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Effect of solar drying methods on total phenolic contents and antioxidant activity of commonly consumed fruits and vegetable (mango, banana, pineapple and tomato) in Tanzania

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The effects of solar drying methods [Cabinet direct (CDD), cabinet mixed mode (CMD) and tunnel (TD) drying] on total phenolic content (TPC) and antioxidant capacities of commonly consumed fruits and vegetable in Tanzania were investigated. The TPC and FRAP in mangoes (*Mangifera indica* cv. *Dodo*, *Viringe* and *Kent*), bananas (*Musa acuminata*, cv. *Kisukari*, *Kimalindi* and *Mtwike*), pineapples (*Ananas comosuss* cv *Smooth cayenne*) and tomatoes (*Lycopersicum esculentum* cv. *Tanya*, *Cal J* and *Onyx*) were evaluated using Folin-Ciocalteu reagent and ferric reducing antioxidant power (FRAP) methods, respectively. There were significant ($p<0.05$) variations in TPC (mg GAE/100 g DM) and FRAP (µmol/100 g DM) among the fresh fruit and vegetable samples. The highest TPC was in tomato (476.6±8.6 - 538.9±1.4) and lowest in banana (139.3±2.3 - 189.2±2.7). Drying methods had significant ($p<0.05$) effect on TPC and antioxidant values of the samples. All fresh samples had higher TPC levels but declined significantly in dried samples with the exception of tunnel dried tomatoes. Among the dried samples, the tunnel dried samples had less TPC loss (6-16%) than the cabinet dried samples (17-42%). The cabinet direct and mixed mode samples were not statistically different ($p>0.05$) from each other. However, tunnel dried samples had less FRAP loss (6-13%) which were statistically different ($p<0.05$) from the cabinet dried samples (14-56%). Percentage TPC and FRAP recoveries (%) differed significantly ($P<0.05$) between the varieties within the fruits/vegetable for both drying methods. A strong correlations between TPC and FRAP in both fresh (R^2= 0.970) and dried samples (R^2=0.8636) suggests that solar drying methods have significant effects on total phenolic contents and antioxidant activities of fruits and vegetables with tunnel drying method giving significantly less effects.

Key words: Mango, banana, pineapple, tomato, solar drying, total phenolic content (TPC), antioxidant activity, FRAP.

INTRODUCTION

Fruit and vegetables are both major food products and key ingredients in many processed foods (Jongen, 2007). They contain many essential vitamins, minerals, fibre and phytochemicals such as phenolic compounds and caretonoids, many of which are antioxidants (Yahia and Berrera, 2009). Various epidemiological studies have demonstrated a strong correlation between adequate consumption of fruits and vegetables with reduced risk of some major diseases such as cardiovascular, diabetes, hypertension, certain types of cancer and some of the degenerative diseases (Segura-Carretero et al., 2010). It has been reported that, up to 2.7 million lives could potentially be saved each year with sufficient intake of fruits and vegetables (WHO/FAO, 2003). The protective role against mutagenicity and cytotoxicity provided by fruits and vegetable has been attributed to the presence of phytochemicals, mainly the phenolic compounds linked with their antioxidant capacity (Rodríguez-Medina et al., 2009; Bennet et al., 2011). The ability of antioxidants to scavenge 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). Therefore, adequate daily consumption of fruits and vegetable is an important health-protecting factor (Wijngaard et al., 2009).

However, despite their nutritional and health benefits, many fruits and vegetables are highly seasonal and perishable resulting into huge postharvest losses (Idah and Aderibigbe, 2007). Post-harvest loss of 30-40% is estimated in developing countries, like Tanzania (Karim and Hawlader, 2005) mainly due to poverty, inadequate postharvest handling techniques, improper processing technology and storage facilities, poor infrastructure as well as poor marketing systems (Perumal, 2007). Drying of fruits and vegetables remains an important method of food preservation. It reduces the moisture content of food to a level, which allows safe storage over an extended period, and prevents the growth of mould and fungi and thus minimizing microbial degradation (Chong and Law, 2010; Doymaz, 2011). Furthermore, it brings about substantial reduction in weight and volume, and in packaging, storage and transportation costs (Chan et al., 2012).

Among all the drying methods, sun drying is a well-known method for drying agricultural commodities in tropical and sub-tropical. However, it has many disadvantages such as long drying time, exposure to contamination from dust, soil, sand particles and insects (Folaranmi, 2008). Consequently the quality of sun dried products may adversely be affected, failing to meet the required local and international standards (Ivanova and Andonov, 2001). To overcome these problems, it is necessary to use alternative drying methods. Solar energy is one of the most promising renewable energy sources in the world because of its abundance, inexhaustible and non-pollutant in nature compared with higher prices and shortage of fossil fuels (Basunai and Abe, 2001). Condori et al. (2001) reported that, attractiveness of solar dryers is further enhanced by its ability to dry the product rapidly, uniformly and hygienically to meet national and international standards with zero energy costs.

