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Expert Opinion Article

Elemental And Proximate Bioprofiling Of *Schweinfurthia Papilionacea* (L.) BOISS As A Potential Nutraceutical Biocandidate

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Abstract
The current research studies the nutritional profile of *Schweinfurthia papilionacea* that belongs to the Scrophulariaceae family, which may be applied in food area, pharmaceuticals, and even nutraceuticals. The atomic absorption spectrometry technique of elemental analysis displayed high levels of essential macro and micronutrients, such as calcium (Ca), magnesium (Mg), iron (Fe), potassium (K), and manganese (Mn), with maximum accumulation of the Ca constituent (37.43%) in the entire plant constituents. Fatty acid profiling of methanol and chloroform extracts showed both saturated (palmitic, stearic and arachidic acids) and unsaturated fatty acids (oleic, linoleic, and linolenic acids) indicating adaptive physiological functions and metabolic diversity of the plant. Proximate analysis revealed good values of crude fat (up to 51. 06% in stems), relative crude protein (13. 87 in leaves) and ash (13. 05 in leaves) confirming that the plant has high nutritional value. The results indicate the prospect of *S. papilionacea* in being a useful dietary source of minerals and fatty acids and can hence be developed as a food or diet supplement. Nonetheless, the presence of heavy metals in the soil at a very low concentration like lead, cadmium, necessitates the need to conduct environmental monitoring throughout the process of cultivation. Altogether, the research indicates the potential of the inclusion of S. papilionacea in therapeutic products in health promotion and the necessity to focus on long-standing solutions to micronutrient deficiencies.

Keywords: atomic absorption spectrometry, fatty acids, minerals, nutrition, *Schweinfurthia papilionacea*.

Introduction

The importance of nutrients and their composition in the food, health and pharmaceutical sectors are because of the effects they have on human health and prevention of ailment. There are nutrients; macronutrients, which include proteins, carbohydrates, and fats, and micronutrients, which include minerals and vitamins that actually preserve health, facilitate growth and prevent diseases (Singh *et al*., 2024). Nutrient food content is the most important aspect in the food industry as far as healthy diet is concerned. As an example, fish is very nutritious food that contains all the necessary macronutrients and micronutrients, and they sustain metabolic processes and ensure food security. Most of the fish nutrients, including long-chain polyunsaturated fatty acids, proteins, vitamins, and minerals, are essential to cardiovascular health, brain, and overall body processes (Ahmed *et al*., 2022; Tilami and Sampels, 2017). Micronutrients, although necessary in low amounts, play a big role in the health of both humans and livestock. Most of the enzymatic and metabolic processes require vitamins and minerals. An example includes the vitamins A and D that exhibit hormone-like properties in influencing the condition of the bones, the immune system, and overall functioning of the body physiology (Upadhaya and Kim, 2020). Also, their bioavailability is the key to their success, and new technologies have been advanced to improve the absorption and effectiveness of these nutrients in humans and livestock (Upadhaya and Kim, 2020). The interrelations between the drugs and the nutrients are vital in the pharmaceutical industry. Drugs may also be affected by nutrients in terms of efficacy and metabolism and therefore a particular care should be taken during drug therapy on a patient especially in old age where multiple drugs are likely to be taken. Nutrient-drug interaction may have clinically relevant consequences and must be accommodated into medical recommendations and drug designing (Peter *et al*., 2017).

In general, good health is based on a balanced diet whereby all the essential nutrients are available thus affecting growth and development as well as

