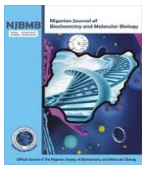
DOI: https://doi.org/10.4314/njbmb.v40i1.2 NJBMB (2025) 40(1) 8-16



Nigerian Journal of Biochemistry and Molecular Biology

The Official Publication of the Nigerian Society of Biochemistry & Molecular Biology (NSBMB). Journal homepage: https://www.nsbmb.org.ng/journals/

e-ISSN: 2659-0042

Research Article

Antioxidant and Enzyme Inhibition Properties of Okra-Orange (*Abelmoschus esculentus–Citrus sinensis*) Juice Blend: Development, Stability, and Potential Function

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ARTICLE HISTORY
Received: 06/08/2025
Reviewed: 04/09/2025
Revised: 21/09/2025
Accepted: 13/10/2025
Published: 31/10/2025

CITATION
Adetuyi F.O., Akintimehin E.S., Karigidi K.O., Makinde P.A., Omogunwa S.T., Ogunbameru F.E., Fapetu A.P. (2025). Antioxidant and enzyme inhibition properties of Okra-Orange (*Abelmoschus esculentus–Citrus sinensis*) Juice blend: Development, stability, and functional potential. *Nigerian Journal of Biochemistry and Molecular Biology*. 40(1), 8-16 https://doi.org/10.4314/njbmb.v40i1.2

ABSTRACT

Functional beverages are a sort of drinks that are free of alcohol but contain bioactive components from plant or microorganism that contribute to strengthening of human health. This work evaluates the antioxidant and antihyperglycemic potential of a functional beverage developed from okra (*Abelmoschus esculentus*) orange (*Citrus sinensis*) juice blend. Orange juice and okra fruit juice were prepared and was blended in the following ratios 98:2 (2%), 96:4 (4%), 94:6 (6%), 92:8 (8%), 90:10 (10%) and control 100:0 (0%) respectively. The okra-orange juice blend was also stored for 14 days. The total phenolic content (TPC), Total flavonoid content (TFC), Antioxidant Capacity, α-amylase and α-glucosidase inhibitory activities were assessed. The total phenol and flavonoid content of orange juice increased significantly ($P < 0.05$) from 135.8 mg (GAE) / g to 231.6 mg (GAE) / g and 45.6 mg QE / g to 100.0 mg QE / g respectively as the percentage of okra juice added increased. In storage, the total phenol and flavonoid content of the okra-orange juice blend was significantly higher than the orange juice at different storage days and they were stable. The juice blend scavenged DPPH and ABTS radicals, the glucose enzyme inhibitory activity increased from 23.9% to 75.4%; α-amylase and 11.4% to 63.7% α-glucosidase enzymes, these activities increased directly as the added okra juice percentage increased. Okra-orange juice blend has the potential of stabilizing free radicals, control postprandial blood glucose level and be used in formulating functional beverage for the mitigation of hyperglycemia.

Keywords: *Antioxidant, Okra-Orange juice blend, Okra juice, Orange juice, Total phenol, Carbohydrate metabolic enzyme*

INTRODUCTION

Blood glucose is a product of the available food carbohydrates (glycemic), made up of simple sugars and starches which are broken down to glucose and subsequently absorbed into the bloodstream through the intestine. Another source of blood glucose is from glycogen (glycogenolysis) or from amino acids or glycerol (gluconeogenesis) (Luhovyy and Kathirvel 2022). Blood glucose is crucial in maintaining a healthy body and preventing different chronic diseases. To avoid cardiovascular diseases and obesity, healthy body and normal blood glucose levels must be maintained. When blood glucose is not controlled it lead to diabetes mellitus which is a major health challenges of uncontrolled blood glucose levels (Thondre, 2013, Karigidi *et al*. 2020). The control of Blood glucose to mitigate against diabetes can be achieved by either pharmacological or lifestyle interventions or both. Many of the antihyperglycemic medications are very effective but with adverse health challenges (Chaudhury *et al*., 2017). The use of functional food products in addition to other strategies can be used at improving metabolic control without adverse effect (Luhovyy and Kathirvel 2022).

