THE TRANSITION OF MACA FROM NEGLECT TO MARKET PROMINENCE

>> Lessons for improving use strategies and market chains of minor crops

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Both authors have lived and worked in Lima, Peru, Michael Hermann from 1988 to 1990 and from 1997 to 2004 and Thomas Bernet from 1997 to the present. The authors have consumed maca, and traveled on several occasions to Junin to witness maca production, trading, processing and local consumption.

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Cover Picture

Rural women in Junin gathering dehydrated maca.
Photo courtesy Ivan Manrique, CIP, Lima.

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1 Introduction

Maca is an edible root crop of the crucifer family endemic to the Puna of the high Andes in Central Peru around Lake Junin, a chilly plateau at 4000 m altitude. Grown in the late 1980s exclusively in its native area, on no more than 50 ha, maca has experienced over the last years a meteoric rise from an overlooked botanical curiosity to Internet notoriety.

Owing to the root's reputed effects on fertility, physical stamina and libido, maca has been touted as the 'Ginseng of the Andes' or as a 'soft' alternative to Viagra and has made headlines world-wide in the natural products industry. The total area cropped to maca increased in the last 15 years by a factor of at least 60 and comprised in 2005 about 3000 ha. However, rather than enjoying the benefits of the sustained growth in the maca economy, it has been a bumpy ride for the crop's poor farmers, who have few alternatives for eking out a living in one of the most inhospitable mountainous environments. Rapidly rising demand in the early boom years of maca's transition to market prominence gained some producers fortunes, but the supply expansion and inevitable price decline hurt those entering the market too late.

In this study, we will narrate the economic history of the crop, and we will examine the players and processes behind its re-emergence from neglect and under-use. The story of maca is a fascinating case, in which inflated expectations of easy profit-making, well-intentioned but ill-advised government policies, food safety-inspired concerns of regulators in export markets, the dispute over 'maca patents' and research of doubtful relevance to maca value chains intertwine to produce a confusing picture. Our challenge is to provide a reasonably objective account of maca's history, and to disentangle the myths from the realities surrounding the crop, its products and protagonists. Our goal is to derive from this study broader lessons for the development of value chains for under-utilized crops.

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The specific objectives of this study are: a) to describe key processes that caused the expansion of maca cultivation and commercialization, b) to identify factors constraining maca market chain development, and c) to assess the effects of market development on rural livelihoods and on maca biodiversity.

In the first sections, we will provide an overview on maca biology and production, in order to lay the basis for the ensuing sections. After examining the traditional use of maca and its nutritional attributes, we proceed to describe what is known about maca's distribution and significance in pre-historic and colonial times. This is followed by a description of the crop's expansion and market development since the early 1990s, the boom and crash years of 1999-2001, and what hopefully will prevail in coming years as the consolidation of maca cultivation and market development. In the final sections, we will examine in greater depth the enabling and constraining factors behind the market development of maca. In particular, we will describe the drivers of demand expansion, the functions of the public and private sectors and the role of national and international policies. Finally, we will derive broader lessons for the market development of neglected and under-utilized species with attributes similar to maca, to yield farmer and consumer benefits.

For this study, we have evaluated a comprehensive body of literature on maca conveniently available from CIP's library, including much grey literature. We also rely on information gathered over the years informally through our interaction with maca growers, exporters and importers. Particularly useful in that regard was the experience we gained as exhibitors of maca products at international trade fairs (Vitafoods-Geneva 2001, ANUGA-Köln 2001, Tisana-Lugano 2001).

For the purpose of this study, we gathered additional data on maca production, export quantities, price series, etc. from various Peruvian entities (see figures for details). We also conducted in late 2006 a series of interviews with key actors of maca supply chains.

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2 The biological and agricultural context of maca supply chains

2.1 Taxonomy and nomenclature

Maca is a fully domesticated species belonging to the genus *Lepidium* of the Cruciferae family, which is also known as Brassicaceae. As a source of numerous vegetables and oil plants of Eurasian origin, this family is of enormous economic importance. Maca, however, is the only domesticate of the Brassicaceae in the New World (Hermann and Heller 1997).