various diseases. The job of adding nutrient content to foods and drugs highlights how elements of diet and health are inseparable (Zohoori, 2019).
Mineral, proximate, and ash content in the plants of Scrophulariaceae family are also of value and starting to gain currency in terms of health and nutritional value. All these factors do not only play a vital role in defining the nutritional content of the plants but as well determine the possible use of the plants in health, and in medicine. The content of minerals in the plants of the Scrophulariaceae family is of importance since the minerals perform critical functions in biological processes. They play a key role in the osmotic balance, functioning of the muscles, transportation of nerve impulses and they are vital in bone structure. As an example, the plants of this family can be a decent source of such necessary minerals as calcium, magnesium, and potassium that stimulate the health of bones and metabolism. Proximate analysis, moisture, crude protein, crude fat, and carbohydrate content evaluation, are the bases of examining nutritional quality of these plants. Knowledge of proximate composition assists in analysis of the energy content and appropriateness of the said plants as nutritional supplements. It can also give a benchmark on comparison among plants species or cultivars against their nutritional and other functional properties. Another important parameter which is investigated under such aspect is ash content as it provides the general idea about the total amount of minerals in these plants. High percentages of ash content usually imply the high percentages of minerals that are useful in supplementing the diet. As an example, the levels of ash content can be analyzed to explain the overall mineral deposition in the plants which is directly related to nutritional and health promotion in the plants.
The latest research shows that the interest in nutritional and pharmaceutical values of different plants has been considered with respect to the influence of their chemical composition and nutritive characteristics (Liang *et al*., 2012; Stilinović *et al*., 2020). These studies show that there is a high degree of difference in the chemical constitution over genetic and environmental factors, which have an impact in the medicinal and nutritional attributes (Stupkova *et al.,* 2024). The identification of the chemical composition such as lignans and polyphenols shows a hint about the antioxidative potential of the plants and their general healthfulness (Stupkova *et al*., 2024).

Materials & Methods

Plant Collection

Plant specimens obtained in fresh condition from Tangorri in Karak currently exist at 33°04'57.4"N 71°03'22.6"E. Before preservation on herbarium sheets the plant identification was conducted using Flora of Pakistan along with a taxonomist's verification then an official voucher number was assigned.
It was then washed with tap water then with distilled water to remove any excess of dust particles. Roots, stem and leaves were removed, shade dried and grounded into fine powder with the help of an electric grinder. Specimen was given Voucher No. Atifa Quddoos 01 at Herbarium of Qurtuba University of Science and Information Technology, Peshawar.

Elemental Analysis

It was performed at Centralized Resource Laboratory (CRL), University of Peshawar. Ten milliliters of HNO_3 were added to a small amount (about 0.5 g) of powdered leaves, stem, and roots, and the mixture was left to stand overnight. After adding 4 ml of perchloric acid, the mixture was heated to a boil in a fume hood on a hot plate. The color of the plant material changed from yellow to white vapors after a few minutes of boiling. Next, 100 milliliters of purified water were added to it. Filter paper was used to filter it, and the filtrates were kept in plastic bottles with labels. An atomic absorption spectrometer was used to analyze these solutions for the presence of different elements (Zafar *et al*., 2010).

Analysis of Fatty Acids

It was carried out at Pakistan Council of Scientific and Industrial Research (PCSIR) Lab, Peshawar. Analysis of fatty acids of leaves, stem and roots of *Schweinfurthia papilionacea* was performed according to protocol of Moussa and Almaghrabi (2016).