Recently, harnessing of solar energy for fruits and vegetable preservation as an alternative to open sun drying and unaffordable mechanical dryers in Tanzania is increasing (Ringo, 2008). Dried fruits and vegetables represent a relatively concentrated form of fresh fruits with higher total energy, nutrient density, fibre content and often significantly greater antioxidant activity (Bennett et al., 2011). According to Vinson et al. (2005), the plasma antioxidant activity may be significantly elevated by consumption of dried fruits, demonstrating bio-availability of antioxidant species. However, drying has been reported to affect the antioxidant activity of fruits and vegetables diversely (Chantaro et al., 2008; Kuljarachanan et al., 2009). Enzymatic and non-enzymatic processes that may occur during drying of fresh plant tissues may lead to significant changes in the composition of phytochemicals (Capecka et al., 2005). Enzymatic browning occurs when the fruit and vegetables polyphenoloxidase (PPO) comes into contact with the endogenous phenolic compounds during drying (Aydemir, 2004). Despite adequate literature review, information on the effect of solar drying methods on total phenolic and antioxidant activities of dried mango, banana, pineapple, and tomatoes is limited. This study therefore, carried out to study the effect of solar drying methods on total phenolic compound and antioxidant capacity of selected fruits and vegetable from Tanzania.

MATERIALS AND METHODS

Study areas

This study was carried out at Sokoine University of Agriculture (SUA), Morogoro, Tanzania and Norwegian University of Life Sciences (NMBU), Aas Norway. Drying activities were conducted at SUA while chemical analyses were carried out at NMBU.

Plant materials

Three common consumed fruits: mango (cv. *Dodo*, *Viringe* and *Kent*), banana (cv. *Kisukari*, *Kimalindi* and *Mtwike*) and pineapple (cv. *Smooth cayenne*) and one vegetable; tomato (cv. *Tanya*, *Cal J*

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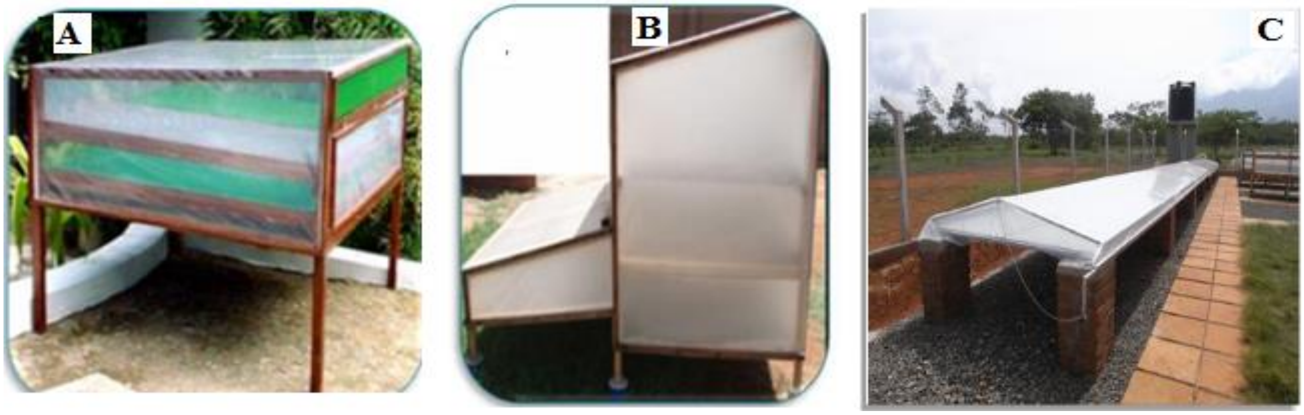

Plate 1. Different solar dryers used in the study: (A) Cabinet direct dryer-CDD, (B) Cabinet mixed mode dryer-CMD and (C) Hoeinheim Tunnel dryer-TD.

and *Onyx*) were procured at physiological maturity and ripeness from selected farmers in Morogoro and Pwani regions, Tanzania.

Drying equipment

Two solar cabinet dryers: direct and mixed modes were locally fabricated and one Hoenheim solar tunnel dryer (Innotech, German) was imported and installed in the study area. The dryers consisted of two parts namely collector and a drying unit/tunnel. In addition, the tunnel dryers consists small fans to provide the required air flow over the products to be dried. The CDD had collector dimension of (1.17 × 2.35 m) and drying section of 0.67 × 1.44 × 2.29 m, respectively while the d CMD had collector dimension of 1.03 × 1.16 plus 90 × 1.16 m for extension and drying section of 1.13 × 1.19 × 1.23 plus 0.99 × 1.23 m for extended part. The tunnel dryer had dimension of 7.1 × 2 m and 10 × 2 m for collector and drying chamber respectively (Plate 1). Both collector and the drying units were covered with UV stabilized visqueen sheets and food grade black paint was used as an absorber in the collectors. The products to be dried were placed in trays in cabinet dryers and a single layer on a wire mesh in the tunnel dryer.

