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Some Biochemical Parameters of Eggplant Species from Turkey and Nigeria

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ABSTRACT

In this study, the amounts of vitamins, beta-carotene, lycopene, glutathione (GSH, GSSG), malondialdehyde (MDA), and hydroxyneoneal (4-HNE) in eggplant samples grown in Turkey (dark and light colored eggplant) and Nigeria (white garden egg, bitter apple and bitter tomato) were determined by HPLC. In addition, the total amount of phenolic, and flavonoid substances and antioxidant capacity (ABTS, IC_{50}) were determined by a UV-Visible spectrophotometer. The amounts of vitamins A, E, β-carotene and lycopene were found to be in the ranged of 0.13 -3.63; 3.63-39.0; 1.87-30.5; 1.52-6.79 µg/g dw, respectively. The amounts of vitamin C, B_1, B_2, B_3, B_5, B_6, B_9 and B_{12} ranged 357-1136; 11.0-95.6; 1.9-5.4; 83-265; 30.16-65.43; 127-348; 24.74-78.6; 0.11-0.68 µg/g dw, respectively. GHS, GSSG, MDA and 4-HNE were found to be in between 364-1930; 225-962; 1.5-8.4; 24.57-38.25 µg/g dw, respectively. While the total phenolic substance was between 706-1260 µg GAE/g dw, the total amount of flavonoid substance was found to be in between 167-356 µg QE/g dw. ABTS values ranged between 365-692 µmol Troloxs/g dw, while IC_{50} values were in 65.1-99.3 µg/mL. It can be said that the differences observed in the parameters observed in eggplant varieties grown both in Turkey and Nigeria are due to genetic and geographical differences.

Türkiye ve Nijerya'dan Patlıcan Türlerinde Bazı Biyokimyasal Parametre İçeriklerinin Araştırılması

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ÖZ

Bu çalışmada, Türkiye (koyu ve açık renkli patlıcan) ve Nijerya'da (white garden egg, bitter apple ve bitter tomato) yetişen patlıcan örneklerinin likopen, beta karoten, vitaminler, glutatyon (GSH, GSSG) malondialdehit (MDA), 4-OH neoneal (HNE) içerikleri HPLC ile belirlenmiştir. Ayrıca toplam fenolik ve flavonoid madde miktarları ve antioksidan kapasitenin (ABTS, IC_{50}) belirlenmesinde ise spektrofotometre kullanılmıştır. Vitamin A, E, β-karoten ve likopen miktarları sırasıyla 0,13-3,63; 3,63-39,0; 1,87-30,5; 1,52-6,79 µg/g dw arasında değişmektedir. Aynı şekilde C, B_1, B_2, B_3, B_5, B_6, B_9 ve B_{12} vitamin miktarları ise sırasıyla 357-1136; 11,0-95,6; 1,9-5,4; 83-265; 30,16-65,43; 127-348; 24,74-78,6; 0,11-0,68 µg/g dw arasında değişmektedir. GHS, GSSG, MDA ve 4-HNE miktarları ise sırasıyla 364-1930; 225-962; 1,5-8,4; 24,57-38,25 µg/g dw arasında bulunmuştur. Total fenolik madde 706-1260 µg GAE/g dw arasında iken, toplam flavonoid madde miktarı 167-356 µg QE/g dw arasında bulunmuştur. ABTS değerleri 365-692 µmol Troloxs/g dw arasında değişirken, IC_{50} değerleri 65,1-99,3 µg/mL arasında bulunmuştur. Hem Türkiye'de hem de Nijerya'da yetiştirilen patlıcan türlerinde yapılan

araştırma sonucunda gözlenen farklılıklar, genetik yapıları ve coğrafi kökenlerinden kaynaklandığı söylenebilir.

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Introduction

The Solanum species comprises some of the world's most economically valuable vegetables/fruits such as tomato, potatoes, pepper, and eggplant. Eggplant is one of the most phenotypically diverse fruits in the world, with a variety of colors, shapes and sizes with important nutritional, economic and ecological functions. Various cultures use eggplants for the traditional treatment of a wide variety of ailments, from diabetes to chest infections, and allergies (Okmen et al., 2009). Eggplant has smooth skin with different colour tones. Its fruit has a spongy texture and can be eaten fresh or cooked. Its fruits are used to flavour and enrich soups and stews (Meyer et al., 2012). Eggplant (*Solanum melongena* L.), also known as melanzana, garden egg and brinjal in different parts of the world, is an important market vegetable in Asian and Mediterranean countries. Whereas eggplant is widely sold and consumed in global markets, it is still a relatively wild and underutilized fruit in parts of Africa and Asia (Wu et al., 2007). An extensive study of traditional medicinal uses of different varieties of eggplant reported to include topical use to treat haemorrhoids, reduce swelling, as an antipyretic, as an emetic, laxative, aphrodisiac, hypoglycemic, for toothache, relieve cough, stop bleeding, weight loss, appetite stimulant, for heartburn, hyperacidity, diuretic, induce sleep, skin compress for swelling, uterus stabilizer after a miscarriage, and to treat cancer, particularly skin cancer (Meyer et al., 2012).