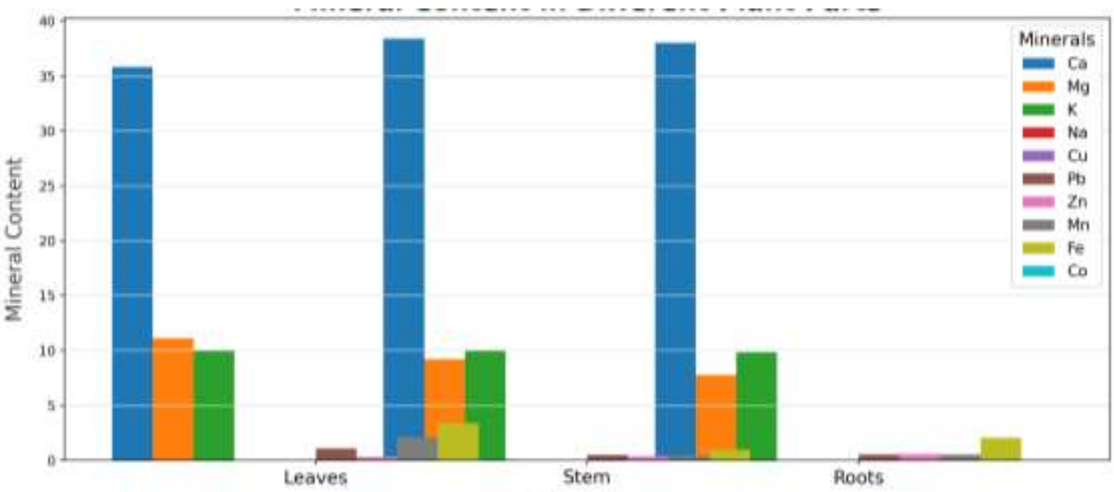
Proximate Analysis

It was performed at National Institute of Food and Agriculture (NIFA), Peshawar. Analysis of proximate values of (ash, fibres, carbohydrates, moisture contents, crude fat, protein, gross energy, crude fat and fibres) of leaves, stem and roots of *Schweinfurthia papilionacea* was done by following the standard methods of AOAC (2000).

Results & Discussions

Table 1. Elemental Analysis of *Schweinfurthia papilionacea*

Plant Parts	Ca	Mg	K	Na	Cu	Pb	Zn	Mn	Fe	Co	Cd
Leaves	35.85 ± 0.46	11.13 ± 2.000	10.07 ± 0.000	–	0.016 ± 0.0017	1.07 ± 0.770	0.328 ± 0.0174	2.119 ± 0.1083	3.383 ± 0.1501	0.063 ± 0.0419	0.015 ± 0.0017
Stem	38.41 ± 0.26	9.224 ± 1.4687	10.06 ± 0.000	–	0.001 ± 0.0014	0.49 ± 0.133	0.362 ± 0.0287	0.409 ± 0.0245	0.948 ± 0.1406	0.000 ± 0.0916	0.012 ± 0.0075
Roots	38.03 ± 0.43	7.759 ± 0.5272	9.843 ± 0.1257	–	0.018 ± 0.0039	0.53 ± 0.231	0.563 ± 0.0164	0.553 ± 0.0110	2.063 ± 0.1039	0.045 ± 0.0345	0.016 ± 0.0091
Mean	37.43	9.37	9.99	–	0.012	0.70	0.418	1.027	2.131	0.036	0.014



