THE AÑU AND THE MACA

TIMOTHY JOHNS

Division of Biological Sciences and Museum of Anthropology
University of Michigan, Ann Arbor, MI 48109

ABSTRACT.–***Tropaeolum tuberosum*, *añu*,** and ***Lepidium meyenii*, *maca*,** are cultivated in the Andes mountains for their edible underground parts. Cultural and medicinal associations between the plants are supported by their similarity in secondary chemistry, and by the pharmacological properties of the isothiocyanates released upon hydrolysis of the glucosinolates present. ***T. tuberosum*** has been reported to contain p-methoxybenzyl glucosinolate; ***L. meyenii*** is reported here to contain benzyl and p-methoxybenzyl glucosinolates. The likelihood that human selection for specific flavor and medicinal properties has altered the secondary chemistry of, at least, the ***añu*** raises questions concerned with both human taste perception and plant domestication.

INTRODUCTION

The relationship between the use of plants for food and medicine and the chemical constituents of these plants involves a combination of biological and cultural factors. The choice of particular plants in many cases reflects their obvious and well studied nutritional and pharmacological properties (Arnason et al. 1981). Where plants are used in ways which have no apparent western scientific basis, their use is thought to be principally of symbolic and cultural significance (Ford 1981). Needless to say effective medicinal agents have considerable cultural significance as well; plants may possess properties which are not yet defined by western scientific methods.

The question of the initial discovery of empirically used plants is intriguing (Ford 1981). The means by which humans (and animals) perceive beneficial or harmful constituents in relation to physiological homeostasis is interesting but not well understood. Plants of solely ritual and mythological importance must be considered in the broader context of human spiritual and social values. However the association of the western empirical and the cultural values of plants with their chemical constituents are both likely. Physiological perception primarily through taste and smell provides the basis for such association.

Lévi-Strauss (1966) discusses briefly the systematization of such sensory data. Although his chemical treatment is rudimentary, he provides insight into the processes by which primitive man might form structures that are ultimately uncovered by science. The differentiation of plants on the basis of organoleptically detectable physical properties and the translation of perceptional differences into culturally important categories can be difficult to appreciate. For the observer who is accustomed to orient his/her universe visually, the taxonomy of taste is a difficult folk taxonomy to come to terms with (Berlin et al. 1974). Analytical techniques which allow the detection of subtle differences in chemical composition and properties are a starting place from which to tackle problems of this type.

Tropaeolum tuberosum Ruiz and Pavon, the *añu, isaño* or *mashua*, and *Lepidium meyenii* Walp., the *maca*, together represent an interesting case of association of chemical properties with deep rooted cultural beliefs and concepts. This association seems to be a combination of both empirically definable and cultural concepts. Both plants contain similar constituents which are readily detectable by taste and which have a physical basis of action in many cases.

The *añu* and the *maca*, in the Tropaeolaceae and Brassicaceae respectively, are two species of plants from Andean South America cultivated for their edible underground parts and for their medicinal uses. The *añu* is presently known from southern Venezuela to northern Argentina although use of the tuber as food is relatively localized in comparison to other tuber crops such as potato (Montaldo 1977). The *añu* grows best between 2500 and 3700 meters above sea level. The varied medicinal uses of the plant have been summarized recently and their efficacy in many cases has been substantiated (Johns et al. 1981). The *maca* is more restricted in distribution. Although it may have been more widespread at the time of the Spanish conquest, it is presently cultivated for its edible root in the Departments of Pasco and Junin, Central Peru, between 3500 and 4000 meters above sea level (Leon 1964). Historically the plants probably grew sympatrically over a much wider geographical range than at present.

These two plants correspond strikingly in terms of the historical and modern folk beliefs associated with their putative effects on human reproductive potential. These beliefs correspond in turn with the similarities in phytochemistry. Although the two families, Tropaeolaceae and Brassicaceae, are usually classified quite separately by systematists, they are both typified by having glucosinolates, the mustard oil glucosides, as their major secondary metabolites.