Okra (*Abelmoschus esculentus*) is known as Ila in Yorubaland, a region in Western Nigeria, and as lady's finger or gumbo in many English-speaking nations. The okra seeds contain a reasonable amount of Protein, fat, fiber, and sugar (Poorva and Sunita, 2017, Adetuyi and Komolafe 2011). It has antioxidant qualities and a high concentration of flavonoid molecules. Okra polysaccharides have been shown to improve glucose tolerance, lower serum total cholesterol, and reduce body weight and glucose levels (Poorva and Sunita, 2017). It has been shown to have antidiabetic qualities, reducing blood glucose levels by modulating sugar absorption rate out of digestive system. It is a great vegetable for people who are fatigued, exhausted, or sad. Asthmatic patients also benefit from okra, which helps to maintain normal blood sugar and cholesterol levels (Sabitha *et al.,* 2011). Furthermore, okra polysaccharide may help in prevention of cancer due to its ability to bind bile acids (Sabitha *et al.,* 2011).

Orange (*Citrus sinensis*) is one of the most popular fruits, with great economic importance. It belongs to the Rutaceae family (Etebu and Nwauzoma, 2014). Orange is widely consumed around the world because it is high in ascorbic acid. Citrus is grown extensively in tropical and subtropical areas especially Nigeria (Etebu and Nwauzoma, 2014). Orange contains phytochemicals and minerals such as liminoids, polyphenols, pectin, flavonoids, potassium and calcium.

It has previously been established that the blending of fruits improve the nutritional and organoleptic qualities of the blends and the synergy of the phytoconstituent of the blend contributes to human well-being (Shaheel *et al*., 2015). The blending of okra juice and orange juice has the capacity of bringing together their respective functional properties to control the blood glucose thereby mitigating diabetes mellitus. This study aimed to evaluate the bioactive compound, antioxidant, antihyperglycemic and storage stability of okra orange juice blends.

MATERIALS AND METHODS

The okra (*Abelmoschus esculentus*) and orange (*Citrus sinensis*) fruits were purchased from the Okitipupa main market. Identified and authenticated in botany department of biological sciences, Olusegun Agagu University of Science and Technology, Okitipupa, Ondo State, Nigeria. The voucher numbers: OAUSTECH/H/00689 and OAUSTECH/H/00695, respectively were deposited.

Okra preparation

This was done according to Wirivutthikorn (2020) with slight modification. One kilogram (1 Kg) of okra was cleaned, sliced, placed in foil paper, and placed in hot air oven to dry for 6hrs at 75^{o}C. 50g of the dried okra was immersed in 100ml of distilled water, with intermittent shaken at 50^{o}C for 2hrs, the mixture was filtered using muslin cloth until there was no sediment.

Orange preparation

The fresh orange fruit was washed, peeled, cut into half, and squeezed using fruit juice extractor, it was then filtered using muslin cloth until there was no sediment.

Production of Okra and Orange juice blends

The orange juice was blended with Okra juice in the following ratios in 100ml bottle blended orange and okra juice 98:2 (2%), 96:4 (4%), 94:6 (6%), 92:8 (8%), 90:10 (10%) and control 100:0 (0%) respectively. The blended juice (orange and okra juice) was separately boiled with constant stirring at 50^{O}C for 15 mins. They were allowed to cool down and ready for further analysis and storage at room temperature.

Total phenolic content (TPC)

The method as reported by Kim *et al.* (2003) was used for the TPC determination. Absorbance was taken at 750 nm. TPC determined from the Gallic acid standard calibration curve and expressed as mg of gallic acid equivalents (GAE) per g.

Total flavonoid content (TFC)

Park *et al.* (2008) method was used for TFC quantification. Absorbance was taken at 506 nm against reagent blank and TFC was expressed as mg of Quercetin equivalent per g.

Total Antioxidant Capacity (TAC)

The phosphomolybdate method by Prieto *et al*., (1999) was deployed in determining TAC. Absorbance measured at 765 nm against a blank. TAC was reported as mg/AAE g (Ascorbic Acid Equivalent).

Ferric Reducing Antioxidant Power (FRAP)

Benzie and Strain (1996) method was used in evaluating FRAP of the juice. Ferrous sulfate calibration curve was used and FRAP was expressed as mg Fe^{2+}/100g

DPPH radical scavenging activity

The estimation of DPPH radical scavenging activity was according to Gyamfi *et al.*, (1999) method. Absorbance measured at 520 nm and calculated thus:

DPPH scavenging ability = [(Abs control - Abs sample)/ (Abs control)] × 100

2,2′ -azino-bis (3-ethylbenzthiazoline-6-sulphonic acid (ABTS) radical scavenging ability

The method of Re *et al.,* (1999) was used in determining ABTS. Absorbance was taken at 735 nm and calculated thus: ABTS = [(Abs control - Abs sample)/ (Abs control)] × 100. It is expressed as mg of trolox equivalent (TEAC) per 100g.