Chemicals

Methanol, acetonitrile, acetic acids, $FeCl_3.6H_2O$, $FeSO_4.7H_2O$, anhydrous sodium carbonate, were obtained from Merck KGaA (Darmstadt, Germany), 6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid (Trolox), 2,4,6-tri(2pyridyl)-s-triazine (TPTZ) were obtained from Fluka Chemie GMBH (Buchs, Switzeland). Folin-Ciocalteu phenol reagent (2.0, N), 3, 4, 5,-Trihydroxybenzoic acid (Gallic acid) were bought from Sigma-Aldrich (St Louis, MO, USA). Liquid nitrogen was supplied by Hydro Gas and Chemicals AS (Oslo, Norway). All chemical and gases were of analytical grade.

Research design

Completely randomized design (CRD) was used in the study and principal factor was solar drying method (Local cabinet direct dryer (CDD), cabinet mixed mode (CMD) and Tunnel dryer (TD). The samples were analyzed for dry matter, total phenolic content and antioxidant. The effect of the principal factor on these parameters was determined. The mathematical expression is:

$$y_{ij} = \mu i + \tau_i + \varepsilon ij \quad (1)$$

i=1,2,..., t, j=1,2,...,ni

Where μis the overall mean, τ*i* is ith treatment effect and ε*ij* is the random effect due to jth replication receiving ith treatment.

Drying process

The drying to assess performance of the dryers in retaining phytochemicals was done following methods described by Leon et al. (2002). Fresh mature ripe fruit and vegetable samples were washed, peeled and sliced to 5 mm thick and each sample divided into three portions that were subjected in equal loading density of 2.91 kg of fresh produce/m^2 of solar aperture to either cabinet direct dryer (CDD) with temperature ranging from 30-55°C for about 3 days, cabinet mixed dryer (CMD) with temperature ranging from 25-49° C for about three days and tunnel dryer (TD) with temperature ranging from 60-73°C, for about two days. Since solar drying solely depends on weather conditions, these temperatures were not preset but obtained during drying process and samples were offloaded from dryers after predetermined duration. The dried products were packed in polyethylene bags and stored at -4°C prior to laboratory analysis.

Determination of dry matter

Dry matter contents of fresh and dried products were determined in triplicate according to the standard methods of AOAC (1995). About 5 g of samples were put in pre-weighed crucibles and oven dried at 105°C for 24 h until constant weight was achieved.

Sample extraction and preparation for phytochemical analyses

Three grammes of each sample was diluted in 30 ml of methanol and sonicated at 0°C for 15 min in an ultrasonic bath (Model 2510, Branson Ultrasonics Corp, USA). The sample was then flushed with nitrogen in order to prevent oxidation and stored frozen at -20°C prior to analysis. During analysis, the homogenate was centrifuged at 31,000 g for 10 min at 4°C using a Beckman J2-21M/E centrifuge (GMI Inc., Ramsey, MIN, USA). The supernatant was decanted and subjected to analysis of total phenols and antioxidant power. All samples were extracted in duplicate and analyzed in triplicate.

Table 1. Dry matter content (%) of fresh and dried fruits and vegetable varieties of three solar drying methods.

Fruit/veg.	Variety	Drying method			
		Fresh DM (%)	CDD DM (%)	CMD DM (%)	TD DM (%)
Mango	*Dodo*	21.0±0.0[a]	83.5±0.01[b]	84.0±0.02[b]	86.0±0.49[c]
	Viringe	20.9±0.3[a]	83.6±0.01[b]	83.8±0.02[b]	85.9±0.06[c]
	Kent	19.1±0.29[a]	82.2±0.0[b]	82.51± 0.01[b]	85.0±0.13[c]
Banana	*Kisukari*	29.2±0.5[a]	83.4±0.17[b]	83.3±0.16[b]	86.1±1.5[c]
	Kimalindi	28.3±0.46[a]	82.2±0.09[b]	82.2±0.24[b]	86.0±2.3[c]
	Mtwike	28.6±0.62[a]	82.3±0.10[b]	82.9±0.03[b]	84.7±2.12[c]
Pineapple	*Smooth cayenne*	19.4±0.31[a]	81.4±0.01[b]	81.2±0.00[b]	84.8±0.28[c]
Tomatoes	*Tanya*	7.8±0.13[a]	85.5±0.01[b]	85.8±0.02[b]	88.9±0.00[c]
	Cal J	7.7±0.00[a]	85.6±0.00[b]	85.4±0.00[b]	88.3±0.01[c]
	Onyx	8.0± 0.00[a]	85.7±0.00[b]	85.1±0.14[b]	88.9± 0.01[c]

Data presented as arithmetic means ± SD (n = 3). Means in row with different small letter are significantly different ($p<0.05$) between drying methods for the same variety.

Determination of total phenolic contents (TPC)

Total phenolic content was determined using a Konelab 30i (Thermo Electron Corp., Vantaa, Finland) clinical chemical analyser. The procedure was based on using the Folin-Ciocalteu reagent (FCR), as described by Singleton et al. (1999). A 20 µl sample were added to 100 µl FCR (diluted 1:10 with distilled water), mixed and incubated at 37°C for 60 s prior to addition of 80 µl 7.5% (w/v) sodium bicarbonate solution. The samples were again mixed and incubated at 37°C for 15 min prior to absorbance reading at 765 nm. TPC were assessed against a calibration curve of gallic acid, and the results presented as mg gallic acid equivalents (GAE) per 100 g dry weight (DW).

