Colour and Antioxidant Activities of Honey From Different Floral Sources and Geographical Origins in Tanzania

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Abstract

Honey is a sweet, yellowish liquid that is produced by honey bees and it has been used for many years for nutrition and therapeutic purposes. Its therapeutic potential has been associated to its antioxidant capacity which plays an important protective role in human health through scavenging of free radicals in the human body and thereby decreases the amount of free radical and damage to biological molecules like lipids and DNA. This study was carried out to investigate the effect of floral source (miombo and acacia) and geographical origin (Central, Coastal, Lake, Northern, and Southern Highland) in mainland Tanzania on colour and antioxidant activity of honey samples. Colour, total flavonoids content (TFC), total phenol phenolic contents (TPC) and antioxidant activities of the samples were evaluated using UV/Vis spectrophotometer, Folin-Ciocalteu reagent and Ferric Reducing Antioxidant Power (FRAP) methods respectively. There were significant ($p<0.05$) differences in all parameters assessed between floral sources. Miombo honey samples had higher pfund values (mm) for colour ranged from 31.55 mm (white) to 143.98 (dark amber) than acacia samples with values ranged from 17.33 (extra white) to 62.28 mm (light amber). Miombo samples had higher TFC values of 13.5±0.25-39.9±0.42 mgRE/100g DM) and TPC of 127.9±2.5-395.2 mg GAE/100g DM) than acacia samples with values of 12.7±0.60-17.5±0.38 mgRE/100g DM and 119.5-168.2 mg GAE/100g DM respectively. Similarly, significantly ($p<0.05$) highest and lowest FRAP values of 488.9-956.3 and 252.6-368.26 µM Fe^{2+}/100g DM were observed in Miombo and acacia honey samples respectively. Moreover, variations in colour, TFC, TPC and FRAP between zones were significant ($p<0.05$). Within the miombo samples, northern and coastal zones had respective lowest and highest values whereas central and northern zones had respective lowest and highest values within the acacia samples. A strong correlation ($R^2= 0.942$) between TPC and antioxidant activities of honey samples suggest that the antioxidant of honey is highly linked to TPC. Therefore, the study has revealed that, floral sources and geographical origins have varied significant effects on colour, flavonoids, total phenols and antioxidant activities of Mainland Tanzania honey. Honey samples from miombo floral source had higher antioxidant activities and hence their consumption is more recommended.

Keyword: Phenol, antioxidant, floral sources, geographical origin

Introduction

Honey is the organic, natural sugar, produced from the nectar and exudation of plant by honey bees and it has been used by humanity for thousands of years for nutrition and therapeutic purposes (Flach *et al.,* 2014). It contains about 600 compounds; including a number of carbohydrates mainly fructose and glucose ranging from 85 to 95% constitute the largest portion of the dry matter (Wang *et al.,* 2014; Alvarez-Suarez, 2010). The minor constituents include certain enzymes (glucose oxidase, catalase), ascorbic acid, carotenoid-like substances and phenolic compounds mainly phenolic acids, flavonoids and polyphenols which are linked to antioxidant properties of the honey (Bertoncelj *et al.,* 2007; da Silva *et al.,* 2013; Escuredo *et al.,* 2013).

The antioxidants play an important protective role in human health through scavenging of free radicals in the human body and thereby decrease the amount of free radical and damage to biological molecules like lipids and DNA may be one of their protective mechanisms (Prior *et al.,* 2004). These free radicals and reactive oxygen species (ROS) are generated endogenously through anaerobic respiration and are potent genotoxins, causing mutation, oxidative damage to DNA, protein and lipids in vitro and in vivo (Perry *et al.,* 2007). Phytochemicals are also known to protect and regenerate other dietary antioxidant and chelate pro-oxidant metal ions (Segura-Carretero *et al.,* 2010). Therapeutic potential of honey has been associated to its antioxidant capacity (Khalil *et al.,* 2010, Sime *et al.,* 2015). It has been useful in improving digestive system, boosting immune system, reducing muscle fatigue of the body and treating surgical wounds, burns, and decubitus ulcers, throat infections and bronchial asthma (Bagde *et al.,* 2013). Recent studies show that, honey can beneficially serve as a natural antioxidant to prevent deteriorative oxidation reaction in foods, such as lipid oxidation in meat and enzymatic browning of fruits and vegetables (Subha and Satarupa, 2014). Besides being a radical scavenger, phenols have also been reported to affect the flavor (Steeg and Montag, 1988), physical appearance of honey, particularly honey colour (Alvarez-Suarez, 2010).

