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Phytochemicals in commonly consumed foods in malawian diets

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ABSTRACT

Background: Plant foods, as functional foods, provide not only the essential nutrients needed to sustain life, but also bioactive compounds (phytochemicals) for health promotion and disease prevention.

Objective of the study: The aim of this research was to screen phytochemicals in commonly consumed fruits and vegetables in Malawi. The effect of processing vegetables on phytochemicals was also evaluated.

Methods: The potential of some commonly consumed fruits and vegetables in their raw and cooked forms as natural source of phytochemicals was evaluated in both aqueous and methanol extracts. These fruits and vegetables were screened for alkaloids, saponin, tannins, flavonoids, quinones, coumarins, terpenoids, steroids, glycosides and anthocyanins, total flavonoids content (TFC) and total phenol content (TPC) using standard procedures. TPC and TFC were also analyzed using spectrophotometric methods.

Results: Almost all the phytochemicals screened were found in some of the studied fruits and vegetables, with indigenous fruits and vegetables having the most, except for glycosides and anthocyanins. TPC in fruits ranged from 715.08 mgGAE/g to 21,119 .66 mgGAE/g, while TFC ranged from 44.10 mg QE/g to 434.74 mg QE/g in vegetables. TPC of uncooked vegetables ranged from 522.22 mgGAE/g (pumpkin leaves) to 33, 684.66 mgGAE/g (ntoriro), while in cooked vegetables it ranged from 135.93 mgQE/g (bonongwe) to 6817.86 mgQE/g (chisoso). Overall, indigenous vegetables showed higher TPC values in comparison to exotic vegetables. It was also observed that processing of vegetables affected total phenolic compounds differently. In some vegetables, TPC values increased with cooking (pumpkin leaves, bonongwe and chisoso), while in others (cabbage, Chinese and rape) it decreased.

Conclusions: The results show that fruits and vegetables can serve as a cheap source of natural antioxidants that could help fight non-communicable diseases, such as hypertension, diabetes, and cancer. As might be expected, a single fruit or vegetable doesn't contain all the necessary phytochemicals. Therefore, an intake of a mixture of fruits and vegetables is recommended for maximum benefit as functional foods.

Keywords: Phytochemicals, fruits, vegetables, total phenolic content, non-communicable diseases

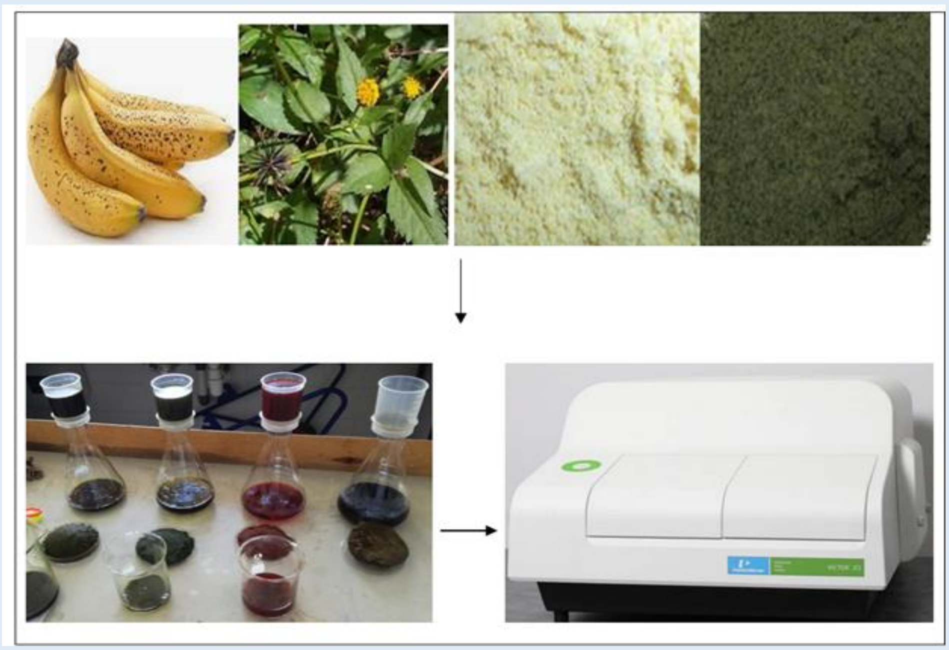

Figure 1. Graphical abstract of main activities from sample collection to analysis.