Determination of ferric reducing antioxidant power (FRAP)

Antioxidant activity in the samples was measured using the ferric reducing ability of plasma (FRAP) assay described by Benzie and Strain (1996) using the KoneLab 30i (Kone Instruments Corp, Espoo, Finland). Briefly, 200 µl of the FRAP reagents (3.0 mM acetate buffer, 10 mM TPTZ in 40 mM HCl, 20 mM $FeCl_3.6H_2O$, ratio 10:1:1) were automatically pipette separately and mixed in the cuvettes; 8 µl of sample were added and mixed and left to incubate at 37°C for 10 min and absorbance read at 595 nm. Trolox (Vitamin E analogue) was used as a control. The antioxidant activity in the samples was calculated as mmol Fe^{2+} per 100 g dry matter.

Statistical analysis

Data obtained was analyzed in triplicates using analysis of variance by R statistical software ((R Development Core Team, Version 3.0.0 Vienna, Austria). One way analysis of variance (ANOVA) was done to determine significant differences between factors. Means were separated by Turkey Honest Significant Difference (THSD) at $p<0.05$. Pearson correlation coefficient was done to determine the relationship between TPC and FRAP.

RESULTS AND DISCUSSION

Dry matter content

Contents of dry matter in fresh and dried samples are shown in Table 1. The results showed significant variations in dry matter contents between fresh and dried samples and within the drying methods. Dry matter contents of all fresh samples increased significantly ($p<0.05$) and the increase was more pronounced in tunnel dried samples for all fruits and vegetables. Cabinet direct and mixed mode dryers were not significantly different in terms of performance for both food products ($p>0.05$). Drying significantly reduces moisture contents of food materials and causes changes in dry matter contents. Lefsrud (2008), reported that the moisture content within biological samples changes during drying and can result in the release of organic compounds, volatile organic compounds (VOCs), destruction of pigments, and changes in chemical composition. The higher dry matter content in tunnel dryer than in cabinet dryers could be associated with its high drying temperature, which caused more moisture release in addition to the release of other of organic compounds.

Total phenols

The mean total phenolic compounds (TPC) of fresh and dried fruit and vegetable varieties are shown in Table 2. Significant differences ($p<0.05$) in TPC among the fresh fruits/ vegetable were observed. The highest TPC contents (g/100 g DM) were found in tomato cv. *Onyx*

Table 2. Total phenolic contents (mgGAE/100g DM) of fresh and dried fruits and vegetable varieties of three solar drying methods.

Fruit/Veg	Variety	Drying method			
		FR	CDD	CMD	TD
		Mean (%)	Mean (%)	Mean (%)	Mean (%)
Mango	*Dodo*	315.3±5.4 (100)^{a}	261.3 ± 6.7 (83)^{b}	263.4 ± 3.1 (84)^{b}	291.8 ± 5.4 (93)^{c}
	Viringe	311.4±1.5 (100)^{a}	261.6 ± 1.3 (84)^{b}	259.2 ± 3.8 (83)^{b}	292.9 ± 0.6 (94)^{c}
	Kent	239.4±7.9 (100)^{a}	184.3 ± 1.8 (77)^{b}	181.1 ± 0.8 (76)^{b}	201.5 ± 4.4 (84)^{c}
Banana	*Kisukari*	139.3±2.3 (100)^{a}	81.2 ± 0.5 (58)^{b}	83.0 ± 0.8 (59)^{b}	105.96 ± 2.1 (76)^{c}
	Kimalindi	189.2±2.7 (100)^{a}	116.9 ± 0.8 (62)^{b}	118.1 ± 1.5 (62)^{b}	145.90 ± 6.4 (77)^{c}
	Mtwike	173.6±4.2 (100)^{a}	98.5 ± 0.4 (57)^{b}	100.3 ± 1.8 (58)^{b}	133.70 ± 4.4 (77)^{c}
Pineapple	*Smooth cayenne*	282.9±4.2 (100)^{a}	226.7 ± 3.1 (80)^{b}	232.8 ± 4.6 (82)^{b}	262.5 ± 4.5 (92)^{c}
Tomato	*Tanya*	476.6±8.6 (100)^{a}	448.2 ± 0.8 (94)^{b}	454.6 ± 3.1 (95)^{b}	587.2 ± 1.3 (123)^{c}
	Cal J	448.2±5.8 (100)^{a}	418.1 ± 4.8 (79)^{b}	415.7 ± 2.8 (79)^{b}	588.1 ± 5.8 (112)^{c}
	Onyx	538.9±1.4 (100)^{a}	512.9 ± 0.9 (95)^{b}	511.6 ± 1.7 (95)^{b}	675.5 ± 1.5 (125)^{c}

Data presented as arithmetic means ± SD (n = 3). Data in parentheses represent percent recovery relative to untreated. Means within fruit/ vegetable in row with different superscript letters are significantly different (p<0.05).