Honey colour is one of the important physicochemical parameters that may be used to assess quality of honey (Muruke, 2014). It is an important characteristic used by producers, packers and end-users and its measurement is vital in quality control processes. The color of honey is amber or gold, however in liquid honey it varies from clear and colorless (like water) to dark amber or black. Studies have shown that, physical properties, chemical composition and bioactive compounds of honey vary with floral sources used by bees to collect nectar, geographical origin, seasonal and climatic conditions (Subha and Satarupa, 2014; Alvarez-Suarez *et al.,* 2014). Vela *et al.* (2007) reported that, antioxidant activity of honey depends on the botanical origin of honey and shows variations in different honeys acquired from different sources. However, information on the effect of different geographical origin and floral sources on colour, total phenolic contents and antioxidant activities of Tanzania honey is missing. Despite a study by Muruke (2014) to assess total phenols and antioxidant activity of honey in Tanzania, the information under the question are still missing. Therefore, this study was conducted to investigate the effect of floral sources and geographical origin on colour and antioxidant capacity of Tanzania honey.

Material and Methods

Study area

The study was conducted in five zones of Tanzania namely, Lake (Kigoma and Simiyu), Northern (Manyara), Central (Tabora and Dodoma) Coastal (Morogoro) and Southern Highland (Katavi). The analytical work was conducted at the Department of Food Technology, Nutrition and Consumer Science laboratory, Sokoine University of Agriculture (SUA), Morogoro and at Tanzania Bureau of Standards (TBS) Laboratory, Dar es Salaam.

Samples and reagents

Honey samples were picked purposively depending on availability and distribution of floral sources which acacia spp and miombo wood land. They were purchased directly from the beekeepers from different regions in the respective zones (Table 1); Analytical food grade reagents and chemicals were purchased from respective suppliers.

Research design

Complete randomized block design (CRBD) with replication was used in this study and the principal factors were floral sources (Miombo and Acacia) and geographical origin (five zones). Samples were analyzed for colour, total phenols, total flavonoids and antioxidant activities. The effect of the principal factors on these parameters were determined and compared. The design mathematical model is depicted in Equation 1.

$$Yij = \mu + \alpha i + \beta j + \varepsilon ij \quad \text{.....(Eq 1)}$$

Table 1: Geographical origin and floral sources

Geographic origin	Floral sources	Region	Number of samples
Central	Acacia	Tabora	3
		Dodoma	6
	Miombo	Tabora	9
Lake	Acacia	Simiyu	9
	Miombo	Kigoma	9
Northern	Acacia	Manyara	9
	Miombo	Manyara	9
Coastal	Miombo	Morogoro	9
Southern Highland	Miombo	Katavi	9

Where the overall (grand) mean,αI is the effect due to the ith treatment (floral sources), ßj the effect due to the jth block (geographical origin) and εij is the error term.

Colour measurement

Colour of honey samples was measured using UV/Vis spectrophotometer (Labomed Inc, USA) as adopted from Ferreira *et al.,* (2009) and Zaza *et al.* (2013). Honey samples were warmed in a water bath at 50°C to dissolve sugar crystals. The samples were rapidly cooled to room temperature and the absorbance was read from honey solution (50% (w/v) at 635 nm. The absorbance were converted and classified according to the Pfund scale (White, 1984). The conversion of the absorbance values (A635) was done using Equation 2.

$$(\text{mm Pfund}) = -38.70 + (371.39.A_{635}) \ldots\ldots \text{Eq } 2$$

Sample extraction and preparation for phytochemical analyses

Three grammes of honey sample was mixed with 30 ml of methanol and sonicated for 15 minutes at 0°C and left overnight. The mixture was centrifuged at 9000 rpm using Universal 320 R centrifuge (Hettich Zentrifugen, German) and the supernatant was decanted and stored at -20°C prior to analyses.

