Available online www.jocpr.com

Journal of Chemical and Pharmaceutical Research, 2016, 8(8):93-101

Review Article

ISSN : 0975-7384
CODEN(USA) : JCPRC5

Qualitative phytochemical analysis of the leaf of *Moringa oleifera* lam. from three climatic zones of Nigeria

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ABSTRACT

Moringa oleifera Lam. (Moringaceae) is one of the most versatile plants cultivated all over the world. It is popular in Nigerian due to its nutritional and medicinal values; almost every part of the plant can be used for food, medication or industrial purposes. They are claimed to treat different ailments in the indigenous system of medicine. The nutritional and medicinal values are due to the presence or absence of certain primary and secondary metabolites synthesized by the plant. Climatic condition, soil composition and other factors are reported to influence the synthesis of these metabolites. Consequently, the nutritional and phytochemical contents of the plant may vary from place to place. Several reports on the qualitative phytochemical analysis of Moringa oleifera leaves from different climatic zones in Nigeria were collated and evaluated. The data revealed the presence of alkaloids, flavonoids, saponins, steroids, tannins and phenolics in Moringa oleifera leaves from all the climatic zones. However, some phytochemicals present in Moringa oleifera leaves from one zone were absent or not detected in the leaves from another zone and this could be attributed to the climatic influence and the solvents used for extraction.

Keywords: *Moringa oleifera*, leaves, phytochemical, climate, zone.

INTRODUCTION

Moringa oleifera Lam. (Moringaceae) is native to the southern foothills of the Himalayas in northwestern India and the most widely cultivated species of the genus Moringa [1]. It has become naturalized in many tropical countries of Africa, Arabia, South East Asia, Pacific Carribean Islands and South America [2]. The common English names are: Moringa, drumstick tree, horseradish tree and benzoil tree. Locally, in Nigeria, it is known as 'Zogale-gandi' in Hausa, 'Ewe igbale' in Yoruba and 'Okweoyibo' in Igbo: it is also known as "Miracle tree", [2-3]. Its young seed pods and leaves are used as vegetables. It is considered as one of the World's most useful trees, as almost every part of the Moringa tree can be used for food, medication and industrial purposes [4].

Nutritive and medicinal uses of *Moringa oleifera*

Moringa is a versatile plant with high nutritive, agricultural, medicinal, domestic, industrial and environmental benefits [1]. It is effective in combating malnutrition, especially among infants and nursing mothers [5].The leaves, seeds and flowers have been reported to have good nutritive and medicinal value [3, 6]. The seeds are consumed raw or roasted while the flowers are cooked in soups and resemble mushrooms [1]; the leaves are cooked as vegetables. The flowers and leaves are rich in vitamins A, B_1, B_2, B_6, E and C. They are among the best sources of minerals. The plant has been implicated in the treatment or suppression of many degenerative diseases among many rural consumers [3].

In Northern Nigeria, *Moringa oleifera*is highly sourced as vegetable because of its nutritional values, health-promoting and disease-preventing properties possibly due to the presence of many phytochemicals [3].

Phytochemicals are a group of non-nutrient bioactive compounds synthesized naturally by plant. They are found in flowers, buds, leaves, fruits, roots, barks, and spices of medicinal plants. Phytochemicals act as defensive mechanism for the plants against diseases and many external attacks. They also provide characteristic colour, aroma and flavour in plants. They are plant metabolites (primary or secondary) [7]. Various phytochemicals have been identified and isolated from different parts of *Moringa oleifera* [3, 8- 9].

Seeds

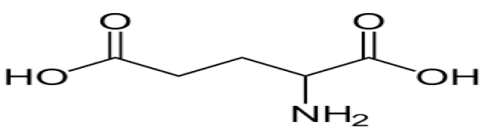
Moringa seeds contain between 19 to 47% of oil [10, 11]. *Moringa oleifera* seed oil (yield 41.47%), has good antioxidant and physico-chemical properties with potential for industrial, nutritional and health applications [12]. The seed oil is colourless and odourless, hence, considered as a great natural emollient, and finds application in cosmetics [13]. It is high in oleic acid (>73%) [14]. The oil from Moringa seeds, is used as a source of antioxidant additives for biodiesels with low oxidation stability [13, 15]. This oil is highly valued by the perfume industries for its power of absorbing and retaining odours, and by watch makers as lubricant [16]. The oil cake is used as a fertilizer [17]. The crushed seeds have been used as effective and low cost method for removing turbidity and bacterial contamination from drinking water in the Sudan [14].