α-amylase inhibition assay

The Worthington (1993) method was used in determining the a-amylase inhibitory activity. Absorbance measured at 540 nm and calculated thus:

% Inhibition = [Abs reference - Abs sample) /Abs reference] ×100

α-glucosidase inhibition assay

The Apostolidis *et al.*, (2007) method was used in determining the a-glucosidase inhibitory activity. Absorbance taken at 405 nm and calculated thus:

% Inhibition = [Abs reference - Abs sample) /Abs reference] ×100

Statistical analysis

Results were expressed as mean of triplicate determination and data obtained were analysed by one-way analysis of variance followed by least square difference post hoc test using Graph Pad Prism 6 software. The level of significance was considered at $P < 0.05$

RESULTS

Total phenol and total flavonoid

Phenol as mg GAE/g, flavonoid as mg QE/g and pH of the orange juice blend with okra juice is presented in Table 1. The total phenol content of the orange juice was found to be 135.8 mgGAE/g and increased significantly ($P < 0.05$) as the percentage of okra juice added increased, it increased to 231.6 mgGAE/g at 10% addition of okra juice to orange juice. In storage, the TPC of orange juice was 135.8 mgGAE/g day 0 of storage, 135.4 mgGAE/g day 7 of storage and 132.8 mgGAE/g day 14 of storage while at the highest okra juice addition of 10% to orange juice the total phenol content was 231.6 mgGAE/g at day 0 storage, 221.5 mgGAE/g at day 7 storage and 224.1 mgGAE/g at day 14 storage. At the different storage days, the total phenol of the okra orange juice blend was significantly higher than the orange juice.

In a similar fashion, TFC of the orange and okra juice blend had a higher value when the okra juice added was at 10% with a value of 100.0 mg QE/g was significantly ($P < 0.05$) higher than TFC of orange juice 45.6 mg QE/g.

Table 1. Total phenol, total flavonoid and pH of Okra Orange Juice blend.

	Total Phenol (mg (GAE) / g)			Total Flavonoid (mg QE / g)			pH		
%okra added	**Day 0**	**Day 7**	**Day 14**	**Day 0**	**Day 7**	**Day 14**	**Day 0**	**Day 7**	**Day 14**
0%	135.8f	135.4f	132.8f	45.6f	42.3f	39.0f	4.0a	3.7a	3.9a
2%	154.7e	157.3e	159.6e	52.1e	50.4e	48.1e	4.0a	3.6a	3.8a
4%	185.7d	182.4d	173.1d	67.0d	63.3d	66.4d	3.8a	3.6a	3.8a
6%	192.6c	187.9c	183.5c	74.9c	69.8c	70.9c	3.7a	3.5a	3.7a
8%	201.7b	200.3b	208.1b	90.7b	89.9b	88.0b	3.8a	3.6a	3.8a
10%	231.6a	221.5a	224.1a	100.0a	107.6a	102.5a	3.8a	3.5a	3.6a

In storage, the total flavonoids have a similar trend like the TPC, the TFC of the okra orange juice blend had a higher value when the okra juice added at different storage periods, at 10% addition of okra juice, the TFC value was 100.0 mg QE/g day 0 storage, 107.6 mg QE/g day 7 storage and 102.5 mg QE/g day 14 storage which were higher than TFC of the orange juice 45.6 mg QE/g day 0 storage, 42.3 mg QE/g day 7 storage and 39.0 mg QE/g day 14 storage.

DPPH and ABT Scavenging ability

The DPPH and ABTS radical scavenging abilities of orange juice and okra juice blend is presented in Figures 1 and 2. The results showed that both the orange juice and the okra orange juice blend scavenged DPPH radicals, the scavenging abilities increases with an increase in the percentage of okra juice added. The orange juice had 15.1% DPPH scavenging ability, which increased to 42.4% when 2% okra juice was added to the orange juice and increased further to 61.4% at 10% addition of okra juice to the orange juice. The freshly prepared orange juice blend recorded the highest DPPH scavenging abilities when compared to the stored juice except at 10% okra juice addition where the value was not significantly ($P < 0.05$) different, 61.4% freshly prepared, 61.6%-day 7 storage and 60.2%-day 14 storage (Figure 1).

