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NUTRITIVE AND ANTIOXIDANT PROPERTIES OF POWDERED LEAVES OF *APIUM GRAVEOLENS, ADANSONIA DIGITATA, TALINUM TRIANGULARE* AND *MORINGA OLEIFERA*

[1]*Valérie Kouakou, [2]Mohamed Ba Koné, [3]Ikpé Kouamé and [4]Kouakou Brou

[1,2]Université Nangui Abrogoua, Côte d'Ivoire.
[3,4]Université de Man, Côte d'Ivoire.

***Corresponding Author:** Valérie Kouakou**
Université Nangui Abrogoua, Côte d'Ivoire.

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ABSTRACT
The general objective of this work is to determine the nutritive and antioxidant properties of the leaf powders of *Apium graveolens*, *Adansonia digitata*, *Talinum Triangulare* and *Moringa oleifera* for their use in the treatment of chronic diseases. The plant material used in this work consists of leaves of *Apium graveolens*, *Adansonia digitata* and *Moringa oleifera*. The analyzes focused on the moisture content, dry matter, ash content, crude protein content, total sugar content, reducing sugar content, lipid content, determination of the fiber content raw materials, the dosage of minerals (sodium, potassium, phosphorus, iron, magnesium, calcium and zinc), the content of carotenoids, the content of beta-carotene, lycopenes and vitamin A. Phenolic compounds, flavonoids and tannins were extracted and quantified. The antioxidant activity of leaf powders was also evaluated. The results showed that the leaf powders contain contents varying from 21.2 to 28.6 mg/100 g of dry matter. Among the leaf powders studied, the greatest antioxidant activity was found in *Adansonia digitata* leaf powder (89.3 µg/ml) with the lowest effective concentration (IC50) being 3.4 µg/ml.

KEYWORDS: Nutritive and antioxidant properties, leaf powders, *Apium graveolens, Adansonia digitata, Talinum Triangulare, Moringa oleifera.*

1. INTRODUCTION
Interest in leafy greens has grown following epidemiological studies relating dietary habits to the prevalence of certain diseases such as obesity, diabetes, cardiovascular disease (CVD) and high blood pressure.[1] Leafy green vegetables are an important part of a healthy diet. They're packed with vitamins, minerals and fiber but low in calories. Eating a diet rich in leafy greens can offer numerous health benefits including reduced risk of obesity, heart disease, high blood pressure and mental decline.[1,2] Indeed, these leaves are valuable sources of nutrients, especially in rural areas where they contribute substantially to the supply of protein, minerals, vitamins, fiber and other nutrients, which are usually scarce in the daily diet.[2] Like the aforementioned nutrients, these leaves contain other substances that play an important role in human health.[3] The richness of these leaves in secondary metabolites is often sought in therapy. Over decades of research, polyphenols have been shown to be widespread throughout the vegetative apparatus of plants. Thus, these active molecules are of great interest for their beneficial effects on health, in particular as anti-inflammatory, anti-cancer, antioxidant and neuroprotective agents.[4] In addition to their nutritional importance, the leaves are of significant economic and social interest due to their relatively low cost and the ease and speed of their preparation.[5] The general objective of this work is to determine the nutritive and antioxidant properties of leaf powders of *Apium graveolens, Adansonia digitata, Talinum Triangulare* and *Moringa oleifera* for their use in the treatment of chronic diseases.

2. MATERIALS AND METHODS
The plant material used in this work consists of leaves of *Apium graveolens* commonly called celery, leaves of *Adansonia digitata* commonly called baobab, leaves of *Talinum triangulare* known as "mamichou" and leaves of *Moringa oleifera*. These leaves were purchased at the Gouro market in the commune of Adjamé (Abidjan, Ivory Coast). The leaves were identified and certified at the Center National de Floristique (CNF) of the Félix Houphouët Boigny University of Cocody (Abidjan, Ivory Coast).

2.1. Preparation of plant material
The leaves of *Apium graveolens, Adansonia digitata* (baobab), *Talinum Triangulare* and *Moringa Oleifera* were cut, washed and then dried at a temperature of 45°C in an oven (Memmert, Germany) for 72 hours. They were ground separately using a Moulinex (France) type mixer. The powders obtained were sieved with a sieve

0.08 mm in diameter. The powders thus obtained were packaged in polystyrene bags and then stored at a temperature of 8°C in the refrigerator until their use.

