Effect of Varieties, Solar Drying and Zeer Pot Refrigeration Lining Media on ~~Phyto – Chemical~~ Phytochemical Properties of Chili Pepper Fruits

ABSTRACT

Chili peppers are rich in ~~phyto – chemical~~ phytochemical compounds such as carotenoids, beta carotene, phenols, flavonoids, capsaicinoids ~~etc~~ which protect human body against diseases such as cancer, heart diseases, diabetes ~~etc~~ but deteriorate ~~quickly~~ more rapidly. Therefore, the main objective of this study is to investigate the effect of varieties, solar drying and zeer pot lining media on ~~phyto – chemical~~ phytochemical characteristics of chili peppers. A 2 x 3 x 3 factorial experimental design in ~~Randomized Complete Block Design (RCBD)~~ a Completely Randomized Design (CRD) was used ~~to collect data~~ ~~for~~ during the laboratory ~~analyses~~ experiment. Results of effect of varieties on ~~phyto – chemical~~ phytochemical characteristics of chili pepper fruits revealed that, red cayenne was significantly greater in total carotenoids (9222ug/100g), beta carotene (934.23ug/100g), total flavonoids (50.04mg/100g), total capsaicinoids (247.30mg/100g) but scotch bonnet was significantly higher in total phenols (301.74mg/100g). Again, on results of effect of solar drying on ~~phyto – chemical~~ phytochemical characteristics of chili pepper fruits showed that, unblanched chili pepper fruits had significantly ($p < 0.05$) higher total phenols (386.64mg/100g), total flavonoids (51.97mg/100g) and total capsaicinoids (260.72mg/100g) while controlled chili pepper fruits had significantly higher total carotenoids (8035.4ug/100g) and beta carotene (812.34ug/100g). Also, on results of effect of lining media of zeer pot refrigeration on ~~phyto – chemical~~ phytochemical characteristics of chili pepper fruits stored in sand lining media of zeer pot refrigeration had significantly ($p < 0.05$) higher total phenols (304.30mg/100g), total flavonoids (49.99mg/100g) and total capsaicinoids (242.17mg/100g) while styrofoam lining media had significantly higher total carotenoids (8506.1ug/100g) and beta carotene (861.64ug/100g).

Keywords: Varieties, solar drying, zeer pot, ~~phyto – chemicals~~ phytochemicals and chili peppers

1. INTRODUCTION

Chili peppers are cultivated all over the world with leading countries been China, Mexico and Turkey which they contribute about 70% of the world's chili pepper cultivation (MiDA, 2010). Ghana is ranked eleventh (11th) ~~larger~~ producer of chili pepper in the world and second (2nd) ~~larger~~ producer in Africa with estimated total production in terms of metric tons been 88, 000 metric tons. (FAOSTAT, 2011). In Ghana, it is normally cultivated by small

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Comment [M2]: CRD is the appropriate design for lab experiment scale ~~(peasant)~~ or commercial farmers for export or for domestic consumption (Norman, 1992).

They contain various food nutrients such as protein, carbohydrate, vitamin A and C, folic acid, fibre and low in sodium and caloric content (Luning, 1995) and ~~phyto – chemical~~ phytochemical substances such as carotenoids, beta carotene, flavonoids, phenols, capsaicinoids etc which are antioxidants which defend human body against disease infections such as cancer, diabetes and heart diseases, diarrhoea and arthritis (Newman, 2017, Pratyusha, 2022 and Mount Sinai, 2023). They are added to food such as meat, fish, vegetable, salad dressing and soup to make it spicy and add flavour to food (Streit, 2019). Heat is extracted from chili peppers to prepare various alcoholic beverages and culinary as well as pharmaceutical products (Paran and Knaap, 2007, Djan – Caporalino. 2009 and Apex Flavours, 2020). Capsaicin is also extracted from chili peppers to prepare tear gas or pepper spray which is used to control crowd or riot by law enforcement officers. They are also used to prepare organic insecticides or pesticides which is environmental friendly and do not pose health threats to humans after consumption of the product (CDC, 2018).

Solar dryer is a drying device which harvest the sun radiation and use for drying agricultural products hygienically (Pangavhane and Sawhney, 2002) by reducing contamination by dust, rain, insect or pests there by improving the quality of agricultural products (Gupta *et al*., 2012).

Zeer pot also referred to as pot – in – pot or evaporative cooler is a storage device use for storing agricultural products which is capable of reducing temperature of the agricultural products by 15 - 40^0F to extend the shelf – life of the agricultural products without using electricity or fossil fuel. It is low cost as compared to electrical refrigerator and environmental friendly (Technology exchange lab, 2019 and Megan, 2020).

Chili peppers deteriorate quickly after harvest, during processing and storage which results in scarcity in the dry season there by depriving humans of the use of chili peppers causing many ailments associated with inadequate consumption of chili peppers and increasing the prices of chili peppers in the lean seasons. Global annual postharvest losses of vegetables is estimated to be 30 – 70% (Weinberger and Acedo, 2011). In Ghana postharvest loss of fruits and vegetables is also estimated to be 20 – 50% (Rutten and Verma, 2014). Therefore, it is important to investigate the effect of varieties, solar drying and zeer pot lining media on ~~phyto – chemical~~ phytochemical characteristics to make chili peppers available all year round for human use.