Determination of total phenolic contents (TPC)

Determination was done by using the Folin-Ciocalteu reagent (FCR) method as described by Singleton (1999). About 0.5 mL of extracted sample was transferred into a separate tube and then 2.5 mL of diluted Folin-Ciocalteu phenol reagent and 2 mL of 7.5% Sodium Carbonate solution were added and mixed thoroughly. The mixture was allowed to stand at room temperature for two hours and the absorbance was read at 765 nm against blank using UV-VIS spectrophotometer (Labomed Inc, USA). All determinations were performed in triplicate. Gallic acid was used as a standard and concentration of 0.01-0.05 mg/ml of gallic acid were prepared in methanol. The total phenolic contents were expressed as gallic acid equivalents GAE (mg GAE/100 g) of honey.

Determination total flavonoid content (TFC)

The total flavonoid content of honey samples was determined based on the method of Isla *et al.* (2011) with some modifications as described by Chua *et al.,* (2013). For each sample, 5 mls of honey solution (0.5g/ml) were mixed with 5 ml of 2% Aluminium chloride (AlCl13) and incubate for 10 minutes at room temperature (28-30ºC). The formation of Flavonoid-Aluminium complex was measured spectrophotometrically at 415 nm using using UV-VIS spectrophotometer (Labomed Inc, USA). Total concentration was calculated using quercetin standard curve, and expressed as Rutin equivalent/100 g of honey.

Determination of ferric reducing antioxidant power (FRAP)

Antioxidant activity in samples was measured using the Ferric Reducing Ability of Plasma (FRAP) method by Benzie and Strain (1996)

and modification by Halvorsen *et al.* (2002). The assay was based on the absorbance change when iron (III) 2, 4, 6-tripyridyl-s-triazine (Fe [TPTZ])$^{3+}$ is reduced to (Fe [TPTZ])$^{2+}$ (intense blue) at 595 nm. The FRAP reagent was prepared by mixing 2.5 mL of a solution of 10 mmol/L TPTZ in 40 mmol/L HCl, 2.5 mL of 20 mmol/L $FeCl_3$ and 25 mL of 0.30mol/L acetate buffer (pH 3.6). About 0.5 mL of sample was placed in a tube and 4.5 mls of FRAP solution were added. The mixture was incubated at 37°C for 10 minutes and absorbance was measured at 595nm using UV VIS spectrophotometer (Labomed Inc, USA). A calibration curve was constructed using $FeSO_4$ solutions (concentrations from 0.1 to 1mM, in 0.2 mM increments) and the absorbance was measured at the same wavelength. The results were expressed as μM $Fe2^+$/100 g of honey.

Data analysis

Data were analysed using the R statistical package (R Development Core Team, Version 3.0.0 Vienna, Austria). Analysis of variance (ANOVA) was done to determine the significant differences in studied parameters between honey floral sources and between geographical origins. Means were separated using Tukey's Honest Significant difference ($p<0.05$). Principal Component Analysis (PCA) (Wold, 1987) was done to determine the systematic variations in colour, total phenols, total flavonoids and total antioxidant activities between floral sources and geographical origin. Results were presented as arithmetic mean and standard deviation and PCA biplot.

Results

Effect of geographical origin and floral sources on colour

The colour ranged from white to dark amber in miombo honey samples and from extra white to light amber in acacia honey samples (Table 2). Variations in colour between zones in each sources were significant ($p<0.05$). In miombo honey sample, Southern Highland zone had the highest Pfund value of 143.98±41.64 mm (Dark amber) while Coastal zone had the lowest value of 31.55 ± 5.34 mm (White). In acacia honey samples, Central zone had highest Pfund value of 62.28±42.61 mm (Light amber) and Lake Zone had the lowest of 17.38±0.55 mm (Extra white).