Aqueous seed extract of *Moringa oleifera* contains tannins, carbohydrate at low concentration, saponins, alkaloids, cardiac glycosides, anthraquinones moderately and high concentration of flavonoids. However, phlobatannins and steroids are absent [9]. Moringa seed also has antimicrobial activity [18]. It is antipyretic and acrid to taste [19]. It is consumed fresh as peas, pounded, roasted, or pressed into sweet non-desiccating oil, commercially known as 'Ben oil' [18]. The anticoagulant activity of crushed Moringa seed indicated that it is one of the best natural coagulant with polypeptides that makes it useful for water treatment [20].

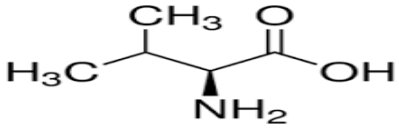
Leaves

Moringa leaf has outstanding nutritional qualities. It is among the best of all perennial vegetables [21]. It is high in β-carotene, amino acids and ascorbic acid. Hence, it is used to increase milk production in lactating mothers and also useful in treating scurvy, respiratory ailments and as emesis remedy [18, 22-23]. *Moringa oleifera*leaves showed antioxidant activity that was stable in pH 4 and 9; therefore, this plant extract is a potential source of natural dietary antioxidants in food supplements due to the presence of various types of antioxidant compounds such as ascorbic acid, flavonoids, phenolics and carotenoids [13, 24]. The juice from the leaf of Moringa can reduce glucose levels; it has purgative, anti-inflammatory and strong antimalarial properties [25-28]. It also serves as an antidote to piles, fevers, sore-throat, bronchitis, catarrh, eye and ear infections as well as sore healing and relieve of headaches [27].

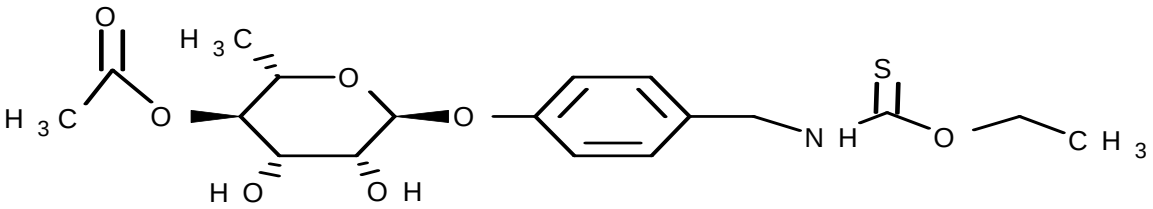
The protein content is 27% and there are also significant quantities of calcium and phosphorous, as well as vitamins A, C and D. This nutritional value is particularly important in areas where food security can be threatened by periods of drought. The leaves can be eaten fresh, cooked or stored as dried powder for many months without refrigeration, and without loss of nutritional value [6]. According to Fuglie and Sreeja [23], Moringa leaf contains up to 25.1% crude protein, 6.5% lipid, 12% ash, 27.1% protein, 2.3% fat, 38.2% carbohydrate, 19.2% fibre, 20.0% calcium (Ca), 1.37% magnesium (Mg), 0.20% phosphorus (P), 1.32% potassium (K), 0.03% iron (Fe) and 0.87% sulphur (S). High levels of vitamins A, B, C and E were also observed in the dried leaves. Teixeir*et al.* [29], observed that Moringa leaf contains 28.7% of crude protein, 7.1% of fat, 44.4% of carbohydrate, 3.0 mg/100 g of calcium and 103.1 mg/100 g of iron. The protein profile revealed levels of 3.1% of albumin, 0.3% of globulins, 2.2% of prolamin, 3.5% of glutelin and 70.1% of insoluble proteins. Three mustard oil glycosides 4-(4-O-acetyl-alpha-L-rahamnosyloxy-benzyl] isothiocyanate, niaziminin A and niaziminin B have been isolated in pure form from the leaves of *Moringa oleifera*along side niazirin and niazirinin [30]. The leaf also contains aspartic acid, glutamic acid, glycine, threonine, alanine, valine, leucine, isoleucine, and histidine [31].



