelo. Results of the study elucidate the important role of K in improving the functional components in 'Magallanes' pummelo.

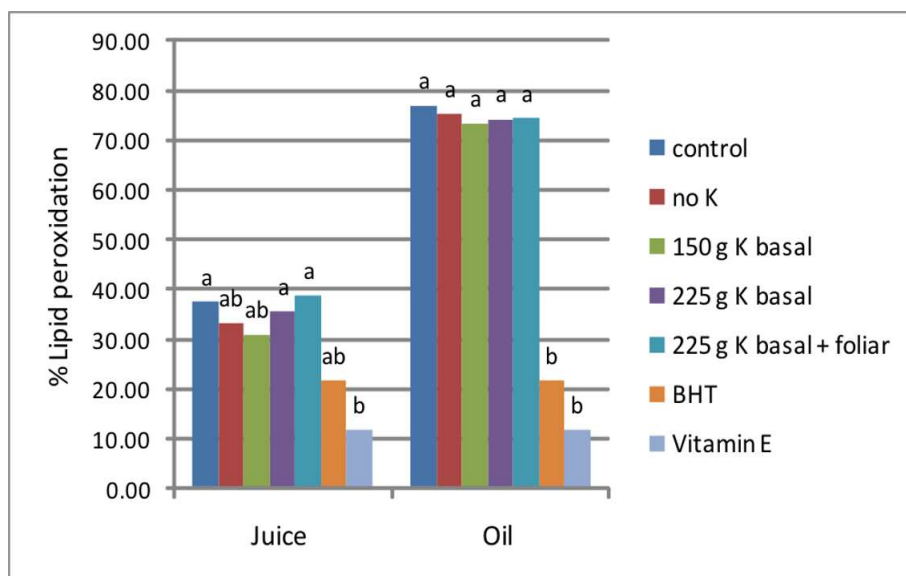


Figure 1. Antioxidant activity of 'Magallanes' pummelo as influenced by K fertilization. Values with a common letter are not significantly different at 0.05 level using HSD. All treatments were applied with recommended rate of NP except for the control (no fertilization).

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