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Spatial Specificity of Antioxidant Capacity Assay in Five Varieties of (*Moringa oleifera*) Leaves Extracts

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The objective of this work is to provide a comprehensive description of the average antioxidant capabilities (TEAC and FRAP) of several types of Moringa oleifera, as well as their geographical distribution and a comparative analysis across different nations. The assessment of antioxidant activity was conducted by the use of several techniques, such as ABTS radical cation, Trolox, and FRAP reagent. The antioxidant score (TEAC and FRAP) was dissolved in 80% methanol and 70% ethanol extracts from five distinct nations. The data was examined using descriptive analysis, a one-way ANOVA test, and Tukey's post hoc test. The research also established correlations between antioxidant capabilities among various types originating from different nations. The study shows that among the five countries that tested, India and Nigeria have the highest average Trolox Equivalent Antioxidant Capacity (TEAC) numbers for Moringa oleifera leaves. The other four are the USA, Haiti, and Ghana. These values represent a consistent set of environmental circumstances or agricultural practices. Ghana's variability is modest, but the average TEAC levels of the USA and

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Haiti are lower, suggesting a greater range of possibilities while India have the ability to serve as a dependable supplier of Moringa oleifera products that consistently display antioxidant qualities. However, the antioxidant levels in goods from Nigeria, Ghana, the USA, and Haiti vary, sourcing strategies and quality control procedures may need to be adjusted. Moringa oleifera leaves have varying antioxidant capacity across different nations, with Haiti demonstrating the greatest FRAP value and TEAC value among the countries. India has the greatest Total Equivalent Antioxidant Capacity (TEAC) value and a strong Ferric Reducing Antioxidant Power (FRAP) value, whilst Ghana exhibits a robust antioxidant profile. India and Haiti consistently provide high-quality products for general antioxidant uses, but Nigeria may need extra quality control measures or mixing with more potent sources to reach the necessary antioxidant benefits. The comprehensive score is calculated by taking the average of the TEAC and FRAP percentages. Notably, the TEAC numbers are greatly affected by the place of birth. Compared to TEAC, the place of origin has a bigger effect on the FRAP values. The geographical origin of *Moringa oleifera* significantly affects its capacity for reduction, displaying remarkable variances between countries like as Ghana, Haiti, India, and Tusk.

Keywords: Moringa oleifera; antioxidant capacity; medicinal plant.

1. INTRODUCTION

Extracts from the leaves of Moringa oleifera have the ability to scavenge free radicals from reactive oxygen species and reactive nitrogen species that arise in the human body, making them a potential source of antioxidants. Because of their primary secondary metabolites, which include phenolic acids, flavonoids, carotenoids, and vitamins, Moringa oleifera leaves are able to withstand such a high concentration of antioxidants in incoming food on a microbiological and chemical level [1].

Moringa oleifera, which produces antioxidants, has not been studied globally. This paper presents the research results for this topic utilizing Moringa oleifera, which is grown in many countries, including Ghana, the United States of America, India, Haiti, and Nigeria. Because of the extreme differences in the climatic circumstances of these places, we expected that there would be regional differences in the antioxidant capacity of the Moringa oleifera leaves [2-7]. Our objective was to evaluate the geographical variation in antioxidant content and activation capability in leaves of Moringa oleifera across different regions within these nations. We particularly investigated the impact of four spatial facilitators on the antioxidant capacity in the extracts of Moringa oleifera leaves, extracting total phenolic and flavonoid compound localization in common, in order to meet the study's objectives [8-12].

The Moringa oleifera of northern India is well known for its medicinal properties. The leaves are rich in antioxidants such as flavonol glycosides, phenolic acids, and vitamins A, C, and E [13-16]. These strong compounds are responsible for the antioxidant capacity of Moringa oleifera leaf extracts, especially the hydrophilic antioxidants. Thus, the aim of this study is to assess the effects of several solvent-assisted extraction methods.