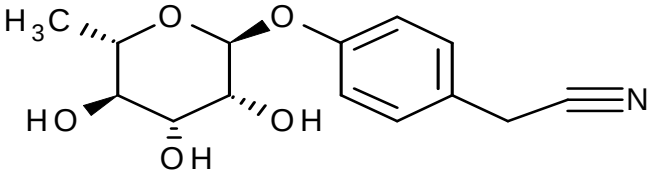
Glutamic acid



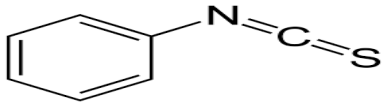
Valine



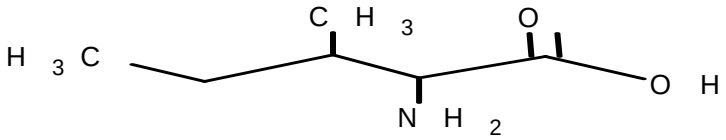
NiaziminA



Niazirin



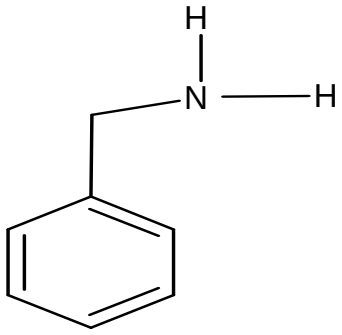
Isothiocyanate



Isoleucine

Bark

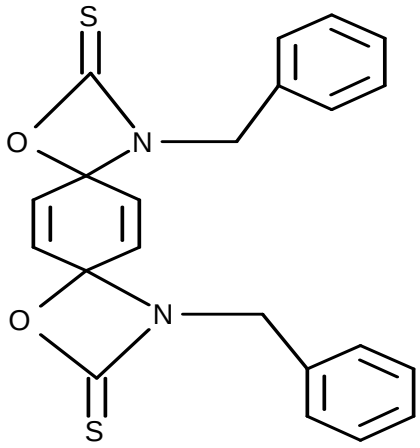
The corky bark yields a coarse fiber which is used in making mats, paper and cordage. Several compounds of proven medicinal values have been isolated from the root and stem bark. The root bark is rich in alkaloids, notably moringine, a toxic compound allied to ephedrine [26]. Moringa bark can be used for tanning of hide also yields a coarse fiber [32].



Moringine(Benzylamine)

Flower

M. oleifera flower is rich in calcium, potassium and antioxidants. It also contains proteases with milk-clotting ability [13]. The phytochemicals in the flowers are: tannins, saponins, flavones, flavonols [33].The flower is reported to contain nine amino acids, sucrose, D-glocuse, traces of alkaloid, wax, and it is also rich in potassium, calcium and some flavonoid pigments [34, 24]. Quercetin, a known flavonoid with hepato-protective activity, has been isolated from the alcohol and aqueous extract of Moringa flower [35]. It is used for the treatment of inflammations, muscle diseases, tumours, and enlargement of the spleen. It is reported to cause decrease in serum cholesterol, phospholipid, triglyceride, hence it is applied in regulation of the ratio of cholesterol to phospholipid [18]. The flowers contain pterygospermin, an antibiotic that is highly effective in the treatment of cholera [36].



Pterygospermin

Root

The roots are extensively used as antidiabetic and for treating inflammation, cardiovascular, liver and renal diseases [37]. The root extract of Moringapossesses anti-spasmodic and anti-inflammatory activities according to Cacerese*t al.*, [38]. Novel compounds with scientifically proven medicinal value have been isolated from the root and root bark of Moringa [39]. One of such compounds is aspterogospermin, an antibiotic that is highly effective in the treatment of cholera [36]. The hepato-protective activity of the root was observed by [34]. The root can act as anti-inflammatory agent, stimulant in paralytic afflictions, and as a cardiac/circulatory tonic. It is also used as a laxative to relieve constipation, in treating rheumatism, lower back or kidney pain. Rao *et al*., [40] reported the antimicrobial activity of the root extract of Moringa. Dried Moringa roots are garnished with vinegar to make food condiment [41].

