Review article prospecting research progress on the nutraceutical properties of Erythroxylum coca Lamarck var. coca

Artigo de revisão que analisa o progresso da pesquisa sobre as propriedades nutracêuticas da Erythroxylum coca Lamarck var. coca

Artículo de revisión sobre los avances en la investigación prospectiva de las propiedades nutracéuticas de Erythroxylum coca Lamarck var. coca

DOI: 10.34188/bjaerv8n3-068

Submetido: 30-05-2025
Aprovado: 15-06-2025

Policarpo Quispe Flores
Maestro en Ciencias mención en Química, Especialidad productos naturales mención en Química, especialidad productos naturales
Universidad Nacional Intercultural de Quillabamba / Universidad Nacional Intercultural de Quillabamba
Cusco. Perú
Correo electrónico: policarpo.quispe@uniq.edu.pe

Nivia Marisol Pilares Estrada
Doctora en Psicologia educacional y tutorial
Universidad Nacional Intercultural de Quillabamba, Escuela Profesional de Ingeniería Agronómica Tropical el Arenal S/N, Quillabamba
Cusco. Perú
Correo electrónico: nivia.pilares@uniq.edu.pe

Magnolia Zúniga Olaguibel
Titulación superior y campo: Magister en Ciencias, mencion en Quimica especialidad Productos Naturales
Universidad Nacional Intercultural de Quillabamba, Escuela Profesional de Ingeniería Agronómica Tropical el Arenal S/N, Quillabamba
Cusco. Perú
Correo electrónico: magnolia.zuniga@uniq.edu.pe

1 INTRODUCTION

Coca is a plant of traditional use in the Andean-Amazonian communities for its enormous richness in nutrients, particularly calcium, zinc, potassium, phosphorus, iron, magnesium, vitamins, essential oil, flavones, alkaloids; reason why it is used as supplementary food, the consumption is under the modality of direct chewing of the organic leaf and coca flour, it is also of multiple medicinal use. In rural people, osteoporosis, anemia and diabetes are not a common problem, despite the enormous effort in agricultural activities. Likewise, mongolism is infrequent; on the contrary, they enjoy mental lucidity and it is attributed to the role of phosphorus, iron and zinc in the

physiology of the body. Due to the precarious economy, they are limited to the consumption of vitamins and minerals offered by the pharmaceutical industry, unlike the urban community.

Illicit trade generates panic and limits research on the nutraceutical benefits, (Zuleta & Daza, 2018) manifests the knowledge of the coca leaf has been blocked for different reasons, the main one being to maintain it as a narcotic drug, on the margin of limiting its research is false by all means.

The potential value of the coca leaf in contemporary medicine is a hypothesis based on both the reports of traditional medicine and the small number of studies that have managed to overcome legal limitations, logistical barriers and the stigma surrounding this plant. There is no instigation on root fertilization of coca, particularly with calcium and zinc sources, Restrepo *et al*. (2019) indicates the literature is limited in volume and constitutes a low level of evidence on all coca applications, but may indicate an important opportunity to use updated techniques to explore the coca hypotheses, in addition, more work is needed to explore the molecules and interactions behind the observed physiological effects, although it is quite possible that alkaloids demand the study of the properties each stereotype of coca drive many of the observations, however, a complete characterization, and nutrients, flavonoids with contemporary techniques is still lacking (Restrepo *et al* .., 2019)

Coca is one of the few plant species that contains zinc and calcium in high concentration despite the fact that the crop occupies marginal soils of low fertility and acidity, this mystery requires explanation. Despite these attributes, there is no research work on root fertilization that can show the behavior of the concentration of minerals in the leaf. In illicit crops, the practice of foliar fertilization by direct spraying is common to obtain higher yields; however, in organic consumption it is not recommended because of the remaining trace minerals in the leaves, which are toxic to human health. The objective of the present work is to promote and return to research on what is known and to improve the nutraceutical benefits of the coca leaf by carrying out root fertilization practices to obtain greater added value and reduce the illicit trade that ends in the production of narcotics, whose waste contaminates the environment.