~~2.~~ MATERIALS AND METHODS

~~2.1.~~ Study Area

The study was conducted in the Dormaa – East District with total land area of 456 Square Kilometres. It lies within the middle belt of Ghana, with latitude between 7^0 08^1 North and 7^0 25^1 degrees and longitude 2^0 35^1 West and 2^0 48^1 West (Dormaa East District, 2006).

Dormaa – East District was separated from Dormaa Municipality, formally Dormaa Central Municipality by legislative instrument (LI851) of 2007 which is approximately 1.8 percent of the Bono Region's total geographical area with Wamfie as the district capital (Dormaa East District, 2006). The District is bordered to the west by Dormaa Municipal, to the north by Berekum Municipal, to the east by Sunyani West District, and to the south by Asuonafo North Municipal and Asutifi North District. Dormaa – East District has a total population of 112,111 with 53,589 males and 58,522 females (Dormaa – East District, 2006).

The district is located in a semi-equatorial zone with two distinct rainy seasons (major and minor) (MoFA, 2020). The main season often peaks between April and June. On the other hand, the minor season lasts from September to November. The yearly rainfall average ranges from 124 to 175 millimetres. There is severe dry season from November to March every year. The District has average temperature of 30°C and lowest of 26°C in August. The main activity in the area is agriculture which constitutes 57 percent of the labour force which are mostly the adults which are engaged in crops, livestock and poultry production. They are also employed in the formal sector such as teachers, nurses, police etc. They predominately speak bono (MoFA, 2020).

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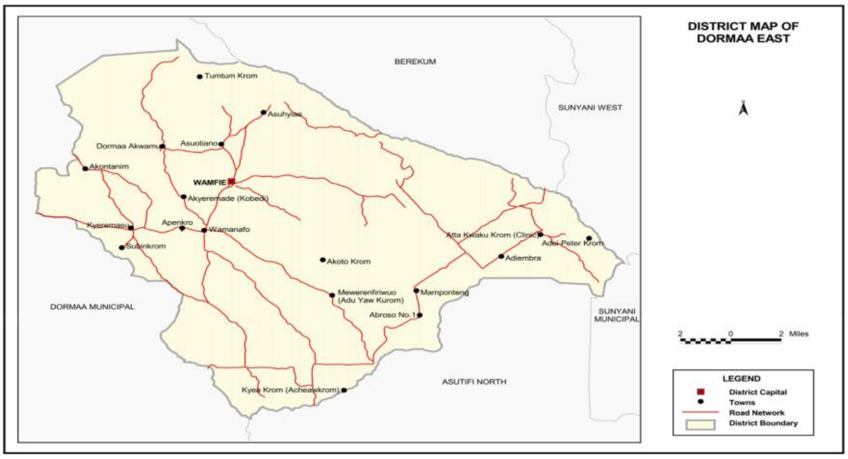

Figure 1. Map of the study area

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2.2. Source of Chili Pepper Fruits and the Various Lining Media for Solar Drying and Zeer Pot Refrigeration

One (1) bag (1) of fresh scotch bonnet and one (1) bag of red cayenne were bought from chili pepper traders in the various major market centres in the respective communities, Asuotiano, Wamfie and Wamanafo. The various lining materials (one (1) bag each) of sand (0.02mm), styrofoam (0.05mm) and wood shaving (thickness = 0.02mm and length = 4.5 cm) were collected from each respective communities.

2.3. Preparation of Chili Pepper Fruits

Chili pepper fruits were sorted to remove diseased fruits, washed and separated into two (2). One (1) group was blanched for minutes (3) minutes at 100^0C using coal pot and thermometer. The other group was unblanched.

2.4. Development of Solar Dryer

Solar dryers were developed using the design of (Nicol *et al*., 1997) with length (60 cm), width (40 cm) and height (85 cm). They were made of wood and the solar collection chambers were made of transparent polythene sheet fabricated to form triangular shape and hinged to one side of the drying chamber and other side provided with handle. The drying chambers were in the form of tables where metal meshes and black polythene sheets were cut and fabricated on the tables of the drying chambers. Inlet holes were created in front of the solar dryer and outlet holes were created at the opposite upper part of the solar dryer.

2.5. Procedures for Solar Drying Chili Pepper Fruits

Blanched chili peppers were dried from 8:00 am to 6:00 pm for two (2) weeks and unblanched chili pepper fruits were dried for three (3) weeks. After drying of chili pepper fruits, the fruit stalks were removed or destalked.

Figure 2. Solar dryer

2.6. Procedures for Making Zeer Pot Refrigerator

Zeer pot refrigerators were developed using zeer pot design described by (Babarinsa and Nwagwa, 1986). They were made of clay obtained in the communities, prepared to make it

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2.7. Procedures for Zeer Pot Refrigeration of Chili Peppers

The zeer pots were labelled with the use of tape and marker. The bottom of the outer clay pots were filled to a height of 6 cm with the various lining materials of zeer pot. The inner clay pots were placed in outer clay pots and the space between inner and outer clay pots were filled with various lining media (sand (sieved), styrofoam (crushed) and wood shavings) to the top level. The weight of the zeer pots were measured using weighing scale with zeer pots filled with styrofoam, wood shavings and sand weighing 6.96kg, 7.18kg and 15.52kg respectively. Solar dried chili pepper varieties were placed in the various labelled zeer pot refrigerators. Each zeer pot refrigerator was kept 14cm apart (14 cm between rows and 14 cm within rows and each experimental set up was kept in each three (3) communities for three (3) month under room temperature (26 - 34^{0}C). Water (600ml) was used to replenish zeer pots every day on each morning.