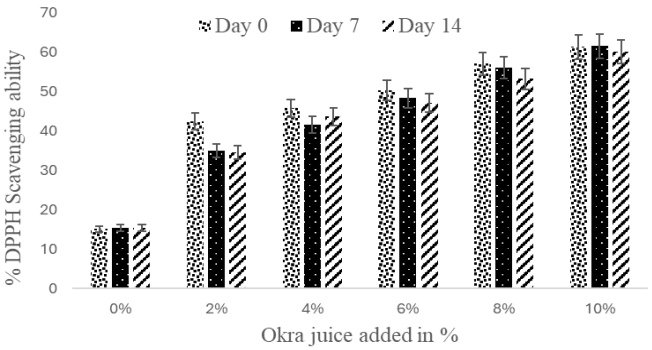

Figure 1. DPPH radical scavenging activities of okra orange juice blend. Values are mean of triplicate determination ± standard deviation.

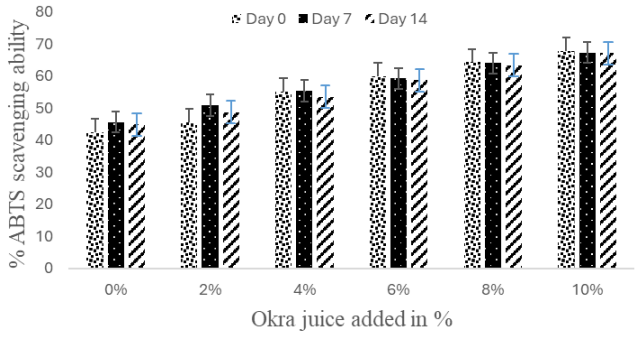

Figure 2. ABTS radical scavenging activities of okra orange juice blend. Values are mean of triplicate determination ± standard deviation.

The ABTS scavenging ability result (fig 2) revealed that orange juice and the okra orange juice blend scavenge ABTS

radicals, the ABTS scavenging ability of the okra orange juice blend increased as the percentage of added okra juice increased. The orange juice had 42.5% ABTS radical scavenging ability, which increased to 45.7% when 2% okra juice was added to the orange juice and increased further to 67.8% at 10% addition of okra juice to the orange juice. The result also showed that at every percentage of okra added, the difference between the freshly prepared juice and stored juice was statistically not significant ($P < 0.05$). At 10% okra juice addition to the orange juice, the ABTS scavenging ability were 67.8% freshly prepared, 67.4%-day 7 storage and 67.2%-day 14 storage.

FRAP and TAC antioxidant properties

The Ferric Reducing Antioxidant Power (FRAP) as mg Fe^{2+}/100g and Total Antioxidant Capacity (TAC) as mg AAE/100g of the okra orange juice blend is presented in Fig 3&4. The result in Figure 3 showed that the orange juice and the okra orange juice blend exhibited a very good ferric reducing antioxidant property. The reducing antioxidant property is percentage okra juice added dependent and as percentage of okra juice added to the orange juice increased FRAP increased. The orange juice had a FRAP of 64.3 mg Fe^{2+}/100g, which increased to 81.3 mg Fe^{2+}/100g when 2% okra juice was added to the orange juice and increased further to 104.7 mg Fe^{2+}/100g at 10% addition of okra juice to the orange juice. The freshly prepared orange juice blend has a significant reducing antioxidant property on iron than the stored orange juice blend except 10% orange juice blend where there was no significant ($P < 0.05$). difference in FRAP (104.7 freshly prepared, 103.5-day 7 storage and 103.0-day 14 storage). It is to be noted that there was no significant difference ($P < 0.05$) in FRAP of stored orange juice blend (day 7 and day 14) at every percentage of okra juice added.

