Biological Effects and Safety of *Lepidium meyenii*, Maca (variety red), a Plant from the Highlands of Peru

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Maca, a matlike perennial, is so small, flat, and inconspicuous that even visiting agronomists sometimes fail to realize they are standing in a farmer's field.
Lepidium meyenii (maca) is a cultivated plant growing exclusively over 4,000 m altitude in the central Andes of Peru.

Maca is cultivated and grows at a minimum temperature of –1.5C and maximum of 12C.
*Lepidium meyenii*

- **FAMILY:** Cruciferae  
  *(Brassicaceae)*
- **GENUS:** Lepidium
- **SPECIES:** *Lepidium meyenii*  
  Walp
- **COMMON NAME:** Maca
The hypocotyls of maca, the eatable part of the plant
**Nutritional profile of dried maca root (average 10 gram serving)**

<table>
<thead>
<tr>
<th>Component</th>
<th>per 10 g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein</td>
<td>1-1.4 g</td>
</tr>
<tr>
<td>Carbohydrates</td>
<td>6-7.5 g</td>
</tr>
<tr>
<td>Fats (lipids)</td>
<td>220 mg</td>
</tr>
<tr>
<td>Fiber</td>
<td>850 mg</td>
</tr>
<tr>
<td>Ash</td>
<td>490 mg</td>
</tr>
<tr>
<td>Sterols</td>
<td>5-10 mg</td>
</tr>
<tr>
<td>Calories</td>
<td>32.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Vitamins</th>
<th>per 10 g</th>
</tr>
</thead>
<tbody>
<tr>
<td>B2</td>
<td>39 mcg</td>
</tr>
<tr>
<td>B6</td>
<td>114 mcg</td>
</tr>
<tr>
<td>C</td>
<td>28.6 mg</td>
</tr>
<tr>
<td>Niacin</td>
<td>565 mcg</td>
</tr>
</tbody>
</table>
Its tuberous roots resemble those of its relative the radish, and are yellow, purple, or yellow with purple bands.
Maca during natural drying processes
Dried maca: black, yellow and red maca
Maca varieties:

- It has been reported 13 varieties of Maca ranged from white to black (Tello et al., 1992).

- Yellow maca was the most frequent variety (47.8%) (Tello et al., 1992).
Varieties of maca
Maca: Biological Effects

- Sexual desire and Sexual behavior
- Spermatogenesis
- Energetic
- Immunity
- Anti-stress
- Mood and anti-anxiety
- Antioxidant activity
- Against Benign Prostatic Hyperplasia
- Increase female fertility
- Learning and memory
Red maca: Properties

- Red maca (neither yellow nor black maca) reduces the prostatic weight and size in male rats in which prostatic hyperplasia has been induced with testosterone enanthate (TE) (Gonzales et al., 2005).

- Red maca could be considered as an alternative for a new treatment of prostatic hyperplasia, a disease that affects to more than 50% of men over 50 years of age.

- Attention has been centered on one of the secondary metabolites from maca, benzyl glucosinolate, as the potential active principal responsible for this effect on prostate.
Effect of red maca on prostate weight of rats (2 g/Kg): 42 days
Effect of testosterone enanthate and red maca on prostate weight in male rats

Inducing Hyperplasia in ventral prostate, 42 days of treatment

Control

TE+H2Od

TE+RM

<0.05
Objectives

- The present study has been designed to determine:
  - A dose-response effect of benzylglucosinolates (0.02-0.08 mg) derived from red maca extracts on rat prostate size in which hyperplasia has been induced with TE.
  - The safety of a hydroalcoholic standardized extract of red maca
  - The content of benzyl glucosinolate and polyphenols in the extract of red maca
  - The presence of heavy metals, microorganisms and pesticides
**Methods**

- Red maca was obtained from Carhuamayo, Junin at 4000 m altitude
- Organically cultivated with non use of pesticides
- Hypocotyls are harvested on June-July every year
- 1 Ha produces 4-5 tons hypocotyls of maca
Spray dried hydroalcoholic extract of red maca

- Pulverized dried hypocotyls of *Lepidium meyenii* were macerated with aqueous ethanol (60%; v/v) at room temperature for 24 h and concentrated by a spray-drying process.