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Figure 3. Zeer pot refrigerators with different lining media

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2.8. Phyto – Chemical Phytochemical Properties Analyses

Phyto – chemical characteristics analyses were carried - out to determine the effect of varieties, solar drying and zeer pot refrigeration lining media on phyto – chemical phytochemical characteristics of chili pepper fruits.

2.8.1. Determination of total carotenoids

The total carotenoid was calculated using the Rodrigue-Amaya and Kimura (2004) method. Glass wool was used to filter the decanted liquid from a 1 g sample that had been pulverised using 50 ml of acetone in a 50 ml volumetric flask. The sample was ground until no more colour could be extracted from it and the extract was colourless. After the filtrate was moved, 30 millilitres of petroleum ether were previously put to a 250 millilitre separating funnel.

A little over 250 millilitres of distilled water were added to the mixture gradually while allowing it to run over the funnel's walls. The aqueous (lower) phase was eliminated once the two phases separated. To get rid of any leftover acetone, the top phase was cleaned four times with 250 ml of distilled water each time. During the final washing, all of the lower phase was thrown away, leaving none of the upper stages behind. After that, the petroleum ether phase was collected in a volumetric flask (50 ml) and any remaining water was removed by passing it through a tiny funnel filled with 10 g of anhydrous sodium sulphate.

Petroleum ether was used to wash the separatory funnel. The washings were collected in a volumetric flask and passed through the funnel with sodium sulphate. Petroleum ether was used to make the solution up to the 50 ml level. Utilising a spectrophotometer (UVMS Excellence UV5, Switzerland) to measure the sample's absorbance at 450 nm, the following formula was used to determine the total carotenoid concentration.

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$$\text{Total carotenoids (ug/g)} = \frac{\text{Asorbance} \ \ \text{x Total volume} \ \ \text{x } 10-4}{\text{Sample} \ \ \text{weight} \ \ \text{x } 2592}$$

2.82. Determination of beta carotene

Using acetone, 2 g of each sample was extracted to assess the amount of beta-carotene. Using a mortar and pestle, the samples were crushed until the residue lost all colour. After the extract was run through a funnel that was packed with glass wool, 25 millilitres of the extract were placed in a flask with a circular bottom and dried at a temperature of roughly 600 degrees Celsius. To dissolve the beta-carotene, 1 millilitre of petroleum ether was added to the evaporated sample. Column chromatography was then used to elute the solution. A slurry composed of silica gel with a mesh size ranging from 60 to 120 and petroleum ether was used to prepare a 15-cm glass column that was equipped with glass wool at the elution point. Following the settling of the slurry, anhydrous Na2SO4 was packed into the column, and 1 millilitre of 100% ethanol was added to activate the silica gel and anhydrous Na2SO4. Petroleum ether was then used to evaporate the mixture till a volume of 25 ml was obtained. In a UV-VIS spectrophotometer (UVMS Excellence UV5, Switzerland), the eluted absorbance was measured at 450 nm. A standard curve was created by plotting the absorbance of five standard solutions of beta-carotene, ranging in concentration from 0.4 to 2.4 ug/g, against their corresponding concentrations. The absorbance was measured at the same wavelength (Okalebo *et al*., 2002).

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2.8.3. Determination of total phenol

The Goldstein and Swain (1963) method was used to calculate total phenols. After homogenising the fruits of the chilli peppers in 0.3N HCl in methanol, the mixture was centrifuged at 10,000 g for ten minutes. After collecting the supernatant, the pellet was once more extracted using 0.3N HCl in methanol and centrifuged. On a water bath, the supernatants were collected and allowed to evaporate. The resultant residue was dissolved in 5 millilitres of distilled water. 0.5 ml of the Folin-phenol reagent was added to this volume, and it was violently shaken. One millilitre of a 35% sodium carbonate solution was added after three minutes, shaken, and let to stand for one hour. Using a UV-Vis Spectrophotometer (UVMS Excellence UV5, Switzerland), absorbance was measured at 650 nm. Tannic acid concentrations were varied to create a calibration curve that was used to calculate the total quantities of phenolics.

2.8.4. Determination of total flavonoids

The measurement of total flavonoid content was conducted using the Ordonez *et al*., (2006) method. 80% ethanol-extracted chilli peppers that were stored for a night. Using a UV-Vis Spectrophometer (UVMS Excellence UV5, Switzerland), 0.5 ml of fruit extract and 0.5 ml of 2% AlCl3 in ethanol were added, and the mixture was left to stand for an hour. The number of total flavonoids was calculated using a calibration curve that was made with varying concentrations of quercetin.

~~.2.8.5.~~ Determination of total capsaicinoids

The method by which capsaicinoids were isolated from the chilli pepper samples is detailed by (Topuz *et al*., 2011). After heating 0.5 g of chilli peppers for 4 hours at 800C in 8 ml of acetonitrile, the capsaicinoids were extracted. Throughout the extraction procedure, the suspensions were frequently shaken every 30 minutes. ~~We let t~~The suspended material settle and cool. The supernatant was utilised for HPLC injections after being filtered through a 0.45 um membrane filter (Millipore) into a 2 ml glass vial.

Using a pump unit (Hitachi L 6200 A) solvent equipped with an autosampler (Hitachi AS 2000), a fluorescence detector (Hitachi FL), and an integrator (HP 3393 A), liquid chromatography was carried out. At room temperature, the separation was carried out on a column (Phenomenex ODS, 5 um, 250 x 4.6 mm i.d.).