Table 2: Variations of Pfund, colour name and optical density between zones in each floral source

Flora source	Zone	Pfund (mm)	Colour name	Optical density
Miombo	Central	121.4±6.5^b	Dark Amber	-
	Lake	71.1±6.7^d	Light Amber	1.389
	Northern	135.3±3.0^c	Dark Amber	3.008
	Southern	143.98±4.6^a	Dark Amber	-
	Coastal	31.55±5.3^e	White	0.378
Acacia	Central	62.28±2.6^a	Light Amber	1.389
	Lake	17.38±0.6^c	Extra White	0.189
	Northern	58.35±1.6^b	Light Amber	1.389

Values are expressed as arithmetic mean ±standard deviation (n = 9)

Mean values with different superscripts letters along the columns are significantly different at p < 0.05.

Table 3 shows variation of pfund between floral origins within each zone. Miombo samples varied significantly ($p<0.05$) from acacia samples within each zone evaluated. Respective higher values of 121.37 (Dark amber), 71.11 (Light amber) and 135.32 mm (Dark amber) were observed in Central, Lake and Northern zones than 62.28 (light amber), 17.38 (Extra white) and 58.35 mm (Light amber) observed in acacia counterparts.

Effect of geographical origin and floral sources on Flavonoids and Total phenols

The total phenolic contents (TPC) of the honey

samples differed significantly ($p<0.05$) between geographical zones in each floral source (Table 4). In miombo honey samples, northern and coastal zones had highest and lowest values of 395.2 and 127.9 mg GAE/100g DM respectively, observed in northern zone sample and17.5±0.38 mgRE/100 g in central zone sample from miombo and acacia sources respectively (Table 3).

Table 3: Variations of Pfund, colour name and optical density between zones in each floral source.

Zone	Floral source	Pfund (mm)	Colour name	Optical density
Central	Miombo	121.4±6.5^{b}	Dark Amber	Not detected
	Acacia	62.28±2.6^{a}	Light Amber	1.389
Lake	Miombo	71.1±6.7^{d}	Light Amber	1.389
	Acacia	17.38±0.6^{c}	Extra White	0.189
Northern	Miombo	135.3±3.0^{c}	Dark Amber	3.008
	Acacia	58.35±1.6^{b}	Light Amber	1.389
Southern	Miombo	143.98±4.6^{a}	Dark Amber	-
	Acacia	-	-	
Coastal	Miombo	31.55±5.3^{e}	White	0.378
	Acacia	-	-	

Values are expressed as arithmetic mean ±standard deviation (n = 3)
Mean values with different superscripts letters along the columns are significantly different at p < 0.05

whereas within the acacia source, samples from central zone had significantly ($p<0.05$) higher TPC value of 168.8mg GAE/100g DM) than Lake and Northern zones which had statistically similar ($p>0.05$) values of 119.5-126.2 mg GAE/100gDM). The variations in flavonoids between zones were also significant ($p<0.05$) showing similar pattern as in total phenols. The highest value of 39.9±0.42 mgRE/100 g was Moreover, the variations in flavonoids and TPC between the two floral sources in each geographical origin were significant ($p<0.05$) as depicted in Table 5. In all zones Miombo source samples had higher TPC values of 186.0±2.8 -395.2±4.2mg GAE/100 g DM than acacia source sample with lower value of 119.5±6.1-168.8±3.8mg GAE/100 g DM. No data obtained from acacia source in coastal and southern

Table 4: Variations of Flavonoids (mgRE/100 g DM) and Total phenols a (mg GAE/100 g DM) and between zones within each floral source