followed by mango cv. *Dodo* pineapple cv. *Smooth cayenne* and the lowest in banana cv. *Kisukari*. The level of polyphenolic compounds present in fruits and vegetable depends on cultivar, growth condition (soil, fertilizer, temperature, and cultivation techniques), storage and transport conditions and processing technology (Bennett et al., 2010). The effect of drying methods on TPC was significant (p<0.05) with all fresh samples having higher TPC levels but declined significantly in dried samples with exception of tunnel dried tomatoes. No significant differences were found between the cabinet direct and mixed modes of drying (p>0.05). These findings suggest that drying has variable effects on TPC contents of plant samples. It could result in little or no change, significant declines or enhancement of the TPC (Hamroun-Sellami et al., 2012). Chan et al. (2009) found that, all methods of thermal drying (microwave, oven and sun drying) resulted in sharp decline in TPC in dried leaf vegetables. The decline is attributed to degradation of phenols during drying (Suvarnakuta et al., 2011). Bennett et al., (2010) explained that, the phenolics present in fresh fruit and vegetables are susceptible to oxidative degradation by polyphenol oxidase (PPO) during drying, which leads to intermolecular condensation reactions and their level decreased. Similar decline in polyphenolic content after drying has been reported in prune (Caro et al., 2004), persimmons (Park et al., 2006), mulberry leaves (Katsube et al., 2009), apricots (Madrau et al., 2009), olive mill waste (Obied et al., 2008) and ginger leaves (Chan et al., 2009). Among the dried samples, the tunnel dried samples had less loss (6-16%) than cabinet dried samples (17-42%). This difference might be ascribed to greater enzymatic degradation by PPO as direct and mixed mode dryers took comparatively longer time for drying compared to tunnel drier resulting to additional enzymatic reactions (Chan et al., 2009).

The higher TPC contents in tunnel dried tomato than fresh samples and generally lower decline in TPC for other tunnel dried samples could be attributed to the release of more bound phenolic compounds from breakdown of cellular constituents due to high drying temperature (Randhir et al 2007; Boateng et al., 2008; Vega-Galves et al., 2009; Marshall et al., 2000). Along with that, the application of temperature in the 70-90°C range associated with faster dehydration reduces the opportunity for PPO oxidation process that accompanies drying (Uhlig and Walker, 1996). This is consistent with the findings of this study.Similar increase in polyphenolic contents after drying has been reported in sweet potatoes (Mao et al., 2010), prune (Caro et al., 2004) tomatoes (Dewanto et al. 2002; Chang et al., 2006) and Shitake (*Lentinus edodes*) mushroom (Choi et al., 2006). In general, the significant effect of different drying methods on total phenolic compound of fruits, vegetables and herbs has widely been reported (Hamrouni-Sellami et al., 2012; Zhang et al., 2012).

The effect of varieties in percentage TPC recovery of dried products in each drying methods are shown in Figure 1. There were significant differences (p<0.05) in recoveries between the fruits and vegetable products and between the varieties within the species in each dryer. The highest recoveries between the species were found in mango varieties (77-94.06%) and the lowest in banana varieties (56.8-77.1%). The highest recoveries between the varieties within the species for all drying methods were found in *Dodo* and *Viringe* for mango (83.2-94.06%), *Kimalindi* for banana (61.8-77.10%) and *Onyx*