The HPLC operating conditions that were utilised by Schweiggert *et al*., (2006a) were as follows. At a flow rate of 1.2 ml/min, the eluent was a combination of a solution of water, and acetic acid (100: 100: 1). The run lasted 35 minutes in total. Ten uL was the injection volume. Every capsaicinoids was measured at 280 nm with a 0.4 mL/min flow rate. Moreover, U/Vis spectra were captured at a spectrum collection rate of 1.25 cans/s (peak width o.2min) in the 200–600 nm range.

~~2.9.~~ Experimental design and treatments

A 2 x 3 x 3 factorial experimental design in ~~Randomized Complete Block Design (RCBD)~~ Completely Randomized Design (CRD) with eighteen (18) treatments (Two (2) levels of chili pepper varieties, three (3) levels of solar drying processes and three (3) levels of types of lining media used in zeer pot storage). The two (2) levels of chili pepper varieties were scotch bonnet and red cayenne, the three (3) levels of solar drying processes were control, blanched and unblanched chili peppers and the three (3) levels of zeer pot lining media were sand, styrofoam and wood shavings. The experiment was replicated three (3) times with total sample population of fifty – four (54). After three (3) months of storage, samples of stored chili peppers were taken into labelled zip bags and placed in ice chest cooler, transported within four (4) hours to Food Science Laboratory, Kwame Nkrumah University of Science and Technology (KNUST) for Laboratory analyses.

~~3.~~ RESULTS

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Comment [M12]: CRD is for lab experiment while RCBD is for field

~~3.1.~~ Effect of Varieties on ~~Phyto – Chemical~~ Phytochemical Characteristics of Chili Pepper Fruits

~~Phyto – chemical~~ Phytochemical analyses were carried - out to determine effect of varieties on ~~phyto – chemical~~ phytochemical characteristics of chili pepper fruits. Table 1 showed the results of effect of varieties on ~~phyto – chemical~~ phytochemical characteristics of chili pepper fruits. The results indicated that, there were significant difference ($p < 0.05$) in ~~phyto – chemical~~ phytochemical characteristics of chili pepper fruits.

~~3.1.1.~~ Total carotenoids of chili pepper fruits

There was significant effect ($p < 0.05$) on the total carotenoids of chili pepper fruits with red cayenne been the highest (9222.4 ug/100g) and the least was recorded in scotch bonnet (4296.1ug/100g).

~~3.1.2.~~ Beta carotene of chili pepper fruits

There was significant difference ($p < 0.05$) in beta carotene which followed same trend as total carotenoids (9222.4ug/100g) with red cayenne recorded significantly ($p < 0.05$) the best beta carotene (934.23ug/100g) but the least beta carotene (429.30ug/100g) been recorded in scotch bonnet.

~~3.1.3.~~ Total phenols of chili pepper fruits

Significantly, there was difference ($p < 0.05$) in total phenols of chili pepper fruits with scotch bonnet been the best in total phenols (301.74mg/100g) whereas red cayenne recorded the least total phenols (229.93mg/100g) of chili peppers.

~~3.1.4.~~ Total flavonoids of chili pepper fruits

Total flavonoids had similar trend as total carotenoids (9222.4ug/100g), beta carotene (934.3ug/100g) where red cayenne had significantly ($p < 0.05$) higher total flavonoids (50.04mg/100g) and the least total flavonoids (26.28mg/100g) been recorded in scotch bonnet.

~~3.1.5.~~ Total capsaicinoids of chili pepper fruits

Total capsaicinoids were significantly ($p < 0.05$) higher in red cayenne (247.30mg/100g) which also continued similar trend as total carotenoids (9222.4ug/100g), beta carotene (934.23ug/100g) and total flavonoids (50.04mg/100g) whereas scotch bonnet recorded the least total capsaicinoids (174.56mg/100g)

Table 1: Effect of varieties on phyto – chemical characteristics of chili pepper fruits

Varieties	Carotenoids	Beta Carotene	Phenol	Flavonoids	Capsaicinoids
	(ug/100g)			(mg/100g)	
~~1~~ Scotch bonnet	4296.1b	429.30b	301.74a	26.28b	174.56b
~~2~~ Red cayenne	9222.4a	934.23a	229.93b	50.04a	247.30a
HSD (0.05)	75.47	7.76	1.62	0.41	0.76
CV	2.02	2.06	1.10	1.95	0.65

Means with the same letters (s) in the column are not significantly different from each other (p > 0.05, according to Tukeys HSD)

~~**NB**: 1 – Scotch bonnet~~

~~2– Red cayenne~~

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~~3.2.~~ Effect of Solar Drying on ~~Phyto – Chemical~~ Phytochemical Characteristics of Chili Pepper Fruits

~~Phyto – chemical~~ phytochemical analyses were done to determine the effect of solar drying on ~~phyto – chemical~~ phytochemical characteristics of chili pepper fruits. The results were demonstrated in table 2 which suggested that, there were significant effect (p ~~–~~< ~~–~~0.05) on ~~phyto – chemical~~ phytochemical characteristics of chili pepper fruits.