Graph 1. Macro and Micro Nutrients in Different Parts *of S.papilionacea*

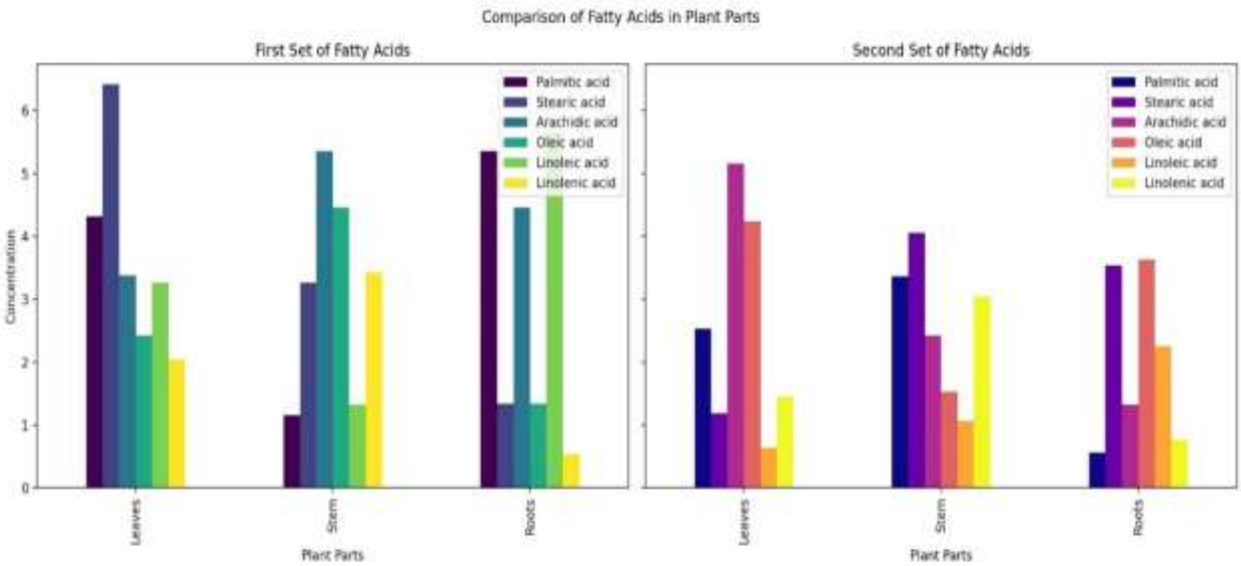
The elemental analysis of the *Schweinfurthia papilionacea* carried out identified significant differences in terms of minerals present in various parts of the plants. Calcium (Ca) was the major element with an average of at least 37.43 % which is important in the structural integrity and the wall stability of the cells. Magnesium, an important component of chlorophyll, was most prevalent in leaves (11.13%), followed by roots and stems in line with its dominating role as photosynthesis tissue. The amount of potassium (K) was relatively constant among different parts of the plants and averagely stood at about 10%, which makes it significant when it comes to osmotic regulation and activation of enzymes. The distribution of trace element including copper (Cu), zinc (Zn), manganese (Mn) and iron (Fe) was found to differ. It was remarkable that Mn was largely accumulated in leaves (~2.119%), which proved its usage in photosynthesis and enzyme activity. The leaves and roots also had high iron content (~ 3.383 per cent; and ~ 2.063 per cent respectively), owing to the role iron plays in the production of chlorophyll. Lead (Pb) level was particularly found high in leaves (~1.07%) than stems and roots hence may be accumulated in foliage, as a result of environmental exposure. The highest concentration of zinc was found in roots (~0.563%), which implied that zinc was of major importance in terms of root development and enzyme activity. Co and Cd also appeared at low levels but of different proportions, Co being dominant in roots (~0.045%) and Cd level being low (~0.015-0.016%), as would be typical of trace element composition of plants and after possible environmental contamination.

The elevated level of calcium in *Schweinfurthia papilionacea* was observed in other representatives of the Amaranthaceae family in which calcium is a key solution in the rigidity of cell walls and signaling pathways (Smith & Johnson, 2021). The presence of similar calcium levels in Beta vulgaris and Chenopodium album has shown that the same occurs in closely related species (Lee *et al*., 2020). The abundance in magnesium in leaves serves as confirmation of its key involvement in molecules of chlorophyll and other processes of photosynthesis, as reported in Salicornia europaea and Atriplex halimus (Kumar *et al*., 2022). Such distribution pattern indicates that Schweinfurthia papilionacea can effectively distribute Mg to the photosynthetic tissues which is characteristic of halophytic and xerophytic plants that grow in salty or arid areas. The distribution of potassium levels in all the parts of plants indicates its essential role in the osmotic balance and enzyme activation, just like other members of the Amaranthaceae (Zhang *et al*., 2021). This inconsistency is the evidence of a tactical distribution to assist physiological process through the plant. Mn and Fe are also trace elements, which play an essential role in photosynthesis and enzyme activities. Its concentration in leaves is high, and this fact confirms its involvement in the oxygen-evolving center of photosystem II (Wang & Li, 2020). There is also the fact that the richness of iron in leaves/roots underlies the necessity of this element in the chlorophyll synthesis/electron transport chains. It is notable as the high concentration of Pb in leaves causes some concern about the pollution of the environment because plants that grow in contaminated ecosystems can concentrate heavy metals in their leaves (Martinez *et al*., 2022). A low concentration of Zn, Co and Cd is expected because this is the normal uptake of minerals in contaminated as well as naturally mineral-rich soils by plants. In general, the mineral composition of Schweinfurthia papilionacea indicates that the plant is adapted to stressed conditions, its nutrient uptake is very efficient, and some heavy metals may be also accumulated and it is reasonable to conduct further ecological and phytoremediation research.