The numerous reports on the supposed effects of *añu* in enhancing female fertility and as an anti-aphrodisiac and anti-reproductive agent in males have been summarized (Johns et al. 1981). References to the *maca* are more scarce; Leon (1964) provides the most accessible and recent overview of its biology and ethnobotany. It is reported by the chroniquilists in the time of the Spanish conquest that the Indians recommended feeding *maca* to domestic animals to combat low reproductive rates at high altitudes, and that the Spanish noticed the positive effects. Leon (1964) reports that *maca* is now eaten by Indian and white women who want to have children. It is sold in the market for this purpose. More recent visitors to the area around Lake Junin (Michael F. Brown, Jefferey Parsons, Kent V. Flannery, personal communications) report that belief in the fertility effects are widespread. However the fact that the belief applies particularly to male fertility seems to contradict the beliefs listed previously.

Maca may be eaten fresh at the time of harvest, but is more commonly dried for long term preservation. It is prepared similarly for both food and medicine. Dried roots are cooked in milk and/or water and are served either in the cooking liquid with perhaps a little sugar, or in a cocktail with aguardiente. *Añu* is usually boiled before use and retains much of its characteristic flavor. It is occasionally preserved in a drying process similar to the production of *chuño* from potatoes; in Bolivia this product is known as *taiacha* (Fernandez 1973). The effects of preparation on medicinal properties or chemical constituents are unknown, but in the case of *maca* and boiled *añu* they appear insignificant.

The glucosinolates characteristic of both of these plants undergo enzyme hydrolysis upon damage of the tissue and release the volatile and distinct tasting isothiocyanates, or mustard oils (Fig. 1). These are the compounds responsible for taste in cruciferous vegetables (MacLeod 1976); they are, as well, biologically active (Benn 1977). A variety of naturally occurring isothiocyanates (and parent glucosinolates) are known. These can be distinguished chemically on the basis of side-chains. Although they all have the sharp taste of mustard, they are also distinguishable by taste to some extent.

Tropaeolum tuberosum has been differentiated into a wild and a cultivated subspecies. This classification is supported chemotaxonomically (Johns and Towers 1981). The obligate cultigen, subsp. *tuberosum* contains only p-methoxybenzyl isothiocyanate (Fig. 2). The wild subsp. *silvestre* is characterized by benzyl, 2-propyl, and 2-butyl ixothiocyanates (Fig. 2) (Kjaer et al. 1978; Johns and Towers 1981).

The literature contains no reports of phytochemical studies of *Lepidium meyenii. Lepidium* species, as members of the family Brassicaceae, are known to contain glucosinolates. Species from other parts of the world have been studied and found to contain a

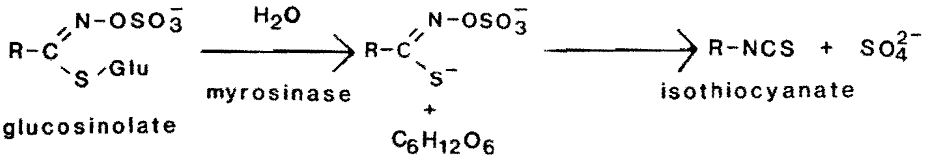

FIG. 1–Formation of isothiocyanates by enzymatic breakdown.

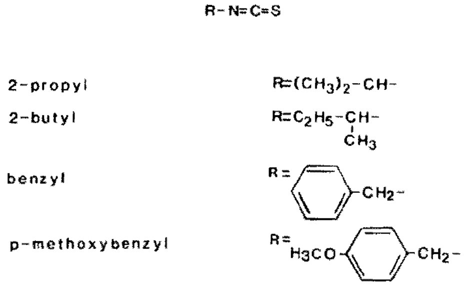

FIG. 2–Isothiocyanates of *Tropaeolum tuberosum* and *Lepidium meyenii.*

variety of glucosinolates including benzyl glucosinolate reported above from *T. tuberosum*. Variation comprising alkyl and alkenyl derivatives occur within the genus although aromatic glucosinolates, with or without hydroxy and methoxy substitutions in m- and p-positions, prevail (Kjaer and Wagniere 1971). 3,4,5-Trimethoxybenzyl glucosinolate occurs in *L. sordida* A. Gray (Kjaer and Wagniere 1971) and *L. hyssopifolium* Desv. (Kjaer et al. 1971). The only species studied from South America, *L. bonariense* L. from Argentina, is reported to contain p-hydroxy and p-methoxybenzyl isothiocyanates.