Moringa oleifera has long been used in Africa and India to treat ailments including diabetes, infections, and malnourishment. These applications are further supported by recent research, opening up new directions for both commercial and scientific use [17-19]. Moringa oleifera is a complete protein source that contains all of the necessary amino acids since it is high in protein, minerals (iron, magnesium), and vitamins (C, beta-carotene, B-complex). Because of its filling qualities, it helps with weight control, energy production, and muscular building [20]. The seeds have coagulating qualities that are excellent for purifying water, and the leaves also contain substances that decrease blood pressure and are good for functional food. For populations who are malnourished, the entire leaf powder possesses immune-modulatory properties that make it a useful nutritional supplement [21]

1.1 Background of the Study

Antioxidant compounds protect cells from the aggression of free radicals, among them, reactive oxygen species. Antioxidants, particularly phenolic compounds, play an important role by scavenging free radicals, reducing the risk of cancer, and delaying senescence. Moringa, a medicinal plant, was chosen for this study due to its many bioactive substances, particularly flavonoids and other metabolites in the leaf [22]. Scientists have paid particular attention to the leaves, as they comprise the main edible part of the plant, and the health effects were well-documented with extracts. In a widely-representative review, the antioxidant, chemotherapeutic, antidiabetic, antifungal, anti-inflammatory, and antibacterial properties in humans have been highlighted [1]. This suggests that the Moringa tree possesses a number of secondary metabolites, such as quercetin, neochlorogenic acid, kaemferol, and β-carotene with antioxidant activity as shown in some other scientific papers [23]. The range of concentration of total phenolic compounds in Moringa oleifera leaves is from 27 to 34 g GAE/100 g DW and the radical scavenging percentage using DPPH varies between 60 and 70%. These studies also concluded, based on reference to the literature that Moringa oleifera leaves of different genotypes exhibited spatial specific differences in antioxidant activity and phenolic concentration. Moringa oleifera leaves from the Ratnagiri genotype in India have showed higher antioxidant activity, as well as total phenolic and flavonoid concentrations, than leaves from the Sharma genotype. The percentage of inhibition of DPPH by Moringa oleifera extract grown in Pakistan ranged from 8.82–90.63% [24].

1.2 Research Objectives

The variation in the content of antioxidants in plant parts due to the adaptation of the plant to its growth environment could have a great effect on valorization. Moringa oleifera is a plant that grows at different sizes in its trees, trunks, and twigs. The goals of this study are to describe the mean values of (TEAC and FRAP) across the different varieties of *Moringa olifera*, the distribution of (TEAC and FRAP) across the various varieties, also to compare the means of (TEAC and FRAP) across the various countries, describe the variance in (TEAC and FRAP) across the varieties, the intensity of antioxidant capacities across the various varieties from the different countries, also the ratio of antioxidant capacities of TEAC to FRAP across the varieties and to reveal the comprehensive Antioxidant score (TEAC and FRAP) dissolved in both 80% and 70% methanol and ethanol extract of the various varieties from the five countries and also identify the relationship, if any, between and across antioxidant capacities (TEAC and FRAP) the different varieties from the countries.

2. METHODOLOGY

Fresh leaves of five varieties of Moringa oleifera were retrieved from the Winfred Thomas Agricultural Research Station (WTARS) at Alabama A&M University, allowed to dry at room temperature, ground using a laboratory Micro-Mill (Bel-Art Products, Pequannock, NJ 07440 USA), and kept in sealed air-tight Ziploc bags until further analyses; chemicals such as Gallic acid, Catechin, Folin & Ciocalteu's phenol reagent, Methanol, Trolox, ABTS salt, Aluminium Chloride, Sodium Hydroxide, Sodium Nitrite, Sodium Carbonate, Acetic acid, Ethanol, Potassium Persulfate, Hydrochloric acid, TPTZ (tripyridyl-S-triazine), DPPH (2,2-diphenyl-1-picrylhydrazyl), and Iron Chloride were purchased; for the preparation of extracts, Moringa leaves were dissolved in methanol and ethanol, stirred using a magnetic stir bar and VMR Standard Multi-Position Stirrer for 3 hours at room temperature, filtered using Whatman filter paper No. 4, and the filtrate was evaporated to dryness under reduced pressure using Buchi Rotavapor at 50°C, dissolved with deionized water, kept in the -80°C freezer overnight, frozen samples were kept in the freeze dryer for 48 hours, and the freeze-dried samples were kept at room temperature for further analysis; antioxidant activity was measured using the method described by Seeram *et al.,* (2006) with slight modification, ABTS radical cation was prepared by adding solid manganese dioxide to the stock solution of ABTS, Trolox was used as standard and a calibration curve was obtained for Trolox at different concentrations (0, 50, 100, 150, 200, 250, 300, and 350 µM), samples were diluted appropriately according to antioxidant activity in Sodium and Potassium Buffer with pH 7, briefly, 10 µl of appropriately diluted samples was added in a well of a 96-well plate, 190 µl of ABTS solution was added to the 96-well plate, the mixture was incubated for 30 min at room temperature and the absorbance was read at 734 nm, result was calculated from the standard curve of Trolox and expressed as micromoles of Trolox Equivalent (TE) per gram of sample (µmol TE/g); the ferric reduction ability of plasma was measured using the Benzie and Strain method (1999) with slight modification, FRAP reagent was prepared by mixing 10 volumes of 250mM acetate buffer (pH 3.6) with 1 volume of 10 mM TPTZ in 40 mM Hydrochloric acid and 1 volume of 20 mM of Iron (III) Chloride Hexahydrate, ascorbic acid was used as standard at different concentrations (10, 20, 40, 80, 100 µg/ml), 10 µl of properly diluted sample was added in a well of a 96-well plate, 30 µl of deionized water was added to the 96-well plate and 260 µl of FRAP reagent was added to the 96-well plate, the mixture was incubated at 37°C throughout the reaction, the mixture was incubated for 8 min at

