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Editorial

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Maca: Botanical Medicine from the Andes

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Maca (*Lepidium meyenii,* Walp) (Brassicaceae) is a biennial herbaceous plant widely dispersed on high plateaus (altitudes between 4000 and 4500 masl) of the mountains in Peru, particularly in Junin. The underground part of the plant, the tuber, is the main product used for human consumption because of its nutritional value and phytochemical content.[1-3] Maca presents three major phenotypes, yellow, red and black based on their hypocotyl and stem coloration (Figure 1).[4] Andean people use maca as boiled or roasted food, in soups, or to prepare drinks, salads, jams, bread, coffee, substitutes, and even beer.[5,6] A sweet aromatic dessert, called mazamorra, is prepared by boiling the roots in water or milk. A fermented drink, maca chichi, is also made and the dried roots are used to impart a special flavor to the sugar cane rum or aguardiente.[1,7]

Figure 1: Yellow, Red and Black Maca.

Maca is rich in sugars, starch, protein (13-16%), glucosinolates and essential minerals, such as iron and iodine.[1] Maca also contains other compounds such as fatty acids (linoleic, palmitic, and oleic acid mainly), aminoacids (lysine and arginine), many microelements, tannins and saponins. An important component of maca is a mixture of alkaloids known as macaines 1,2,3 and 4 and alkamides (macamides), including alcamide 1 to 5. Some authors suggest that active substances are not just prostaglandins and sterols, but also aromatic isothiocyanates, such as benzyl-isothiocyanate or p-methoxy-benzyl-isothiocyanate to which the aphrodisiac qualities are attributed. Also, the antioxidative activity of maca is linked to those substances.[1,6-8] The main functional properties of maca are shown in table 1.

Maca is an important source of glucosinolates mainly of the aromatic type (glucotropaeolin). Yábar et al.[35] identified six glucosinolates in the yellow, red and black ecotypes. These glucosinolates corresponded to 5-methylsulfinylpentyl, 4-hydroxybenzyl, benzyl, 3-methoxybenzyl, 4-hydroxy-3-indolylm- ethyl and 4-methoxy-3-indolylmethyl. Glucosinolates and their derived products have received scientific attention because of their biological activities, mainly against cancer. The anticancer properties of maca have been also attributed to its flavonoid content. Bai et al.[36] found three flavonoids in maca roots consisting of a tricin unit. Tricin has been considered as a potential cancer chemopreventive agent in humans. A specific study with red maca determined its efficacy on the regulation of prostatic growth by reducing prostate zinc levels in rats. As pointed out by Gonzales et al.[37] the determination of prostate weight and zinc levels can be considered as alternative markers to discriminate the effect of red maca from