2.2. Chemical analysis of leaf powders

Several chemical analyzes were carried out on the powders of the leaves of the three plants:

- Humidity and dry matter content, the ash content and the crude protein.
- The total sugar
- The lipid content
- The determination of the crude fiber
- The determination of minerals (sodium, potassium, phosphorus, iron, magnesium, calcium and zinc)
- The carotenoid content
- The determination of the content of beta-carotene, lycopene and vitamin A
- The phenolic compounds
- The determination of the tannin content
- The flavonoid
- The antioxidant activity of leaf powders

3. RESULTS

3.1. Chemical Characteristics of Leaf Powders

Table I presents the chemical characteristics of the leaf powders of *Apium graveolens*, *Adansonia digitata*, *Talinum triangulare* and *Moringa oleifera*. The results show that the dry matter rates vary from 76.67±1.15% to 91.94±0.03%. The highest dry matter content is observed in the leaf powder of *Adansonia digitata* (91.94±0.03%). On the other hand, the lowest dry matter content (76.67±1.15%) was determined in *Talinum triangulare* leaf powders. Concerning the protein contents of the different leaf powders, the values obtained are significantly different at the 5% threshold, and are 23.4 ±0.00%; 26.6±0.01%; 28.6±0.00% and 21.2±0.00% respectively for *Apium graveolens*, *Adansonia digitata*, *Talinum triangulare* and *Moringa oleifera*. As for the fat contents in the leaf powders, they are significantly different ($P \leq 0.05$). *Apium graveolens* (3.4±0.01%) and *Moringa oleifera* (3.5±0.00%) powders have the highest levels. The lowest value was determined in leaf powders of *Adansonia digitata* with a rate of 2.2±0.01%. The different powders analyzed are excellent sources of fibers whose average contents are between 30.77±0.46% dry matter (DM) for *Apium graveolens* and 45.33±0.58% DM for *Talinum triangulare* and vary significantly ($P \leq 0.05$) from sheet to sheet. *Apium graveolens* appears richer in total fiber. With regard to the total ashes of the different leaf powders, the analysis of the results indicates that their contents differ very significantly at the 5% threshold. The leaf powder of *Adansonia digitata* presents the highest value with 20.04±0.32% DM. The lowest value is 10.58±0.03% DM for *Talinum triangulare* leaves. The analysis of the nutrient content of these powders in relation to the dry matter shows that the dominant macronutrients are total sugars and proteins. With regard to total sugars, their content varies from 1434.81 ± 24.24 mg / 100 g for *Talinum triangulare* to 3818.01 ± 42.43 mg / 100 g for the leaves of *Adansonia digitata*. The other contents are respectively 2092.73 ± 15.16 mg / 100 g for *Apium graveolens* and 3079.61 ± 39.40 mg / 100 g for *Moringa oleifera.* Thus, the total sugar contents vary according to the different leaf powders. Statistical analysis revealed a significant difference at the 5% level in the level of total sugars in the different leaves. As regards the reducing sugar contents of the leaf powders, they are between 38.13±1.48 mg/100g and 1064.24±6.43 mg/100 g of dry matter. Statistical analysis showed that these levels are very significantly different ($P \leq 0.05$). *Adansonia digitata* has the highest content of reducing sugars while the lowest content is observed in the leaves of *Talinum triangulare*. The results on the mineral composition of the various leaf powders analyzed are presented in Table II. The different leaf powders analyzed are very rich in minerals, particularly potassium and calcium with contents varying respectively from 766.95±12.05 mg/100g (*Apium graveolens*) to 1094.96±7.58 mg/100g (*Moringa oleifera*) ash for potassium and 1045.40±5.05mg/100g *Talinum triangulare* to 3229.49±29.34mg/100g *Apium graveolens* ash for calcium. On the other hand, the iron and zinc contents are relatively low in these leaf powders with respective values of 66.68±1.19mg/100g *Apium graveolens* for iron and 5.79±0.66mg/100g *Adansonia digitata* for zinc. The values of the phosphorus, magnesium and sodium contents are respectively between 169.60±2.51mg/100g *Talinum triangulare* and 499.12±7.97mg/100g *Apium graveolens* for phosphorus, 147.58±5.44mg/100g *Moringa oleifera* and 555.07±4.00mg/100g *Talinum triangulare* for magnesium and 28.26±2.62mg/100g *Adansonia digitata* and 381.52±8.73mg/100g *Apium graveolens* for sodium.