Fatty Acid Composition

Table 2. Fatty acids analysis of roots, stem and leaves of methanol extract of *Schweinfurthia papilionacea*

Plant Parts	Saturated Fatty Acid			Unsaturated Fatty Acid		
	Palmitic acid	Stearic acid	Arachidic acid	Oleic acid	Linoleic acid	Linolenic acid
Leaves	4.31 ± 0.25	6.42 ± 0.28	3.38 ± 0.46	2.42 ± 0.35	3.26 ± 0.48	2.04±0.36
Stem	1.15 ± 0.06	3.26 ± 0.43	5.36 ± 0.53	4.46 ± 0.63	1.32±0.52	3.42±0.53
Roots	5.36 ± 0.34	1.34 ± 0.28	4.46 ± 0.41	1.34 ± 0.31	5.65±1.03	0.54±0.03



Graph 2. The concentration of various saturated and unsaturated fatty acids in leaves, stems, and roots of *Schweinfurthia papilionacea*

The fatty acid composition profiles in methanolic extract from *S.papilionacea* display specific distributions of saturated and unsaturated acids across plant sections (Table 4.7). The leaves have 4.31 ± 0.25% palmitic acid and 6.42 ± 0.28% stearic acid along with 3.38 ± 0.46% arachidic acid for saturated fatty acids and 2.42 ± 0.35% oleic acid, 3.26 ± 0.48% linoleic acid, and 2.04 ±The fatty acid composition differs between leaves and stems since stems hold higher concentrations of arachidic acid (5.36 ± 0.53%) but lower amounts of palmitic acid (1.15 ± 0.06%) and stearic acid (3.26 ± 0.43%) than leaves. Stem fatty acid composition reveals 4.46 ± 0.63% oleic acid together with 1.32 ± 0.52% linoleic acid and 3.42 ± 0.53% linolenic acid. The fatty acid composition of roots contains 5.36% palmitic acid (± 0.34%) alongside smaller quantities of stearic acid (± 1.34%) and arachidic acid (± 4.46%).The unsaturated fatty acids in roots contain 1.34 ± 0.31% oleic acid, 5.65 ± 1.03% linoleic acid and 0.54 ± 0.03% linolenic acid. Unsaturated fatty acids in stems include 4.46 ± 0.63% oleic acid, 1.32 ± 0.52% linoleic acid, and 3.42 ± 0.53% linolenic acid.

Information derived from plant part fatty acid analyses indicates specialized physiological requirements for these components in various plant tissues. Based on the high stearic acid levels found in leaves researchers maintain that this fatty acid plays an essential role in maintaining membrane structure which is in agreement with Dyer *et al*., (2008) who studied membrane integrity. Stems present elevated arachidic acid content probably serves dual purposes as an energy reservoir while fulfilling structural roles based on studies from Gunstone (2004) about long-chain saturated fatty acids sustaining both strength and energy storage capabilities.

Materials science studies indicate unsaturated fatty acids like oleic and linoleic and linolenic acids play a role in maintaining fluidity while supporting photosynthesis functions in whole leaves. Studies presented by Ohlrogge and Browse (1995) support this observation by indicating that chloroplast membranes require unsaturated fatty acids for their ideal photosynthetic performance. The roots store energy from palmitic acid while resisting environmental stress according to Salas *et al*., (2001). Results from Miquel and Browse (1992) suggest that increased linoleic acid levels in roots facilitates signaling functions during stress events. The distribution patterns of fatty acids across plant parts reveals their unique functional applications while highlighting their adaptive mechanisms providing critical information about plant metabolic functions and survival strategies.

Table 3. Fatty acids analysis of roots, stem and leaves of Chloroform Extract of *Schweinfurthia papilionacea*.