In 1843, the species was first described and named as *Lepidium meyenii* by Walpers, who based his description on the specimen of a wild plant collected in Puno, in Southern Peru, far away from the maca crop's endemic and insular distribution in the Central Peruvian highlands. This type specimen has only a slightly thickened tap root, and is clearly not derived from the cultivated form of *L. meyenii.* Nevertheless, León in his classic text on maca and other Andean root and tuber crops (León 1964) recognized maca as pertaining to *L. meyenii*.

In 1990, Chacon proposed *Lepidium peruvianum* as a new species and name for domesticated maca only (Chacon 1990). She justified her decision to recognize maca as a species separate from *L. meyenii* mainly by the dissimilarity of the type specimen with the cultigen in terms of the absence of a pronouncedly tuberous root and the state of domestication. Chacon's name change remained largely unnoticed over the following years, and the limited number of publications on cultivated maca before 1995 used mostly the binomial *Lepidium meyenii*. However, after the explosion of commercial interest in the crop, especially after 2000, Chacon's proposal of the binomial *L. peruvianum* as the 'correct' name for maca won over an increasing number of followers, mainly for reasons that lie outside of taxonomic and nomenclatural considerations. Firstly, Chacon's reasoning, although unconvincing as we will see below from a taxonomist's

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point of view, seems to appeal to 'common sense'. Secondly, with the sporadic appearance of maca cropping in Andean countries outside of Peru, notably in Bolivia, public outrage over the granting of maca patents in the US (see Section 7.4.2.), a species epithet suggestive of Peruvian ownership of maca (*peruvianum*), rather than the non-descript *meyenii*, appealed to the sentiment of the public in general and value chain actors in particular[1]. Also, the new name continues to be a welcome opportunity for some companies to differentiate their product on the market, particularly in the US, or legitimize their promotion of the 'genuine' Peruvian maca (Mr Percy Rojas, personal communication, 2006).

In our opinion, Chacon's stated reasons for justifying her decision to give cultivated maca species status are not consistent with modern taxonomic and nomenclatural practice. Although somewhat counter-intuitive, a type specimen, as the one used in the description of *L. meyenii*, does not have to be 'typical' of the species, but can also represent a less common variant. Also, the status of domestication or the size of a vegetative plant part in a particular intra-specific population is considered today as insufficient for the description of a new species, even more so in the case of cultivated maca, which is known to commonly segregate in individuals of widely varying storage root thickness, with up to 20% of plants not having tuberous roots at all (Mr Alberto Salas, personal communication, 2006)! Chacon did not present evidence for discontinuous variation or reproductive barriers between wild and domesticated forms of *L. meyenii*.

Based on these considerations we conclude that the possibility of the two forms being different species is very low, and in the absence of substantiating evidence for such a separation, it is prudent and generally accepted best practice to retain the original species name. In this view we are fully confirmed by Brassicaceae expert taxonomist Al-Shehbaz, Missouri Botanical Garden, who, based on

[1] The authors of this paper assisted in various gatherings of 'maca stakeholders' of the public and private sector from 2001 to 2003, in which the need for the exclusive use of the name *L. meyenii* was forcefully argued.

his inspection of the isotype of *L. peruvianum* stated that this species is indistinguishable from *L. meyenii* (Personal communication, 2002[2]).

It should be noted that an influential consortium of Peruvian maca companies, namely the Instituto Peruano de Productos Naturales (IPPN) recommends the continued use of the name *L. meyenii* (Mr Percy Rojas, personal communication, 2006).