Table I: Chemical characteristics of the different leaf powders of the plants studied.

	Apium graveolens	***Adansonia digitata***	***Talinum triangulare***	***Moringa oleifera***
Dry matter %	87,44±0,03^{c}	91,94±0,03^{d}	76,67±0,03 ^{a}	78,45±0,04^{b}
Proteins %	23,4±0,00^{b}	26,6±0,01^{c}	28,6±0,00^{d}	21,2±0,00^{a}
Lipids %	3,4±0,01^{b}	2,2±0,01^{a}	5,8±0,00^{c}	3,5±0,00^{b}
Fibers %	30,77±0,46^{a}	41,67±0,29^{c}	45,33±0,58^{d}	36,10±0,17^{b}
Ash %	19,27±0,12^{c}	20,04±0,32^{d}	10,58±0,03 ^{b}	9,87±0,12^{a}
Total Sugar mg/100g	2092,73±15,16^{b}	3818,01±42,43^{d}	1434,81±24,24^{a}	3079,61±39,40^{c}
Reducing sugar mg/100g	180,32±0,00^{b}	1064,24±6,43^{d}	38,13±1,48^{a}	321,36±2,21^{c}

The means followed by the same lowercase letter on a line are not significantly different at the 5% level according to Duncan's test.

Table II: Mineral composition of the leaf powders of the plants studied in mg per 100g of dry matter.

	Apium graveolens	*Adansonia digitata*	*Talinum triangulare*	*Moringa oleifera*
Sodium	381,52±8,73^{d}	28,26±2,62^{a}	225,07±3,58^{c}	49,20±3,87^{b}
Magnesium	425,50±9,12^{c}	196,46±3,44^{b}	555,07±4,00^{d}	147,58±5,44^{a}
Phosphorus	499,12±7,97^{c}	246,88±1,49^{b}	169,60±2,51^{a}	242,68±4,50^{b}
Potassium	766,95±12,05^{a}	1092,16±11,84^{c}	938,67±4,04^{b}	1094,96±7,58^{c}
Calcium	3229,49±29,34^{d}	1560,57±10,03^{c}	1045,40±5,05^{a}	1130,70±4,11^{b}
Iron	66,68±1,19^{c}	39,22±1,67^{b}	9,53±0,47^{a}	82,33±2,52^{d}
Zinc	4,13±0,81^{a}	5,79±0,66^{b}	5,50±0,20^{b}	3,85±0,66^{a}

The means followed by the same lowercase letter on a line are not significantly different at the 5% level according to Duncan's test.

3.2. Phytochemical characteristics of leaf powders

The results of the analyzes of some chemical groups responsible for the therapeutic effects carried out on the powders of the leaves of *Adansonia digitata*, *Talinum triangulare*, *Apium graveolens* and *Moringa oleifera* are grouped in the table. This table shows that these different powders contain polyphenols, beta-carotenes, vitamin A, lycopene, flavonoids, tannins and antinutritional factors such as phytates and oxalates. The analysis of the results shows that the total polyphenol content of leaf powders varies from 441.01 ± 16.22 to 1350.91 ± 1.10 mg Emg / 100 g of dry matter. The lowest content of phenolic compounds was recorded in Talinum triangulare leaf powders (441.01±16.22mg Emg/100g) and the highest content in *Adansonia digitata* leaf powders (1350.91±1 ,10mg/100g). Statistical analysis shows significant differences at the 5% level between the different leaf powders. As regards the flavonoid contents, they vary from 2.98±0.18 to 52.62±1.60 mg/100 g of dry matter. The lowest levels were recorded in the leaf powders of *Apium graveolens* and *Talinum triangulare* with respective values of 2.98 ± 0.18 and 4.12 ± 0.25 mg / 100 g, followed by *Moringa oleifera* with 39.75 ±0.97mg / 100g. The highest value was observed in *Adansonia digitata* powders (52.62±1.60 mg/100 g). Thus, the statistical analysis showed a significant difference between the different leaves. Relative to the carotenoid contents of the different leaf powders, they are 40.54±0.94 mg/100g; 63.19±0.37mg/100g; 49.39±0.01mg/100g and 98.03±0.61mg/100g respectively for *Apium graveolens*, *Adansonia digitata*, *Talinum triangulare* and *Moringa oleifera*. The highest content was obtained in *Moringa oleifera* leaf powders while the lowest content in Apium graveolens leaf powders. The carotenoid contents in the different leaves are very significantly different at the 5% threshold. The powders from the different leaves are also very rich in vitamin A and their content is correlated with the beta-carotene content. Vitamin A contents vary from 1119.16±93.82µg/100g to 1752.83±13.19µg/100g of dry matter. The lowest vitamin A content was recorded in *Moringa oleifera* leaf powder and is 1119.16±93.82µg/100g. On the other hand, the highest content was observed in the leaf powders of *Apium graveolens* and is 1752.83±13.19µg/100g of dry matter. Statistical analysis does not show any significant difference between the vitamin A contents of the leaf powders of *Adansonia digitata*, *Talinum triangulare* and *Moringa oleifera*, while there is a significant difference ($P<0.05$) between the leaf powder of Apium graveolens and all other leaf powders.

