ORIGINAL PAPER

https://dx.doi.org/10.4314/njpr.v20i1.2s

Nig. J. Pharm. Res. 2024, 20 (S) pp 13-19
ISSN 0189-8434 e-ISSN 2635-3555

Available online at http://www.nigjpharmres.com

Assessment of Heavy Metal Content in *Erythrina senegalensis* and their Human Health Risk Index

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A – research concept and design; B – collection and/or assembly of data; C – data analysis and interpretation; D – writing the article; E – critical revision of the article; F – final approval of article.

Abstract

Background: The general use of herbal drugs is gaining wide popularity. Part of the quality attributes of a drug is its safety and efficacy, as these are important components of quality assurance in the production and use of drugs. The presence of heavy metals in herbal drugs can have severe health consequences. Therefore, there is need to evaluate the quality of plant materials used for therapeutic and drug development purposes.
Objectives: The aim of this study is to determine the level of cadmium, lead, zinc, calcium, magnesium and nickel, and evaluate their health risk index in herbal plant, *Erythrina senegalensis*.
Materials and Methods: The leaves of the plant were obtained from traditional medicine suppliers at the local market of Mushin, Lagos. The plant extract was digested using a mixture of hydrochloric acid and nitric acid in the ratio of 3:1. cadmium, lead, zinc, calcium, magnesium and nickel were determined using Atomic Absorption Spectrophotometer and health risk index was determined.
Results: The results obtained showed that cadmium concentration (3.21 mg/kg) was above the permissive limit set by FAO/WHO. The health risk index (HRI) showed that cadmium (8504, 15765) and zinc (62.6617, 167.0977) values in adults and children were respectively greater than 1 which implies that users are considered to be at risk of various health complications that arise from the consumption of heavy metals beyond the required daily intake.
Conclusion: This study highlights the concerning levels of cadmium and lead in the herbal plant, which pose potential health risks despite the presence of beneficial minerals like calcium and magnesium; and the presence of nickel and zinc at concentrations below the expected limits. The findings underscore the urgent need for stringent monitoring and regulation of heavy metal content in herbal products to ensure consumer safety.

Keywords: Extract, Health risk index, Herbal plant, Metal contamination

INTRODUCTION

The general use of herbal drugs is gaining wide popularity. As a result, researchers have started investigations into activity, efficacy and safety of variety of herbal medicines. Part of the quality attributes of a drug is its safety and efficacy, as these are important components of quality assurance in the production and use of drugs.

Evaluating the quality of plant material is a big challenge since they are of natural origin. As plants are produced from soil, they need materials like optimum

sun light, irrigation and additional nutrients in form of various metallic elements etc., for proper growth and development. On consideration of these points, it appears that there are many factors which may influence the quality of plant materials being used for drug development. Hence, it is very much required to evaluate the quality of plant materials before using it for drug development (Singh, 2013).

Heavy metal analysis is one of the parameters which have been established for evaluating the quality of plant materials (W.H.O, 2005). Heavy metals pose a great health risk to humans, especially when above concentrations required by the body. As they come from natural sources, plants have been affected by manmade activities such as mining, fossil fuels and improper waste disposal which has significantly increased the amount of heavy metals present in them. With this, there is a high chance that human exposure is on the rise.

Typically, the mining, automotive, battery, metal plating, fossil fuel, and electronic sectors release heavy metals into the environment. Some metals have the ability to bioconcentrate from the base of the food chain to the top, rendering them hazardous. This process is known as bio-magnification (Pakade *et al*., 2012). Exposure to these metals can occur through various pathways, including ingestion, inhalation, and dermal contact. The health effects associated with heavy metal exposure range from acute toxicity to chronic conditions such as cancer, neurological disorders, and reproductive issues.

Plant: *Erythrina senegalensis* (Fabaceae)

Common Name: Coral flower.

African Names*:* Hausa: *majiriya*; Igbo: *echichi*; Yoruba; *ologun sheshe*; Bini: *eranigbonyakehi*; Efik: *edeng*; Jukun: *ankai*; Tiv*: showoh*.