Unfortunately, defenders of *L. meyenii* as the valid name for maca have been accused of improper motives[3]. The ongoing public debate over the 'correct' botanical name for maca is an interesting case where taxonomic and nomenclatural disagreements get in the way of the functioning of supply chains. In January 2007, a Google search in the Internet still produced the epithet *meyenii* five times as often as *peruvianum*. However, the co-existence of two binomials for maca in this readily accessible information source as well as in science papers has not only confused Peruvian audiences and maca stakeholders but also European regulators banning maca as a food from the EU (see Section 7.2.2.). Several decisions denying the authorization to market maca refer *inter alia* to the purportedly uncertain taxonomic status of maca and the (erroneous) perception that domesticated maca may consist of two species requiring separate food safety assessments[4].

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[2] "I have seen the isotype of *L. peruvianum*, and it is indistinguishable from the wild and cultivated plants that I have been calling *L. meyenii* since the mid 1980s. I have been hunting to find the type of *L. meyenii*, but without much luck. Hitchcock who has somehow seen authentic material of the species has a concept much similar to mine. Unless someone convinces me that the two species are different, I continue to recognize one species with both wild and cultivated forms, just as spp. of *Brassica*, *Eruca*, and, yes, *Lepidium sativum*."

[3] The journal Alimentación y Salud (Lima, Peru), in its issue of December 2003, on p. 48: "Hay intereses comerciales en denominar la maca *Lepidium meyenii* Walpers para arrebatarle el origen al Perú".

[4] AFSSA (Agence Française de Sécurité Sanitaire des Aliments)-Saisine Nro. 2004-SA-0155, 8 September 2004. "La Afssa estima que para evitar los riesgos relacionados a la sustitución de la especie tradicionalmente consumida, la denominación científica, *Lepidium meyenii* Walpers o *Lepidium peruvianum* Chacon, debe ser verificada."

2.2 Life form and agro-ecology

Several sources are ambivalent about the life form of maca (e.g. Wikipedia, accessed 28 January 2007; Quiros & Aliaga 1997), but this seed-propagated crop invariably behaves as a biennial plant in its native habitat, as correctly stated by some authoritative texts (León 1964, Tello et al. 1992). Some authors appear to have observed premature flowering (Quiros et al. 1996) or extended vegetative growth in maca (such as the authors of this study in greenhouse-cultivated plants in Quito, Ecuador), but such phenomena are restricted to locations with day length and temperature regimes substantially different from the Peruvian puna, in which maca has evolved. For example, Quiros et al. (1996) conclude from observations of maca field cultivation under winter conditions in Davis, California, that the plant is annual since it (weakly?) flowers within one growing season. Under such 'artificial' circumstances, the ontogeny of maca may indeed deviate from the plant's behaviour in its natural environment, which is at 11–12°S latitude and altitudes of 3800–4400 m above sea level. But this cannot be construed as evidence for its annual nature.

Based on the observation that maca plants formed storage roots in growth chambers with 12 and 14 hours constant daylength, Quiros et al. (1996) concluded that maca's storage root formation is daylength-neutral. However, the authors failed to recognize that this experiment is unsuitable to determine the daylength sensitivity of maca. Their observation would also be consistent with maca behaving as a short-day plant with a critical daylength over 14 hours under the highly artificial conditions of the experiment. The same authors observed good maca storage root formation (up to 3.5–5 cm diameter) in field cultivation at Davis, California, from September to May. Maca roots had reached maximum enlargement by the end of April. Thus, root enlargement must have taken place in days less than 13 hours long. Maca sown in Berlin (ca. 52°N latitude) in June and harvested in September did not show at all root enlargement (Mr H-J Brinkjans, personal communication, 1990). Maca cultivated in Gatersleben, Germany (near Berlin), from April to November, produced only very small roots (1–1.5 cm) (Marthe et al. 2003). These observations under long-daylength conditions in higher latitudes suggest that maca is indeed a short-day plant, perhaps with strong interaction between critical daylength and temperatures.