Flora source	Zone	Flavonoids (mg GAE/100 g DM)	Total phenols (mg GAE/100 g DM)
Miombo	Central	19.2±0.28^{d}	186.0±2.8^{d}
	Lake	23.3±0.50^{c}	227.3±5.3^{e}
	Northern	39.9±0.42^{a}	395.2±4.2^{a}
	Southern	29.1±0.34^{b}	286.2±3.4^{b}
	Coastal	13.5±0.25^{e}	127.9±2.5^{e}
Acacia	Central	17.5±0.38^{a}	168.83±3.8^{a}
	Lake	13.3±0.35^{b}	126.2±3.5^{b}
	Northern	12.7±0.60^{b}	119.5±6.1^{b}

Values are expressed as arithmetic mean ±standard deviation (n = 9)
Mean values with different superscripts letters along the columns are significantly different at p < 0.05.

highland zones. Similar higher and significant ($p<0.05$) flavonoid content in miombo source (19.2±0.28 -39.9±0.42 mg GAE/100 g DM) than in acacia source (12.7±0.60 - 17.5±0.38) was observed in all zones.

Moreover, the variations in antioxidant activities of honey samples between the two floral samples of 368.3 µM Fe^{2+}/100 g DM in *acacia* honey sample.

Table 5: Variations of Flavonoids (mgRE/100 g DM) and Total phenols (mg GAE/100 g DM) between the floral sources within each zone

Zone	Floral origin	Total phenols (mg GAE/100 g DM)	Flavonoids (mgRE/100g DM)
Central	Miombo	186.0±2.8^{a}	19.2±0.28^{a}
	Acacia	168.8±3.8^{b}	17.5±0.38^{b}
Lake	Miombo	227.3±5.3^{a}	23.3±0.50^{c}
	Acacia	126.2±3.5^{b}	13.3±0.35^{b}
Northern	Miombo	395.2±4.2^{a}	39.9±0.42^{a}
	Acacia	119.5±6.1^{b}	12.7±0.60^{b}
Southern	Miombo	286.2±3.4	29.1±0.34^{b}
	Acacia	-	
Coastal	Miombo	127.9±2.5	13.5±0.25^{e}
	Acacia	-	-

Values are expressed as arithmetic mean ±standard deviation (n = 3)
Mean values with different superscripts letters along the columns are significantly different at p < 0.05

Effect of geographical origin and floral sources on FRAP

There was significant difference ($p<0.05$) in FRAP contents between all zones within sample from each floral sources as depicted in Table 6. In miombo honey samples, Northern and Coastal zones had significant ($p<0.05$) higher and lower antioxidant values of 956.3 and 401.68 µM Fe^{2+}/100 g DM respectively. Contrary to this, central zone had the highest antioxidant value in each zone were significant ($p<0.05$) with Miombo honey sample having higher values of 488.9 - 956.3µM Fe^{2+}/100 g DM) than their acacia counterparts with values of 252.6-368.2 µM Fe^{2+}/100 g DM (Table 7).

The principal component analysis bioplot (Figure 1) showed that, principal component 1 (PC1) accounted for 98.6% of the variations while PC2 accounted 1.4% of total variations

Table 6: Variations of FRAP (µM Fe^{2+}/100 g DM) between zones within each floral sources

Floral source	Zone	FRAP (µM Fe^{2+}/100 g DM)
Miombo	Central	488.9±8.60^{d}
	Lake	528.4±4.23^{c}
	Northern	956.3±18.39^{a}
	Southern	598.9±4.49^{b}
	Coastal	401.7±2.67^{e}
Acacia	Central	368.2±4.52^{a}
	Lake	279.2±1.03^{b}
	Northern	252.6±2.52^{c}

Values are expressed as arithmetic mean ±standard deviation (n = 3)
Mean values with different superscripts letters along the columns are significantly different at p < 0.05.