MATERIALS AND METHODS

Roots of *L. meyenii* collected in Wayri, Department of Junin, Peru on July 15, 1973 by Michael F. Brown and subsequently preserved in p-dichlorobenzene and deposited at room temperature in the Museum of Anthropology, University of Michigan were examined in 1980. Isothiocyanates liberated enzymatically from ground root material (7 g) were studied using the methods described previously for *T. tuberosum* (Johns and Towers 1981). Extracts were examined for isothiocyanates, thiocyanate ions and cyclic oxazolidinethiones (Ettlinger and Thompson 1962).

RESULTS

Lepidium meyenii gave a negative test for thiocyanates and cyclic oxazolidinethiones. Therefore the plant does not contain p-hydroxybenzyl isothiocyanate. Paper chromatography (PC) of thiourea derivatives using a solvent system of benzene-ethanol-water (5:1:2) (Ettlinger et al. 1966) showed only one spot corresponding to benzyl isothiocyanate.

Reverse phase High Performance Liquid Chromatography (HPLC) showed one large peak corresponding to benzyl or p-methoxybenzyl isothiocyanates, and one smaller unidentified peak. By normal phase HPLC this sample was resolved into four peaks. The largest of these corresponded to benzyl isothiocyanate and a smaller one to p-methoxybenzyl isothiocyanate. The area of the 'benzyl' peak in reverse phase was 63%, while the area of the combined benzyl and p-methoxybenzyl peaks in normal phase was 65%. This rough measure supports the supposition that the two peaks were resolved from the major peak in the reverse phase system. The identity of the two other peaks remains unknown.

PC and HPLC data combined indicate that *L. meyenii* contains benzyl isothiocyanate as its principal isothiocyanate and p-methoxybenzyl isothiocyanate in relatively smaller amounts. Because only one thiourea spot was seen by PC the unidentified spots on HPLC are likely not isothiocyanates. Until more samples are examined and other methods of analysis can be used to confirm the identity of the compounds present, these results must be viewed as preliminary.

DISCUSSION

The parallels between the *añu* and the *maca* as agents affecting fertility appear more than coincidental. Reproductive rates are indeed lower and a concern at high altitudes (Sobrevilla et al. 1968; Buck et al. 1968) and folk beliefs associated with fertility are to be expected. However, the association of two glucosinolate-containing 'root' crops with this concern is highly suggestive. Chemical analysis shows that both plants are characterized by aromatic glucosinolates. They appear to both produce p-methoxybenzyl isothiocyanate while the *maca* also produces benzyl isothiocyanate. At least in the conception of Andean peoples there is a relationship between aromatic isothiocyanates and human reproductive processes. The overlap of constituents between the two plants suggests that association may be as specific as between p-methoxybenzyl isothiocyanate and human reproduction.

The use of *T. tuberosum* subsp. *tuberosum,* and *añu,* to negatively affect male reproductive processes was supported by pharmacological studies with rats (Johns et al. 1981). The mechanism for this activity, while apparently indirect, supports the empirical use of the plant by Andean peoples. The proposed mechanism is likely to account for similar effects for the *maca,* as well as for any isothiocyanate containing plants, whether they be aromatic or not.

Therefore, although the use of isothiocyanates in general has a western scientific basis, the specific emphasis on aromatic isothiocyanates seems culturally determined. It may be strictly coincidental that both 'root' crops contained these compounds, and that associations were easily drawn by people familiar with both plants. However, studies on the botanical origin of the cultigen, *T. tuberosum* subsp. *tuberosum,* indicates that the situation is not so straight forward (Johns and Towers 1981). Although a hybrid origin of the cultigen from the wild taxon is likely, this process has resulted in the replacement of the three constituents of subsp. *silvestre* with p-methoxybenzyl isothiocyanate. Although this is conceivable without human intervention, in light of the selection that has gone on in producing the *añu,* a plant cultural artifact (Ford 1980), it seems likely that human selection for the particular chemistry of the cultigen has played a role. Such selection with regards to cultural concerns of flavor and medicinal use underlines the association of the *añu* and the *maca.* The origin of *Lepidium meyenii* is not known, and whether it has as well been chemically selected by humans is an intriguing question.