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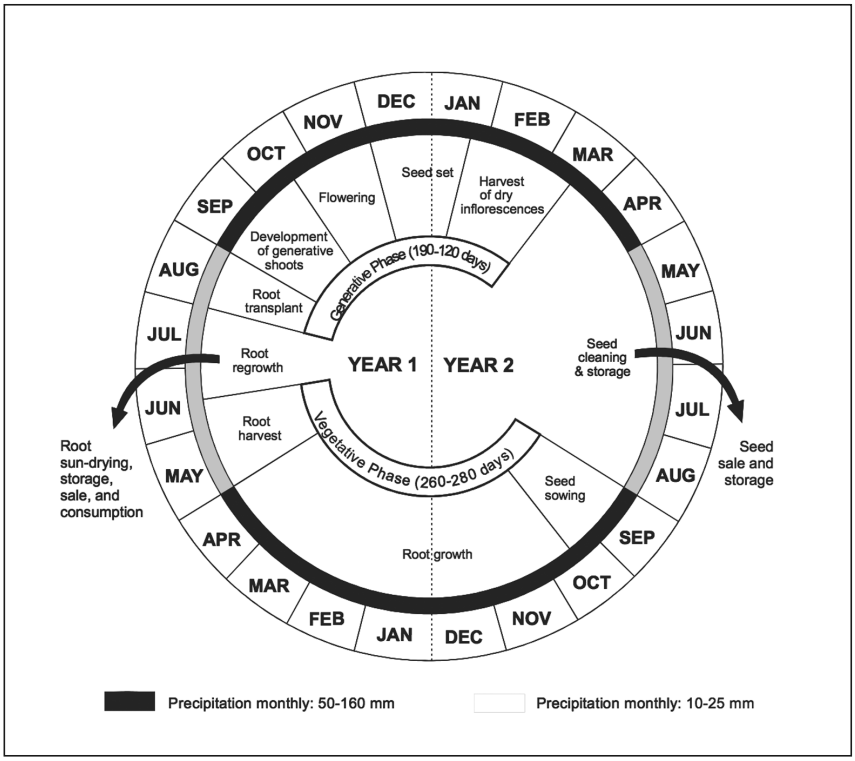

Figure 1.
The life cycle of maca (redrawn from Tello et al. 1992).

As schematically presented in Figure 1, the maca seedling emerges after the onset of the rainy season in October, a month after sowing (Fig. 2). The seedling develops into a prostrate herb consisting of a rosette of some 10–25 basal leaves, which form a mat near the soil surface (Fig. 3). The upper part of its tap root together with the lower part of the hypocotyls thickens just below the soil surface to eventually yield the edible maca root. From May to June, after 260–280 days of vegetative growth, the beginning drought and decreasing temperatures constrain plant development and severe night frosts eventually kill the leaves (Fig. 4). Maca roots, either left in the field or harvested and maintained in earthen pits for seed propagation, will remain dormant for two to three months, throughout the cold dry season. With the onset of rains and warmer temperatures in September, the re-planted root develops a mighty generative shoot (Fig. 5), which yields the seeds five months later (February to March). Seed production exhausts the plant's resources and leads to its death. Thus, after nearly two years maca has concluded its life cycle, very much like many cruciferous crops in the Old World, hence the term *biennial*.

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Figure 2.
Maca seedling plants.

Figure 3.
Vegetative maca plants in full growth, Junin, March 2006.

Figure 4.
Senescent maca plants ready for harvest.

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Figure 5.
Seed-bearing maca plants with strong generative shoots. Junín, early 1990s.

Figure 6.
Maca seeds (scale units: mm).

Each maca plant has the capacity to develop several hundreds or even thousands of seeds. Therefore in cultivation, only a few dozen plants are needed to reproduce the crop area typical of a smallholder. The fruits are dehiscent, hence the need to harvest the plants prematurely and dry them in a location where the seeds are not lost. The seeds are tiny and 1600 seeds weigh approximately one gram (Fig. 6).

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2.3 Economic plant part and vernacular name

The word maca, as used in Peru, is believed to be of Quechua origin, and it refers both to the plant *Lepidium meyenii* as well as to its fleshy and edible underground parts (Fig. 7). These comprise the main value of the crop, although the leaves may serve as animal fodder, and, when tender, also make a pleasant ingredient in salads, similar in taste to watercress (although the latter use is not reported from Peru).