- Hydroalcoholic extract of red maca was provided by Eng. Alfonso Higa (Agroindustrial Chanchamayo, Lima, Peru).

- One kilogram of dried red maca hypocotyls produced 86 grams of hydroalcoholic red maca.

- Maca recovered after hydroalcoholic extraction was dissolved in water at the time of the experiments.
Freeze-dried aqueous extract of red maca

- A group of animals were treated for 84 days with an aqueous extract of red maca (1 g/Kg).

- The aqueous extract of the hypocotyls was prepared by pulverizing dried hypocotyls of red maca and placed in a container with 600 ml of water per 100 g maca, and boiled for 60 minutes.

- The preparation was left standing to cool, filtered, and freeze-dried. One Kilogram of dried hypocotyls of RM produced 400 grams of freeze-dried aqueous extract.

- The freeze-dried maca extracts were further diluted to obtain a dose equivalent of 1g/kg bw in 2ml of vehicle.
Methods

- The glucosinolate content was measured using high-performance liquid chromatography (HPLC) in spray-dried hydroalcoholic red maca extracts.

- Total Phenolic content was measured by spectrophotometric method at 760 nm
Absorption Atomic Spectrophotometric (AAS) measurements

- ASBI atomic absorption spectrophotometer (SOLAAR-M6, Thermo Jarrell Ash Co, USA) was used to analyze the red maca for arsenic, lead, cadmium, mercury, copper, and cobalt (As, Pb, Cd, Hg, Cu and Co).

- The instrument was pre-calibrated using standard solutions of As, Pb, Cd, Hg, Cu and Co salts of AR/HP grade.
Determination of organochlorine by gas chromatography

The standards mixtures were made with:

1. tecnazene, hexachlorobenzene,
2. \( \alpha \)-BHC, pentachloronitrobenzene (PCNB),
3. \( \gamma \)-BHC, heptachlor,
4. aldrin,
5. methyl pentachlorophenyl sulphide (MPCPS),
6. \( \beta \)-BHC, \( \delta \)-BHC,
7. heptachlor epoxide,
8. \( \alpha \)-endosulfan,
9. trans-chlorodane,
10. cis-chlorodane, \( p,p' \)-DDT,
11. \( p,p' \)-DDD and \( p,p' \)-DDT.
Determination of organophosphorated by gas chromatography

- The standards mixtures were made with:
  1. Dichlorvos,
  2. Methamidophos,
  3. Acephate,
  4. Thimet,
  5. Omethoate,
  6. Dimethoate,
  7. Chlorpyrifos,
  8. Methyl-parathion,
  9. Parathion,
  10. Quinalphos and Imidan.
Standard and sample of bencil glucosinolate (Glucotropaeoline)
Results

- An extract of red maca has 2.05 mg of benzyl glucosinolate /g (HPLC) and 27.84 mg of total phenolic compounds/g.

- A dose-dependent reduction of prostate weight was observed with increasing dose of benzylglucosinolates derived from red maca extracts.
Maca and prostate size in TE-induced hyperplasia
Maca and seminal vesicles

Graph showing the relationship between Glucosinolate (mg) and Seminal Vesicles weight (mg)
Red maca and prostate hyperplasia (No published)
Antioxidant activity of different concentrations of ethyl acetate extract, hydroalcoholic extract and ascorbic acid in DPPH radical scavenging.
Red maca acute median lethal dose (LD50)

- For oral route: >9.2 g/kg bw
- For dermal route: >5.6 g/kg bw
- For intraperitoneal route: >2.0 g/kg bw

Demonstrating a low order of toxicity.
Mutagenicity tests for red maca

- Mutagenic activity of the extract was evaluated using the rat micronucleus assay, and red maca showed no significant increases in the frequency of micronucleated polychromatic erythrocytes MN-PCE at doses of 500, 1000 and 2000 mg/kg bw of red maca.