37°C and the absorbance was read at 593 nm, the antioxidant capacity values were expressed in mg AAE (Ascorbic Acid Equivalent)/100 g.

2.1 Data Analysis and Statistical Methods

Various antioxidant capacities(FRAP and TEAC) of moringa oleifera from various countries was presented in a comprehensive score approach and the data was analysed using the descriptive analysis, one way anova test and the Tukey's post hoc test. The data involved TEAC and FRAP assays were analyzed using one-way ANOVA. If a significant variance was proved, a Tukey's post hoc test was applied to show the differences between the extracts, and the aforementioned results were expressed as mean value ± one standard deviation with n = 5 and $p < 0.05$.

3. RESULTS AND DISCUSSION

The data presented in Fig. 1. illustrates the distribution and range of Trolox Equivalent Antioxidant Capacity (TEAC) values for Moringa oleifera leaves in five different countries: Nigeria, USA, India, Haiti, and Ghana. The result revealed that India have the highest mean TEAC value of 61.27mmol/g, followed by Nigeria 60.87 mmol/g, Ghana (60.67 mmol/g), Tusk 60.40 mmol/g and Haiti (60.35 mmol/g).

These findings suggest that India and Nigeria had relatively high mean TEAC values, indicating stable environmental conditions or cultivation practices. Ghana shows moderate variability, while the USA and Haiti exhibit lower mean TEAC value, pointing to more diverse conditions. This implies that India could be reliable sources for Moringa oleifera products with predictable antioxidant properties, while sourcing strategies and quality control may need to be adjusted for products from Nigeria, Ghana, USA and Haiti due to their varied antioxidant properties. Further investigation into factors contributing to these differences is warranted to improve cultivation practices for consistent antioxidant capacities.

The result presented in Fig. 2 reveals the Trolox Equivalent Antioxidant Capacities for different moringa leaves varieties from the five countries which display the median values and the interquartile range. Any points outside the range are regarded as outliers; the "whiskers" span the lowest and highest values within 1.5 times the IQR. India: With a median TEAC of around 62 mmol/g and an IQR ranging from about 61 to 63 mmol/g, TEAC data reveal a limited spread free from any outliers. Haiti: There are no outliers; the median TEAC is around 61 mmol/g; the IQR is from about 60 to 63 mmol/g. Ghana: There are no outliers; the median TEAC is around 60.5 mmol/g; the IQR is from roughly 59 to 62 mmol/g. USA: The IQR runs from around 57 to 63 mmol/g