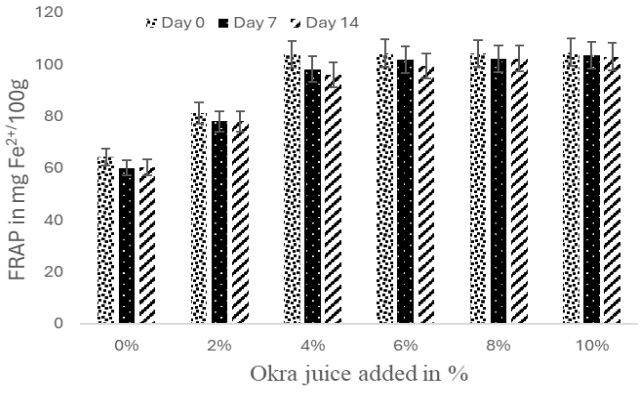

Figure 3. Ferric Reducing Antioxidant Power (FRAP) of okra orange juice blend. Values are mean of triplicate determination ± standard deviation.

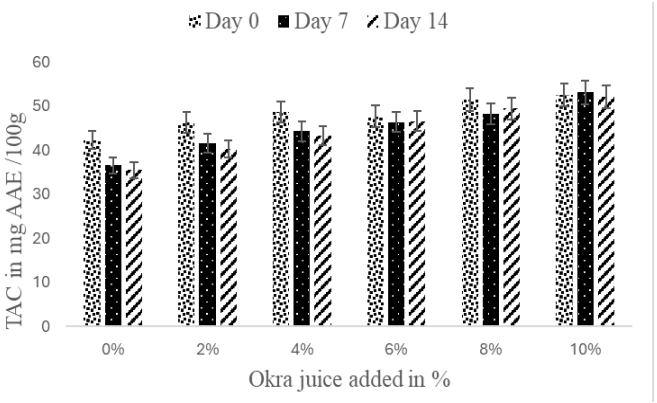

Figure 4. Total Antioxidant Capacity (TAC) of okra orange juice blend. Values are mean of triplicate determination ± standard deviation.

Phosphomolybdate assay is a quantitative method used for TAC determination of orange juice and okra orange juice blend (Figure 4). It showed from our study that the antioxidant capacity of both orange juice and okra orange juice blend repressed Mo^{5+} complex. The TAC of the orange juice blend showed the same trend as the FRAP. The freshly prepared orange juice blend had a significant ($P < 0.05$) total antioxidant capacity than the stored orange juice blend except 10% orange juice blend (52.5 freshly prepared, 53.1-day 7 storage and 52.7-day 14 storage). The antioxidant capacity of both orange juice and okra orange juice blend to repress Mo^{5+} complex was not significantly different ($P < 0.05$) in storage (day 7 and day 14) at every percentage of okra juice added.

α-amylase and α-glucosidase

It showed from this result that orange juice and okra orange juice blend inhibit α-amylase and α-glucosidase (Fig 5&6). When okra juice was added to the orange juice, the inhibitory activity against α-amylase and α-glucosidase increased as the percentage of okra juice added increased.

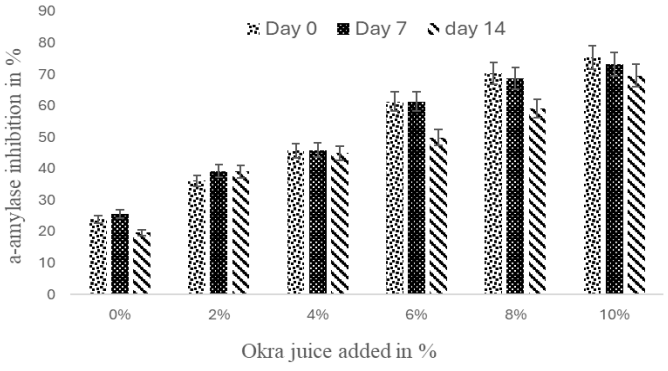

Figure 5. a-amylase activity inhibition by okra orange juice blend. Values are mean of triplicate determination ± standard deviation.

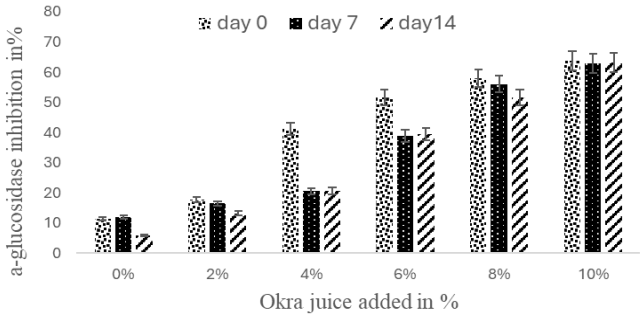

Figure 6. a-glucosidase activity inhibition by okra orange juice blend. Values are mean of triplicate determination ± standard deviation.