INTRODUCTION: Plant foods provide not only essential nutrients needed to sustain life, but also bioactive compounds (phytochemicals) for health promotion and disease prevention [1 – 4]. Phytochemicals are plant secondary metabolites, that in plants, have little or no role in photosynthesis, respiration, or growth and development, but may accumulate in surprisingly high concentrations [1]. Phytochemicals include phenolic compounds, alkaloids, nitrogen containing compounds, saponins, terpenoids, organosulfur compounds and carotenoids [5, 6]. About 200,000 structures of phytochemicals are known and there are close to 20,000 (10%) of them that have been identified as originating from fruits, vegetables, and grains [7, 8]. In addition, more than 5000 individual dietary phytochemicals have been identified in plant foods, including fruits, vegetables, whole grains, legumes, and nuts with varying content and composition [9]. Fruits and vegetables are among the most important sources of phytochemicals in the human diet [10]. In cereals, phenolic compounds are the major phytochemical [11].

Phytochemicals, naturally occurring bioactive compounds in plant foods (3), have been associated with a reduction in the risks of developing non-communicable diseases [1, 5, 12, 13]. According to the Functional food center (FF), functional foods are natural or processed foods that contain bio-active compounds, which in defined, effective, non-toxic amounts provide a clinically proven and documented health benefit utilizing specific biomarkers, to promote optimal health and reduce the risk of chronic diseases and manage symptoms [14]. Food scientists and nutrition specialists reported that phytochemicals offer many health benefits due to high antioxidant activity, especially when consumed in the average human diet [8, 15, 16]. Moreover, phytochemicals are significantly and positively correlated with a higher antioxidant activity [17, 18]. Furthermore, most epidemiological studies have shown that diet plays a vital role in the prevention of non-communicable diseases (NCDs) (chronic diseases) [5, 19]. Non communicable diseases (NCDs) such as diabetes, cardiovascular diseases, cancers, and chronic respiratory diseases cause 71% of the deaths worldwide [20], despite being preventable through diet. In Malawi, NCDs account for 28% of the country's death, 12% of which is due to cardiovascular diseases with a prevalence of 8.9% [21], 5% cancer, 1% diabetes, 2% chronic respiratory diseases and 8% other NCDs [22].

The main staple food in Malawi, maize, which is used to make thick porridge and served with vegetables and protein dishes such as beans, fish, meat etc. Thick porridge has low fiber and a high glycemic index (94.06), with a potential 50 % increased risk of developing diabetes [23]. Lower risk of developing type 2 diabetes was attributed to intake of fruit and vegetables, which contain high fiber and antioxidants, such as phenolic compounds, carotenoids and vitamin C and E [24].

In Malawi, phytochemicals have mainly been studied in medicinal plants [25,26] and with limited information in commonly consumed fruits, vegetables,[27] and grains, specifically thick porridge. To promote classification and utilization of Malawian fruits and vegetables as functional foods, knowledge of their phytochemicals and health benefits is critical.

MATERIALS AND METHODS:

Sample collection: Fresh fruits and vegetable samples (Table 1 and 2) were collected or purchased from forest or homestead farms or markets from the three regions of Malawi. Indigenous and exotic fruit samples including *Parinari Curatellifolia*, *Strychnoscocculoides* and *Musa acuminate* were purchased *from* Mzimba (Mzuzu, Kafukule and Embangweni) and Nkhata-Bay (Sanga); *Adansonia digitata*, *Ziziphus mauritiana and Tamarindus indica* from Mangochi. Indigenous and exotic vegetables including *Bidens pilosa* and *Amaranths* were purchased from Thyolo (Bvumbwe); *Galinsoga parviflora* and Rape from Zomba produce market, while Chinese cabbage and Cauliflower were purchased from Ntcheu.