In the English literature, maca is mostly referred to as a root[5] or a tuberous root. We will maintain the usage of the term 'root' in this paper, for want of a better common word that describes appropriately the anatomical structure of the fleshy underground plant part. Tello et al. (1992) recognized that the maca root results from secondary parenchymatic growth of the tissue of hypocotyl and the upper part of the tap root, much like in a radish (*Raphanus* spp.). Unfortunately, since the appearance of that paper, the use of the term "hipocótilo' to denote the maca root has been widely adopted in the Peruvian literature, also in the technical product norms of INDECOPI expected to be published in 2007 (see Section 7.3.). The English term 'hypocotyl' has also been used in recent papers in international journals (e.g. Quiros et al. 1996, Ganzera et al. 2002). This is misleading for a hypocotyl is an entirely different thing (part of the axis of a developed seedling immediately below the cotyledons), and the use of this term should be discontinued.

The issue of finding an appropriate name for maca roots and adhering consistently to its usage is not a trivial or irrelevant matter. It has implications for general purposes of categorization, the keywording of literature, the assignation of tariff codes (upon which the degree of taxation depends), etc.

[5] According to Webster's Online Dictionary, a tuber is "a fleshy underground stem or root serving for reproductive and food storage".

Figure 7.
Freshly harvested maca storage roots.

2.4 Reproductive biology, genetic diversity and ploidy

According to Quiros & Aliaga (1997) maca is an autogamous species and reproduces predominantly by self-pollination (cleistogamy). Progenies from single plants are morphologically alike with few exceptions and it is straightforward to obtain homogeneous lines of particular morphotypes.

Toledo et al. (1998) found that the similarity among 29 accessions of cultivated maca was high indicating a low level of polymorphism.

Maca is an octoploid with $2n=8x=64$ chromosomes as first established by Quiros et al. (1996). Its meiosis is normal, with the chromosomes associating as bivalents, suggesting that maca is a disomic polyploid.

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Figure 8.
Maca field in full vegetative growth, Junin, 4300 m altitude (Photo 1990).

2.5 Production

Good accounts of maca production can be found in León (1964a, 1964b), Tello et al. (1992) and Quiros & Aliaga (1997). It is confined to the puna of Central Peru, the cold, barren extensions where sheep grazing is the dominant occupation. Maca cultivation is practiced up to an altitude of 4500 m above sea level, where no other crop gives economic returns except certain varieties of bitter potatoes. In Carhuamayo, a major production site for maca at 4080 m altitude, the monthly mean maximum and minimum temperature ranges during the growing season are 11–13°C, and -2–2°C, respectively (Tello et al. 1992). A casual observer might be forgiven for mistaking maca fields for sparsely populated expanses of mosses or other wild vegetation (Fig. 8).

Traditionally, maca is grown on grazing land after long fallows, with no or minimal use of mineral fertilizers. Before the maca boom, farmers would hardly grow more than small plots (Mr Javier Castillo Güere, personal communication, 2006). Fallows traditionally lasted over 10 years, but the expansion of maca cultivation in recent years

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has led to a shortage of suitable land, forcing farmers to reduce the duration of fallows. In her recent survey of maca farmers near Cerro de Pasco, Locher (2006) found that only 17% of farmers let maca land rest for 10 or more years between successive crops, while 58% re-plant the same area of maca in less than 5 years.

Maca cultivation is strictly seasonal: it is sown from September to October and the roots are harvested beginning in May over a period of six weeks. Land preparation was traditionally done manually, but contract ploughing with tractors now seems to be the norm (Locher 2006).

Maca is sown by broadcasting seed mixed with floral debris (known locally as *pita*) in small plots in grazing fields, which are then trampled by sheep released for that purpose. This facilitates the movement of seeds into the soil for germination.