The genus *Erythroxylum* contains species used by the indigenous peoples of South America before the domestication of *E. coca* and *E. novogranatense* plants. *novogranatense*, have been used for thousands of years for their urocan alkaloid content, these species and their wild relatives contain untapped resources for the benefit of mankind in the form of food, pharmaceuticals, phytotherapeutic products and other high value metabolites derived from plants and recent advances in the field of molecular biology and biochemistry (Restrepo *et al* .., 2019)

The traditional use of coca as a natural stimulant among South American natives led to a surge of scientific interest during the 19th and early 20th centuries. Gootemberg (2008) extensively investigates this history. This initial scientific interest led to the isolation of cocaine and its

derivatives, the first anesthetics identified by science, which contributed to the rise of modern anesthesia-assisted surgery and pharmaceuticals, as well as the emergence of the soft drink industry (including Coca Cola, which still contains decocainized coca leaf extracts (Restrepo *et al* .., 2019)

Little research on the nutrient content of E. coca and E. novogranatense species has focused on obtaining the highest possible yield to obtain cocaine, both for legal use in medicine and illegal recreational use. (Zuleta & Daza, 2018) .

The high content of zinc and calcium in coca leaf and the absorption of these elements by the roots from the soil is still not well studied. Specifically, coca is cultivated in marginal lands with a generalized shortage of zinc, however, this plant stands out in high concentration in the leaf. This element is probably one of the most relevant in number of interventions in plant physiology, in particular with biosynthesis and irreplaceable enzymatic activator; in the same way zinc, despite the scarcity of organic sources, plays a very relevant role in human nutrition. The vulnerable population has little access to these nutrients offered by the centers of sale, however, this alternative is a good option for them; this evidence reflects that consumers of oral coca leaf by chewing show little evidence of malnutrition.

E. coca is a preferred choice in Bolivian traditional folk medicine and is used as a general stimulant. (Sauvain *et al*., 1997) .

Due to the scarcity of zinc in food, genetic improvement is a tool to increase the intake of bioavailable zinc from staple food crops in the poor population in developing countries. (Ruel & Bouis, 1998) .

The objective of this paper is to review the state of the art of fertilization with calcium and zinc sources in coca cultivation and its human health benefit in natural organic consumption. The review articles deal with the availability and absorption of zinc and calcium by coca cultivation and the importance of coca leaf consumption on human health.

2 MATERIALS AND METHODS

The materials used by the researchers were foliar fertilizers applied by direct spraying to the coca leaf to solve the zinc deficiency because there is no work on root fertilization in particular for coca cultivation.

For the clinical investigations, the materials used were coca leaf and coca flour.

The essential oil obtained by steam distillation system. (Gamarra Ochoa, 2018) .

Mineral analysis was performed by inductively coupled plasma mass spectrometry (ICPMS) (Penny *et al* .., 2009)

Vitamins A (retinol and β-carotene), were analyzed by high performance liquid chromatography (HPLC) (Aquanal Pessac, amino acid was evaluated by ion exchange chromatography OAC International, cited by (Penny *et al* .., 2009)

The determination of the chemical composition of coconut essential oil was determined by Gas Chromatography/Mass Spectrometry (GC/MS) (Ventura *et al* . ., 2009)

In clinical investigations, patients have been used.

3 RESULTS AND DISCUSSION

In the chemical composition of coca leaf, minerals, vitamins, protein, secondary metabolites, antioxidants and fibers have been found. The results are shady, in many works are still to be concluded, in other cases to be replicated, and leaves open the research in the field of medicine, nutrition and agriculture.

Coca leaf has been promoted as a food of organic and natural consumption in the Andean community that could solve the dietary deficiencies of the population based on the following results.

Regarding the nutritional potential of coca, several studies have provided comparatively high information Collazos, C. (1965), Duke, J. (1965), Olivier, J. (2012) cited by Restrepo *et al*., (2019) indicate, in particular, coca leaf contains significant amounts of protein, carbohydrates, fiber, minerals (especially calcium, phosphorus and iron) and vitamins, such as thiamine, riboflavin and carotene. When consumed as tea, coca provides minerals such as calcium, magnesium, potassium, iron, manganese, zinc, phosphorus, copper, sulfur, sodium and aluminum. Potentially harmful minerals are found in such low amounts that they do not appear to pose a health risk Olivier, J. (2012) cited by. (Restrepo et al., 2019) .

Table No.1: Chemical composition of coca leaf.

Chemical composition	quantity (mg/100 gWD)
Protein	20.28
(Lysine the limiting amino acid)	
Calcium	99.00 y 1033.17
(in different laboratories)	
Iron	29.16 y 29.16
Zinc	2.71 y 2.63
Magnesium	225.19 y 196.69
Vitamin E	16.72
Traces of vitamin D	0

Source: Penny et al., (2 009).