There is fragmented literature on the nutritional composition of a large percentage of eggplant varieties, especially wild species. Eggplants are reported to be rich in fiber, vitamins, minerals and secondary metabolites (Gürbüz et al., 2018). Vitamins are organic molecules that have a variety of biochemical functions and are needed in small quantities for the proper functioning of metabolism. Deficiency or excess of vitamins can cause clinically important diseases as well (Awuchi et al., 2020).

Glutathione, a tripeptide, is an important antioxidant for all living things, protecting cells against oxidative damage and scavenging reactive oxygen species. Available in reduced (GSH) and oxidized (GSSG) forms. The oxidized form of glutathione is an indicator of oxidative stress (Cnubben et al., 2001).

Oxidative stress caused by the environmental factors in biological systems causes an increase in lipid peroxidation and causes to decrease in the antioxidant defense system (Jemai et al., 2007). Malondialdehyde (MDA) and 4-hydroxyneoneal (4-HNE) levels formed as a result of lipid peroxidation also serve as good markers in determining cellular damage caused by reactive oxygen species depending on stress conditions (Gawel et al., 2004; Schaur et al., 2015).

Antioxidants are molecules that are generally produced from natural sources, contain phenolic groups and inhibit the free radical formation or neutralize them (Su et al., 2007). Phenolic compounds, which are found as secondary metabolites in plants, consist of various compounds such as complex flavonoids, simple flavonoids, phenolic acids and anthocyanins. In addition to causing the colouration of fruits and vegetables, they play an important role in the activity of some enzymes (Babbar et al., 2012). These substances were found to have antioxidative, anti-inflammatory, anti-cancer and anti-mutagenic properties (Panche et al., 2016).

The aim of this study is to compare the results of eggplant samples from Elazig/Turkey and Kano/Nigeria by determining the amounts of vitamins, glutathione, MDA, 4-HNE, antioxidant capacity, total phenolic and flavonoids compounds.

Materials and Methods

Material

In this study, fresh eggplant fruits were purchased from local markets in Elazig City, Turkey, and Kano, Nigeria in October 2019. Five types of varieties of eggplant (Figure 1) were used, white garden egg, bitter apple, bitter tomato (Kano), dark eggplant and light eggplant (Elazig) throughout the experiment. Each sample was washed thoroughly and stored in the refrigerator at 4 °C until required for further use.

Figure 1. The eggplant species used for this study and their common names

2.2. Determination of vitamin A, E, β-Carotene, lycopene and 4-HNE

1.0 gram of homogenate was taken and analyses were carried out using an ODS-2 column in HPLC, according to the method used by Ibrahim et al., (2017).

Determination of B vitamins

1.0 grams of homogenized eggplant samples were taken and analyses were performed using a Supelcosil LC-18-DB column (150 mm x 4,6 mm ID, 5 μm) in HPLC (Amidžić et al., 2005; İbrahim et al., 2017).

Determination of Vitamin C, GSH, GSSG, MDA

Analyses of homogenized eggplant samples were performed by HPLC according to İbrahim et al. (2017).

Determination of total phenolic, flavonoid substance and antioxidant capacity

Extraction

Eggplant samples were homogenized with a blender, and 25 g of homogenized sample was transferred into the paper thimble and extracted with CH_3OH in Soxhlet apparatus for 4 hours. The extracts were dried in rotary evaporator and dissolved in a 50 mL CH_3OH and the solution was stored in the freezer until analysis. The prepared extract was used to determine the total phenolic and flavonoid substances and antioxidant capacity. Determination of total phenolic and flavonoid substances were performed by UV-visible spectrophotometer described by Dewanto et al. (2002) and the results were given in as gallic acid equivalent (μg GAE g^{-1} dw) and quercetin equivalent (μg QE g^{-1} dw) respectively.

Total antioxidant capacity was determined according to two different methods, DPPH (Nile et al. (2013) and TEAC (Re et al. (1999).

2.3. Statistical Analysis

All measurements were triplicated and Mean ± Standard deviation was determined. The results were subjected to Variance Analysis by SPSS 10,0 for Windows. Differences between the group's means were analysed for significance using Tukey test. The level of statistical significance was expressed as $p<0,05$. Insignificant changes were indicated as $p>0.05$ and given in Table 1.

White garden egg samples are compared with other eggplant types, the significant difference is shown with the symbol **a**, and the insignificant difference is shown with the symbol **b**. When compared to other types of bitter apples the significant difference is indicated by the **c** symbol and the insignificant difference is indicated by the **d** symbol. When comparing the bitter tomato example with other species, the significant difference is indicated by the symbol **e**, and the insignificant difference is indicated by the symbol **f**. Compared to the dark eggplant and light eggplant example, the significant difference is indicated by the symbol **g** and the insignificant difference by the symbol **h**.