Weeding of maca fields is not required as most weeds do not grow vigorously in the puna at very high altitudes. Fungicides are now sometimes used against mildew (Locher 2006), which is unfortunate because mildew poses no serious threat to maca yields or quality and the use of fungicides unnecessarily compromises the traditional organic quality of maca.

According to Rea (1994), fresh matter yields of maca roots can be as low as 2–3 t/ha under extensive, low input management, but in conditions of good soil fertility or fertilizer application can reach 15–16 t/ha. Tello et al. (1992) recorded in a field experiment at 4200 m altitude a fresh root matter yield of about 14.7 t ha^{-1}. Mean individual plant weight was 18 g, planting density 105 m^{-2} and harvest index 0.77. According to data provided by the Peruvian Ministry of Agriculture, average maca yields in 2005 were about 7 t/ha, but varied greatly between departments (Table 1). Maca production data have been recorded nation-wide only since 2004, but yield records are difficult to interpret since it is often unclear whether they refer to fresh or dehydrated roots.

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Table 1: Crop area, production and root fresh matter yield of maca in Peru in the year 2005.

Department	Crop area (ha)	Share of total crop area (%)	Production (t)	Yield (t ha^{-1})
Junin	1681	57	15257	9.08
Pasco	1138	39	4333	3.81
La Libertad	51	2	346	6.78
Huancavelica	48	2	249	5.19
Puno	10	<1	39	3.90
Apurimac	8	<1	31	3.88
Cusco	7	<1	6	0.86
Huánuco	4	<1	28	7.00
Total	2947	100	20289	6.88

Source: Ministerio de Agricultura, Dirección General de Promoción Agraria, Lima, Peru.

The harvest is done exclusively manually. At harvest the maca leaves are severed from the roots and left in the field to serve as feed for livestock or as green manure.

2.6 Seed production

For the production of botanical seeds for crop reproduction, farmers select at harvest maca roots in good health and with preferred skin colours. These roots are placed in pits 50–100 cm deep, and arranged in alternate layers of soil and grass sods. The reason for covering the roots is presumably to protect them against dehydration until planting is possible, since the roots would quickly dry and become unsuitable due to the high atmospheric water saturation deficits in the puna. At the onset of rains, the roots are planted in small, nutrient-rich plots (e.g. in enclosures where animals have been kept) and they develop into generative plants with myriad infructescences.

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The mature generative plants are harvested before they scatter the seed; they are then dried in the shade and threshed. In Pasco, half of the farmers use exclusively their own seed, while others rely on external seed sources in addition to their own production, a practice believed by farmers to maintain the vigour of the plants and their resistance to pests and diseases (Locher 2006). The price for one kilogramme of pure seeds reached 400 Soles in 1999 (Mr David Ponce, personal communication, 2006), and was still Soles 150–300 (US$ 46–92 kg^{-1}) in 2006 (Locher 2006). Three to five kilogrammes of seed are needed to sow one hectare. Seed germination is generally well over 80% (Tello et al. 1992).

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3 Maca use

3.1 Chemical composition and nutritional value

Maca has high nutritional density as determined by Dini et al. (1994). Dried roots, as obtained through the traditional procedures described in Section 3.2., contain about 10% water, 55–65% highly digestible carbohydrates, 2.2% lipids, 10–13% protein and 8.5% fibre. Maca seems to be particularly rich in iron, calcium, copper, zinc and potassium (Dini et al.1994, Canales et al. 2000). The maca protein is high in essential amino acids, with serine, arginine, phenylalanine, valine, isoleucine, leucine and lysine, each occurring at contents of 50–150 mg/g protein (Dini et al. 1994). The main fatty acids include linoleic, linolenic, palmitic and oleic acid (Dini et al. 1994, Ganzera et al. 2002) as well as the polyunsaturated acids and their amides, the macaenes and macamides (Zheng et al. 2000, Ganzera et al. 2002, Muhammed et al. 2002). Ganzera et al. (2002) described the first HPLC method suitable for the qualitative and quantitative determination of the main macamides and macaenes in maca and also a standardization protocol for these compounds.