Description: *Erythrina senegalensis* is a medium-size shrubby tree, 3–4.5m high but sometimes growing up to 15 m in height and 1.5 m in girth, and prickly. The bark is very rough and fissured, becoming remarkably so in old trees. It has crooked branches with an irregular crown; the thorns on the old wood are slightly curved, with thick woody bases. The flowers are produced September-January in slender racemes up to 30 cm long and scarlet, but they turn black over time. The petals are about 2.5-5cm long, and when leafless, are folded very flat so that the stamens are hidden. The pods are about 12cm long and irregularly constricted but usually between seeds; the seeds are red, glossy, with a white hilium about 0.6 cm long (Iwu, 2014).

Ethnomedicinal Uses: The root infusion is used in Nigeria as a toothache remedy and in the Ivory Coast for venereal diseases. The stem bark is employed extensively in traditional medicine, and several trees in homesteads are often stripped of the barks. The aqueous extract of the bark is used for the treatment of jaundice in northern Nigeria; an infusion mixed with lime and pepper is administered for venereal diseases. A decoction of the bark has been used for the treatment of bronchial infections, coughs, and throat inflammation. The pounded bark and leaves are used in soups to treat female infertility. Extract of the bark is given to women during childbirth; in Guinea, it is administered after delivery, whereas in Nigeria it is given to women during labor to ease pain. The wood is reputed to be an aphrodisiac. In central Africa, infusion of the bark and roots is used as an enema for fevers, inflammation, and stomach ache (Iwu, 2014). Erythrina senegalensis is commonly found in Mali, Senegal and Nigeria. It is mainly grown in West Africa as an ornamental plant (Tepongning et al, 2013). The leaves are used to treat malaria, gastrointestinal disorders, fever, diarrhea, jaundice and pain (Togola et al, 2008). To assess the potential health risks associated with exposure to heavy metals, the Health Risk Index (HRI) has been widely used. It is a vital component of risk assessment frameworks, especially in evaluating health risks from environmental contaminants.

Health risk index: This is a useful method for estimating the possible harm to human health from different pollutants through multiple exposure routes. Urban soil contaminated with heavy metals may be harmful to human health, and the dangers go beyond only the metals. According to Ayaz *et al*., (2024), carcinogenic and noncarcinogenic risks were the two separate categories into which the Human Health Risk Assessment (HHRA) was separated. The assessment of the dangers connected to metal or metalloid exposure served as the basis for this classification.

Risk assessment depends on exposure and hazard (Adamu *et al*., 2014) is the process of calculating the probability that an occurrence will happen and the likely severity of harmful health impacts on people exposed to the hazards over a given time period. Each potentially hazardous metal's health risk evaluation is often determined by quantifying the risk level and is stated as either a carcinogenic or non-carcinogenic health risk (Lim *et al*., 2008)

Human health is seriously endangered by heavy metals. Because they can gradually build up in the human body, their existence in plants including medicinal plants is a serious concern. Furthermore, the adverse health risks associated with heavy metals can differ based on the particular metal, exposure intensity and duration, and individual sensitivity. Hazard Quotient (HQ) calculation is used in the estimation of the health risk index. It is widely used, non-carcinogenic risk assessment method developed by the United State Environmental Protection Agency (USEPA). It calculates the risk associated with exposure to specific contaminants, typically heavy

metals, by comparing the estimated daily intake of the metal to its reference dose.

It is clear that not all products from natural sources are safe for consumption. They can cause various diseases and organ malfunction or even death. The study aims to determine heavy metal levels in ethanolic extract of *Erythrina senegalensis* leaf.

METHODOLOGY

Sample Collection, Identification and Pretreatment

The leaves of the plant (*Erythrina senegalensis*) were obtained from traditional medicine suppliers at the local Mushin market, Lagos and identified by Nodza G. I. at the University of Lagos Herbarium, with tag number: LUH-7942 and subsequently collected in large quantities. A sample of the plant was deposited at the herbarium. The leaves were left to air-dry for 35 days. After drying, the dried leaves were de-stalked and dry-blended to powdered form.

The powdered leaves were then macerated in HPLC-grade absolute ethanol in three separate amber-coloured glass containers with an approximate ratio of 100g of plant material to every 0.8 litre of absolute ethanol. This was done for 4 days with frequent manual agitation of the containers over the course of the 4 days. After 4 days, the mixture of plant and ethanol was filtered with the aid of a muslin bag. The supernatant was then filtered with a 32cm Whatman No. 1 filter paper. Next, the filtrate was made to undergo rotary evaporation at 45^{o}C until a concentrate of thicker consistency was obtained.