Result and Discussion

The amounts of fat and water-soluble vitamins, GSH, GSSG, MDA, and 4-HNE, total phenolic and flavonoid substance, antioxidant capacity in five different eggplant fruits were measured and the results are given in Table 1 and Figure 2-7.

Table 1. Amounts of some biochemical parameters in the five different varieties of eggplant fruits.

Species	White Garden Egg	Bitter Apple	Bitter Tomato	Dark Eggplant	Light Eggplant
Vitamin A	2.33 ±0.03	3.63±0.10 [a]	2.65±0.15 [a c]	0.63±0.04 [a c e]	0.13±0.01 [a c e g]
Vitamin E	11.0±0.30	3.63±0.10 [a]	35.0±1.50 [a c]	39.0±1.6 [a c e]	4.8±0.2 [b c e g]
β-Carotene	4.29±0.10	5.13±0.15[a]	21.4±1.3 [a c]	30.5±1.6 [a c e]	1.87±0.05 [a c e g]
Lycopene	6.79±0.24	4.33±0.20 [a]	3.2±0.26 [a c]	1.78±0.08 [a c e]	1.52±0.03[a c e g]
Vitamin C	1136.0±24.0	579.0±11.0 [a]	357±7.5 [a c]	476±8.60 [a c e]	422.0±6.10 [a c e g]
Vitamin B_1	95.60±2.20	54.0±1.72 [a]	46.0±1.54 [a c]	11.0±0.50 [a c e]	19.0±1.13[a c e g]
Vitamin B_2	5.40±0.22	3.80±0.13 [a]	1.9±0.09 [a c]	4.74±0.24 [a c e]	5.18±0.21 [b c e h]
Vitamin B_3	265.0±6.45	96.20±2.70 [a]	119±3.0 [a c]	83±2.20 [a c e]	104.0±2.80 [a c e g]
Vitamin B_5	30.16±1.60	36.40±1.70 [a]	48.5±2.25 [a c]	65.43±3.0 [a c e]	58.0±2.10 [a c e g]
Vitamin B_6	348.0±9.10	226.0±4.90 [a]	141.0±3.40 [a c]	127±2.9 [a c e]	202.0±3.9 [a c e g]
Vitamin B_9	55.87±3.49	26.86±1.51 [a]	102±4.10 [a c]	24.74±1.28 [a d e]	78.6±3.0 [a c e g]
Vitamin B_{12}	0.68±0.03	0.39±0.02 [a]	0.38±0.02 [a d]	0.11±0.01 [a c e]	0.2±0.01 [a c e g]
GSH	1930.0±86.0	1512.0±63.0 [a]	364±14.0 [a c]	408.0±15.8 [a c e]	812.0±35.0 [a c e g]
GSSG	962.0±27.0	666.0±15.0 [a]	225.0±7.80 [a c]	230.0±8.6 [a c f]	418.0±12.0 [a c e g]
MDA	8.40±0.33	3.62±0.24 [a]	1.50±0.10 [a c]	1.9±0.10 [a c e]	3.16±0.15 [a c e g]
4-HNE	38.25±1.55	36.29±1.63 [b]	24.57±1.38 [a c]	31.81±1.43 [a c e]	33.56±1.50 [a d e h]
T. Phenolic S.	1260.0±25.0	869.0±12.0 [a]	732.0±9.0 [a c]	1121.0±21.0 [a c e]	706.0±10.0 [a c e g]
T. Flavonoid S.	356.0±9.0	167.0±5.0 [a]	214.7±6.9 [a c]	264.0±7.2 [a c e]	192.0±5.4 [a c e g]
ABTS	692.0±11.0	464.0±10.0 [a]	365.0±9.0 [a c]	610.0±14.0 [a c e]	532.0±9.0 [a c e g]
IC_{50}	65.1±3.0	86.9±4.0 [a]	99.3±4.8 [a c]	73.0±3.30 [a c e]	80.8±3.8 [a d e g]

Concentration of vitamins, β-Carotene, Lycopene, GSH, GSSG, MDA and 4-HNE given as (μg/g dw), Total phenolic substance (μg GAE/g dw), Total Flavonoid (μg QE/g dw), ABTS (μmol Troloxs/g) dw) IC_{50} (μg/mL)