CONCLUSION

Considerable work remains to explore fully the exciting implications of this association between the *maca* and the *añu.* Ethnobotany has traditionally linked the interests of botanists and anthropologists. Problems of this sort require the collaborative efforts of phytochemists and anthropologists as well as of physiological psychologists. Basic investigations are necessary to understand the biological aspects of human perception and recognition of chemical stimuli, the cultural categories into which stimuli are differentiated and the process by which perceived chemicals are interpreted in relation to human chemical taxonomies.

ACKNOWLEDGEMENTS

I would like to thank Prof. G.H.N. Towers, University of British Columbia, for support and advice with the experimental portion of this paper, and Prof. R.I. Ford, University of Michigan, for his helpful interpretative insights. I am grateful to the Natural Sciences and Engineering Research Council Canada for support in the form of a Postgraduate Scholarship.

LITERATURE CITED

ARNASON, T., R.J. HEBDA, and T. JOHNS. 1981. Use of plants for food and medicine by native peoples of Eastern Canada. Canadian J. Botany: In press.

BENN, M. 1977. Glucosinolates. Pure Appl. Chem. 49:197-210.

BERLIN, B., D.E. BREEDLOVE, and P.H. RAVEN. 1974. Principles of Tzeltal plant classification. Academic Press, New York.

BUCK, A.A., T.T. SASAKI, and R.I. ANDERSON. 1968. Health and disease in four Peruvian villages. The Johns Hopkins Press, Baltimore.

ETTLINGER, M.G. and C.P. THOMPSON. 1962. Studies of mustard oil glucosides (II). Final Report Contract DA-19-129-QM1689, U.S. Dept. Commerce AD 290 747.

ETTLINGER, M.G., A. KJAER, C.P. THOMPSON, and M. WAGNIERES. 1966. Veratryl isothiocyanates, a new mustard oil from *Heliophilia longifolia* DC (Cruciferae). Acta Chem. Scand. 20:1778-1782.

FERNANDEZ, J. 1973. Sobre la dispersion meridional de *Tropaeolum tuberosum* R.&P. Boletin de la Sociedad Argentina de Botanica. 15:106-112.

FORD, R.I. 1980. 'Artifacts' that grew: their roots in Mexico. Early Man 2:19-23.

FORD, R.I. 1981. Ethnobotany in North America: An historical phytogeographical perspective. Canadian J. Botany: In press.

JOHNS, T., W.D. KITTS, F. NEWSOME, and G.H.N. TOWERS. 1981. Anti-reproductive and other medicinal effects of *Tropaeolum tuberosum*. J. Ethnopharmac.: In press.

JOHNS, T., and G.H.N. TOWERS. 1981. Isothiocyanates and thioureas of *Tropaeolum tuberosum* from Andean South America. Phytochemistry 20: In press.

KJAER, A., J.O. MADSEN, and Y. MAEDA. 1978. Seed volatiles within the family Tropaeolaceae. Phytochemistry 17:1285-1287.

KJAER, A., and A. SCHUSTER. 1968. Glucosinolates in *Lepidium bonariense* L. Phytochemistry 7:1663-1666.

KJAER, A., A. SCHUSTER, and R.J. PARK. 1971. Glucosinolates in *Lepidium* species from Queensland. Phytochemistry 10:455-457.

KJAER, A., and M. WAGNIERE. 1971. 3,4,5-Trimethoxybenzylglucosinolate: a constituent of *Lepidium sordidum*. Phytochemistry 10: 2195-2198.

LEON, J. 1964. The "Maca" *(Lepidium meyenii)*, a little known food plant of Peru. Econ. Botany 18:122-127.

LEVI-STRAUSS, C. 1966. The Savage Mind. Weidenfeld and Nicolson, London.

MACLEOD, A.J. 1976. Volatile flavour compounds in the Cruciferae. Pp. 307-330, *in* The biology and chemistry of the Cruciferae (J.G. Vaughan, A.J. MacLeod and B.M.G. Jones, eds.). Academic Press, New York.

MONTALDO, A. 1977. Cultivo de raices y tuberculos tropicales. Instituto Interamericano de Ciencias Agricolas de la OEA, San Jose, Costa Rica.

SOBREVILLA, L.A., I. ROMERO, F. KRUGER, and J. WHITTEMBURY. 1968. Low estrogen excretion during pregnancy at high altitude. Amer. J. Obst. Gyn. 120:828-833.