~~3.2.1.~~ Total carotenoids of chili pepper fruits

There were significant difference (p ~~–~~< ~~–~~0.05) in total carotenoids of chili peppers with controlled chili peppers significantly (p ~~-~~< ~~-~~0.05) had higher total carotenoids (8035.4ug/100g) followed by blanched – solar dried (6647.0ug/100g) chili pepper fruits and the least total carotenoids been unblanched (5595.5ug/100g) chili pepper fruits.

~~3.2.2.~~ Beta carotene of chili pepper fruits

Significantly, the higher beta carotene was noted in controlled (812.34ug/100g) followed by blanched – solar dried (670.78ug/100g) and the least beta carotene was recorded in unblanched – solar dried (562.18ug/100g) of chili pepper fruits.

~~3.2.3.~~ Total phenols of chili pepper fruits

The best total phenols was significantly (p ~~–~~< ~~–~~0.05) recorded in unblanched – solar dried (386.64mg/100g) chili pepper samples which was followed by blanched – solar dried (327.11mg/100g) chili pepper samples and the lowest total phenols was determined in controlled chili pepper samples (83.75mg/100g).

~~3.2.4.~~ Total flavonoids of chili pepper fruits

There was significant effect (p-<-0.05) on total flavonoids of chili pepper fruits. Unblanched chili pepper fruits had significantly (p < 0.05) highest total flavonoids (51.97mg/100g) which continued same trend as total phenols (386.64mg/100g) followed by blanched (39.60mg/100g) chili pepper fruits while the least was recorded in controlled (22.91mg/100g) of chili pepper samples.

~~3.2.5.~~ Total capsaicinoids of chili pepper fruits

There was significant difference (p < 0.05) in total capsaicinoids where unblanched chili pepper samples had the best total capsaicinoids content (260.72mg/100g) which continued similar trend as total phenols (386.64mg/100g) and total flavonoids (51.97mg/100g) followed by blanched – solar dried (207.67mg/100g) but the least total capsaicinoids was recorded in controlled chili pepper samples (164.39mg/100g).

Table 2: Effect of solar drying on phyto - chemical characteristics of chili pepper fruits

	Carotenoids	Beta Carotene	Phenol	Flavonoids	Capsaicinoids
Solar drying	(ug/100g)		(mg/100g)		
~~1~~ controlled chilli peppers	8035.4a	812.34a	83.75c	22.91c	164.39c
~~2~~ Blanched solar dried	6647.0b	670.78b	327.11b	39.60b	207.67b
~~3~~ Unblanched solar dried	5595.5c	562.18c	386.64a	51.97a	260.72a
HSD (0.05)	111.61	11.48	2.39	0.61	1.12
CV	2.02	2.06	1.10	1.95	0.65

Means with the same letters (s) in the column are not significantly different from each other (p > 0.05, according to Tukeys HSD)

~~NB: 1 = Controlled chili peppers~~
~~2= Blanched solar dried chili peppers~~
~~3 = Unblanched solar dried chili peppers~~

~~3.3.~~ Effect of Zeer Pot Refrigeration Lining Media on ~~Phyto - Chemical~~ Phytochemical Characteristics of Chili Pepper fruits

~~Phyto - chemical~~ phytochemical analyses were conducted to determine the effect of zeer pot refrigeration lining media on ~~phyto - chemical~~ phytochemical characteristics of chili pepper fruits. Table 3 revealed the results of the ~~phyto - chemical~~ phytochemical analyses and the results indicated that, there were significant difference (p-<-0.05) in the ~~phyto - chemical~~ phytochemical characteristics of chili pepper fruits.

~~3.3.1.~~ Total carotenoids of chili pepper fruits

Significantly, the best total carotenoids were shown in styrofoam lining material of zeer pot refrigeration (8506.1ug/100g) which was followed by sand lining media of zeer pot refrigeration (6327.7ug/100g) and the lowest indicated in wood shavings lining media of zeer pot (5444.0ug/100g).

~~3.3.2.~~ Beta carotene of chili pepper fruits

The trend continued as similar to total carotenoids where styrofoam lining media of zeer pot refrigeration had significantly (p-<-0.05) higher beta carotene of chili pepper fruits

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(861.64ug/100g) followed by sand lining media of zeer pot refrigeration (636.88ug/100g) and the least was recorded in wood shavings lining media of zeer pot refrigeration (546.79ug/100g).

~~3.3.3.~~ Total phenols of chili pepper fruits

Sand used as lining material in zeer pot storage had significantly (p-<-0.05) the best effect (304.30mg/100g) on total phenols of chili pepper fruits followed by styrofoam (268.55mg/100g) and the least was determined in wood shavings lining media of zeer pot refrigeration (221.61mg/100g).

~~3.3.4.~~ Total flavonoids of chili pepper fruits

Same trend continued with total phenols where sand used as lining media of zeer pot storage had significantly (p–<–0.05) higher total flavonoids (49.99mg/100g). There were no significant difference (p–>–0.05) between styrofoam (32.06mg/100g) and wood shavings (32.43mg/100g) thus they were same. Comparatively, styrofoam had the least effect on total flavonoids (32.06mg/100g) of chili pepper fruits.

~~3.3.5.~~ Total capsaicinoids of chili pepper fruits

Significantly, higher total capsaicinoids were recorded in sand (242.17mg/100g) used as lining media of zeer pot refrigeration which had similar trend as total phenols (304.30mg/100g) and total flavonoids (49.99mg/100g) while wood shavings used as zeer pot lining media had the least total capsaicinoids (185.72mg/100g).