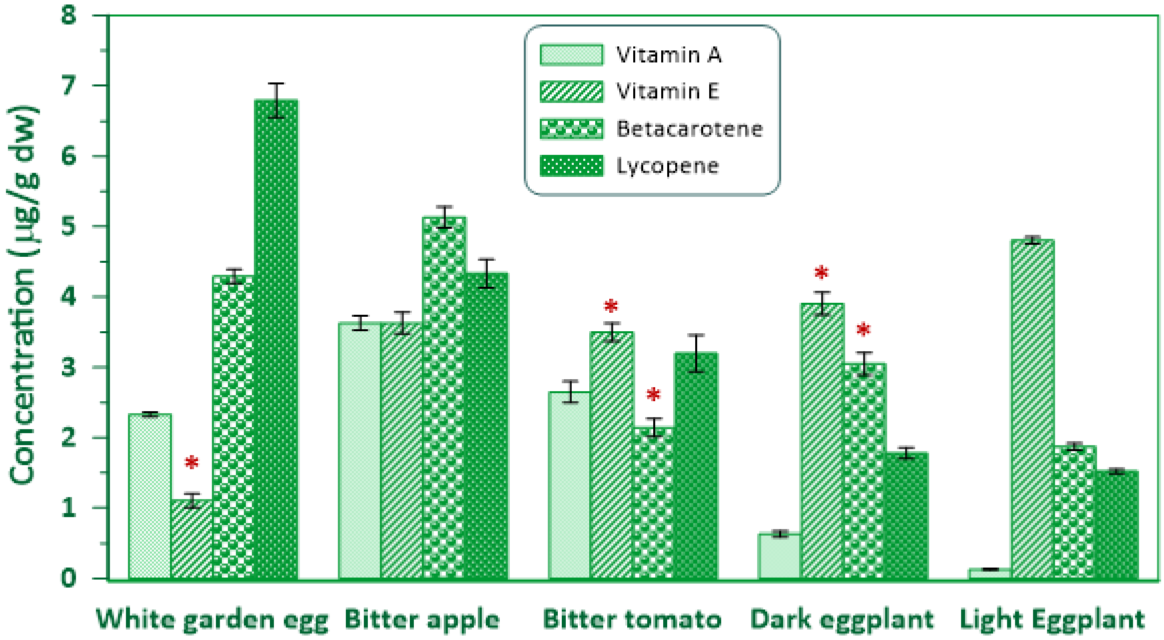

Figure 2. The amounts of fat-soluble vitamins, β-Carotene and Lycopene in eggplant samples. (* values divided by 10)

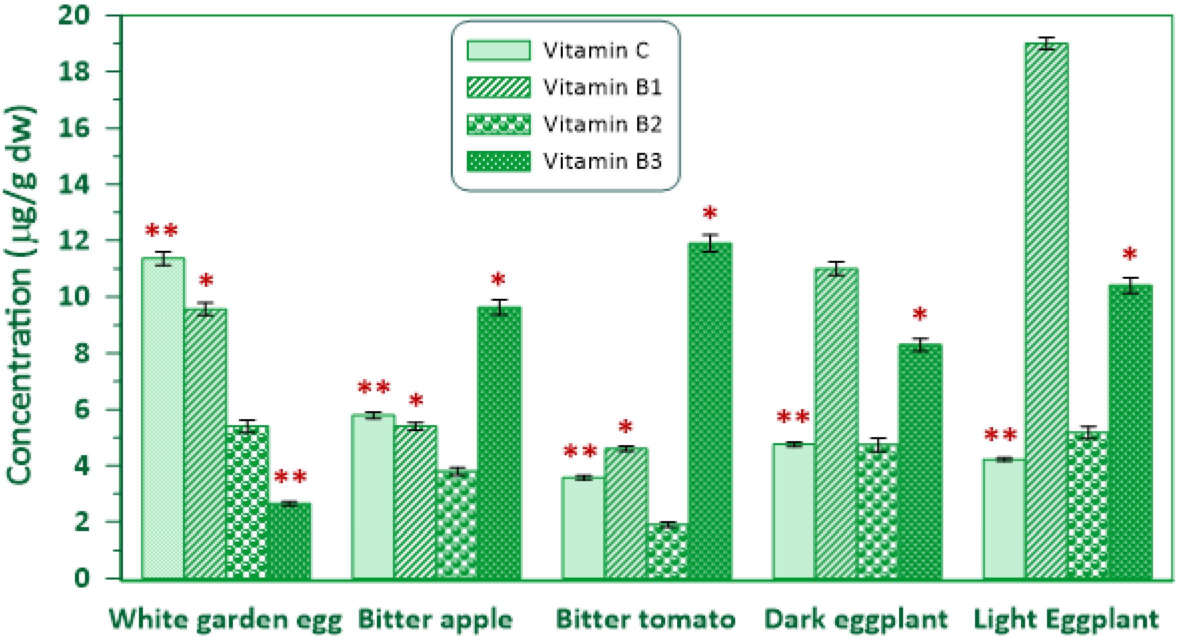

Figure 3. The amounts of vitamins C, B_1, B_2 and B_3 in eggplant samples. (* values divided by 10, ** values divided by 100)