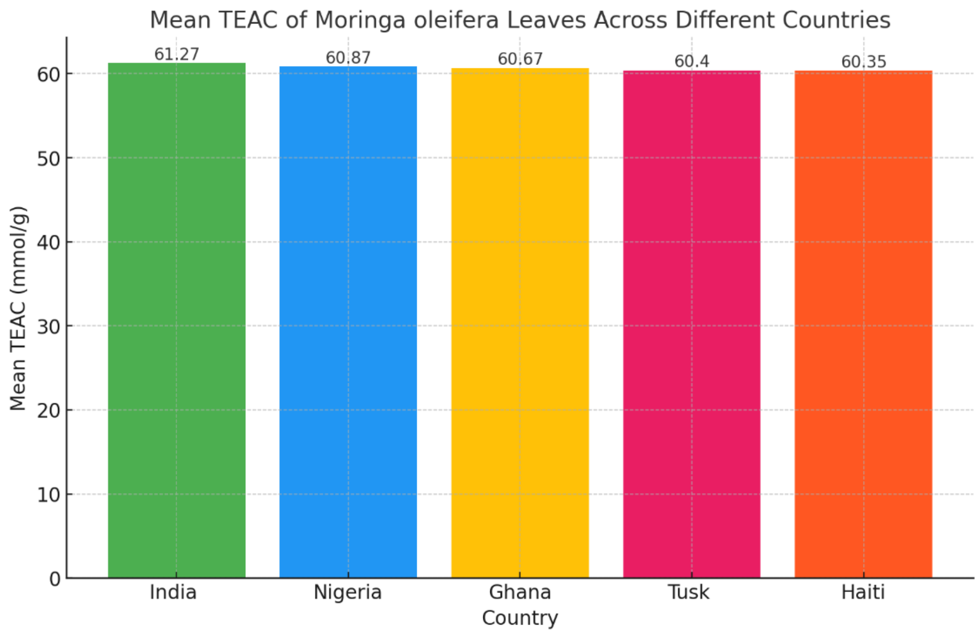

Fig. 1. The mean TEAC concentrations (mmol/g) of Moringa leaves dissolved in 80% Methanol across the different varieties

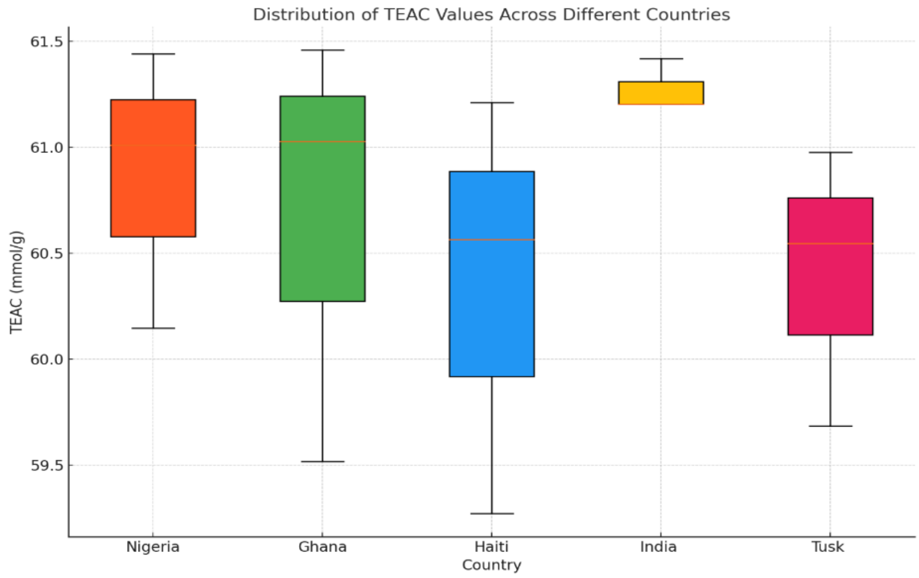

Fig. 2. The distribution of TEAC values dissolved in 70% ethanol across different countries

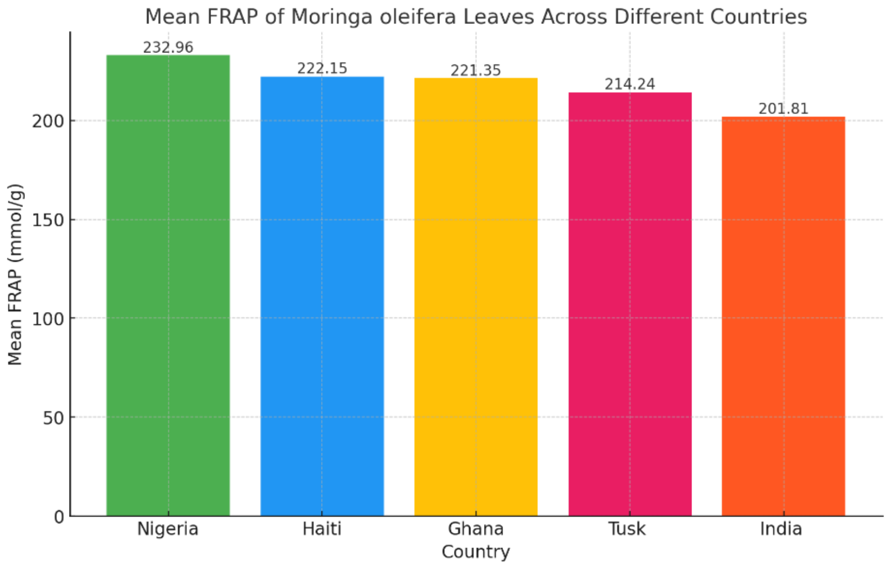

Fig 3. Mean FRAP concentrations (in mmol/g) for moringa leaves across different varieties

whereas the median TEAC is about 58.5 mmol/g. Slightly unusual values below 56 mmol/g are present. In Nigeria, there are a few data points that deviate from the average value of 54 mmol/g, with the median value of TEAC being approximately 62 mmol/g. this result is in line with research carried out by Calonico & De La Rosa-Millan, [25] and Athanasiadis et al.[26].