Table 7: Variations of FRAP between the two floral origins within each zone

Zone	Floral origin	FRAP (μM Fe^{2+}/100 g DM)
Central	Miombo	488.9±8.60[a]
	Acacia	368.2±4.52[b]
Lake	Miombo	528.4±4.23[a]
	Acacia	279.2±1.03[b]
Northern	Miombo	956.3±18.39[a]
	Acacia	252.6±02.5[b]
Southern	Miombo	598.9±4.49
	Acacia	-
Coastal	Miombo	401.7±2.67
	Acacia	-

Values are expressed as arithmetic mean ±standard deviation (n = 3)
Mean values with different superscripts letters along the columns are significantly different at p < 0.05

and it is a clear contrast between miombo and acacia honey samples and between zones in total phenols, flavonoids and FRAP. Miombo honey samples from northern, southern highland and lake zones had higher correlation with total phenol and antioxidant activity along PC1 than acacia samples which was in agreement with the above findings.

Correlation analysis between phenolic compounds and antioxidant activities

The correlation between Pfund, total phenols, flavonoids and FRAP of the honey samples are shown in Fig. 2. There was a strong positive correlation between Pfund and flavonoids (R^2=0.65, p=0, 0473) (Fig. 2 A), between flavonoids and total phenolic content (R^2= 0.989,

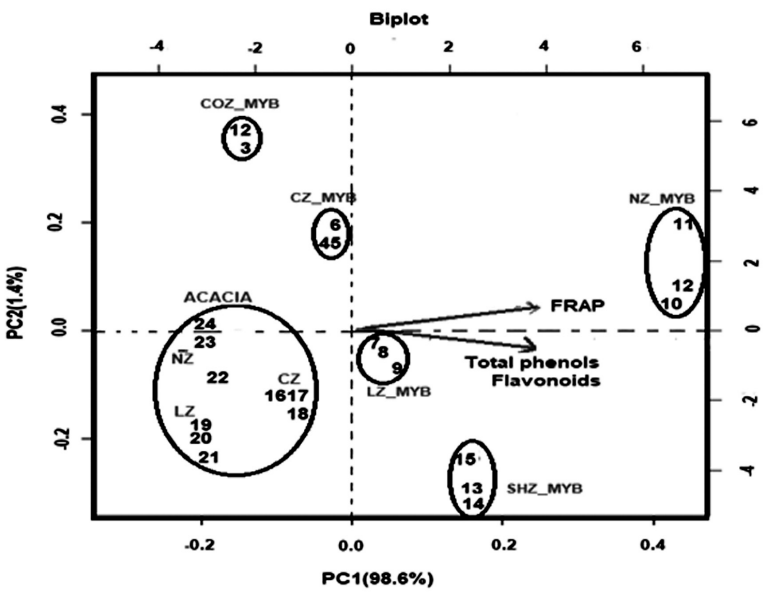

Figure 1: PCA Bi-plot showing variation in Flavonoids, Total phenols and FRAP values in honey samples from different geographical origin and floral sources. COZ is Costal zone, NZ is Northern zone, LZ is Lake zone, CZ is central zone, SHZ is Southern highland zone and MY is Miombo

p=0.0001) Fig. 2 D) and between total phenols and FRAP (R^2= 0.942, p=0.0003) as depicted in Fig. 2 F. These findings imply that, about 65.1% of variation in flavonoids in honey samples were significantly (p<0.05) explained by its colour, about 98.9 % of the total variability in total phenols values was significantly (p<0.01) explained by flavonoids content and about 94.2% of variability in FRAP was explained by total phenols present in the samples.

could be explained by the fact that, discrepancy in honey sensorial and physicochemical characteristics are due to diverse climatic and environmental conditions and various origins of plants from which it is harvested (Saric *et al.,* 2012). Honey samples from different floral sources may consist of different compositions and concentrations of pigments mainly polyphenols and carotenoids (Ram, 2011) and hence different colour. Moreover, contamination