Table 1: Fruits samples and thick porridge (nsima)

English/Common Names	Local name	Scientific names
Tamarind,	Bwemba	*Tamarindus indica*
Indian jujube, Indian plum,	Masau	*Ziziphus mauritiana*
Baobab,	Malambe	*Adansonia digitata*
Monkey oranges,	Kabeza	*Strychnoscocculoides*
Natal orange	Mazaye, Mateme	*Strychnos spinosa*
Mobola Plum	Mbula/Maula	*ParinariCuratellifolia*
Banana-Mulanje	Nthochi	*Musa acuminate* (Mulanje)
Banana- Uganda	Nthochi	*Musa acuminate* (Uganda)
Plantains	Matoki	*Musa × paradisiacal*
Sugar apple	Mpoza	*Annona squamosa*
Pawpaw	Payaya	*Carica papaya*
Polished maize grain thick porridge	*Nsima*	*Zea mays*
Whole maize grain thick porridge	*Nsima*	*Zea mays*

Table 2: Vegetables samples

English/Common Names	Local name	Scientific names
Pigweed/Poor man's spinach	Bonongwe	*Amaranthus hybridus*
Pumkin leaves	Nkhwani	*Curcunita pepo*
Black jack	Chisoso	*Bidens Pilosa*
Gallant soldier	Mamunaaligone	*Galinsoga parviflora*
Local Brinjals	Mabirngaya	*Solanum melongena*
Sweetpotato leaves,	Ntoriro	*Ipomea batatas*
Jute mallow	Denje	*Corchorus olitorius*
Okra	Thererelobala	*Abelmoschus esculentus*
Rape	Rape	*Brassica napus L.*
Chinese	Chinezi	*Brassica rapa*
Cabbage	Cabbage	*Brassica oleracea*
Cauliflower	Cauliflower	*Brassica oleracea var.botrytis*

Sample preparation: Vegetable leaves were air dried and ground into a fine powder. The phytochemicals were extracted by placing 10.000 g of each powdered sample into a conical flask, containing 100 mL of the solvent (methanol or water) followed by a magnetic stirrer. The mixtures in the conical flasks were then covered with aluminum foil and stirred continuously on a magnetic stirrer for 24 hours. This was followed by centrifugation of the mixture. The supernatant was filtered using Whatman No. 41 filter paper and stored in the refrigerator at 4 ^{o} C until analysis.

Qualitative phytochemical analysis: Phytochemicals such as alkaloids, flavonoids, tannins, phlobatannins, saponins, coumarins, terpenoids, glycosides, steroids, quinones, anthocyanins were screened using standard procedures, as described by several researchers [28 - 30].

Quantitative phytochemicals analysis: Extraction of phytochemicals from fresh fruits and vegetables was undertaken as described by Sun et al. (2013) [31], with some modifications using methanol [32]. Fresh food samples (5.00 g) were dissolved in methanol (80% v/v, 150 mL). The mixture was homogenized using a domestic blender (Kenwood Chef Classic, model KM 330) operated at medium speed for 10 min. The resultant mixture was transferred into falcon tubes (50 mL) and centrifuged at 5000 rpm for 15 min at 4 °C in a Beckman Coulter Centrifuge (Allegra, model X-22) to separate the pulp from the remaining liquid juice, which was finally decanted through Whatman No.1 paper.

Total Phenolic Content (TPC): The total phenol content (TPC) in sample extracts was measured spectrophotometrically according to the Folin–Ciocalteu protocol [33]. Tenfold diluted sample extract was used. Within 3-8 min, to sample extract /standards (1 mL), Folin reagent (5 mL) and sodium carbonate solution (1.0 M, 4 mL) were added, vortexed (15 s) and left to stand for 2 hours at 26 °C in a water bath. Absorbance of the samples and blank was measured at 765 nm using the spectrophotometer. Total phenolic content was expressed as mg gallic acid equivalent (GAE) per gram of fresh weight (FW).

Total Flavonoid Concentration (TFC): Total flavonoid content was determined using an aluminum chloride colorimetric assay [34], as described by Mwamatope and coworkers [17]. Sample extract (1 mL) was transferred into falcon tubes and diluted 10-fold with methanol (80% v/v). Then, 1 mL of the diluted extracts was transferred into another falcon tube to which aluminum chloride hexahydrate (2%, 1mL) was added. The mixture was incubated at room temperature. Absorbance of samples and standards was measured using UV-Vis Spectrophotometer at 420 nm. Total flavonoids content was expressed as milligram of quercetin equivalents per gram of dry weight (mg QEg^{-1} DW).