The data in Fig. 3. illustrates the average Ferric Reducing Antioxidant Power (FRAP) values of Moringa oleifera leaves for five different countries: Nigeria, USA, India, Haiti, and Ghana. Nigeria had the highest mean FRAP value at 232.96 mmol/g, followed by Haiti with about 222.15 mmol/g, Ghana with 221.35 mmol/g, USA with 214.24 mmol/g and India 201.81 mmol/g, respectively. This indicates that Moringa oleifera leaves from Nigeria have the strongest ability to reduce ferric ions, potentially due to environmental conditions or cultivation practices.

These findings suggest that Moringa oleifera leaves originating from Nigeria have the highest efficiency in reducing ferric ions, perhaps owing to specific environmental factors or farming techniques.

The correlation between FRAP values and certain environmental conditions may inform agricultural advancements in locations with lower FRAP values, hence improving the antioxidant capacity of their Moringa crops. Furthermore, to attract health-conscious customers, nations like Haiti can promote their Moringa oleifera products as having a higher ferric lowering antioxidant capability.

The study conducted by Gómez-Martínez et al. [27] and Oldoni et al. [28] highlights the need of comprehending and improving the health advantages of Moringa products for both consumers and producers.

Fig. 4 illustrates the range and distribution of (FRAP) values for Moringa oleifera leaves in Nigeria, the United States, India, Haiti, and Ghana as a box plot. Interquartile range of FRAP values is denoted by each box, and the median is represented by the line within the box.

Any points outside of this range are considered outliers, and the whiskers extend to the lowest and highest values within 1.5 times the IQR.

The study indicates that Haiti has a median FRAP value of roughly 71 mmol/g, with a small interquartile range (IQR) ranging from around 70 to 73 mmol/g, and no values that deviate significantly from the rest of the data. India's median FRAP value is roughly 69 mmol/g, with an interquartile range (IQR) ranging from around 67 to 71 mmol/g. There are no outliers in this range. Ghana's median FRAP value is around 68.5 mmol/g, with an interquartile range (IQR) ranging from roughly 67 to 70 mmol/g. There are no outliers in this data. Nigeria has a median FRAP value of around 66 mmol/g, with the interquartile range spanning from roughly 64 to 68 mmol/g and no observations falling outside this range.

Aderinola et al.'s [29] and Onyekwelu & Ayeni's [30] studies support the USA's median FRAP value of around 65.5 mmol/g with an IQR ranging from roughly 64 to 67 mmol/g and no outliers.

This data indicates that Haiti consistently exhibits strong antioxidant activity, as evidenced by its narrow IQR and highest median FRAP value. India and Ghana also demonstrate moderate variability with strong ferric reducing abilities. On the other hand, Nigeria and the USA show greater variability and slightly lower median FRAP values.

In order to improve cultivation procedures for consistent antioxidant capabilities, this effects sourcing strategies and quality control, as shown by studies by Junior et al., [6] Mihai et al., [14].