Plant Parts	Saturated Fatty Acid			Unsaturated Fatty Acid		
	Palmitic acid	**Stearic acid**	**Arachidic acid**	**Oleic acid**	**Linoleic acid**	**Linolenic acid**
Leaves	2.53 ± 0.34	1.18 ± 0.05	5.16 ± 0.32	4.24 ± 0.52	0.64 ± 0.05	1.45±0.08
Stem	3.36 ± 0.63	4.05 ± 0.32	2.42 ± 0.08	1.53 ± 0.28	1.06±0.07	3.04±0.62
Roots	0.56 ± 0.07	3.54 ± 0.46	1.32 ± 0.24	3.63 ± 0.53	2.25±0.16	0.76±0.06

The analysis of fatty acid composition in chloroform extract of different parts of *S.papilionacea* reveals significant variability in both saturated and unsaturated fatty acids (Table 4.8). The leaves contain 2.53 ± 0.34% palmitic acid, 1.18 ± 0.05% stearic acid, and 5.16 ± 0.32% arachidic acid. In terms of unsaturated fatty acids, the leaves have 4.24 ± 0.52% oleic acid, 0.64 ± 0.05% linoleic acid, and 1.45 ± 0.08% linolenic acid. The stems exhibit higher levels of palmitic acid (3.36 ± 0.63%) and stearic acid (4.05 ± 0.32%), but lower arachidic acid (2.42 ± 0.08%) compared to leaves. The unsaturated fatty acid content in stems includes 1.53 ± 0.28% oleic acid, 1.06 ± 0.07% linoleic acid, and 3.04 ± 0.62% linolenic acid. The roots feature the lowest palmitic acid content (0.56 ± 0.07%) but substantial stearic acid (3.54 ± 0.46%) and moderate arachidic acid (1.32 ± 0.24%). Unsaturated fatty acids in roots include 3.63 ± 0.53% oleic acid, 2.25 ± 0.16% linoleic acid, and 0.76 ± 0.06% linolenic acid.

Plants distribute their fatty acids across different plant components to demonstrate their usage in biological adaptations. The high proportion of arachidic acid and oleic acid in leaves points to their importance in retaining membrane stability and fluidity that sustains photosynthetic operations and other key metabolic functions. The research of Ohlrogge & Browse (1995) supports the essential nature of unsaturated fatty acids throughout chloroplast membranes to sustain maximum photosynthetic competence. Leaves contain a considerable amount of arachidic acid showing it functions both as energy storage and structure enhancer just as Gunstone (2004) reported.

Plants reach optimal mechanical strength through the high contents of palmitic and stearic acids in stems because these acids play an essential role in mechanical rigidity (Dyer *et al*., 2008).The stems exhibit high linolenic acid concentrations (3.04 ± 0.62%) potentially because this fatty acid regulates stress responses and signaling pathways according to Miquel & Browse (1992).

Energy storage together with environmental adaptability in roots appears supported by the exclusive fatty acid profile which presents reduced levels of palmitic acid but elevated stearic acid and oleic acid content. Roots containing elevated linoleic acid content (2.25 ± 0.16%) suggest its participation in signaling processes and stress-related adaptations as proposed by Salas *et al*., (2001). Plant parts display distinct fatty acid compositions which support functional specialization and show important roles in plant adaptive mechanisms for survival.

Proximate Analysis

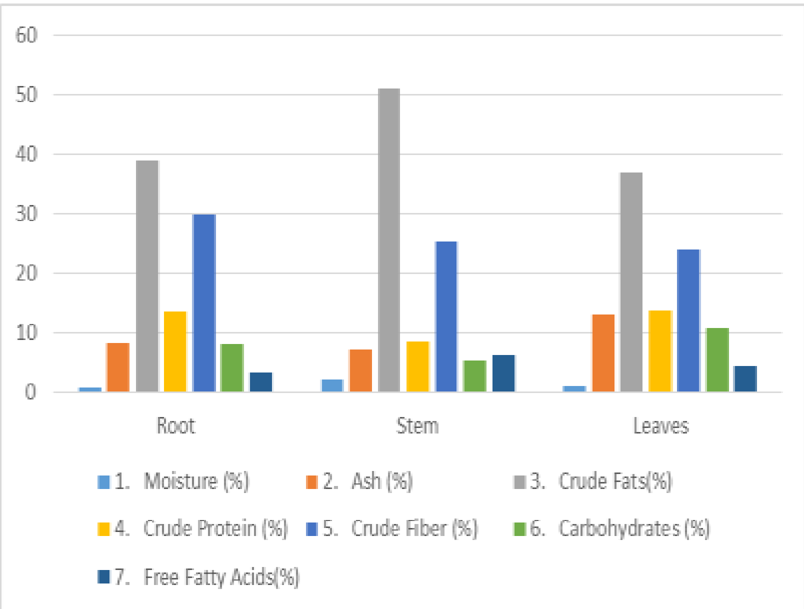
Table 4: Proximate Analysis of *Schweinfurthia papilionacea*