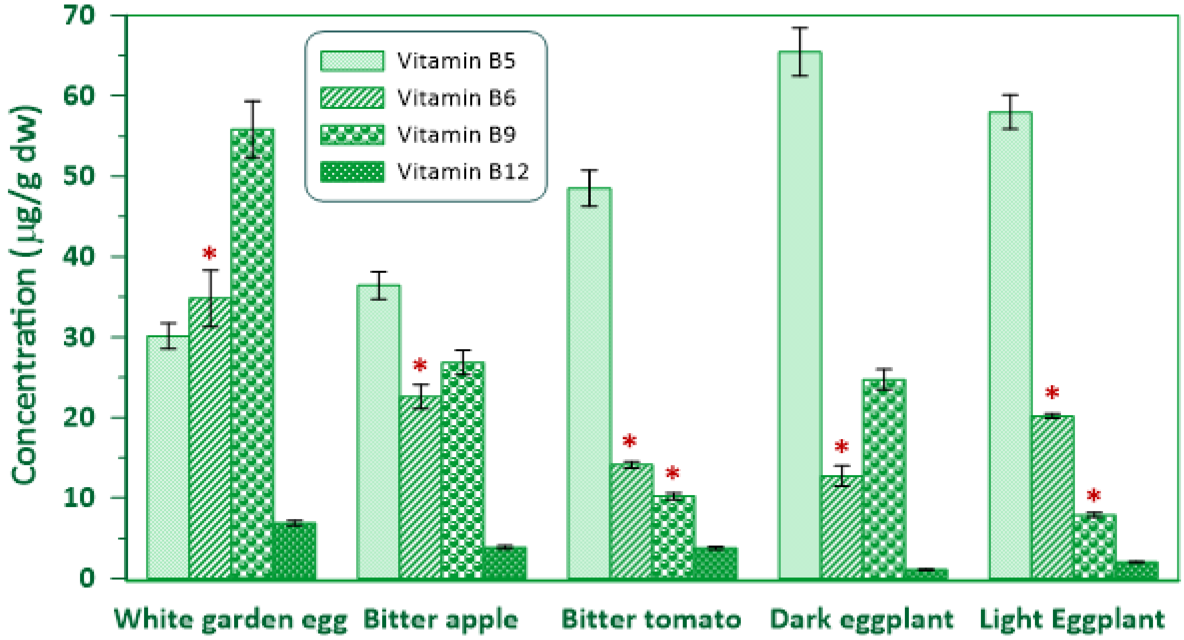

Figure 4. The amounts of vitamins B_5, B_6, B_9 and B_{12} in eggplant samples. (**x** values multiplied by ten and * values divided by 10)

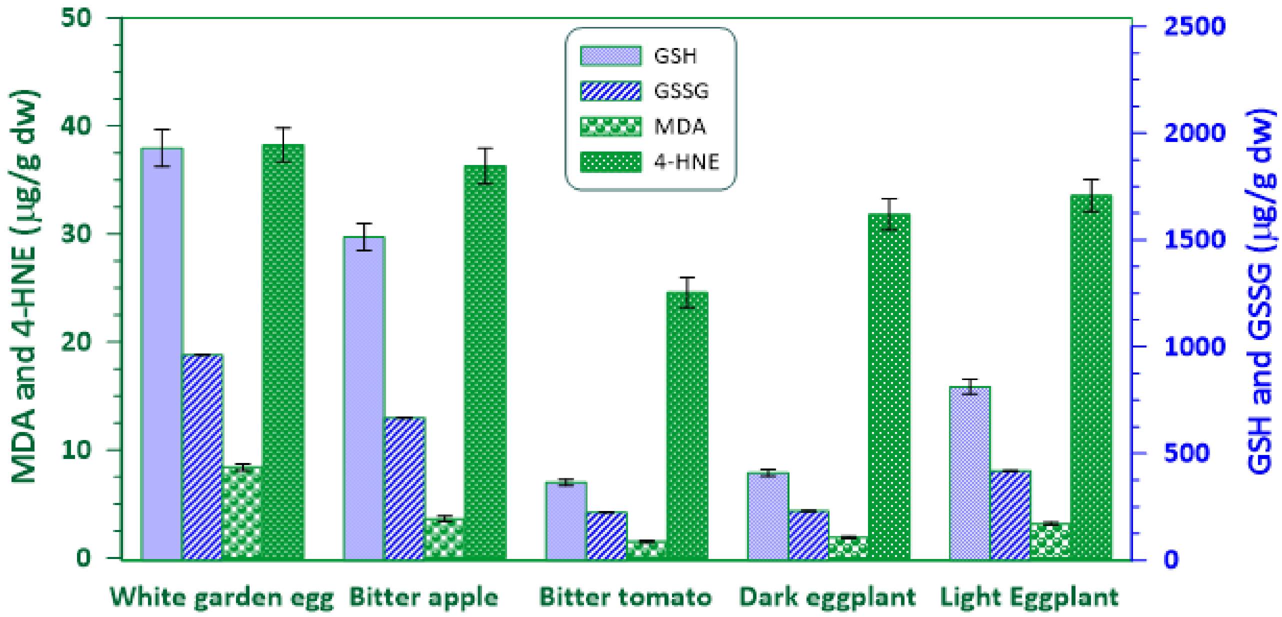

Figure 5. The amounts of vitamins GSH, GSSG, MDA and 4-HNE in eggplant samples.