The inhibition of α-amylase by freshly prepared okra orange juice blend is not significantly different from okra juice blend stored for 7 days at every percentage okra juice added. The lowest and significant ($P < 0.05$) inhibition was exhibited by juice blend stored for 14 days (0% okra juice addition 19.6% inhibition, 2% okra juice addition 37.0% inhibition, 4% okra juice addition 45.9% inhibition, 6% okra juice addition 53.9% inhibition, 8% okra juice addition 59.1% inhibition, 10% okra juice addition 69.6% inhibition), (Fig 5). In the case of α-glucosidase, the freshly prepared orange juice blend at every percentage of okra juice added was significantly ($P < 0.05$) higher than when stored except at 10% okra juice addition (63.7% day 0, 62.8% day 7 and 63.2% day 14). The okra orange juice blend stored for 14 days also exhibited the lowest α-glucosidase inhibition (Fig 6). It is to be noted that the okra orange juice blend exhibited a higher α-amylase inhibition when compared with α-glucosidase even in storage.

DISCUSSION

Type 2 Diabetes mellitus (T2DM), a metabolic disease exemplified by hyperglycemia as a result of abnormal insulin secretion or action with polydipsia, polyuria and polyphagia as symptoms (Khodija *et al.,* 2020). The most popular fruit juice worldwide is orange juice, this is because of its fruity flavour and nutraceutical compounds like vitamin C, hesperidin, naringenin, and carotenoids with powerful radical scavenging and antioxidant properties (Tobolkova et al 2024). Okra plays an important role in diets due to its content of minerals, fibre, blood glucose reduction properties and Glucagon like peptide 1 receptor (GLP-1R). Okra fibre and polysaccharide content can cause delay in emptying the stomach leading to reduction in carbohydrate absorption in small intestine and thus longer satiety. Okra is full of antioxidants that can counter free radicals and prevent oxidative stress thus an awakened interest in the potential of okra as food and pharmaceuticals (Khodija *et al.,* 2020, Williams *et al.,* 2023).

The total phenol content (TPC) of the orange juice increased significantly ($P < 0.05$) as the percentage of okra juice added increased, when okra was incorporated into foods and juice, it always increases the total phenol and total flavonoids as reported by various researchers (Samakradhamrongthai *et al.,* 2024, Nuramalia and Damyanthi 2018, Ray *et al.,* 2017, Adetuyi and Komolafe 2011). Total phenolic compound has been suggested by several studies, to be the main contributors to okra fruits antioxidant potential and okra most abundant antioxidant substances (Fabianova *et al.,* 2022). It has been previously reported in different studies that okra fruits (peels and seeds) contain high polyphenolic compounds, like quercetin derivatives (rutin, quercetin-3-O-glucoside (isoquercitrin) and quercetin-3-O-gentiobioside), quercetin-3-O-gentiobioside was the most abundant of the phenolic compounds Arapitsas, 2008, Elkhalifa *et al.,* 2021). Plant phenolics is laced with ample biological effects, they constitute the major phytochemical compounds with antioxidant or terminator of free radical (Zarena and Sankar, 2009). This high phenolic content of okra juice and orange juice blend is an indication that the resultant juice will be of high antioxidant activity. The redox properties exhibited by total phenolic makes them to act as a powerful antioxidant (Nuramalia and Damayanthi 2018). At the different storage days, the total phenol of the okra orange juice blend was significantly higher than the orange juice. TFC of the orange and okra juice blend had a higher value as the okra juice were added. Flavonoids are oxidized by free radicals forming less reactive species using four pathways, inhibition of these enzymes nitric-oxide synthase and xanthine oxidase, modulation of channel pathways and interaction of enzyme systems. Its antioxidant potential depends on its molecular structure, precisely, location and total number of hydroxyl (–OH) (Ullah et al, 2020). Flavonoids exhibit a more powerful antioxidant than vitamin C and E (Prochazkova *et al.,* 2011). In storage, the total flavonoids have a similar trend like the TPC, the TFC of the okra orange juice blend had a higher value when the okra juice added at different storage periods.