However, it has been reported that climatic factors could cause variation in the presence of phytochemicals in *Moringa oleifera* from place to place [42]. Climatic zones have been reported to have effect on plant biodiversity and differences in chemical profiles of same species of a plant [43]. Popoola*et al*., [44] observed that *Moringa oleifera* from different climatic zones in Nigeria may have variation in their genetic makeup.

Climate variation from the south to northern Nigeria can influence the constituents of *Moringa oleifera*. The expected variations in temperature, precipitation, atmospheric carbon content, soil composition, water availability have profound effects on growth, yields, nutritional value and phytochemical content of plants [45].The remarkable change in temperature moving from south to north will alter soil moisture content, the timing and length of growing seasons will be affected too. Rise in ambient temperatures may influence plant phytochemical constituents as it is well documented that some plant metabolic processes begin to break down above 40°C [46]. Increase or decrease in the concentration of carbon-dioxide will result in greater water use efficiency and higher rate of photosynthesis by plant. These effects are strongest for plants with the C3 photosynthetic pathway [47]. Water availability is also a critical factor in determining the impact of climate variation in plant. A number of studies suggest that precipitation and the length of the growing season are critical in determining whether climate variation positively or negatively affects plant growth, nutritive and phytochemical constituents [46, 48-50].

Climate refers to the summary of the average weather and atmospheric condition experienced in a particular region or location over a considerable period [51]. The climate in a given region is characterized by the average values of the atmospheric parameters such as temperature, precipitation and wind [52]. Rainfall variability, temperature variability and other climatic factors can affect plant physicochemical composition. Therefore, adequate knowledge of the climatic condition of a place is imperative for cultivation of medicinal plants such as *Moringa oleifera* due to the fact that climate-crop relationship can affect the nutritive, anti-nutritive composition and yield of the crop [53].
Nigeria is a country in West Africa. It is found in the tropics, where the climate is seasonally damp and very humid. Nigeria is dominated by four climate types which are distinguishable from the southern part of the country through the middle belt to its northern part. The climatic zones in Nigeria include tropical monsoon climate, tropical savanna climate, sahel climate and alpine climate.

Tropical Monsoon Climate

The Tropical Monsoon Climate Zone has a temperature of 28^{o}C (82.4^{o}F) in its hottest month while its lowest temperature is 26^{o}C (78.8^{o}F). The temperature difference is not more than 2^{o}C (5^{o}F), which is almost constant throughout the year [51]. The region experiences heavy and abundant rainfall throughout the year. The annual

rainfall in the tropical monsoon region is very high, usually above the 2000 mm rainfall total given for tropical rainfall climates worldwide [54].

Tropical Savanna Climate

Tropical Savanna Climate is extensive and covers most of the Eastern, Western and parts of Northern Nigeria to Central Nigeria, beginning from the tropical rainforest climate boundary in Southern Nigeria, where this climate exerts enormous influence on the region. Temperatures are above 18^{o}C (64^{o}F) throughout the year. Abuja, the capital of Nigeria located in Central Nigeria, has a temperature range of 18.45^{o}C (65.21^{o}F) to 36.9^{o}C (98.4^{o}F), and annual rainfall of about 1500 mm [51].

Sahel Climate

Sahel Climate is the predominant climate type in Northern Nigeria. Annual rainfall totals are lower compared to southern and central part of the country. Rainy season in the northern part of Nigeria lasts for only three to four months, the rest of the year is hot and dry with temperature climbing as high as 40^{o}C (104^{o}F).

Alpine Climate

This is also known as highland climate and is found in highland regions in Nigeria. Highlands with the alpine climate in Nigeria are well over 1,520 meters (4,987 ft) above sea level. Due to its location in the tropics, this elevation is high enough to reach the temperature level of Western countries. Example is Plateau State. It is cold because of its high altitudes. The alpine biome is one of the coldest biomes in the world. Summer temperature ranges between -10 to 12°C. The average precipitation is 30 cm a year. The growing season is about 180 days. The night temperature is almost always below freezing point. Unlike the arctic tundra, the alpine soil is well drained. The problem of light is quite different in alpine biomes than in other biomes. The little amount of atmosphere at high altitudes exposes the alpine area to sunlight. Some of the plants in an alpine biome are tussock grasses, dwarf trees, small-leafed shrubs, and heaths [55].