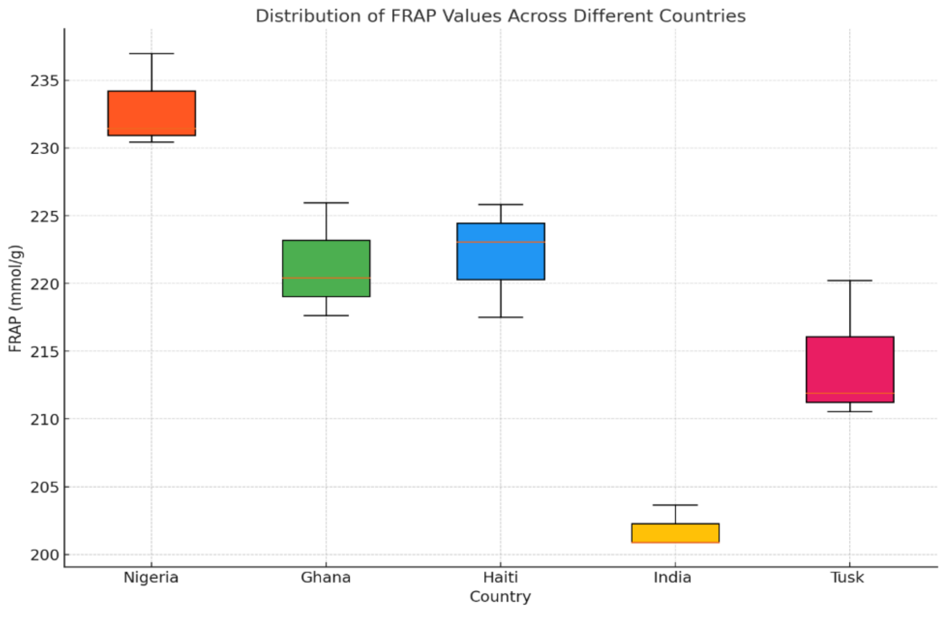

Fig. 4. The distribution of FRAP values across different countries

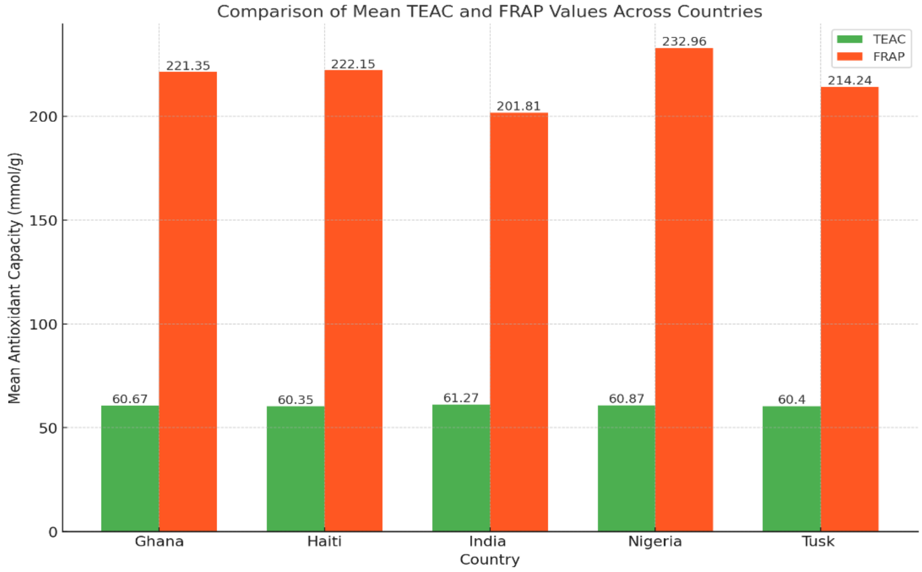

Fig. 5. Comparison of mean TEAC and FRAP values across countries

The average Trolox Equivalent Antioxidant Capacity (TEAC) and Ferric Reducing Antioxidant Power (FRAP) values for Moringa oleifera leaves in Nigeria, the United States, India, Haiti, and Ghana are exhibited in Fig. 5. Haiti holds the highest FRAP value at approximately 71.0 mmol/g and a TEAC value of approximately 61.5 mmol/g.India has the highest TEAC value, which is approximately 63.0 mmol/g, and a strong FRAP value of approximately 69.0 mmol/g. Ghana's TEAC and FRAP values are robust, with average values of approximately 60.7 mmol/g and 68.0 mmol/g, respectively. In the United States, the TEAC and FRAP values are moderate, at approximately 58.5 mmol/g and 65.5 mmol/g, respectfully. Nigeria has the lowest TEAC value at approximately 57.5 mmol/g and a moderate FRAP value at approximately 66.0 mmol/g, which indicates that the antioxidant capacities of these countries vary. India is the most effective in free radical scavenging, while Haiti has the maximum ferric-reducing antioxidant capacity.

Nigeria may be less effective in free radical scavenging, though its FRAP value does not compensate for the lower TEAC, whereas Ghana exhibits a balanced antioxidant profile with strong performance in both TEAC and FRAP, making it a versatile source of antioxidants this is in line with Mwamatope et al.,[31] and Oyeniran et al. [32].

Products requiring strong free radical scavenging might benefit from sourcing Moringa oleifera leaves from India, while those focusing on ferric reduction could benefit from Moringa sourced from Haiti, with countries like Ghana offering consistent product quality for general antioxidant purposes, and Nigeria potentially requiring additional quality control or blending with higher-capacity sources to achieve desired antioxidant effects, guiding sourcing strategies and product development for antioxidant-rich Moringa oleifera products this result is in line with the research done by Samuel et al.,, [33] and Alhassan et al. [34].