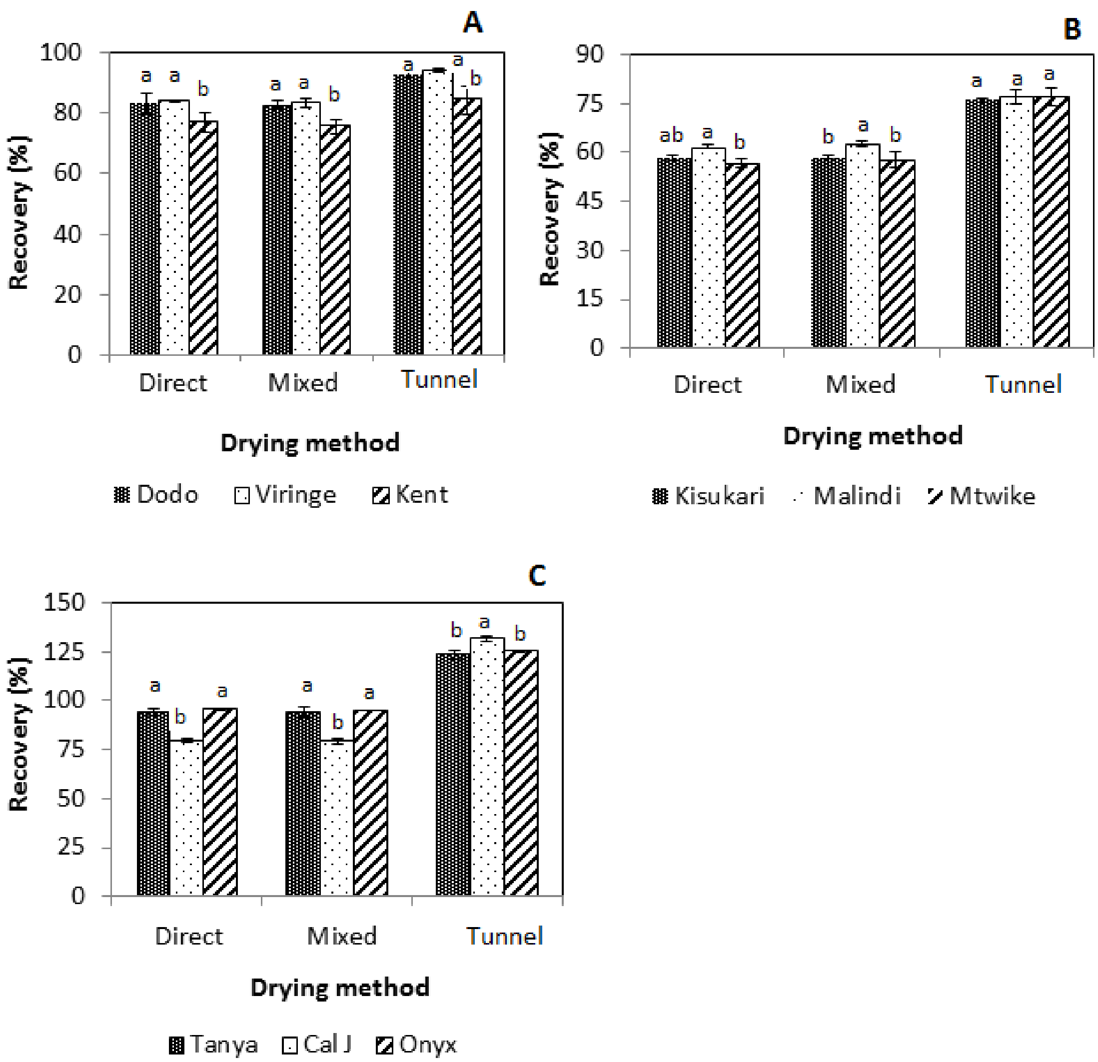

Figure 1. Recoveries of TPC in varieties of Mango (A), Banana (B) and Tomato (C) in three drying methods (mean±SD, n=3). Bars with different letter indicates means are significantly different at p<0.05 for varieties in each drying method.

and *Tanya* for tomato (94-125%). *Kent*, *Kisukari*and *Cal J* varieties of mango, banana and tomato had the lowest percentage recoveries in all drying methods. These findings suggest that, amongst other factors, such as maturity stage and light exposure, phenolic composition varies with cultivars (Segura-Carretero et al., 2010). Similar variation in TPC between varieties of the fruits were reported in dried apricot (Madrau et al., 2009), palm (Piga et al., 2005) and mango (Ribeiro, et al., 2007).

Ferric reducing antioxidant power (FRAP)

The mean ferric reducing antioxidant power (FRAP) of fresh and dried fruits and vegetables varieties are shown in Table 3. Significant differences (p<0.05) in FRAP between fresh fruits/vegetable were observed. The highest FRAP contents (µmol/100 g DM) were found in tomato cv. *Tanya* followed by mango cv. *Viringe* pineapple cv. *Smooth cayenne* (and the lowest in banana cv. *Kisukari*). The differences in the antioxidant activities among the fruits and vegetables samples could be attributed to their polyphenol contents and composition and to other non-phenolic antioxidants present in samples such as vitamin C, vitamin E, Mallard reaction products, β-carotene and lycopene (Hassanien, 2008; Ali et al., 2010). Fresh samples had higher FRAP levels than dried samples. However, these decreased significantly in dried samples for all drying methods. Tunnel dried samples had significantly less FRAP loss (6-13%) than cabinet dried samples (14-56%), confirming the finding that the two drying methods were statistically different (p<0.05). However, the direct and mixed dried samples were statistically similar (p>0.05) in antioxidant activity.

Table 3. Ferric Reducing Antioxidant Power (FRAP) (µmol/100 g DM) of fresh and dried fruits and vegetable varieties of three solar drying methods.