This review compares the phytochemical constituents of leaves of *Moringa oleifera* from some State within three of the four major climatic zones in Nigeria using data obtained from literatures.

EXPERIMENTAL SECTION

This review was conducted as a historical research using information obtained from literature, which include internet search engine such as PubMed, google scholar, etc., and library textbooks on medicinal plants.

RESULTS AND DISCUSSION

The comparative analyses of phytochemicals in *Moringa oleifera* between States in the same climatic zone, and then between zones were conducted. Tables 1 to 3 show results of phytochemical constituents of *Moringa oleifera* in States within Monsoon, Savannah and Sahel Climatic Zones respectively. The quantum of States reported for each zone was dependent on the available reports in literature. For instance, reports were only available from Kano State in the Sahel Zone.

Table 1: Phytochemical constituents of *Moringa oleifera* leaves from Monsoon Climatic Zone (Delta, Cross River, and River State)

Phytochemicals	Delta State (Ethanol)	Cross River State (Ethanol)	Cross River state (Aqueous)	Rivers State (Aqueous)
Alkaloids	++	++	+	+
Terpenoids	+	++	+	ND
Flavonoids	+	+++	++	+++
Saponins	++	+	++	++
Steroids	+	+	+	+
Cardiac glycosides	+	ND	ND	ND
Condensed tannins	++	ND	ND	ND
Ellagitannins	-	ND	ND	ND
Phlobatannins	+	-	-	ND
Reducing Sugars	++	++	+	ND
Phenolics	++	++	+++	ND
Anthraquinones	ND	-	-	-
Hydroxymethylanthraquinone	ND	-	-	ND
Glycosides	ND	++	+	+
Tannins	ND	++	+	-

Key: EtOH = Ethanol, Aqs = Aqueous, Ethyl A = Ethyl Acetate, MeOH = Methanol, + = Present, - = Absent, ND = Not Done

Table 1 shows the phytochemical constituents detected from three States in the Monsoon Climatic Zone of Nigeria. The result showed that alkaloids, terpenoids, flavonoids, saponins, steroids, condensed tannins, reducing sugars, phenolics and glycosides were usually present while anthraquinones and hydoxymethylanthraquinones were usually absent from the leaf of *M. oleifera* grown in the Monsoon Climatic Zone of Nigeria. Phlobatannins were sometimes absent or present. The method and solvent used for extraction usually affects the profile of phytochemicals detected since molecules are extracted based on their affinity for the solvents at specific experimental conditions of temperature, pressure, etc. The profile of the results in Table 1 suggests that the extraction solvents, most of which have comparative polarity, did not significantly affect the classes of phytochemicals detected from the leaf extract in the zone.

In the Tropical Savanna Climatic Zone as presented in Table 2, phytochemicals such as flavonoids, saponins and tannins were consistent. Alkaloids were reported in all the samples in the States except Ekiti. However, other phytochemicals are not consistent across the zone. This is suggestive of climatic variation within the zone which may create species or chemical profile variation among species. This is consistent with the fact that the Savanna Climatic Zone of Nigeria is probably the largest and the most varied climatic zone, and contains different ecological zones. Other phytochemicals reported from species in the zone include steroids, terpenoids, cardiac glycosides, anthocyanin, tannins, carotenoids, phenols, glycosides, anthraquinones and phlobatannins. This zone is extensive and covers most Eastern, Western and some parts of Northern Nigeria. Hydroxymethylanthraquinone and ellagitannins were not determined in the zone. However, the phytochemicals detected in this report vary from state to state, this could be as a result of the largeness of this climatic zone. Some parts of the savanna climatic zone have relatively lower rain fall and high temperature moving north-ward Nigeria.