RESULTS:

Phytochemicals in fruits and thick maize porridge in water and methanolic extracts: In this study, the indigenous fruits and exotic fruits were screened for alkaloids, saponin, tannins, flavonoids, quinones, coumarins, terpenoids, steroids, glycosides, and anthocyanins. Results show these phytochemicals are present in some of the fruits. For example, in water extracts, saponins, tannins, flavonoid, quinones, coumarins, terpenoids were more available in most indigenous fruits, rather than the exotic fruits (Table 3). Alkaloid, glycosides, and anthocyanins were not available in nearly all the fruits studied. In both thick porridge samples, only tannins were present.

In methanolic extracts, tannins, flavonoid, coumarins and terpenoids were the most present phytochemicals in indigenous fruits (IFTs), whereas quinones and steroids were found in some of the indigenous fruits (Table 3). Saponins were only found in Masau. For exotic fruits, tannins, flavonoids, and steroids were the most common phytochemicals. Unlike the indigenous fruits, quinones and coumarins were only present in pawpaw. Saponins were present in mpoza, mulanje banana and Uganda banana. Glycosides were present in both thick porridge samples.

Phytochemicals of vegetable in aqueous and methanolic extracts: In this study, the indigenous vegetables were screened for alkaloids, saponin, tannins, flavonoids, quinones, coumarins, terpenoids, steroids, glycosides and anthocyanins (Table 4). Results show these phytochemicals are present in some of the vegetables. For example, saponins, tannins, flavonoid and coumarins, were available in most indigenous and exotic vegetables. Quinones, terpenoids and steroids were found in some of the indigenous and exotic vegetables.

In methanolic extracts, tannins, flavonoids, quinones and coumarin were the most available in both indigenous and exotic vegetables (Table 4). On the other hand, saponins were mostly present in indigenous vegetable compared to exotic vegetables. Steroids and terpenoids were barely present in indigenous vegetables however in exotic vegetables, only cabbage and cauliflower showed the presence of these phytochemicals. Glycosides and anthocyanins were absent in all vegetable types. Unlike in water extract, only glycosides and anthocyanins weren't present in all vegetable types.

Table 3: Phytochemical screening of water and methanolic extracts from fruits and thick porridge

Sample	Alkaloids		Saponins		Tannins		Flavonoids		Quinones		Cumarins		Tepenoids		Steroids		Glycosides		Anthocynins	
	H_2O	MeOH	H_2O	MeOH	H_2O	MeOH	H_2O	MeOH	H_2O	MeOH	H_2O	MeOH	H_2O	MeOH	H_2O	MeOH	H_2O	MeOH	H_2O	MeOH
Tamarindus indica	-	-	+	-	++	+	+	++	+	+++	+++	+	-	++	-	++	-	-	-	-
Ziziphus mauritiana	-	-	++	+	++	+	+	++	+	+	+++	+	-	++	-	++	-	-	-	-
Adansonia digitata	-	-	++	-	++	+++	+	++	+	+++	+++	-	+	+++	++	-	++	-	-	-
Strychnoscocculoides	-	-	+	-	+	++	-	++	-	-	+	+	+	+++	-	--	-	-	-	-
Strychnos spinosa)	-	-	++	-	+++	+++	+	++	-	-	++	++	++	+++	-	-	-	-	-	-
ParinariCuratellifolia	-	-	++	-	-	-	+	++	-	-	-	+	+	+++	-	-	-	-	-	-
Exotic fruits																				
Banana (*Musa acuminate)*	-	-	++	+	++	+	+	+	-	-	+++	-	-	-	-	++	-	-	-	-
Banana *(Musa acuminate)*	-	-	++	+	+	+	+	+	-	-	-	-	-	-	-	++	-	-	-	-
Musa × paradisiaca	-	-	+	-	++	+	++	+	-	-	-	-	-	-	-	++	-	-	-	-
Annona squamosal	-	-	++	+	++	++	++	+	-	-	+	-	-	++	-	++	-	-	-	-
Carica papaya	-	-	+	-	++	++	++	+	+	+	-	+	++	+	+++	+	-	-	-	-
Cereals																				
Zea mays (white thick porridge)	-	-	-	-	+	-	+	-	-	-	+++	-	-	-	-	-	-	+	-	-
Zea mays (Whole thick porridge	-	-	-	-	++	-	+	-		-	-	-	-	-	-	-	-	+	-	-