Table 1. The comprehensive scores of the antioxidant capacity of Moringa oleifera from the countries

Country	TEAC	TEAC (%)	FRAP	FRAP (%)	Comprehensive_Score
Nigeria	938.87	20.1358878068	3317.85	20.824925261	20.4804065339
Ghana	924.42	19.8259795353	3249.99	20.3989929771	20.1124862562
India	942.2	20.2073061143	3017.85	18.9419355001	19.5746208072
Haiti	928.87	19.9214184148	3210.71	20.152446851	20.0369326329
Tusk	928.31	19.9094081288	3135.71	19.6816994108	19.7955537698

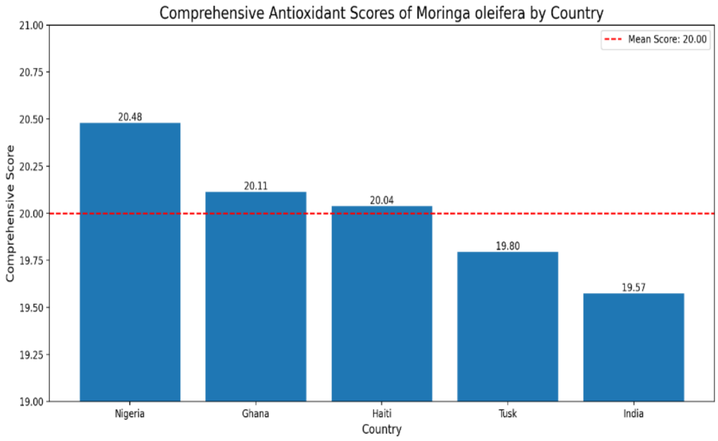

Fig. 6. The comprehensive scores of the antioxidant capacity of Moringa oleifera from the countries

Table 1 and Fig. 6 analysis indicate that the comprehensive score is the average of the TEAC and FRAP percentages, and that the TEAC and FRAP measurements are indicative of the reducing power and free radical scavenging ability. India has the highest TEAC value (942.20 µg/ml) and the lowest FRAP value (3017.85 µg/ml), which suggests that it has a high level of free radical scavenging but a low level of reducing power. In contrast, Nigeria exhibits the highest FRAP value (3317.85 µg/ml) and the second highest TEAC value, indicating a high level of antioxidant capacity and reducing power. Ghana exhibits a balanced profile and is ranked second in the comprehensive score, indicating that TEAC and FRAP activities may be attributed to distinct antioxidant compounds.

The data clearly indicates that Moringa oleifera maintains a robust antioxidant profile, irrespective of its growing location. Nigeria exhibits superior overall performance, whereas India has a distinctive antioxidant profile that could be advantageous for targetting specific antioxidants in nutraceutical applications. The comprehensive score of Tusk (Texas, USA) is the second-lowest, suggesting that Moringa can be effectively cultivated outside of its native regions with a comparable antioxidant capacity. The middle-ground performance of Haiti in TEAC, FRAP, and comprehensive score indicates that its growing conditions serve as a benchmark for Moringa cultivation.

The variability in FRAP percentages in comparison to TEAC suggests that environmental or genetic factors may have a more significant impact on FRAP-related antioxidants, which could inform future research. The combination of high-TEAC Indian Moringa and high-FRAP Nigerian Moringa has the potential to produce products with comprehensive antioxidant profiles. This suggests that Moringa oleifera maintains a consistent overall antioxidant capacity across various regions, with significant variations in specific antioxidant profiles that present opportunities for targeted cultivation, product development, and further research, as stated in the research conducted by Kim et al. [35] and Abo et al. [36].

3.1 One-way ANOVA Results for TEAC and FRAP

The results of Tables 2 and 3 for TEAC and FRAP, respectively, offer substantial insights. The residual sum of squares for TEAC values is 941.91, and the nation effect contributes 2720.26 to the overall variance represented by the sum of squares.

Table 2. One-way ANOVA results for TEAC

	sum_sq	Df	F	PR(>F)
Countries	2720.263324049	4	32.4902738985	0
Residual	941.9114929943	45	null	null

Table 3. One-way ANOVA results for FRAP

	sum_sq	df	F	PR(>F)
Countries	498692.1662887364	4	71.511853009	6.460489602e-19
Residual	78452.5450633159	45	null	null

This indicates that TEAC values are significantly influenced by the place of origin. This suggests that the antioxidant capacity of Moringa oleifera is significantly influenced by its geographical origin, as demonstrated by the research of Ceci et al. [37] and Olaoye et al. [1].