Heavy Metal Analysis

The extract (2g) was weighed and immersed in 5ml of deionized water in a 100ml beaker. Then 10mLs of aqua regia (a combination of hydrochloric acid and nitric acid in a ratio of 3:1) was added, the entire mixture was then placed on a heating mantle for 5 minutes in a fume cupboard to obtain a clear solution. The solution was filtered, transferred to a 25ml volumetric flask and made up to mark using deionized water. Metals like Cadmium (Cd), Lead (Pb), Zinc (Zn), Calcium (Ca), Magnesium (Mg) and Nickel (Ni) were the metals to be analyzed in the extract of *Erythrina senegalensis* using the Atomic Absorption Spectrophotometer. The analysis was done in triplicate.

Risk Assessment of Analyzed Metals

Health Risk Index (HRI): The HRI obtained from the use of *Erythrina senegalensis* was evaluated using the Hazard Quotient (HQ) calculation. The values of these indices are based on the daily intake of metals (DIM) and oral reference dose (RfD) which were calculated as the daily exposure of metal in relation to human body (weight in kg). The HQ is calculated by dividing the estimated daily intake of metal by its reference dose.

The daily intake for this study was determined by utilizing the rate of adult vegetable consumption, which is 187 kg / person / day and 130 kg / person / day for children. The average body weight (BW) of adult consumers 60kg and 22.5kg for children. The conversion factor of fresh to dry weight of vegetables was taken as 0.085 (Ghosh et al., 2012; Atikpo. *et al*., 2021).

$$\text{DIM} = \frac{\text{Conc. of metal x food weight consumed (g) x fresh to dry weight conversion factor}}{\text{BW (kg)}}$$

Health Risk Index (HRI) was evaluated using the expression: $\text{HQ} = \frac{\text{DIM}}{\text{RfD}}$

HQ = HRI

RfD for Cd = 0.001, Zn = 0.300, Ca = 800, Mg = 350, Ni = 0.02 and Pb = 0.004 (mg/kg BW/day).

In an event that the health risk index was found to be less than (<1), the users are considered to be safe, however if the health risk index is greater than or equal (≥1), then the users are considered to be unsafe.

RESULT

Heavy Metal Concentration in *Erythrina senegalensis* Leaf Extract

The concentration of the metals determined in the ethanolic leaf extract of *Erythrina senegalensis* are presented in Table 1.

Table 1: Metals Concentrations in *Erythrina senegalensis* Leaf Extract

Metals	Concentration (mg/kg)	FAO/WHO (2012)
Cadmium	3.21±0.02	0.2
Lead	BDL	0.3
Zinc	70.96±0.04	40*
Calcium	23.67±0.01	75
Magnesium	11.42±0.01	30
Nickel	BDL	67.9

BDL: Below Detectable Limit *Institute of Medicine (2001). NIH (2024)

The concentration of cadmium in the extract used for this study was found to be 3.21 mg/kg which exceeds the allowable threshold of 0.2 mg/kg set by joint FAO/WHO, 2012. Cadmium is a non-essential element and has no beneficial role in living organisms.

Factors like the type of food, agricultural practices, weather conditions, and human-induced environmental pollution all play a crucial role in determining the amount of cadmium present in food (Janković et al., 2022). Cadmium is a serious threat to both human health and the environment due to its toxicity and carcinogenic properties (Genchi, *et al*., 2020; Peng *et al*., 2023).

Zinc concentration in the extract (70.96 mg/kg) was higher than the permissive level recommended by the Institute of Medicine (40 mg/kg). Zinc is a micronutrient necessary for development of plants. However, only a small quantity is needed (25–150 µg/g). Zinc is necessary to maintain and defend the immune system, and is also an essential part of human nutrition. It is often regarded as the least harmful; a zinc deficiency may be more harmful to human health than too much of it. I in the diet. Its deficit in the body can negatively impact multiple organs in the gastrointestinal, immunological, skeletal and reproductive systems. Reportedly, taking zinc supplements has a beneficial effect in reducing conditions linked to zinc deficiency, such as diarrheal episodes, diarrhea-related morbidity, premature births, and acute lower respiratory tract infections. Additionally, it promotes linear growth and weight gain in children. (Liu *et al*., 2018). Consequently, it is strongly advised that zinc supplements be incorporated into national food, nutrition, and health initiatives (Sangeetha, *et al.* 2022).