- Furthermore, the Ames test using the *Salmonella* assay did not show a mutagenic effect for red maca.
Results from the *in vivo* micronucleus test in rats of the extract hydroalcoholic *L. meyenii* (Red Maca).

<table>
<thead>
<tr>
<th>Treatment</th>
<th>N&lt;sup&gt;a&lt;/sup&gt; (5F, 5M)</th>
<th>Medullary Toxicity PCE/NCE&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Genotoxicity % MPCE&lt;sup&gt;c&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negative control (distilled water)</td>
<td>10</td>
<td>2.6 ± 0.35&lt;sup&gt;e&lt;/sup&gt;</td>
<td>0.07 ± 0.06</td>
</tr>
<tr>
<td>Positive control (Cyclophosphamide) 25 mg/kg</td>
<td>10</td>
<td>3.1 ± 1.06</td>
<td>6.12 ± 0.65 *</td>
</tr>
<tr>
<td>Red Maca extract:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.0 g/kg</td>
<td>10</td>
<td>2.9 ± 0.53</td>
<td>0.11 ± 0.02</td>
</tr>
<tr>
<td>1.0 g/kg</td>
<td>10</td>
<td>2.4 ± 0.48</td>
<td>0.13 ± 0.05</td>
</tr>
<tr>
<td>0.5 g/kg</td>
<td>10</td>
<td>2.7 ± 0.37</td>
<td>0.12 ± 0.08</td>
</tr>
</tbody>
</table>

* Significantly greater than the corresponding negative control, *p*<0.05.

<sup>a</sup> Number of rat (5 female, 5 male); 2000 PCE were examined from each animal.

<sup>b</sup> Ratio of polychromatic PCE to normochromatic NCE cells, based upon the number of NCE in the optical fields containing 2000 PCE.

<sup>c</sup> Percent micronucleated cells based on the total polychromatic cells present in the scored optic field.

<sup>e</sup> Data are means and standard deviations.
Heavy metal concentrations measured in hydroalcoholic extracts of *L. meyenii* (Red Maca) hypocotyls.

<table>
<thead>
<tr>
<th>Element</th>
<th>Concentration (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenic (As)</td>
<td>0.12</td>
</tr>
<tr>
<td>Lead (Pb)</td>
<td>0.14</td>
</tr>
<tr>
<td>Cadmio (Cd)</td>
<td>0.065</td>
</tr>
<tr>
<td>Mercury (Hg)</td>
<td>0.013</td>
</tr>
<tr>
<td>Cupper (Cu)</td>
<td>5.44</td>
</tr>
<tr>
<td>Cobalt (Co)</td>
<td>0.19</td>
</tr>
</tbody>
</table>

Maximum limits followed were the Finnish ones (1993); Cd (0.1mg/kg), Cu (10mg/kg), Pb (0.5 mg/kg) extrapolated from limit of the Codex Committee on Heavy Metals (1996).
Metals and pesticides assessment in red maca

- Levels of arsenic, cadmium, cobalt, lead, and mercury were <0.5 mg/Kg and copper <10 mg/kg

- These levels were found to be below the maximum permissible recommended by FAO/WHO in vegetables

- Red maca was also free of 16 organochlorinated pesticides and 11 organophosphorous pesticides
Red maca: subchronic study

- In the subchronic study, all animals increased body weight after 84 days of treatment.

- The average weight gain was 67.42 g. Weight of reproductive and non-reproductive organs were not significantly different in rats treated with red maca or controls (vehicle).
Conclusions

- In conclusion, the hydroalcoholic extract of red maca tested, reduced prostate size and had an acceptable safety profile under the toxicity assays performed.

- The data obtained was the first with such experimental evidence and was very useful for evaluating the safety of red maca extracts under consideration of the usual dose ingested by humans.