Table 3: Effect of zeer pot refrigeration lining media on phyto - chemical characteristics of chili pepper fruits

Lining media	Carotenoids	Beta Carotene	Phenol	Flavonoids	Capsaicinoids
	(ug/100g)			(mg/100g)	
~~1~~	6327.7b	636.88b	307.34a	49.99a	242.17a
~~2~~	8506.1a	861.64a	268.55b	32.06b	204.89b
~~3~~	5444.0c	546.79c	221.61c	32.43b	185.72c
HSD (0.05)	111.61	11.48	2.39	0.61	1.12
CV	2.02	2.06	1.10	1.95	0.65

Means with the same letters (s) in the column are not significantly different from each other (p > 0.05, according to Tukeys HSD)

~~NB: 1 = Sand~~
~~2= Styrofoam~~
~~3 = Wood shavings~~

Comment [M15]: As corrected in table 1 & 2

Comment [M16]: As shown in table 1 & 2

~~4.~~ DISCUSSION

~~4.1.~~ Effect of Varieties, Solar Drying and Zeer Pot Refrigeration Lining Media on ~~Phyto – Chemical~~ Phytochemical Properties of Chili Pepper Fruits

~~Phyto – chemical~~ phytochemical analyses were conducted to determine effect of varieties, solar drying and zeer pot refrigeration lining media on ~~phyto – chemical~~ phytochemical properties of chili pepper fruits. The results from the analyses suggested that, there were significant difference (p-<-0.05) in ~~phyto – chemical~~ phytochemical properties of chili pepper fruits.

~~4.1.1.~~ Effect of varieties on ~~phyto – chemical~~ phytochemical properties of chili pepper fruits

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Phyto – chemical analyses were carried - out to determine effect of varieties on phyto – chemical characteristics of chili pepper fruits. The results from table 1 demonstrated that, there were significant difference ($p < 0.05$) in phyto – chemical properties of chili pepper fruits.

~~4.1.2.~~ Total carotenoids of chili pepper fruits

Red cayenne was significantly ($p < 0.05$) greater in total carotenoids (9222.4ug/100g) of chili pepper fruits (Minguez – Mosquera and Hornero – Mendez, 1994). The increased in total carotenoids in red cayenne could be due to environmental conditions such as light intensity and temperature in which red cayenne was grown (Chavez – Mendoza *et al*., 2015) and good agronomical practices such as application of fertilizers, irrigation which increased the size of the fruits to cause increased in total carotenoid content in red cayenne (Duan *et al*., 2023). Carotenoids act as antioxidants which protect the human body against diseases by improving the human immune system (Wilson, 2018).

~~4.1.3. Beta carotene of chili pepper fruits~~

Red cayenne had significantly ($p < 0.05$) higher beta carotene (934.23ug/100g) of chili pepper fruits (Ihns *et al*., 2011). The increased in beta carotene in red cayenne could be attributed to genetic characteristics of red cayenne and the environmental conditions such as light intensity and temperature were suitable for cultivating red cayenne (Chavez – Mendoza *et al*., 2015). Beta carotene is a precursor for vitamin A which is good for vision or eye health, healthy skin, mucous membrane, lower the risk of heart diseases, cancer and stronger immune system (Newman, 2017 and Mount Sinai, 2023).

~~4.1.4. Total phenols of chili pepper fruits~~

Scotch bonnet recorded significantly ($p < 0.05$) higher in total phenols (301.74mg/100g) of chili pepper fruits (Mikulic – Petkovsek *et al*., 2012). The increased in total phenols in scotch bonnet could be as a result of the cultivar, growing conditions, fruit stage of maturity and postharvest handling of the scotch bonnet fruits (Howard *et al*., 2016). Total phenols protects the human body against diseases such as diabetes, cancer and cardiovascular diseases. It has anti – bacterial and anti – fungal properties which reduce the activities of bacteria and fungi (Pratyusha, 2022).

~~4.1.5. Total flavonoids of chili pepper fruits~~

Red cayenne had significantly ($p < 0.05$) higher total flavonoids (50.04mg/100g) of chili pepper fruits (Jin – Yuarn and Ching – Yin, 2007). High total flavonoids in red cayenne may be due to the genotype of red cayenne and the ripening stage of the red cayenne at which it was harvested (Ribes – Moya *et al*., 2020). Flavonoids function as detoxifying agent, antimicrobial defensive compound, capable of neutralizing free radicals, protect the human body against cancer, alzheimer, antherosclerosis, cardiovascular diseases such as heart attacks, ulcer, inflammation, osteoporosis, diarrhoea and arthritis (Burak and Imen, 1999).

~~4.1.6. Total capsaicinoids of chili pepper fruits~~

Red cayenne had significantly ($p < 0.05$) higher total capsaicinoids (247.30mg/100g) of chili pepper fruits (Gonzalez – Zamora *et al*., 2013). The increased in total capsaicinoids in red cayenne could be attributed to intrinsic genetic characteristics of red cayenne and the environmental conditions where the red cayenne fruits were cultivated (Sarpras *et al*., 2016). Capsaicinoids are used for flavouring and preserving food due to high pungency as well as used as medical purposes. It is used as food additive and also used for treating various pathogenic infections (Rezazadeh *et al.*, 2021). Again, heat in pepper fruits is added to a wide range of alcoholic beverages to give better taste and flavour (Apex Flavours, 2020 and Hultquist, 2020). Capsaicin is extracted from chili peppers to use as active ingredient in preparation of tear gas or pepper spray and organic insecticides or pesticides (CDC, 2018).