The analysis of Table II also shows that the various leaf powders studied contain several anti-nutritional factors, in particular tannins, phytates and oxalates. As regards the tannin contents, they oscillate between 94.57±0.52 and 281.19±7.09 mg / 100 g of dry matter. Statistical analysis showed significant differences ($P \leq 0.05$) between these different leaf powders. The highest tannin content was determined in leaf powders of *Adansonia digitata*. Phytate results showed a variation from 20.22±0.57 mg/100g to 80.32±0.56 mg/100g, respectively for *Moringa oleifera* and *Talinum triangulare* powder. These different contents vary significantly in the different powders ($P<0.05$). The highest values are found in *Talinum triangulare* leaf powders while the lowest value is observed in *Moringa oleifera*. On the other hand, the oxalate content is considerably high in *Moringa oleifera* (1863.33±11.55mg / 100g). The lowest content was observed in *Talinum triangulare* powder (385.00±11.00mg/100g). The oxalate contents of the leaves of *Apium graveolens*, *Adansonia digitata*, *Talinum triangulare* and *Moringa oleifera* are very significantly different ($P<0.05$).

3.3. Antioxidant activity of leaf powders

The antioxidant activity of leaf powders is shown in Figure 1. Different leaf powders show significant and variable antioxidant activities. Thus, the lowest concentration of extract that results in a percentage inhibition of 50% (IC50) or (IC50) is observed with *Adansonia digitata* leaf powder (3.45 µg/ml). *Adansonia digitata* leaf powder therefore has a higher antioxidant activity than other leaf powders. It is followed respectively by the antioxidant activity of *Moringa oleifera* with an IC50 of 8.02 µg / ml and of *Apium graveolens* with an IC50 of 13.58 µg / ml. The lowest antioxidant activity was obtained with *Talinum triangulare* with an IC50 of 112.82µg/ml.

Table II: Phytochemical composition of the leaf powders of the plants studied.

	Apium graveolens (P1)	*Adansonia digitata* (P2)	*Talinum triangulare* (P3)	*Moringa oleifera* (P4)
Polyphenols (mg Emg/100g)	848,25±3,37^{b}	1350,91±1,10^{d}	441,01±16,22^{a}	1142,15±1,85^{c}
Flavonoids (mg Eq/100g)	4,12±0,25^{b}	52,62±1,60^{d}	2,98±0,18^{a}	39,75±0,97^{c}
Lycopene (mg/100g)	1,34±0,02^{b}	3,25±0,17^{c}	1,36±0,01^{b}	1,12±0,04^{a}
Total carotenoids (mg/100g)	40,54±0,94^{a}	63,19±0,37^{c}	49,39±0,01^{b}	98,03±0,61^{d}
Beta-carotene (mg/100g)	21,03±0,16^{b}	13,97±0,57^{a}	13,56±0,01^{a}	13,43±1,13^{a}
Vitamin A (µg/100g)	1752,83±13,19^{b}	1164,45±47,22^{a}	1129,72±0,96^{a}	1119,16±93,82^{a}
Tannins (mg/100g)	104,31±1,57^{a}	281,19±7,09^{c}	94,57±0,52^{a}	202,23±1,71^{b}
Phytate (mg/100g)	38,04±0,15^{b}	45,21±0,04^{c}	80,32±0,56^{d}	20,22±0,57^{a}
Oxalate (mg/100g)	1265,00±11,00^{c}	509,67±16,80^{b}	385,00±11,00^{a}	1863,33±11,55^{d}

The means followed by the same lowercase letter on a line are not significantly different at the 5% level according to Duncan's test.