Fruit	Variety	Drying method			
		Fresh	Direct	Mixed	Tunnel
		Mean (%)	Mean (%)	Mean (%)	Mean (%)
Mango	*Dodo*	27.3 ± 0.3 (100)[a]	21.3 ± 0.2[b] (79)	21.6 ± 0.1[b] (80)	25.1 ± 0.4[c] (93)
	Viringe	28.5 ± 0.4 (100)[a]	24.2 ± 0.5[b](86)	24.1 ± 0.1[b] (86)	26.9 ±0.5[c] (96)
	Kent	23.1 ± 0.4 (100)[a]	15.1 ± 0.2[b] (65)	14.9 ± 0.2[b] (64)	20.3 ± 0.2[c] (88)
Banana	*Kisukari*	10.8±0.1 (100)[a]	5.7 ± 0.1[b] (53)	6.0 ± 0.2[b] (55)	8.5 ± 0.2[c] (78)
	Kimalindi	15.8±0.2 (100)[a]	8.6 ± 0.0[b] (55)	8.9 ± 0.0[b] (57)	12.6 ± 0.5[c] (80)
	Mtwike	14.5±0.2 (100)[a]	6.4 ± 0.0[b] (44)	6.7±0.0[b] (46)	13.1 ± 0.3[c] (90)
Pineapple	*Smooth cayenne*	24.8±0.5 (100)[a]	18.4 ± 0.2[b] (74)	18.2 ± 0.1[b] (73)	23.1 ± 0.3[c] (93)
Tomato	*Tanya*	46.8±0.5 (100)[a]	27.9±0.3[b] (60)	28.3±0.4[b] (60)	43.0±0.4[c] (92)
	Cal J	44.6±1.6 (100)[a]	23.8±0.5[b] (53)	24.4±0.3[b] (55)	39.2±0.4[c] (88)
	Onyx	44.6± 0.3 (100)[a]	26.5±0.2 [b](59)	25.7±0.6[b] (58)	38.6± 0.3[c] (87)

Data presented as arithmetic means ± SD (n = 3). Data in parentheses represent percent recovery relative to untreated. Means within fruit/vegetable in row with different superscript letter are significantly different ($p<0.05$).

Drying affects the antioxidant activity of fruits and vegetables differently (Kuljarachanan et al., 2009; Chantaro et al., 2008; Choi et al., 2006). Chemical and enzymatic processes during drying and/or storage can lead to either loss of phenolic-related antioxidant capacity or may generate chemical derivatives with little or no change, significant declines or enhancement in antioxidant capacity (Bennet et al., 2011).Nevertheless, the best drying method leads to the least alteration in phenolic content and enhances antioxidant activity of the sample. Madrau et al. (2009) found that, high drying temperature gave a product with better polyphenol content with enhanced antioxidant activity. Similar effect of drying on antioxidant capacity of fruits and vegetable has been reported in apple (Anwar et al., 2012), sage (Hamrouni-Sellami et al., 2012) and *Enicostemma littorale (Blume*) (Sathishkumar et al., 2009).

The influence of varieties in percentage FRAP recoveries within each fruit/vegetable samples in each drying method was significant ($p<0.05$) as indicated in Figure 2. The highest recoveries were found in *Viringe* for mango (85.6-95.8%), *Kimalindi* and *Mtwike* for banana (54.6-56.5 and 89.9% respectively) and for tomato (81.88-90.62%). The influence of varieties in antioxidant capacity of dried fruits has also been reported in apricot (Madrau et al., 2009).

Correlation analysis between total phenolic contents and FRAP

The correlation analysis between total phenolic and antioxidant activity of the fresh and dried fruits and vegetable are shown in Figure 3. There was a strong positive correlation between both the TPC and antioxidant activities in fresh (R^2=0.9709) and dried samples (R^2= 0.8636). This finding implies that, the antioxidant activity of plants materials including fruits and vegetables is strongly correlated to the TPC contents (Anwar et al., 2012; Zhang et al., 2012). Similar correlation between total phenols and antioxidant activity in plants have been reported (Ichuen et al., 2010; Sreeramulu et al, 2010; Mao et al., 2010).

Conclusion and recommendations

Solar drying has significant effect on total phenolic contents and antioxidants activities of dried mango, banana, pineapple and tomato which varies depending on the method used. Tunnel dried samples have lower decline in TPC and antioxidant activities than cabinet dried samples due to higher drying temperature and shorter drying rate. Moreover, the percentage recoveries of total phenols and antioxidant capacities of dried fruits and vegetables differ according to varieties. Finally, the antioxidant capacities of plants materials including fruits and vegetables are strongly depend on the total phenolic compounds present. Based on the better performance of the tunnel dryer over local ones in retaining and enhancing TPC associated with higher antioxidant activities, then its use in drying and extending shelf life of agricultural produces is highly recommended and should be advocated in Tanzania and in developing countries at large.

Conflict of interests

The authors did not declare any conflict of interest.