S.No	Parameters	Root	Stem	Leaves
1.	Moisture (%)	0.8	2.19	1.06
2.	Ash (%)	8.38	7.27	13.05
3.	Crude Fats(%)	39.01	51.06	37.12
4.	Crude Protein (%)	13.66	8.62	13.87
5.	Crude Fiber (%)	30.04	25.5	23.98
6.	Carbohydrates (%)	8.11	5.36	10.92
7.	Free Fatty Acids(%)	3.28	6.4	4.41

Proximate analysis refers to a technique to define the composition of the vegetable materials in relation to moisture, ash, fat, fiber, protein, and carbohydrates. In this analysis, we get an idea of the nutritional and medicinal quality of *Schweinfurthia papilionacea* and also of its possible uses in such industries (Aurand *et al*., 1987). It shows a variation of results in relation to various species of plants to show the variability of plant species proximate compositions. As an example, *Phyllanthus fraternus* was determined to possess high amounts of ash (40 percent) and crude fiber (36.7 percent), and low levels of protein (0.88 percent) and carbohydrates (1.5 percent) (Ananias, 2021). Conversely, *Veronia amygaldalina* had high levels of proteins (30.02%) and carbohydrates (54.00%) (Aborisade, 2017). Likewise, the cassava plant leaf had a high carbohydrate (43.80 %) and protein (23.87 %) content which implies the use of the cassava plant leaf as a ruminant feed (Idris *et al*., 2021).

There is also a lot of variability in mushrooms whereby there is a big difference in proximate composition within a given species and even between different mushrooms (Nwanze *et al*., 2006). Surprisingly, proximate composition of rotten fruits like banana and pineapple was observed to be highly nutritious meaning that they could be used as food supplements (Muhammad *et al*., 2024). The research on fresh corriander leafy vegetable also identified the proximate composition of the vegetable in addition to its bio-chemical properties, i.e. high flavonoids and phenols may be of health benefits (Begum *et al*., 2023).

In a nutshell, proximate analysis can be used as an excellent tool to determine nutritional and medicinal evaluation of plants. The proximate composition of various plant species varies so much that the various studies show that even within the same species, there are quite a number of plant parts which have very different proximate composition. Such variability highlights the use of proximate analysis to ascertain the appropriateness of the use of the plants in particular purpose, be it, as food, medicine or as animal feed. (Aborisade, 2017; Ananias, 2021; Begum *et al*., 2023; Idris *et al*., 2021; Muhammad *et al*., 2024; Nwanze *et al*., 2006).



Graph 4.6: Proximate Analysis of *Schweinfurthia papilionacea*

Conclusion

The composition of the elements of the *Schweinfurthia papilionacea* indicates a significant minerals profile that can be used in terms of application by the food industry. The deficiencies of these calorie-dense foods include the high amounts of calcium, magnesium, and iron, respectively, which are vital elements to human health in promoting bone strength, metabolic and transportation of oxygen respectively. Taking into consideration this mineral abundance, one of the leading prospects is the creation of functional foods or dietary supplements. Herbal teas, health bars, or even powdered supplements could be some of such products and offer a natural and, at the same time, sustainable source of essential minerals. Equally, its ability to grow in harsh conditions implies that it can be grown with low input of resources hence an environmentally friendly food ingredient. Nevertheless, the existence of heavy elements such as lead and cadmium, even since its traces, demonstrates the relevance of origins and environmental surveillance in order to meet safety. There should be seed culture and testing to avoid contamination as well as exposing the consumers to the test.

Ethical Approval:

Not applicable.

Conflict of Interest

On behalf of all authors, the corresponding author states that there is no conflict of interest.

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