Table 2: Phytochemical Constituents of *Moringa oleifera*Lam. Leaves from Tropical Savanna Climatic Zone of Nigeria

Phytochemicals	Enugu State (EtoH)	Enugu State (Aqs)	Anambra State (EtoH)	Anambra State (Hexane)	Anambra State (Ethyl A)	Ogun State (EtoH)	Ogun State (Aqs)	Ogun State (MeoH)	Ekiti State (EtoH)	Ekiti State (Aqs)
Flavonoids	+	+	ND	ND	ND	+	+	+	+	+
Anthraquinones	+	+	ND	ND	ND	ND	ND	ND	-	-
Alkaloids	+	+	+	+	+	+	+	-	-	-
Saponins	+	+	+	-	+	+	+	+	+	+
Steroids	+	+	ND	ND	ND	ND	ND	ND	+	-
Terpenoids	+	+	ND	ND	ND	-	+	-	+	+
Cardiac glycosides	+	+	ND	ND	ND	ND	ND	ND	+	+
Anthocyanin	+	+	ND	ND	ND	ND	ND	ND	ND	ND
Tannins	+	+	+	+	+	+	+	-	+	+
Carotenoids	+	+	ND	ND	ND	ND	ND	ND	ND	ND
Phenols	ND	ND	+	-	+	-	-	-	ND	ND
Phlobatannins	ND	ND	-	+	-	ND	ND	ND	-	-
Glycosides	+	ND	ND	ND	ND	+	-	-	ND	ND

Table 3: Phytochemical constituents of *Moringa oleifera* Lam. Leaves from Sahel Climatic Zone

Phytochemicals	Kano State (EtOH)	Kano State (Aqs)	Kano State (MeoH)
Alkaloids	-	+	+
Tannins	+	+	-
Phenolics	ND	+	+
Saponins	+	+	+
Flavonoids	+	+	+
Steroids	ND	+	+
Phlobatannins	ND	-	-
Triterpenoids	ND	-	-

The phytochemical constituents obtained in the Sahel Climatic Zone, are presented in Table 3. Alkaloids, tannins, phenols, saponins, flavonoids and steroids were present in the extracts of *Moringaoliefera* leaves from this climatic zone, while phlobatannins and triterpenoids were absent.

Table 4: Comparative phytochemical profile between the Monsoon, Savanna and Sahel Climatic Zones

Phytochemicals	Monsoon	Savanna	Sahel
Alkaloids	+	+	+
Terpenoids	+	+	-
Flavonoids	+	+	+
Saponins	+	+	+
Steroids	+	+	+
Cardiac glycosides	+	+	ND
Condensed tannins	+	ND	ND
Ellagitannins	-	ND	ND
Phlobatannins	+	+	-
Reducing Sugars	+	ND	ND
Phenolics	+	+	+
Anthraquinones	+	+	ND
Hydroxymethylanthraquinone	+	ND	ND
Glycosides	+	+	ND
Tannins	+	+	+

Key: + = present, - = absent, ND = not done

The result of comparative phytochemical profile of the climatic zones (Table 4), was derived from summary report of each zone. Hence (+) means the secondary metabolite was present in at least one of the reports of the zone. The result showed that the profile of secondary metabolites was similar for all phytochemicals determined across the zones except for terpenoids and phlobatannins, which were absent in the Sahel Climatic Zone. Samples from the three climatic zones showed the presence of alkaloids, flavonoids, saponins, steroids, phenolics and tannins. Cardiac glycosides, condensed tannins, reducing sugars, anthraquinones, hydroxymethylanthraquinones, and glycosides were detected in the Mansoon and Savanna climatic zones where the tests were performed, which gave an indication that they may be present in the Sahel climatic zone, where the test was not performed. Thus, it could be inferred that there exist great similarities in the phytochemical profiles of *M.oleifera* grown in Monsoon and Savanna Climatic Zones, while relative difference exists in the phytochemical profile of the same plant grown in the Sahel Climatic Zone.

CONCLUSION

The reports showed that alkaloids, tannins, phenolics, saponins, steroids and flavonoids were the major phytochemicals commonly available in the *M.oleifera* leaves from all the zones. Cardiac glycosides, condensed tannins, reducing sugars, anthraquinones, hydroxymethylanthraquinones, and glycosides were however not consistent in the reported study within a particular zone. Terpenoids and phlobatannins were absent in the Sahel Zone, suggesting that the pharmacological activity of plant from this climatic zone may differ. The results of this study suggests that samples from the Monsoon and Savanna Climatic Zones, which contain more phytochemicals, could be of wider pharmacological application than those from Sahel Climatic Zone. The specific nature of the compounds constituting each class of metabolites and comparative pharmacological study of samples from the different climatic zones would make an interesting investigation.

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