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4.2. Effect of Solar Drying on Phyto – Chemical Phytochemical Properties of Chili Pepper Fruits

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Phyto – chemical phytochemical analyses were conducted to determine effect of solar drying on phyto – chemical phytochemical properties of chili pepper fruits. The results from table 2 suggested that, there were significant difference ($p < 0.05$) in the phyto – chemical phytochemical characteristics of chili pepper fruits.

4.2.1. Total carotenoids of chili pepper fruits

Controlled chili pepper samples significantly ($p < 0.05$) had higher total carotenoids (8035.4ug/100g) of chili pepper fruit (Babar *et al*., 2021). The high carotenoids in controlled chili peppers could be due to genotype which determines the specific carotenoids biosynthetic enzymes (Giuffrida *et al*., 2013). Carotenoids act as antioxidants which protect the human body against diseases by improving the human immune system (Wilson, 2018).

4.2.2. Beta carotene of chili pepper fruits

Controlled chili pepper samples had significantly ($p < 0.05$) higher beta – carotene (812.34ug/100g) of chili pepper fruits (Romauli, 2021). Increased in beta carotene in controlled chili peppers could be due to difference in cultivars, maturity, growing practices, climates and postharvest handling which increased beta carotene (Mozarfar, 1994). Beta carotene is a precursor of vitamin A which is good for vision or eye health, healthy skin, mucous membrane, lower the risk of heart diseases, cancer prevention and stronger immune system (Newman, 2017 and Mount Sinai, 2023).

4.2.3. Total phenols of chili pepper fruits

Unblanched chili pepper fruits had significantly ($p < 0.05$) higher total phenols (386.64mg/100g) of chili pepper fruits (Mongi *et al*., 2015). The increased in total phenols in unblanched chili peppers might be due to inactive of enzymes at high temperature (75^0C) of drying that caused mininal degradation of total phenols by polyphenol oxidase to increase total phenols in unblanched chili peppers (Madrau, 2009). Total phenols protect the human body against diseases such as diabetes, cancer and cardiovascular diseases. It has anti – bacterial and anti – fungal properties which reduce the activities of bacteria and fungi (Pratyusha, 2021).

4.2.4. Total flavonoids of chili pepper fruits

Unblanched chili pepper fruits significantly ($p < 0.05$) had the highest total flavonoids (51.97mg/100g) of chili pepper fruits (Mongi *et al*., 2015). The increased in total flavonoids could be attributed to removal of moisture content from the unblanched chili pepper fruits which caused the deactivation of degradative enzymes to increase total flavonoids (Korbel *et al*., 2013). Again, the increment in flavonoids in unblanched chili peppers might be due to the release of flavonoids from the cell wall by disrupting hydrogen bonds (Asano *et al*., 1982). Flavonoids function as detoxifying agent, antimicrobial defensive compound, capable of neutralizing free radicals, protect the human body against cancer, alzheimer, antherosclerosis, cardiovascular diseases such as heart attacks, ulcer, inflammation, osteoporosis, diarrhoea and arthritis (Burak and Imen, 1999).

~~**4.2.5. Total capsaicinoids of chili pepper fruits**~~

Unblanched chili pepper fruits had significantly ($p < 0.05$) higher total capsaicinoids (260.72mg/100g) of chili pepper fruits (Maurya *et al*., 2018). Increased in total capsaicinoid content could be as a result of high temperature been harvested by solar dryer that induced the capsaicinods through their deassociation from the cell wall (placenta) and quicker removal of water that increased the concentration of total capsaicinoid content (Chaaban *et al*., 2016). Capsaicinoids are used for flavouring and preserving food due to high pungency as well as used as medicinal purposes. It is used as food additive and also used for treating various pathogenic infections (Rezazadeh *et al.*, 2021). Again, heat in pepper fruits is added to a wide range of alcoholic beverages to give better taste and flavour (Apex Flavours, 2020 and Hultquist 2020). Capsaicin is extracted from chili peppers to use as active ingredient in preparation of tear gas or pepper spray and organic insecticides or pesticides (CDC, 2018).

~~4.3.~~ Effect of Lining Media of Zeer Pot Storage on ~~Phyto – Chemical~~ Phytochemical Properties of Chili Pepper Fruits

~~Phyto – chemical~~ Phytochemical analyses were done to determine effect of lining media of zeer pot refrigeration on ~~phyto – chemical~~ phytochemical characteristics of chili pepper fruits. The results from table 3 indicated that, there were significant difference ($p < 0.05$) in the ~~phyto – chemical~~ phytochemical characteristics of chili pepper fruits.

~~**4.3.1. Total carotenoids of chili pepper fruits**~~

Styrofoam material used as zeer pot lining media had significantly ($p < 0.05$) higher total carotenoids (8506.1ug/100g) of chili pepper fruits (Kan *et al.*, 2007). The increased in total carotenoids in styrofoam lining media might be due to styrofoam containing more air (98%) to aid in easy movement of air for effective evaporative cooling to increase total carotenoid content in chili peppers (FOAMEX, 2021). Carotenoids act as antioxidants which protect the human body against diseases by improving the human immune system (Wilson, 2018).