Abbreviation: H_2O: Water, MeOH: methanol, (+): Present, (-): Absent

Table 4: Phytochemical screening of water and methanolic extracts from indigenous and exotic vegetables

Indigenous vegetables	Alkaloids		Saponins		Tannins		Flavonoids		Quinones		Cumarins		Terpenoids		Steroids		Glycosides		Anthocynins	
	H_2O	MeOH	H_2O	MeOH	H_2O	MeOH	H_2O	MeOH	H_2O	MeOH	H_2O	MeOH	H_2O	MeOH	H_2O	MeOH	H_2O	MeOH	H_2O	MeOH
Uncooked *Amaranthus*	-	+++	++	-	-	-	-	++	+	++	-	+	-	-	-	-	-	-	-	-
Cooked *Amaranthus*	-	+++	++	++	+	+	+	++	-	++	++	+	-	-	-	-	-	-	-	-
Uncooked *Curcunita pepo*	-	+	++	+	+	+	+	++	-	++	-	+	-	-	-	-	-	-	-	-
Cooked *Curcunita pepo*	-	+	+	++	+	-	++	++	-	++	-	+	-	+	-	-	-	-	-	-
Uncooked *Bidens pilosa*	-	-	++	-	++	++	-	++	+	++	-	+	-	+	-	-	-	-	-	-
Cooked *Bidens pilosa*	-	-	++	++	+++	+	++	++	+	++	+	+	-	++	-	-	-	-	-	-
Uncooked *Galinsoga parviflora*	-	+	++	+++	++	-	+	++	+	++	+++	+	++	-	+++	-	-	-	-	-
Cooked *Galinsoga parviflora*	-	+	++	-	+	-	+	++	-	++	+++	+	-	+	-	-	-	-	-	-
Uncooked Local egg plant	-	-	++	+++	++	++	+	++	+	++	+++	+	-	-	-	-	-	-	-	-
Uncooked *Ipomeabatatas*	-	-	-	+	+	+	+	++	-	++	+	+	+++	-	+	-	-	-	-	-
Uncooked Corchorus olitorius	-	-	-	++	+	+	-	++	+	++	+	+	++	-	++	-	-	-	-	-
Therere (chewe)	-	-	+	++	+	+	++	++	++	++	+	+	++	-	-	-	+	-	-	-
Uncooked Abelmoschus esculentus	-	-	-	+	+	+	++	++	-	++	++	+	++	-	++	++	+	-	-	-
Uncooked Nkhungudzu	-	-	+	+	++	++	+	++	-	++	++	+	-	+	-	+	-	-	-	-
Exotic vegetables														-						
Uncooked *Brassica napus L.*	-	+	++	-	++	+	+	++	+	++	+	+	-	-	-	-	-	-	-	-
Cooked Brassica napus L.	-	+	+	-	+	+	-	++	-	++	++	+	-	-	-	-	-	-	-	-
Uncooked *Brassica rapa*	-	+	+	-	+	+	-	++	+	++	+	++	-	-	-	-	-	-	-	-
Cooked *Brassicarapa*	-	+	+	-	+	+	+	++	-	++	++	+	-	-	-	-	-	-	-	-
Uncooked *Brassica oleracea*	-	++	++	++	++	++	+	++	-	-	+	+	-	+	++	++	-	-	-	-
Cooked *Brassica oleracea*	-	+	+	+	+	+++	+	++	-	-	+	+	-	++	++	++	-	-	-	-
Uncooked *Brassica oleracea var.botrytis*	-	+	+	++	+	+++	+	++	+	-	+++	+	++	++	++	++	-	-	-	-
Cooked *Brassica oleracea var.botrytis*	-	+	+	-	+	+++	+	++	-	-	++	+	-	+	++	++	-	-	-	-

Abbreviation: H_2O: Water, MeOH: methanol, (+): Present, (-): Absent

Quantitative Analysis of Phytochemicals: Total phenolic content (TPC) was determined in selected fruits, vegetables, and thick porridge samples. The study results showed that fruits contain TPC ranging from 715.08 to 21,119 .66 mgGAE/g, while TFC ranged from 44.10 to 434.74 mgQE/g (Table 5).