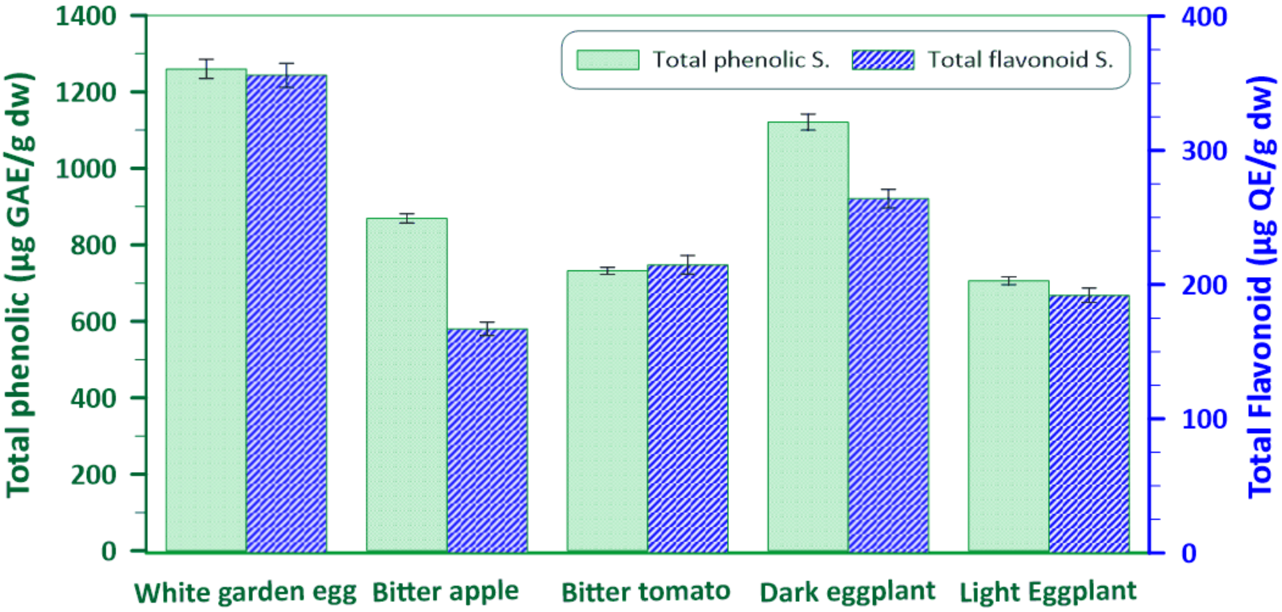

Figure 6. Total phenolic and flavonoid substance in eggplant samples.