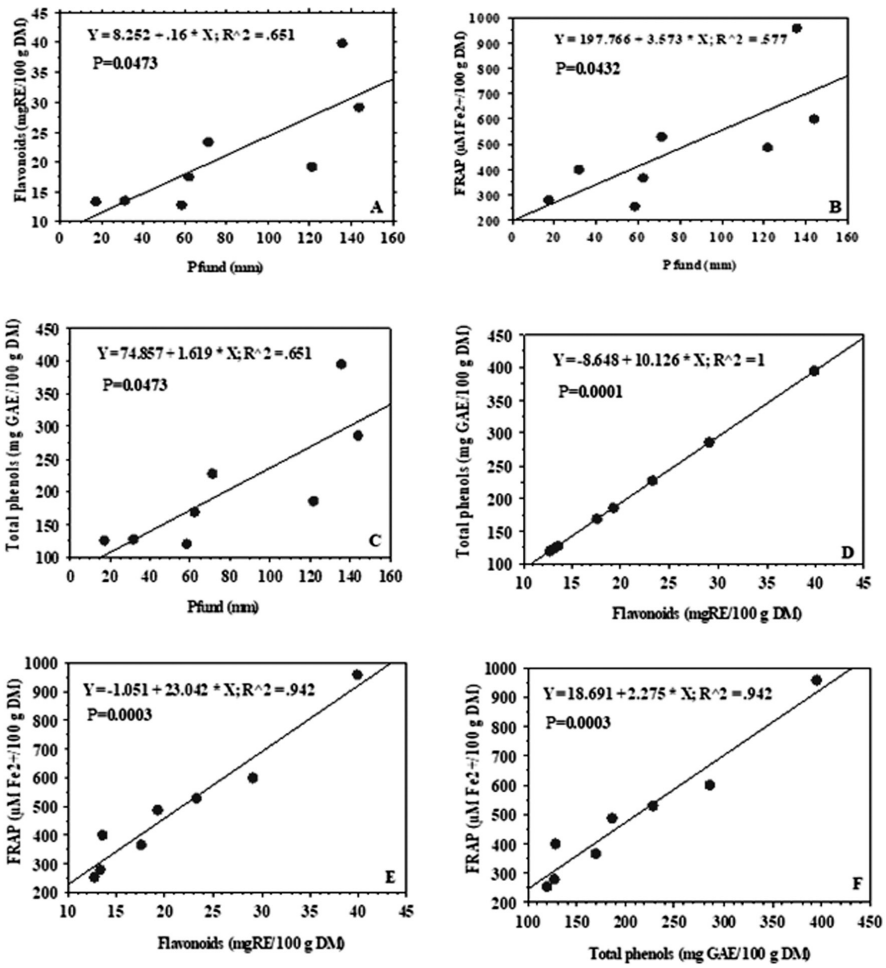

Figure 2: Correlation between pfund, flavonoids, total phenols and FRAP of honey samples

Discussion

Colour is one of the factors that determine honey quality, price as well as its acceptance in the world market (Viuda-Martos *et al.,* 2010). The varied pfund values observed in this study of honey with heavy metals, presence of high minerals ash content and storage of honey at high temperature has been linked to darker colour of honey (El-Metwally, 2015). Usually dark-colored honeys are associated with higher

ash and antioxidant content while light-colored honeys with low ash content (Alvarez-Suarez *et al.,* 2010). The light colour in acacia honey sample and dark colour in miombo honey samples revealed in this study were previously reported by Blasa *et al.* (2006) and Bertoncelj *et al.,* 2007). Based on these findings, colour may be used for identification of honey sample from miombo and acacia sources as well as from different sources and zones in Tanzania.

The findings suggest that geographical origins and floral sources have variable effects on flavonoids and TPC contents of honey samples as previously reported by Bertoncelj *et al.* (2007) and Alvarez-Suarez (2014) that, the phenolic profile of honeys and consequently their antioxidant capacity depend on the botanical and geographical origins of plants from which it is harvested, seasonal and diverse climatic and environmental conditions. Environmental factors may cause the biotic and abiotic stresses that are able to trigger changes in the plant's metabolism (Munoz *et al.,* 2007) and Cheynier (2005). These changes may affect the polyphenol biosynthesis, especially phenolic acids, which represent the evolutionary response to plants adaptation to different environmental characteristics. Therefore, honey types produced in a certain country, zone or area represent the floral or nectar sources in that place, whose presence solely depends on the climate, topography and agricultural pattern of that area (Mohammed, 2003). The TPC value (119.5-395 mg GAE/100 g DM) and flavonoids value (12.7±0.60-39.9±0.42 mgRE/100g DM) observed in this study were in agreement with findings by Muruke (2014) who studied total phenolic content of Tanzania honey and obtained a TPC value of 31-618 mg GAE/100 g DM and flavonoid value of y. However the TPC findings are lower than 330-610 mg GAE/100 g DM obtained by Sime *et al.* (2015). Similar lower TPC and flavonoid contents in acacia honey sample than other floral sources were also reported (Krpan, 2009, Saric, 2012, Chua *et al.,* 2013, Azad *et al.,* 2016).