~~**4.3.2. Beta carotene of chili pepper fruits**~~

Styrofoam material used as zeer pot lining media had significantly ($p < 0.05$) higher beta carotene (861.64ug/100g) of chili pepper fruits (Desobry *et al*., 1998). The high beta carotene in styrofoam lining media could be due to styrofoam containing more air (98%) to aid in easy movement of air for effective evaporative cooling to reduce oxidation of beta carotene in order to increase beta carotene content in chili peppers (FOAMEX, 2021). Beta carotene is a precursor of vitamin A which is good for vision or eye health, healthy skin, mucous membrane, lower the risk of heart diseases, cancer prevention and stronger immune system (Newman, 2017 and Mount Sinai, 2023).

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4.3.3. Total phenols of chili pepper fruits

Sand used as zeer pot lining media had significantly ($p < 0.05$) higher total phenols (304.30mg/100g) of chili pepper fruits (Ouaabou *et al*., 2020). The high total phenols in chili peppers stored in sand lining media may be attributed to sand been able to warm up quickly to increase the temperature of water and large air spaces between particles for easy movement of air to increase evaporative cooling and declined the temperature of chili peppers stored in the zeer pot to increase total phenols in chili peppers (Benneth, 2023). Total phenols protect the human body against diseases such as diabetics, cancer and cardiovascular diseases. It has anti – bacterial and anti – fungal properties which reduce the activities of bacteria and fungi (Pratyusha, 2021).

4.3.4. Total flavonoids of chili pepper fruits

Sand lining media of zeer pot refrigeration had significantly ($p < 0.05$) higher total flavonoids (49.99mg/100g) of chili pepper fruits (Tsantili *et al*., 2011). The high total flavonoids in chili peppers stored in sand lining media may be due to sand been able to conduct heat quickly to increase the temperature of water and high porosity of sand for free circulation of air to increase evaporative cooling to reduce the temperature of chili peppers stored in the zeer pot to increase total flavonoids in chili peppers (Benneth, 2023). Flavonoids function as detoxifying agent, antimicrobial defensive compound, capable of neutralizing free radicals, protect the human body against cancer, alzheimer, antherosclerosis, cardiovascular diseases such as heart attacks, ulcer, inflammation, osteoporosis, diarrhea and arthritis (Burak and Imen, 1999).

4.3.5. Total capsaicinoids of Chili Pepper Fruits

Sand lining media of zeer pot refrigeration had significantly ($p < 0.05$) higher total capsaicinoids (242.17mg/100g) of chili pepper fruits (Giuffride *et al*., 2014). The high total capsaicinods in chili peppers stored in sand lining media may be attributed to sand been able to warm up quickly to increase the temperature of water and large air spaces between particles of sand for easy movement of air to increase evaporative cooling and decreased the temperature of chili peppers kept in the zeer pot to increase total capsaicinoids in chili peppers (Benneth, 2023). Capsaicinoids are used for flavouring and preserving food due to high pungency as well as used as medicinal purposes. It is used as food additive and also used for treating various pathogenic infections (Rezazadeh *et al.*, 2021). Again, heat in pepper fruits is added to a wide range of alcoholic beverages to give better taste and flavour (Apex Flavours, 2020 and Hultquist, 2020). Capsaicin is extracted from chili peppers to use as active ingredient in preparation of tear gas or pepper spray and organic insecticides or pesticides (CDC, 2018).

Comment [M19]: Same as comment 15 & 16

5. CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

On effect of varieties, solar drying and zeer pot refrigeration lining media on phyto – chemical characteristics of chili pepper fruits. For effect of varieties on phyto – chemical phytochemical characteristics of chili pepper fruits, red cayenne was significantly ($p < 0.05$) high in total carotenoids (9222.4ug/100g), beta carotene (934.23ug/100g), total flavonoids (50.04mg/100g), total capsaicinoids (247.30mg/100g) but total phenols were significantly higher in scotch bonnet (301.74mg/100g). In addition, on effect of solar drying on phyto – chemical characteristics of chili pepper fruits, unblanched chili pepper fruits had significantly (p < 0.05) higher total phenols (386.64mg/100g), total flavonoids (51.97mg/100g) and total capsaicinods (260.72mg/100g) while controlled chili pepper fruits had significantly higher total carotenoids (8035.4ug/100g) and beta carotene (812.34ug/100g). Furthermore, on effect of lining media of zeer pot refrigeration on phyto – chemical characteristics of chili pepper fruits, sand lining media of zeer pot refrigeration had significantly (p < 0.05) higher total phenols (304.30mg/100g), total flavonoids (49.99mg/100g) and total capsaicinoids (242.17mg/100g) whereas styrofoam lining media had significantly higher total carotenoids (8506.1ug/100g) and beta carotene (861.64ug/100g).

Comment [M20]: Values are required in your conclusion. Please, reconstruct your conclusion in an orderly manner

5.2. Recommendations

i. More studies should be conducted by research institutions on why scotch bonnet recorded the least total carotenoids, total flavonoids and total capsaicinoids as well as studies on why red cayenne had low beta carotene and total phenols.

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ii. In addition, research should be done by research institutions to investigate why unblanched chili peppers had the least total carotenoids and beta carotene as well as research on why controlled chili peppers had low total phenols, total flavonoids and total capsaicinoids.

iii.i. Further research should be conducted by research institutions on why wood shavings used as lining media had the lowest total carotenoids, beta carotene, total phenols and total capsaicinoids together with investigations on why styrofoam used as lining media of zeer pot had least total flavonoids.

Comment [M21]: Recommendations not needed

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Declare conflict of interest among authors

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