The DPPH assay is a method used for the evaluation of the radical-scavenging capacity of antioxidant compounds, either individually or combined. It is a lipid-soluble free radical that forms a stable product upon receiving an electron or hydrogen atom from an antioxidant, a simple and renowned method, cost-effective, fast, while also delivering highly reproducible results (Silva *et al.,* 2024, Agunbiade *et al.,* 2022). DPPH assay depends on spectrophotometric assessments of the capacity of antioxidants to scavenge DPPH radicals. The orange juice and the okra orange juice blend scavenged DPPH radicals and the scavenging abilities increases with an increase in the percentage of okra juice added. In the assessment of the antioxidant ability of bioactive compounds, ABTS is a commonly used substrate (Agunbiade, *et al.* 2022). It is a spectrophotometric method which relies on the quenching capability of stable-colored radicals, thereby showing the radical-scavenging ability of antioxidants. This method can evaluate the antioxidant abilities in hydrophilic and lipophilic samples because ABTS radical is soluble in both water and organic solvents. A key limitation of this assay is the instability of the radicals formed, making the results not reproducible. Despite this, the ABTS assay remains widely used for measuring antioxidant activity (Shah and Modi 2015). The ABTS scavenging ability result revealed that

orange juice and the okra orange juice blend scavenge ABTS radicals and the ABTS scavenging ability of the okra orange juice blend increased as the percentage of added okra juice increased. These results indicated that there is a synergistic effect between orange juice and okra juice which makes the blend to exhibit a higher ABTS scavenging ability than the orange juice. The observed DPPH and ABTS radical scavenging ability in this work may be attributed to the higher amount of phenols and flavonoids in okra orange juice blend than orange juice. Phenolics and flavonoids donate electrons or hydrogen to DPPH radical for stabilization and to scavenge it, the DPPH results are used to confirm the results obtained in total phenolic content (Adetuyi *et al.,* 2020).

The orange juice and the okra orange juice blend exhibited a high ferric reducing antioxidant power FRAP. The reducing antioxidant property is percentage okra added dependent and as percentage of okra juice added to the orange juice increased, FRAP increased. Performing FRAP assay is easy and very quick; it is a reproducible reaction and directly proportional to the antioxidant molar concentration (Hodzic et al. 2009). There are two major specific glucopyranoside compounds methylflavonol-3-O-β-D-glucopyranoside and flavonol, 3-O- [β -D-glucopyranosyl-(1,6)]-β-D-glucopyranoside identified as the antioxidant that carried out the ferric reducing activities of okra (Liao et al 2012). The phosphomolybdate assay depend on molybdenum (IV) been reduced to molybdenum (V) a green colour, by the antioxidant. This assay has been reported to be very effective in evaluating the total antioxidant capability of different plant extracts (Mbinda and Musangi 2019). Phosphomolybdate assay is a quantitative method used for TAC determination, the antioxidant capacity of both orange juice and okra orange juice blend repressed Mo^{5+} complex. The TAC of the orange juice blend showed the same trend as the FRAP. Excess glucose can cause increase in Acetyl-CoA and nicotinamide adenine dinucleotide in the mitochondria leading to accumulation of free radicals and oxidative stress (Nikpayam *et al.,* 2021). Oxidative stress does alter the function of β-cells leading to type 2 diabetes (Russell *et al.,* 2002). Polyphenolics in okra can cause improvement in the pancreatic β-cells functions by decreasing oxidative stress and effects of free radical (Nikpayam *et al.,* 2021). The synergy of the action of phenolics, flavonoids, scavenging abilities and reducing potentials of the okra orange juice blend coupled with the high vitamin C content of orange juice resulted into increased total antioxidant capacity TAC of the okra orange juice blend thus the okra orange juice blend has a potential benefit of decreasing free radicals when consumed in sufficient quantity.

α-amylase and α-glucosidase in the intestine are key enzymes in carbohydrate digestion in humans. These enzymes inhibitors may be effective in slowing down carbohydrate digestion and glucose absorption to repress postprandial hyperglycemia (Tadera *et al.,* 2006). When okra juice was added to the orange juice, the inhibitory activity against α-amylase and α-glucosidase increased as the percentage of okra juice added increased. Inhibiting these carbohydrate metabolic enzymes is the major way used to thwart the metabolic activities related to hyperglycemia and diabetes. There are many studies that has showed that okra fruits extract exhibits remarkable α-amylase and α-glucosidase inhibitory activities (Wu *et al.,* 2020). Okra fruit has been reported to contain proanthocyanidins (epi - gallocatechins and epi – catechins) which has a significant inhibition effect on the α-glucosidase and α-amylase activities (Shen et al., 2019). Okra powder and okra extract has been found to reduce blood glucose when administered on Wistar rat (Nikpayam *et al.,* 2021).