The FRAP assay gives a direct estimation of the antioxidants or reductants present in a sample based on its ability to reduce the Fe3+/Fe^{2+} couple (Islam *et al.,* 2012). It is considered to be a good indicator of antioxidant activity due to its reducing power test, in which the capacity of breaking radical chain reactions is, reflected (Dong *et al.,* 2011). The antioxidant activities among honey samples could be attributed to their polyphenol contents such as phenolic acids, flavonoids and polyphenols (Al-Mamary *et al.,* 2002; Aljadi and Yusoff, 2003). Estevinho *et al.* (2008) and Ferreira *et al.,* 2009) have demonstrated that the antioxidant activity of honey is due to the large amount of phenolic contents present. The observed difference in antioxidant activities between zones and floral sources in this study strengthen the widely accepted theory that the antioxidant activity of honey varies greatly depending on the floral sources and on external factors, such as season and environment, as well as the processing method used (Gomez-Caravaca *et al.,* 2006; Bertoncelj *et al.,* 2007 and Alvarez-Suarez *et al.,* 2014). The higher value in antioxidant capacity in miombo honey sample than in acacia honey sample could be explained by the fact that honey collected from different nectar of plant flower species contains different levels of phenolic that possess antioxidant activity (Rababah *et al.,* 2014). The FRAP values obtained in this study corresponds well to that determined by Pena *et al.* (2013) who obtained a range of 216.57 to 695.64 µM Fe^{2+}/100 g DM in Italian honey, Das *et al.* (2013) who obtained a range of 101-622 µM Fe (II) equivalence) and Moniruzzaman et al. (2014) who obtained a range of 116.00 to 786.22 µM Fe^{2+}/100 g DM of honey. However, higher values of (23000-116000 µM Fe^{2+}/100 g DM) were reported by Salgueiro *et al.* (2014).

The observed correlation coefficient findings suggest that color has moderate significant correlation to flavonoids contents and its linked antioxidant activities as previously reported by Meda *et al.* (2005) and Eleazu *et al.* (2013). Dark honeys have been associated with higher phenolic content and antioxidant activities than light coloured honey (Subha and Satarupa, 2014; Eleazu *et al.,* 2013) which seems to be consistent with the finding of this study. Strong significant correlation between flavonoids and

total phenols agrees with the available literature that, flavonoids are among the commonly phenolic compounds found in honey (Escuredo *et al.,* 2013). Similarly, Muruke (2014) showed a similar high significant correlation between phenolic content and flavonoid content in Tanzania raw honey and stingless bees honey. Finally, the findings have demonstrated that the antioxidant activity of honey samples is strongly correlated to the flavonoids and total phenols as reported in many previous honey, fruits and vegetables studies (Mongi *et al.,* 2013; Pena *et al.,* 2013; Krpan *et al.,* 2009).

Conclusion

It has been demonstrated in this study that, floral sources and geographical zones had significant effects on the colour, flavonoids, total phenols and antioxidant activities of Tanzania honey. Miombo honey sample had higher colour, flavonoids, total phenols and antioxidant activity than acacia honey samples between the floral sources. Within the miombo honey samples, northern and coastal zones had significantly highest and lowest antioxidant activity respectively whereas within the acacia honey sample central zone was observed to have higher phenolic content and total antioxidant activity.

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