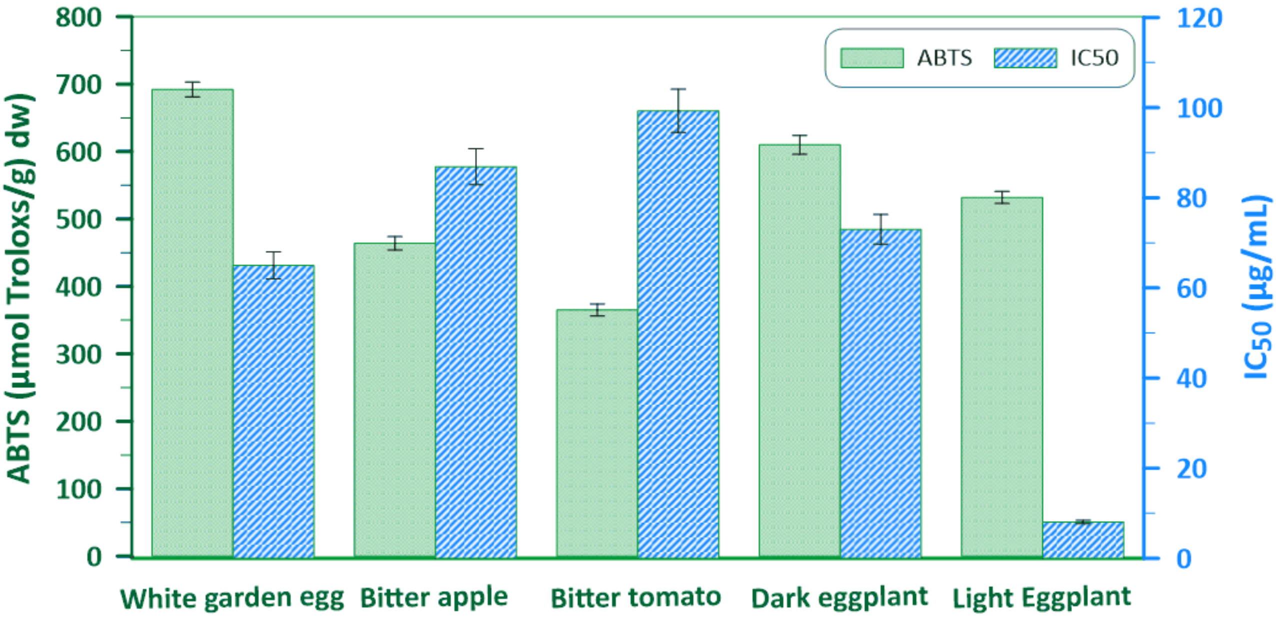

Figure 7. Antioxidant capacity values in eggplant samples.

Vitamins are distinctly different from other nutrients both in structure, dietary requirement and metabolic roles. They are also distinct because they are not involved in structural formations and their breakdown does not generate significant amounts of energy to be used by the cell. Rather, they have specific metabolic and physiological roles that aid the metabolism of other nutrients and are required in trace amounts. Most vitamins exist in foods as a pro-vitamin that is an inactive form that necessitates metabolic activation to perform their functions (Gerald et al., 2017).

While the highest amounts of fat-soluble vitamins A, E, β-carotene and lycopene were found in bitter apple, dark eggplant, dark eggplant and white garden egg, respectively. On the other hand the lowest amounts of vitamins A, E, β-carotene and lycopene were found in light eggplant, bitter apple, light eggplant and light eggplant species, respectively (Table 1 and Figure 2). The amounts of vitamin A and lycopene in eggplant samples grown in Nigeria were found to be higher than in eggplant samples grown in Turkey.

It was reported by Horna et al. (2007) that the amount of vitamin A in eggplant samples was 0.7 μg/g, Fraikue et al. (2016) found the amount of vitamin E in eggplant samples were between 2-3 μg/g. Msogoya et al. (2014) reported that the amount of β-carotene in eggplant samples was between 7.09 and 8.14 μg/g. Arkoub-Djermoune et al. (2016) reported that the amount of lycopene in the eggplant sample was 128.4 ±16.6 μg/g dw.

While the highest amount of vitamins C, B_1, B_2 and B_3 were observed in the white garden egg, the lowest amounts were observed in bitter tomato, dark eggplant, bitter tomato and dark eggplant samples, respectively. The vitamin B_1 content of eggplants grown in Nigeria was found to be higher than the eggplant samples grown in Turkey (Table 1 and Figure 3).

Nıño-Medina et al. (2014) found that the amount of vitamin C in eggplant samples grown in different countries was in the range of 86 - 220 μg/g. Gürbüz et al. (2018) reported the amounts of vitamins C, B_1, B_2 and B_3 in the eggplant sample as 22; 0.39; 0.37 and 6.49 μg/g, respectively.

The highest amount of B_5, B_6, B_9 and B_{12} vitamins was observed in dark eggplant, white garden egg, bitter tomato and white garden egg eggplant samples, respectively. The lowest vitamins (B_5, B_6, B_9 and B_{12}) were observed in white garden egg and dark eggplant species. While vitamin B_5 was higher in samples grown in Turkey, on the other hand, B_{12} was found to be higher in samples grown in Nigeria. (Table 1 and Figure 4).

Sharma and Kaushik (2021) reported the amount of vitamins B_5, B_6 and B_9 in the eggplant sample to be 2.81; 1.0 and 220 μg/g, respectively. Imo et al. (2019) reported that the amount of vitamin B_{12} in the eggplant sample was 3.65 μg/g.

Glutathione is a common antioxidant that protects cells from oxidative stress and toxic compounds, thus essential for maintaining redox balance and overall homeostasis. It exists in reduced (GSH) and oxidized (GSSG) forms. A balance between these two forms where most of the glutathione is in the reduced form; is necessary to maintain physiological redox homeostasis (Masella et al., 2005).

The imbalance in the amount of pro-oxidant and antioxidant compounds in foods leads to both enzymatic and non-enzymatic oxidation of polyunsaturated fatty acids, resulting in the formation of peroxidation products such as MDA and 4-HNE, which are known as markers of oxidative stress (Niki, 2014).

While the highest amounts of GSH, GSSG, MDA and 4-HNE were found in the white garden egg sample, the lowest values were found in bitter tomato. The amount of GSH, GSSG, MDA and HNE in eggplant samples produced in Nigeria is higher than those grown in Turkey except for bitter tomato (Table 1 and Figure 5). This situation may be related to genetic structure and environmental factors.