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	SUBJECT OF STUDY	MAIN FINDING (S)	SOURCE
REPRODUCTION Male Reproduction:			
Sperm function	Rats	Treatment of rats with maca at high altitude prevented high altitude-induced spermatogenic disruption.	9
	Rats	Maca prevented lead acetate-induced spermatogenic disruption in rats and it may become in a potential treatment of male infertility associated with lead exposure.	10
	Mice	Maca enhances spermatogenesis following spermatogenic damage caused by the organophosphorous pesticide.	11
	Rats	Black maca appeared to have more beneficial effect on sperm counts and epididymal sperm motility.	12
	Men	Maca improved sperm production and sperm motility by mechanisms not related to luteinizing hormone, follicle stimulating hormone, prolactin, testosterone and estradiol.	13
Prostate function	Rats	The hydroalcoholic or aqueous extract of red maca containing 0.1 mg of benzylglucosinolate can reduce prostate size in male rats in which prostatic hyperplasia had been induced by testosterone enanthate.	14
	Rats	Red maca reduced ventral prostate size in normal and testosterone enanthate treated rats.	15
	Rats	Red maca administered orally in rats seems to exert an inhibitory effect at a level post dihydrotestosterone conversion, on the benign prostatic hyperplasia -induced experimentally, although a direct measure of reductase action would still be required.	16
	in vitro	Maca extracts (obtained with different solvents: methanol, ethanol, hexane and chloroform) are not able to regulate glucocorticoid response element activation.	17
Serum hormone	*in vitro*	Maca extracts (obtained with different solvents: methanol, ethanol, hexane and chloroform) are not able to regulate glucocorticoid response element activation. Thus maca does not exert direct androgenic activities.	17
Female Reproduction/Hormonal balance/Menopause	Rats	Serum estradiol levels were not affected.	12,16
	Mice	Progesterone levels increased significantly in mice that received maca, while testosterone levels increased significantly in mice that received both *L. meyenii*Walp and *J. macrantha*. However, there were no marked changes in blood levels of estradiol-17beta or the rate of embryo implantation.	18
	Men	Treatment with maca does not affect serum reproductive hormone levels.	3
	Mice	Administration of aqueous extract of yellow maca to adult female mice increases the litter size and also increases the uterine weight in ovariectomized animals.	19
	Rats	Red and black maca have protective effects on bone architecture in ovariectomized rats without showing estrogenic effects on uterine weight.	20
	Women	These randomized clinical trials demonstrated the favorable effects of maca on menopausal symptoms in healthy perimenopausal, early postmenopausal, and late postmenopausal women. However, the total number of trials, the total sample size, and the average methodological quality of the primary studies, were too limited to draw firm conclusions.	21
OSTEOPOROSIS	Rats	The higher dose of ethanol extract of maca was effective in the prevention of estrogen deficient bone loss.	22
SEXUAL FUNCTION	Rats	Acute and short-term administration of maca produced a small effect of rat male sexual behavior and long-term administration did not increase anxiety.	23
	Rats	Acute and chronic oral administration of maca significantly improve sexual performance parameters in male rats.	24
	Mice and rats	Oral administration of lipidicmaca extract enhanced the sexual function of the mice and rats. as evidenced by an increase in the number of complete intromissions and the number of sperm-positive females in normal mice, and a decrease in the latent period of erection in male rats with erectile dysfunction.	25

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SEXUAL FUNCTION	Rats	Hexanic and methanolic extracts were able to increase mount frequency, while only hexanic fraction significantly improved mount latency. Sub-acute oral administration of hexanicmaca extract improved sexual performance parameters in sexually inexperienced male rats most effectively.	26
	Women	Maca reduces psychological symptoms, including anxiety and depression, and lowers measures of sexual dysfunction in postmenopausal women independent of estrogenic and androgenic activity.	27
	Men	Treatment with maca improved sexual desire.	28
	Men	Small but significant effect of maca supplementation on subjective perception of general and sexual well-being in adult patients with mild erectile dysfunction.	29
VITALITY AND STRESS TOLERANCE	Women	Maca was shown to have significant effects on psychological symptoms including effects on anxiety and depression as measured by the Green Climacteric Scale (GCS) and its subscales.	27
	Mice	The methanolicmaca extract is capable of attenuating or even eliminating variations in homeostasis produced by stress since it reduces or abolishes stress-induced ulcers, elevated corticosterone levels, the reduction of glucose and the increase in the weight of adrenal glands produced by stress.	30
MEMORY & LEARNING	Mice	Black maca presented the better response with respect to latent learning in ovariectomized mice.	31
	Mice	Black maca improves scopolamine-induced memory deficits in male mice.	32
IMMUNITY/NUTRITION	Rainbow trout alevins and juveniles	Maca tuber meal inclusion at least 5% improves growth rate, feed utilization, immunity by increased leucocyte number, and survival of rainbow trout alevins and juveniles.	33
	Rainbow trout juveniles	The results indicate that certain compounds in maca meal have growth enhancing effects in rainbow trout juveniles.	34

Table 1: Main Functional Properties of Maca.

different sources. Flavonoids in maca have shown to be potent inhibitors of monoamine oxidase activity, thus mimicking the actions of monoamine oxidase antidepressant medication. However the specific role of flavonoids in maca remains to be established.[27]

In addition, maca is marketed for its reported benefit in relieving menopausal symptoms, although additional scientific data is necessary to support any efficacy. To this respect,[27] showed the ability of maca to reduce psychological symptoms associated with menopause, including anxiety and depression, along with sexual dysfunction. It is difficult to postulate how maca is acting to reduce psychological symptoms, given the complex nature of psychological control; thus the mechanisms need further investigation.