Table 5: Total phenolic content and total flavonoids content from fruits

Samples Names	Methanolic Extract	
	TPC (mg GAE/g)	TFC (mg QE/g)
Musa × paradisiaca)	734.00 ± 75.50	336.59 ± 7.46
Musa acuminate	715.08 ± 71.41	384.22 ± 1.31
Tamarindus indica	2449.38 ± 108.54	229.90 ± 3.84
Parinaricuratellifolia(Kafukule)	905.08 ± 107.90	159.34 ± 5.02
Parinaricuratellifolia (Embangweni)	1859.88 ± 156.25	434.74 ± 7.95
Adasoniadigitata	21119.66 ± 64.10	91.43 ± 20.45
Ziziphus mauritiana	2082.87 ± 102.33	44.10 ± 2.94
Ziziphus mauritiana (Green)	16214.50 ± 67.79	265.21±7.85
Strychnoscocculoides	3199.25 ± 90.68	339.72 ±1.31
Strychnos spinosa)	1950.92 ± 61.53	162.82 ± 2.19

Abbreviation: TPC; total phenolic content, TFC: total flavonoids content, mg GAE/g; milligram of gallic acid equivalents per gram, mg QE/g;milligram of quercetin equivalents per gram. Each value is expressed as mean ± standard deviation (*n* = 3).

Among the fruits, malambe showed the highest TPC, followed by masau (green), while banana had the least TPC. For total flavonoids, mbula had the highest, followed by banana, with masau having the least TFC. TPC of uncooked vegetables ranged from 522.22 (pumpkin leaves) to 33, 684.66 mgGAE/g (ntoriro), while in cooked vegetables, it ranged from 135.93 mgQE/g (bonongwe) to 6817.86 mgQE/g (chisoso) (Table 6).

Table 6: Total phenolic content in indigenous, exotic vegetables and thick porridge

Samples Names	Methanolic Extract TPC (mg GAE/g)
Uncooked *Curcunita pepo*	522.22 ± 11.90
Cooked *Curcunita pepo*	2183.76 ± 185.73
Uncooked *Galinsoga parviflora*	3992.74 ± 121.21
Uncooked *Amaranthus*	619.32 ± 87.39
Cooked *Amaranthus*	135.93 ± 10.44
Uncooked *Ipomea batatas*	33684.66 ± 660.62
Therere (chewe) uncooked	1956.10 ± 17.75
Uncooked *Abelmoschus esculentus*	1552.87 ± 32.72
Uncooked *Corchorus olitorius*	1251.23 ± 171.40
Uncooked *Brassica oleracea*	550.44 ± 47.61
Cooked *Brassica oleracea*	253.53 ± 3.25
Uncooked Brassica rapa	1213.71 ± 6.48
Cooked Brassica rapa	194.72 ± 11.61
Uncooked *Bidens Pilosa*	3495.40 ± 127.51
Cooked *Bidens Pilosa*	6817.86 ± 125.56
Uncooked *Brassica napus L.*	10930.11 ± 700.62
Cooked *Brassica napus L.*	370.71 ± 62.22
Uncooked *Brassica oleracea var.botrytis*	2671.60 ± 134.97
Cooked *Brassica oleracea var.botrytis*	227.29 ± 2.18
Zea mays (thick porridge from polished grain)	188.17 ± 13.95
Zea mays (thick porridge from whole grain)	211.92 ± 30.63

Abbreviation: TPC; total phenolic content, mg GAE/g; milligram of gallic acid equivalents per gram. Each value is expressed as mean ± standard deviation (*n* = 3).