Few species exceed the zinc content in coca leaf International Zinc Nutrition Consultative (I ZiNcG 2004), indicates seeds and nuts 2.9 to 7.8mg/100g, phytate content 1 760 to 4 710 mg/100g cited by (López de Romaña et al., 2010) .

Zinc chelates formed with organic matter tremendously increase zinc availability to the plant. (Al & Panama, 2001) .

Due to the lack of research on the fertilization of the coca plant by the root route, we refer to the experience in other crops. Calcareous, sandy, peaty soils, high content of phosphorus and silicon are susceptible to zinc deficiency and prolongs the ripening of the crop, also generates sterility of wheat spikelets that affects the quality of the harvest. (Hafeez, 2013) .

Foliar fertilization in illicit coca cultivation is common as in other crops. The uptake of Cu, Zn and Mn through leaves *Saccharum officinarum* L., (var. H53-263) (Bowen, 1969) .

Coca extracts zinc from acid soil Sadeghzadeh & Rengel, (2011) conclude, zinc availability in rice, wheat and other crops, in flooded soils and fertilization with relatively high phosphate, and calcareous reaction soils has reduced zinc availability; this implies studying Bayovar phosphate rock for use.

Organic fertilization is limited to areas declared legal crops such as Bolivia with 12,000 ha legal and 7,880 ha permitted, and Peru with more than 25,000 ha (Sephu, 2010) .

Most research has focused on the study of alkaloids. Between the years 1950 and 2017 there are 358 publications on ecgonine, focused on addiction issues, which is more than three times the total number of publications on the medicinal uses of coca and its derivatives (Zuleta & Daza, 2018).

Studies conducted by (Conzelman & White, 2016) , indicate the protein concentration is approximately 20% in dry weight, but the digestibility and quality of this protein should be evaluated. Regarding vitamins and minerals they found that the average amount of coca leaves chewed by an adult per day (50 g) would cover the following daily needs: calcium 51%, iron 81%, magnesium 26%, vitamin A 32%, vitamin D 20%, vitamin E 100%, zinc 9%.

Zinc has multiple functions in the human body, absorption occurs in the small intestine and is together with excretion, the control points of homeostasis; it is an essential nutrient with a specific role in more than 300 enzymes, which participate in all important biochemical reactions in the human body, therefore, zinc status has a direct effect on growth, neurological and behavioral development and the immune system (Lopez de Romaña *et al.* ., 2010)

There are still many gaps in the biological role of iron and zinc, a recent review of the effect of iron and zinc interaction on biochemical and functional parameters in supplementation interventions concluded that the evidence does not show an adverse effect of iron supplementation on biochemical indicators of zinc and that joint iron and zinc supplementation does not seem to have

a negative effect on serum zinc either Hess S. Pearson (2007), cited by (López de Romaña *et al.* ., 2010)

Coca leaf for natural and organic consumption should not be allowed to be supplied with zinc by the foliar route because it is a heavy metal. In other crops its use is common because it acts as a biostimulant that improves crop quality (Novák *et al.* ., 1984)

No micronutrient is as relevant as zinc in human physiology as an essential nutrient, and it is involved in more than 300 enzymes that participate in all important biochemical reactions in the human body; zinc has a direct effect on growth, neurological and behavioral development, and the immune system. (López de Romaña *et al.* .., 2010)

The evaluation of the aqueous extract of coca micropulverized showed antioxidant activity in both techniques, free radical scavenging (ABTS.+) and iron reducing potential (FRAP); it also showed a total phenol content comparable to other plant resources considered as sources of polyphenols; the IC50 against the ABTS radical was 21.64 µg/mL, further indicating, compared to the $IC_{50}$of green tea of 209.74 µg/mL and concluding that 9 times less coca powder than green tea is required, considerably less to inhibit the oxidation of ABTS.+. furthermore, could contribute in the cytoprotective mechanisms of bone remodeling (Trigo-pérez & Suárez-cunza, 2017) .

The potential use in contemporary medicine of coca, the available literature explores several effects on the endocrine and vascular systems, associated with improved physical performance, the presumed increase in glucose availability, especially during physical exertion Galarza, M. (1997), Brust, S. (1995), Favier, R. (1996), Spielvogel, H. & Hurtado, S.(1996) cited by Restrepo, et al., (2019), further indicate, may be achieved through coca's effects on promoting fatty acid metabolism (Casikar, V. 2010); secondly, Weil's (1981) review identified a subjectively reported temporary suppression of appetite, which may be related to coca's promotion of increased glucose availability; and thirdly, there is a hypothesis that coca consumption is associated with improved blood flow and reduced heat loss (Huna, j. 1 991) & Litle, M. (1970), possibly related to a mild vasoconstriction, increased hemoglobin levels and blood thinning effects (Rodriguez, A.,1997). This may be due to the behavior of coca alkaloids, similar to atropine, which temporarily reduce the rate of red blood cell production, resulting in lower blood viscosity (Fusch, R. (1978) cited by. (Restrepo *et al* ., 2019).