Agoreyo et al. (2013) reported that the amount of glutathione in different eggplant samples was between 25 and 105 nmol/g fw. The amount of MDA in the fresh eggplant sample was reported as 38 pm/g (Das et al., 2011).

Phenolic compounds, commonly found in fruits, legumes, grains and vegetables, have effective antioxidant properties and protect plants against environmental factors such as UV radiation and parasites (Onyilagha and Grotewold, 2004).

Flavonoids are the substances that cause the colouring of fruits and involve the activity of some enzymes (Panche et al., 2016). The highest total phenolic and flavonoid substance content was found in the white garden egg, while the lowest total phenolic and flavonoid substance content was found in light eggplant and bitter apple, respectively (Table 1 and Figure 6). Hanson et al., (2006) investigated the total phenolic compound in the methanol extracts of 33 different eggplant cultivars sampled from diverse countries and found it to range from 74-1400 mg/100g dw.

The Total flavonoid compound in eggplants has been reported to range from 16.13-18.52 mg QE/100 g (161.30 – 180.52 µg QE/g) dw, by Boulekbache-Makhlouf et al. (2013). Antioxidants are biomolecules synthesized in the organism or taken into the diet and protect the cell by neutralizing the free radical species (Sharma et al., 2012).

Total antioxidant capacity is a measure of the cumulative activity of antioxidant capacity rather than the individual capacity of antioxidants based on an electron transfer reaction with a colored oxidant (Fraga et al., 2014). Trolox equivalent antioxidant capacity (ABTS or TEAC) and DPPH radical scavenging methods were applied to determine the total antioxidant capacity. IC_{50} values were determined using the DPPH method and the Trolox equivalent was determined using the TEAC method.

The highest Trolox equivalent antioxidant capacity as an ABTS value was observed in white garden egg, while the lowest was observed in bitter tomato sample. Likewise, while the high IC_{50} value was observed in the bitter tomato sample, the lowest value was observed in the white garden egg. The results of two different methods are compatible with each other. Low IC_{50} value means it has the high antioxidant capacity (Table 1 and Figure 7).

As seen in Table 1 and Figure 6, 7, it can be concluded that the samples with higher total phenolic and flavonoid substance content have higher antioxidant capacity.

The recommended daily nutrient intake (RDA) is the amount that will meet the nutritional needs of almost all healthy people of a certain age and gender. RDA values vary for different countries due to dietary habits, climate and other regional factors.

As it can be seen in Table 2, the percentage of RDAs met by people consuming 100 g dw/day of eggplant is given, taking into account the RDA values of vitamins.

It can be seen from Table 2 that the highest RDA values of lycopene, vitamins C, B_1, B_2, B_3, B_6, B_9 and B_{12} are in the white garden egg sample. The statistical comparison of the parameters examined in the eggplant samples grown in Turkey and Nigeria are shown in Table 1 with the letters specified in the statistical analysis section.

Table 2. Shows the percentage of RDA (WHO, 2004) in µg/100 g dw of each of the varieties of eggplant fruits.

Vitamin	RDA (mg/day)	White garden egg	Bitter apple	Bitter tomato	Dark eggplant	Light eggplant
Vitamin A	0.8	29	45	33	7.9	1.7
Vitamin E	15	7.3	2.4	23	26	3
Lycopene	8	8.5	5.4	4	2.2	2
Vitamin C	46	246	129	79	106	94
Vitamin B_1	0.9	1062	598	506	123	212
Vitamin B_2	1	54	38	19	47	52
Vitamin B_3	15	176	64	79.4	56	69
Vitamin B_5	4	75	91	121	163	145
Vitamin B_6	1.4	2485	1614	1007	907	1442
Vitamin B_9	0.5	1117	537	2040	495	1572
Vitamin B_{12}	0.2	34	19	19	5.5	10

Conclusion

Dark eggplant is richer in vitamins E and B_5 and beta-carotene compared to other species. white garden egg is richer than the others in terms of lycopene, vitamins C, B_1, B_2, B_3, B_6 and B_{12}, GSH, GSSG, total phenolic total flavonoid and antioxidant capacity. Vitamin B_9 in the bitter tomato is higher than in other types. As the total amount of phenolic and flavonoid substances increases, the total antioxidant capacity value increases. MDA and 4-HNE, formed as a result of lipid peroxidation and accepted as stress markers, were found to be higher in white garden egg types. These differences in vitamin A, E, beta-carotene, lycopene, C, B_1, B_2, B_3, B_5, B_6, B_9 and B_{12} vitamins, GSH, GSSG, MDA, 4-HNE, total phenolic, flavonoid and antioxidant capacity of eggplant fruits, maybe due to genetic and geographical differences

Statement of Conflict of Interest

The authors have declared no conflict of interest.

Author's Contributions

The contribution of the authors is equal

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