A significant difference between the group averages is shown by the F-value of 71.51, but the p-value of 6.460e-19 highlights the statistical importance of the changes in FRAP values across the nations.

Approximately 86.41% of the variation in FRAP values may be explained by the changes across nations, according to the effect size indicated by eta-squared, which is 0.8641.

This highlights the significant impact of the country of origin on FRAP values.

This evidence suggests that the geographical origin of Moringa oleifera has a substantial impact on its reducing capacity. Nigeria, Ghana, and Haiti exhibit high FRAP values, while India has the lowest.

As seen by the very large impact size, the research conducted by Shakour et al. [38] indicates that the country of origin influences FRAP values more significantly than TEAC.

3.2 Tukey's Post Hoc Test Results for Teac and Frap for The *Moringa olifera* Leaves from the Different Countries

Tukey's post-hoc analysis is used to analyse the results in Tables 4 and 5 based on different *Moringa olifera* leaves from different nations. The results indicate a substantial disparity between Ghana and Haiti, with a mean difference of 6.6358 and a p-value of 0.018. While there is no discernible difference between Ghana and Tusk, comparisons of Ghana with India and Nigeria show notable variances as well. Similarly, there

Table 4. Showing the comparisons between countries for TEAC

Group1	Group2	Mean-diff	P-adj	Lower	Upper	Decision
Ghana	Haiti	6.6358	0.018	0.8221	12.4495	True
Ghana	India	17.8573	0.0	12.0436	23.671	True
Ghana	Nigeria	18.4301	12.6164	24.2438	0.0	True
Ghana	Tusk	4.6028	0.1806	-1.2109	10.4165	False
Haiti	India	11.2215	0.0	5.4078	17.0352	True
Haiti	Nigeria	11.7943	0.0	5.9806	17.608	True
Haiti	Tusk	-2.033	0.8568	-7.8467	3.7807	False
India	Nigeria	0.5728	0.9986	-5.2409	6.3865	False
India	Tusk	-13.2544	0.0	-19.0682	-7.4407	True
Nigeria	Tusk	-13.8273	0.0	-19.641	-8.0135	True

Table 5. Showing the comparisons between countries for frap

Group1	Group2	Mean-diff	P-adj	Lower	Upper	Decision
Ghana	Haiti	-18.002	0.8697	-71.0602	35.0562	False
Ghana	India	236.8073	0.0	-289.8655	-183.7491	True
Ghana	Nigeria	46.3194	0.1133	-6.7388	99.3775	False
Ghana	Tusk	-104.4314	0.0	-157.4896	-51.3732	True
Haiti	India	-218.8053	0.0	-271.8635	-165.7471	True
Haiti	Nigeria	64.3214	0.0104	11.2632	117.3795	True
Haiti	Tusk	-86.4294	0.0003	-139.4876	-33.3713	True
India	Nigeria	283.1267	0.0	230.0685	336.1848	True
India	Tusk	132.3759	0.0	79.3177	185.434	True
Nigeria	Tusk	150.7508	0.0	-203.809	-97.6926	True

are substantial disparities between Haiti and India, Haiti and Nigeria, and India and Tusk, but not between Haiti and Tusk and India and Nigeria. The research conducted on moringa leaves by Palacios [39] Wireko-Manu et al., [40] and Asante et al., [41] also supports this assertion.

The FRAP data indicate notable differences in the predominance of country pairings, except for Ghana against Haiti and Ghana versus Nigeria with notable differences in TEAC and FRAP values across countries, as well as certain pairwise comparisons.

4. CONCLUSION

There are statistically significant differences in both TEAC and FRAP values among *Moringa oleifera* varieties from different countries. The antioxidant properties (TEAC and FRAP) of *Moringa oleifera* are influenced by their geographical origin, but the relationship is not linear. For TEAC, Nigeria and India show the highest values, with no significant difference between them, while Ghana and Haiti have intermediate values, and Tusk has the lowest values. For FRAP, Nigeria shows the highest values, Ghana and Haiti have intermediate values with no significant difference between them, Tusk has lower values than Ghana, Haiti, and Nigeria, and India has the lowest FRAP values.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that generative AI technologies such as Large Language Models, etc have been used during writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology.

Details of the AI usage are given below:

1. The version of ChatGPT-4 is released by open AI.
2. Used for some part of the Introduction
3. Used for some part of the methodology

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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