DISCUSSION: Phytochemicals were more available in most indigenous fruits than exotic fruits. This could be attributed to more polar phytochemicals in indigenous fruits compared to exotic fruits. In water extracts, alkaloids, glycosides, and anthocyanins were not available in vegetables, indigenous and exotic fruits. Alkaloids and some glycosides may be less polar than water. Studies have shown that methanol extracts alkaloid better than other solvents [32]. Although solvents might have an effect in the extraction of these phytochemicals, the absence of alkaloids would imply that they may not be available in fruits. For glycosides, this suggests that they may be absent or may be available in trace amounts and may also mean the solvents used in this study could not extract them. On the other hand, the absence of anthocyanin would be attributed to the color of the selected fruits. Anthocyanins constitute a pigment group responsible for the red, blue, and purple colors of a variety of fruits, leaves, and flowers [4]. Generally, the results showed that fruits are good source of phytochemicals, and this agrees with the results from other studies [15, 35].

Generally, indigenous vegetables showed higher TPC values in comparison to exotic ones. It was observed that processing affected the total phenolic compounds differently. In some vegetables, TPC values increased with cooking (pumpkin leaves, bonongwe and chisoso) while in others (cabbage, Chinese and rape) it decreased. This is consistent with phytochemical screening results. This could be attributed to some chemical compounds absorbing in the same wavelength range (180 to 300 nm). For example, in pumpkin leaves, bonongwe and chisoso extracts, saponins were only present in cooked samples. Saponins absorb in the same wavelength range as phenols, which would have enhanced the absorption and increased TPC values. Heating may have also affected sample matrices differently. Furthermore, the study observed that the commonly consumed thick porridge from maize grains showed some significant levels of TPC, with thick porridge from unpolished grain (mgaiwa) having higher values, although in the screening process fewer phytochemicals were observed.

Phenolic compounds such as quercetin (flavonoid) and some alkaloids have antioxidant properties [36, 37], therefore their presence in varied amounts in the studied Malawian fruits and vegetables suggest that they are a good source. Hence, they can be used in the diet to prevent, combat, and possibly treat non-communicable diseases. Cellular damage is caused by an imbalance between antioxidants and reactive oxygen species (ROS), which result in oxidative stress. Oxidative stress is the main cause of diseases such as cancer, cardiovascular diseases, diabetes, cataracts, age-related illnesses, Parkinson's disease, and inflammation in the body [38]. Studies have shown that antioxidants reduce oxidative stress in cells, as such they can be used in prevention or treatment of non-communicable diseases. In addition, there is a strong correlation between consumption of food with high antioxidant activity and lowering the risk of these non-communicable diseases.

CONCLUSION: The studied fruits and vegetables represent a good source of a variety of phytochemicals. Hence, they are a potential functional food and can serve as an inexpensive source of natural antioxidants, which could help in the fight against non-communicable diseases such as hypertension, diabetes, and cancer. As might be expected, a single fruit or vegetable doesn't contain all the necessary phytochemicals. Therefore, an intake of a mixture of fruits and vegetables is recommended for maximum benefit as functional foods. It would be interesting to analyze a wide range of fruits and vegetables in all seasons in Malawi, using more sensitive and selective analytical techniques such as LC/MS and NMR to identify specific phytochemicals which could result in the classification of these foods as functional foods.

List of abbreviations: FW: Fresh weight, H_2O: Water, LC/MS-Liquid Chromatography Mass spectrometry, MeOH: Methanol, mgGAE/g: Milligram of gallic acid equivalents per gram, mgQE/g: Milligram of quercetin equivalents per gram, NCD: Non communicable diseases, NMR: Nuclear Magnetic Resonance, ROS: Reactive oxygen species, TFC: Total flavonoids content, TPC: Total phenol content.

Authors Contributions: Victorian Ndolo (VN) conceived the project, designed the experiments, and acquired the research grant. David Tembo (DT), Margaret Maoni (MM) and Victoria Ndolo (VN) collected samples from different sites and performed qualitative phytochemical analysis experiments, while Bonface Mwamatope (BM) did quantitative phytochemical analysis experiments. Further, VN, DT, MM and BM analyzed and interpreted data, prepared figures and tables, drafted, and edited the manuscript collectively.

Competing Interests: The authors declare that there are no conflicts of interest.

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