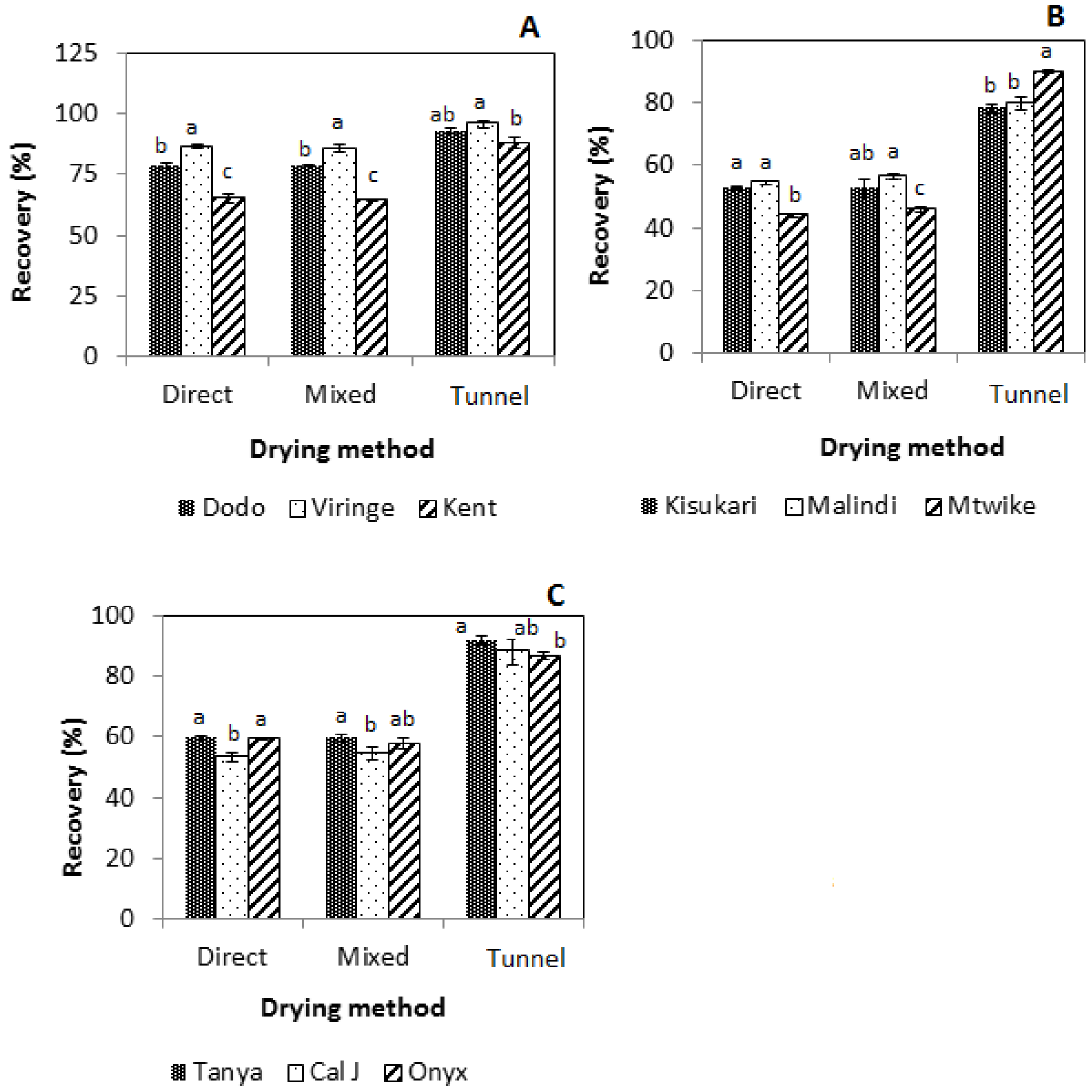

Figure 2. Recoveries of FRAP in three varieties of Mango (A), Banana (B) and Tomato (C) in three drying methods (mean±SEM, n=3). Bar means with different letter are significantly different at p<0.05 for varieties in each drying method.

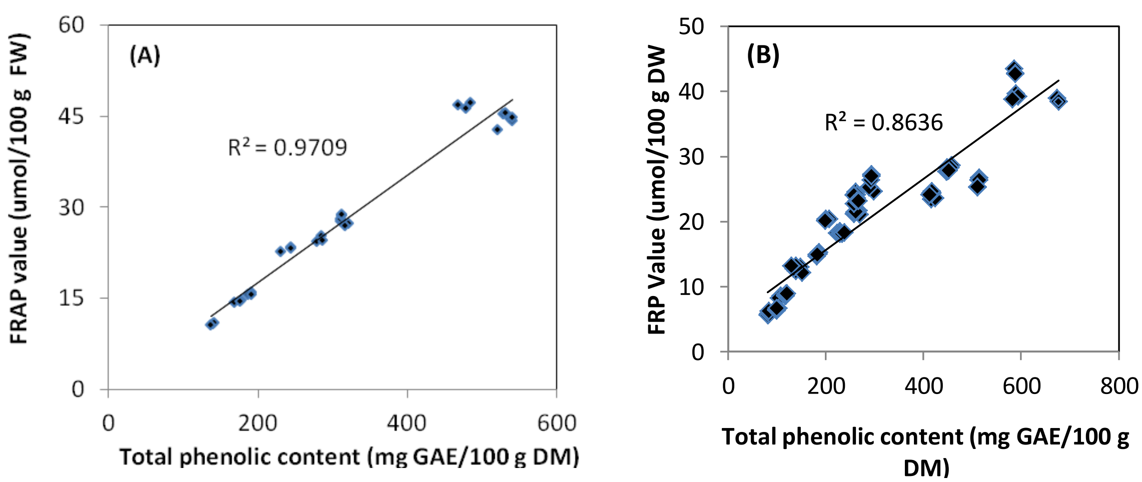

Figure 3. Correlation between total phenolic contents and FRAP in Fresh (A) and Dried (B) Fruits and vegetable.

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