There is increasing interest in Okra to be utilized as ingredients of functional food because of its various benefits to human health like α-glucosidase and α-amylase inhibition properties (Yu *et al.,* 2023). The antihyperglycemic benefit of okra orange juice blend is as a result of the postprandial blood glucose level control via the inhibition of carbohydrate-digesting enzymes α-amylase and α-glucosidase. It was revealed through this study that the okra orange juice blend exhibited a higher α-amylase inhibition when compared with α-glucosidase even in storage. This is an indication that less amounts of polysaccharides are converted to oligosaccharides and to monosaccharides (glucose) thereby reducing the rate of absorption of glucose in the small intestine. This is because α-amylase, a protein enzyme, assist in breaking down of polysaccharides like starch into oligosaccharides while α-Glucosidase, a membrane-bound enzyme aids in the hydrolysis of oligosaccharides into monosaccharides (Reyes, et al 2018). A promising approach for the control of blood glucose and management of diabetes, especially type 2, is to reduce postprandial hyperglycemia through inhibition of these carbohydrate hydrolyzing enzymes. These enzyme inhibitors made carbohydrate digestion to slow down thereby prolonging total digestion time, leading to a reduction in absorption of glucose with a consequent postprandial plasma glucose blunt (Li *et al*., 2018).

CONCLUSION

This study showed that the total phenol and flavonoid content of orange juice was enhanced by the addition of okra juice and increased significantly ($P < 0.05$) with an increase in the percentage of okra juice added. In storage, the TPC and TFC of the okra orange juice blend was significantly higher than the orange juice at different storage days and they were stable. The orange juice and the okra orange juice blend scavenged DPPH and ABTS radicals, the scavenging abilities increases with an increase in the percentage of okra juice added. The freshly prepared okra orange juice blend recorded the highest DPPH scavenging abilities when compared to the stored juice except at 10% okra juice addition. The result of ABTS scavenging ability showed that at every percentage of okra added, there difference was not significant ($P < 0.05$) between the freshly prepared juice and stored juice. The orange juice and the okra orange juice blend exhibited a very good FRAP and total TAC properties. The FRAP and TAC of the okra orange juice increased with an increase in the percentage of okra juice added. The freshly prepared okra orange juice blend had a significant reducing antioxidant property on iron and total antioxidant capacity than the

stored okra orange juice blend except 10% orange juice blend where the difference was not significant ($P < 0.05$). The orange juice and okra orange juice blend inhibit α-amylase and α-glucosidase, the inhibitory activity of okra orange juice against α-amylase and α-glucosidase increased with an increase in the percentage of okra juice added. The inhibition of α-amylase by freshly prepared okra orange juice blend is not significantly different from okra orange juice blend stored for 7 days at every percentage of okra juice added. In the case of α-glucosidase, the freshly prepared okra orange juice blend at every percentage of okra juice added was significantly ($P < 0.05$) higher except at 10% okra juice addition where the difference was not significant ($P < 0.05$) to stored sample. The okra orange juice blend exhibited a higher α-amylase inhibition when compared with α-glucosidase even in storage. Hence, the okra orange juice blend has the potential of stabilizing free radicals and control the postprandial blood glucose level. The 10% okra orange juice blend can be a better natural antioxidants source and be used in formulating functional beverage for the mitigation of hyperglycemia, thus prevention and management of diabetes. The future research will be focused on in-vivo study to ascertain the safety of the produced juice, sensory evaluation and extension of the storage period.

AUTHORS' CONTRIBUTIONS

FUNDING STATEMENT

This research work was funded by Tertiary Education Trust Fund (TETFUND) under grant YEAR(S) 2022/2024 (merged) Tetfund Intervention in research project (rp). OAUSTECH/TETFund/VOL.4/002.

CONFLICT OF INTEREST

No potential conflict of interest was reported by the author(s).

CONFLICT OF INTEREST

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ACKNOWLEDGEMENT

The authors would like to appreciate Tertiary Education Trust Fund (TETFUND) of the Federal Government of Nigeria for supporting this study.

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