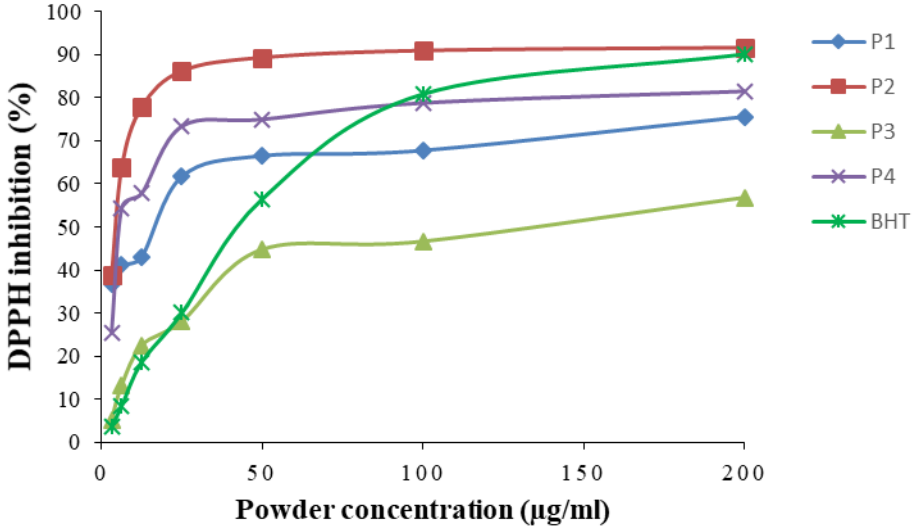

Figure 1: Activité antioxydante des différentes poudres de feuilles.
(P1): *Apium graveolens*, (P2): *Adansonia digitata*, (P3): *Talinum triangulare*, (P4): *Moringa oleifera* et (BHT) : Butylhydroxytoluène (Témoin)

4. DISCUSSION

The objective of this work was to characterize the leaf powders of *Apium graveolens*, *Adansonia digitata*, Talinum Triangulare and Moringa oleifera in order to use them in the treatment of chronic diseases. The chemical and phytochemical analysis of these leaf powders showed that they are rich in total ash and contain minerals, fibres, proteins and certain phytochemical compounds mainly total polyphenols, flavonoids, tannins, carotenoids and B-carotene.[6] With regard to total ashes, the results revealed that their contents are between 9.87% for *Moringa oleifera* and 20.04% for *Talinum triangulare*. These high ash contents reflect the richness in mineral elements studied leaves. Regarding lipids, the results showed that the leaf powders contain very little lipids. Indeed, it has been shown in previous works that vegetable fat contains mono and polyunsaturated fatty acids; they play a very important role in the constitution and fluidity of cell membranes.[7,8] Thus, their regular consumption could help reduce the risk of cardiovascular disease, obesity, high blood pressure and other associated coronary diseases, sometimes linked to the deposition of saturated fatty acids in the arteries. Relative to the protein content, the results showed that the leaf powders contain contents ranging from 21.2 to 28.6 mg/100 g of dry matter.[8] They could also contribute to the proper functioning of the body and in particular strengthen the immune system against diseases. At the level of raw fibers, the results showed that their contents in leaf powders vary from 30.77% to 45.33% of dry matter. These values show a richness in crude fibers of the different leaf powders. Regarding minerals, the present study revealed that the different leaf powders are good sources. These minerals (sodium, potassium, calcium, magnesium and iron) are very important in human nutrition. It has also been shown that mineral elements are endowed with human health promoting activity.[9] For example, calcium, which is the most abundant mineral in the different leaf powders with levels between 1045.40mg/100g and 3229.49mg/100g of dry matter, contributes to anticarcinogenic activity by reducing the risk of colorectal cancer.[10,11] Calcium also plays a major role in ossification and the formation of the nervous system as