Metabolic and cardiovascular effects among the areas of interest for contemporary medicine, a key topic explored in the literature has been the value of coca as a stimulant and its effect on physical performance, which is the application most akin to the traditional use of coca. (Restrepo *et al* .., 2019)

In general, the effects of coca on physical performance are relatively mild, but potentially clinically significant. Biondich and Joslin (2015, 2016) cited by Restrepo. The impact of coca on glucose availability appears to be the most scientifically validated metabolic effect (Casikar, V. 2010), further indicating the value of coca use in reducing symptoms of altitude sickness.

The effects on glucose metabolism may provide a basis for appetite suppression which, as hypothesized by Weil (1981), could support the use of coca in weight control regimens, as well as, potentially, in the control of diabetes. The anticoagulant effects of coca, speculated in Fuchs (1978), may also contribute to the low incidence of thrombosis in native Bolivian populations, as noted by Rodriguez (1997). This would indicate the potential of coca products for stroke prevention, provided that the vasoconstrictor effects are taken into account and properly managed. (Restrepo et al., 2019) .Coca leaves also have significant amounts of polyphenols. We found 3.8 g/100 g based on dry weight and 66 mg per serving of infusion (data not shown) as gallic acid equivalents (Penny et al., 2009) .

An investigation concludes that the coca leaf E. coca, reduces glycemia, significant in both forms of consumption mate and chewing compared to the control group. (Pedro & Revilla, 2013)

The essential oil of coca leaf was obtained using the steam distillation system, obtaining a yield of 0.08% w/w. (Ventura *et al.*, 2009; Gamarra Ochoa, 2018) .

The therapeutic effects of the essential oil of E. coca demonstrate the presence of greater antibacterial activity against Gram-positive bacteria *Bacillus subtilis* clinical strain, *Staphylococcus aureus* ATCC 25923, *Staphylococcus epidermidis* clinical strain; with greater activity against *Staphylococcus aureus* ATCC 25923 and lesser against Gram-negative bacteria: (*Escherichia coli* clinical strain and *Pseudomonas aeruginosa* ATCC 27853 (Ventura et al., 2009).

In coca essential oil, hydrocarbon chemical components, oxygenates and organic acids have been identified, among which the following substances stand out: Guanine-1(5), (11)-diene, t-cadinene, (2E,7R,11R)-3,7,11,15-tetramethyl-2-hexadecen-1-ol. Eudesm-4(14)-en-11-ol, hexahrydrofarnesyl, hexadecanoic ketone, phytol, sis-9-octadecenoic acid and octadecanoic acid (Ventura *et al* .., 2009)

4 CONCLUSION

The legal problem of coca is a brake that generates a climate of discouragement among researchers despite its enormous nutraceutical potential; research is infrequent, which is why there is little updated literature; the studies show many gaps, in other cases they recommend replicating the results. Research has focused on the study of methyl (1R,2R,3S,5S)-3- (benzoyloxy)-8-methyl-8-azabicyclo [3.2.1] octane-2-carboxylate (cocaine). The tools and apparatus used in the leaf

research are modern, which validate the certainty of the results. There is no literature on root fertilization to evaluate the behavior of the concentration of minerals and secondary metabolites in the coca leaf; if the results are favorable, this can be the beginning to promote legal production, protecting the soil from erosion and restricting the illicit trade of the leaf that ends up contaminating the environment.

REFERENCES

Al, P., & Panama, M. A. L. D. E. (2001). Influence of zinc on the resistance of banana to Panama disease (Fusarium oxysporum f.sp. cubense). *Journal of Chemistry*, *15*(1), 7–16.

Bowen, J. E. (1969). Absorption of Copper, Zinc, and Manganese by Sugarcane Leaf Tissue. *Plant Physiology*,*44* (2), 255-261. https://doi.org/10.1104/pp.44.2.255

Conzelman, C. S., & White, D. M. (2016). The botanical science and cultural value of coca leaf in South America. *Roadmaps to Regulation: Coca, Cocaine, and Derivatives*, *April*, 1-18. http://beckleyfoundation.org/policy/roadmaps-to-regulation-coca-cocaine-derivatives/the-botanical-science-and-cultural-value-of-coca-leaf-in-south-america/

Evaluation of the effect of powdered coca leaf consumption on bone turnover markers in postmenopausal women. (n.d.).