The extract was found to contain 23.67mg/kg of calcium. Calcium could be a major nutrient required in recommended quantities as it needed for skeletal teeth, nerve and muscle development.

Consuming leafy vegetables and medicinal plants as part of the diet can provide a range of health benefits. Calcium in plant materials are primarily complexes with certain anti-nutrients found in plants, such as oxalate, phytate, fiber, and various phenolic compounds (Manivannan *et al*., 2022).

Consuming too much calcium raises the risk of kidney stones and can lead to psychological or nervous system issues. In addition, it may result in loss of appetite, nausea, vomiting, and muscle pain (Alexis *et al*., 2014).

The extract concentration of magnesium was found to be 11.42mg/kg. Magnesium has antagonistic properties towards calcium. This element is predominantly found in the bones, making up a significant portion of the body's total content. It is essential for muscle contraction, nerve activity, blood vessel tone, heart function, and the release of neurotransmitters (Schwalfenberg & Genuis, 2017; Amin *et al*., 2022). The results for the concentrations of lead and nickel were below detection limits.

Health Risk Index (HRI):

The health risk index associated with the intake of *Erythrina senegalensis* as herbal medicine was evaluated in relation to food chain and reference oral dose. The daily intake of Cd for Children (1.5765) was higher than adult (0.8504) (Table 2), hence the corresponding high health index in children. The observed values exceeded the recommended daily

intake of 0.01–0.02 mg/person set by the European Commission in 1996. For infants and children, cadmium intake on a body weight basis is generally higher than that estimated for adults. Children are at greater risk of adverse effects from cadmium compared to adults (Janković *et al*., 2022).

This study showed that the daily intake of zinc calculated was 18.7985 for adult and 50.1293 for children (Table 2). The recommended daily zinc intake is 15-20 mg according to the World Health Organization's 2006 guidelines, but individual needs may vary based on age (W.H.O 2006; Arigbebe *et al*., 2019). Daily consumption of zinc in its appropriate dose aids in maintaining stability and also reduces cadmium and copper toxicity.

Table 2: Health Risk Index for the Metals Analyzed in *Erythrina senegalensis*

Metal		DIM (mg/kg bw/day)	HRI	STATUS
Cd	Adult	0.8504	8504 (>1)	unsafe
	Children	1.5765	15765 (>1)	unsafe
Pb	Adult	0.0000	0.0000 (<1)	safe
	Children	0.0000	0.0000 (<1)	safe
Zn	Adult	18.7985	62.6617 (>1)	unsafe
	Children	50.1293	167.0977 (>1)	unsafe
Ca	Adult	6.2706	0.0073 (<1)	safe
	Children	16.7215	0.0209 (<1)	safe
Mg	Adult	3.0253	0.0086 (<1)	safe
	Children	8.0676	0.0231 (<1)	safe
Ni	Adult	0.0000	0.0000 (<1)	safe
	Children	0.0000	0.0000 (<1)	safe

The daily intake of calcium was found to be 6.2706 for adult and 16.7215 for children. The advised maximum daily calcium intake is 2,500 mg for adults aged 19 to 50. Adults over 50 should not exceed a daily calcium intake of 2,000 mg. For children aged 1–18, the recommended daily intake is 700–1300 mg a day (Institute of Medicine, 2011). The daily requirement for magnesium is in the average of 350 mg. In cases of intense physical activity, the requirements may increase due to the substantial loss of magnesium through sweating. (Alexis *et al*., 2014). The health risk index (HRI) indicated that cadmium and zinc are of human health risk (HRI > 1) when the herbal plant, *Erythrina senegalensis* is consumed therefore it is unsafe.

CONCLUSION

This study assessed the level of cadmium (Cd), lead (Pb), zinc (Zn), calcium (Ca), magnesium (Mg) and nickel (Ni) in the herbal plant, *Erythrina senegalensis* leaf extract, and also evaluated their health risk indices. The analysis revealed that while some elements, such as lead, calcium, magnesium and nickel, were within acceptable limits and contribute beneficially to health, cadmium and zinc concentrations exceeded the acceptable levels set by FAO/WHO and NIH. The calculated health risk index for these heavy metals indicated possible adverse effects, underscoring the importance of monitoring and regulating heavy metal content in herbal plants. Hence, it is very much required to evaluate the quality of plant materials before using it for drug development.

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Conflict of Interest: None declared
Received: October, 2024
Accepted: December, 2024