well as blood clotting. In combination with phosphorus, calcium helps fight against osteoporosis.[11] The results also showed that the leaf powders studied are also rich in potassium. Potassium plays a role in skeletal muscle contraction and acid-base balance.[12] It is the main intracellular cation and is involved in the polarization of cell membranes, neuromuscular potential, cardiac automatism and certain enzymatic activities. It is therefore possible that the ingestion of these powders regulates blood pressure in hypertensive patients. *Apium graveolens* presented an average sodium content, eight times higher than that found in *Moringa oleifera* leaf powder and much higher in the other two leaf powders. Given their richness in sodium, the consumption of these leaves could have a natriuresis effect, a reflection of the state of intracellular hydration and would play a role in the acid-base balance.[13] The regular consumption of these leaf powders as food supplements could thus contribute to an additional intake of calories, vitamins, fibres, mineral salts and proteins in the diet. The phytochemical analysis of the powders made it possible to characterize the polyphenols, the flavonoids, the tannins and the carotenoids. The dosage of these compounds was carried out in this study because the majority of the pharmacological effects of plants are attributed to these substances.[14] Regarding phenolic compounds, the results showed that the highest values are found in the leaves of Adansonia digitata. Plant polyphenols are secondary metabolites that are effective in traditional therapeutic use.[15] As for the tannins and flavonoids found in leaf powders, they are also secondary metabolites known for their ability to increase capillary resistance, venous tone and collagen stability. Flavonoids are particularly active antioxidant substances in maintaining blood circulation in the body.[16] They help increase the production of nitric oxide in blood platelets by limiting the formation of clots, thus preventing platelets from clumping together and preventing atherosclerosis.[17] Natural pigments form a very wide range and consist of chlorophyll, carotenoids and lycopene which are among the pigments most used in the food and pharmaceutical industries. The results showed that the studied leaf powders are rich in these compounds and could be used as sources of these molecules.[18] Additionally, carotenoids are sources of provitamin A in plants and are powerful antioxidants. Beta carotene neutralizes one of the most toxic free radicals, singlet oxygen, and thus prevents the oxidation of several biological substrates including unsaturated fatty acids.[19] The consumption of these leaves could contribute to the protection of cells against oxidative stress and chronic diseases such as cancer, cardiovascular diseases, osteoporosis and diabetes. The body develops several strategies to defend itself against stress related to oxidative activity by producing its antioxidants or through food intake.[20] These antioxidants can thus activate the defense system and reduce the risk of cancer and degenerative diseases. From the results obtained in this work, it is clearly indicated that the leaf powders of the studied plants possess strong antioxidant activities, which is consistent with their high contents of total phenolic compounds and carotenoids. Among the leaf powders studied, the greatest antioxidant activity was found in *Adansonia digitata* leaf powder (89.3 µg/ml) with the lowest effective concentration (IC50) being 3.4 µg/ml.[21] It is therefore this strong antioxidant activity that would explain why *Adansonia digitata* leaf powder has an antiradical power superior to that of many widely consumed fruits and vegetables such as orange (10µg / ml), kiwi (34 µg / ml), lentils (8.1 µg/ml), and tomatoes (6.7 µg/ml), all of which are known to be rich in antioxidants.[22,23] Consumption of these leaves could therefore make it possible to fight against degenerative diseases such as diabetes, hypertension and cardiovascular diseases. It is highly probable that the strong antioxidant activity of the leaf powders studied in the present work contributes to their various therapeutic activities.[24]

5. CONCLUSION

The characterization of the different leaf powders revealed the different chemical and phytochemical compounds. The leaf powders of *Apium graveolens*, *Adansonia digitata*, *Talinum triangulare* and *Moringa oleifera* have been found to be rich in protein, fiber and minerals. Of these minerals, potassium and calcium are the most abundant. In addition, these leaf powders contain large amounts of phytonutrients with varying levels and strong antioxidant activity. Thus, the highest content of phenolic compounds was observed in the leaf powder of *Adansonia digitata*. *Moringa oleifera* leaf powder recorded the highest carotenoid content. Evaluation of antioxidant activity of leaf powders indicated that *Adansonia digitata* exhibits the highest activity followed by *Moringa oleifera* and *Apium graveolens*. The lowest activity was obtained with *Talinum triangulare* leaf powder.

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