Gamarra Ochoa, V. R. (2018). *Study of alkaloids and flavonoids from the leaves of Erythroxylum coca Lam and Erythroxylum novogranatense (Morris) Hieron; and evaluation of their antioxidant, antibacterial, toxic and cytotoxic activity*. 97. http://cybertesis.unmsm.edu.pe/bitstream/handle/cybertesis/7857/Gamarra_ov.pdf?sequence=1&isAllowed=y

Hafeez, B. (2013). Role of Zinc in Plant Nutrition- A Review. *American Journal of Experimental Agriculture*,*3* (2), 374-391. https://doi.org/10.9734/ajea/2013/2746

López de Romaña, D., Castillo D, C., & Diazgranados, D. (2010). EL ZINC EN LA SALUD HUMANA -1. *Revista Chilena de Nutrición*,*37* (2), 234-239. https://doi.org/10.4067/S0717-75182010000200013

Novák, M., Salemink, C. A., & Khan, I. (1984). Biological activity of the alkaloids of Erythroxylum coca and Erythroxylum novogranatense. *Journal of Ethnopharmacology*,*10* (3), 261-274. https://doi.org/10.1016/0378-8741(84)90015-1

Pedro, C., & Revilla, E. (2013). Evaluation of the post-ingestion glycemic response of coca leaf (Erythroxylum coca) in people with no pathological metabolic history. *Scientific Journal Medical Science*, *16*(1), 20–24.

Penny, M. E., Zavaleta, A., Lemay, M., Liria, M. R., Huaylinas, M. L., Alminger, M., Mcchesney, J., Alcaraz, F., & Reddy, B. M. (2009). Can Coca leaves contribute to improving the nutritional status of the Andean population? *Food and Nutrition Bulletin*,*30* (3), 205-216. https://doi.org/10.1177/156482650903000301

Restrepo, Saenz, E., Jara-Muñoz, Calixto, I., Rodríguez-Suárez, Zuleta, Chavez, B., Sanchez, & D'Auria, J. (2019). Erythroxylum in Focus: An Interdisciplinary Review of an Overlooked Genus. *Molecules*,*24* , 3788. https://doi.org/10.3390/molecules24203788

Ruel, M. T., & Bouis, H. E. (1998). Plant breeding: A long-term strategy for the control of zinc deficiency in vulnerable populations. *American Journal of Clinical Nutrition*,*68* (2 SUPPL.), 488-494. https://doi.org/10.1093/ajcn/68.2.488S.

Sadeghzadeh, B., & Rengel, Z. (2011). Zinc in Soils and Crop Nutrition. *The Molecular and Physiological Basis of Nutrient Use Efficiency in Crops*, 335-375. https://doi.org/10.1002/9780470960707.ch16

Sauvain, M., Rerat, C., Moretti, C., Saravia, E., Arrazola, S., Gutierrez, E., Lema, A. M., & Muñoz,

V. (1997). A study of the chemical composition of Erythroxylum coca var. coca leaves collected in two ecological regions of Bolivia. *Journal of Ethnopharmacology*,*56* (3), 179-191. https://doi.org/10.1016/S0378-8741(97)00030-5

Sephu (2010). *The Legal Cultivation of Organic Coca and Recommendations for its Fertilization*. *045*, 15. https://www.interempresas.net/FeriaVirtual/Catalogos_y_documentos/81972/045---10.05.10---Cultivo-Legal-de-Coca-Orga--769-nica.pdf

Trigo-pérez, K., & Suárez-cunza, S. (2017). Evaluation of the effect of coca leaf powder consumption on bone turnover in postmenopausal women. *Revista Peruana de Ginecología y Obstetricia*,*63* (4), 519-527. https://doi.org/10.31403/rpgo.v63i2023

Ventura, G., Castro, A., Roque, M., & Ruiz, J. (2009). Chemical composition of the essential oil of Erythroxylum coca Lam var. Coca (coca) and evaluation of its antibacterial activity. *Science and Research*,*12* (1), 24-28. https://doi.org/10.15381/ci.v12i1.3382

Zuleta, P., & Daza, D. (2018). Systematic review of scientific articles on medicinal, nutritional and agroindustrial use of coca leaf and its derivatives. *DDHH Elemental*, 1–19.