Regarding the role of maca supplementation in endurance capacity and exercise performance, Stone et al.[38] determined that 14 days supplementation with maca extract significantly improved time to complete a 40 km time trial in trained male cyclists. Thus, the efficacy of maca extract on the improvement of exercise performance was demonstrated. Similarly, supplementation with the lipid-soluble maca extract for 3 weeks increased swimming time to exhaustion in weight- loaded forced swimming rats that can be partially explained by attenuation of exercise-induced oxidative stress.[39]

Maca is also known for its supportive effect on fertility and enhancing and aphrodisiac properties.[6,27] Some studies reported the beneficial effects of maca in sexual function of mice and rats. Ethanol maca extract enhanced the sexual function of the mice and rats, as evidenced by an increase in the number of complete intromissions and the number of sperm-positive females in normal mice. Also, a decrease in the latent period of erection in male rats with erectile dysfunction was observed.[25] Here, the aphrodisiac activity of *L. meyenii* was revealed. Additionally, the hexanicmaca extract improved the majority of the sexual parameters measured such as mount latency in sexually inexperienced male rats most effectively.[26] The effect of maca on fertility has been also supported by Uchiyama et al.[40] They investigated the effect of maca on the serum pituitary hormone levels during the pro-oestrus phase. It was demonstrated that maca uniquely enhances the luteinising hormone (LH) serum levels of pituitary hormones in female rats during the pro-oestrus LH surge and acts in a pharmacological, dose-dependent manner.

As mentioned above, the varieties of maca are based on the root color. Black maca enhanced daily sperm production and increased epididymal sperm motility, in adult rats, compared to red and yellow maca. In relation to the prostate weight, black or yellow maca did not affect it while red maca did reduce the weight. Thus, black maca appeared to have more beneficial effect on sperm counts and epididymal sperm motility than red and yellow maca.[12] In a similar study, Rubio et al.[10] determined that maca reduced the harmful effect on daily sperm production caused by lead acetate treatment. Consequently, maca may become a potential treatment of male infertility associated with lead exposure. The acetate fraction of the hydroalcoholic black

maca extract was also found to have the greatest effect in spermatogenesis in rats. As cited by the authors, antioxidant components could also play a role in the effect of increased epididymal sperm concentration.[41]

On the other hand, no increase in testosterone levels was observed in healthy men after 12 weeks of maca administration. Further studies are needed to determine the effect of maca administration in subjects with sexual dysfunction.[3] Even tough, maca treatment produced a small effect of rat male sexual behavior, an increase in ejaculation latency and post ejaculatory interval was observed. Also, a long-term administration of maca did not increase anxiety.[23]

Furthermore, maca is recommended for malabsorption syndrome, ethylism, as a laxative, and during reconvalescence, owing to its excellence nutritional characteristics. Also, it is used to combat anemia and insomnia, reduce plasma glucose levels and free fatty acids and as a regulator of female menstruation and menopause.[5,6]

Maca contains several compounds but their specific biological activity and mechanisms of action have not been fully elucidated as yet. Given the maca's compounds potential as anticarcinogenic, antioxidant, performance exercise enhancer among other benefits such as its positive effects on fertility and sexual dysfunction, this plant needs much more intense examination in the future that include human studies. Particularly, continued studies related to glucosinolates in cruciferous vegetables, mainly maca will create more confidence in people whose tendency of healthy eating habits is incessantly growing.

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