Locher (2006) based on a review of Dini et al. (1994) and Zheng et al. (2000) lists as the main secondary metabolites of maca: glucosinolates, flavonoids, steroids, benzyl alcamides and essential oil. Sitosterol (45.5%) appears to be the main component of the sterol fraction, followed by campesterol (27.3%), erosterol (13.6%), brassicasterol (9.1%), Δ7.22-ergostadienol (4.5%), stigmasterol and beta-sistosterol.

Maca contains high concentrations of aromatic glucosinolates (benzyl and p-methoxybenzyl glucosinolates in particular) and their derivatives, the isothiocyanates (Johns 1981), which are the compounds responsible for the pungent flavour of raw maca (Li et al. 2001). The absolute content of glucosinolates in fresh maca roots is higher than in other crops of the Brassicaceae (Li et al. 2001).

Li et al. (2001) isolated from the tissue of maca roots the glucosinolates, benzyl glucosinolates (glucotropaoeline) and p-methoxy-benzyl glu-

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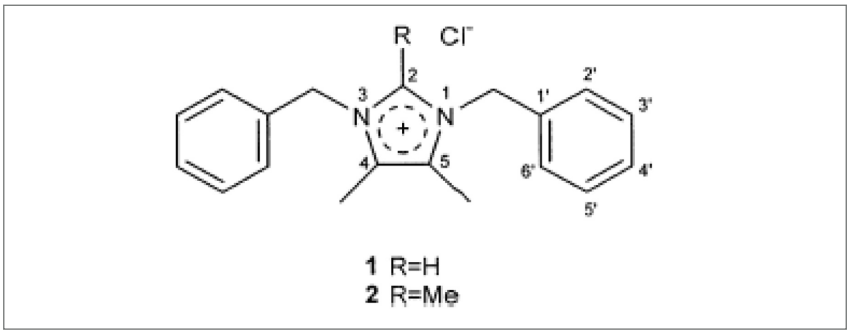

Figure 9.
Imidazole alkaloids identified in maca roots by Cui et al. (2003).

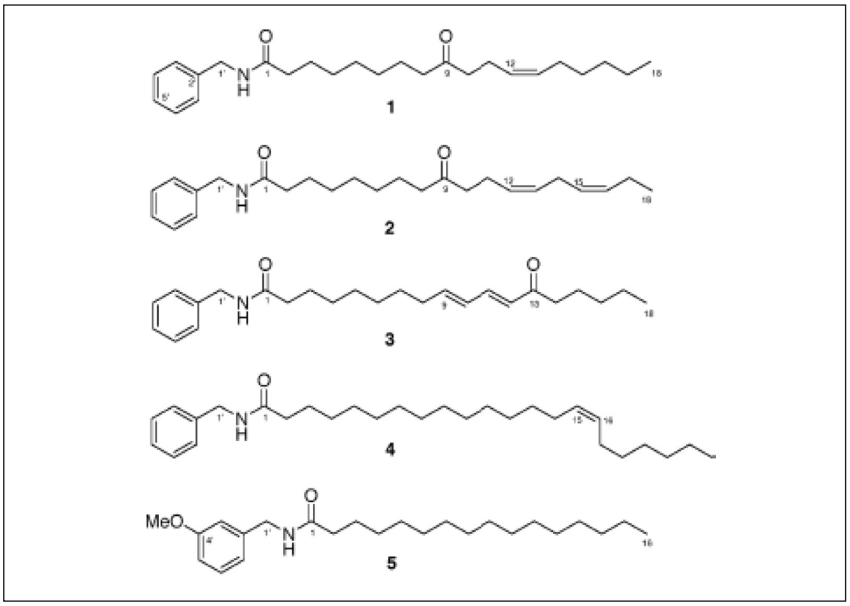

Figure 10.
Structures of alkamides from maca roots (Source: Zhao et al. 2005).

cosinolates, together with 5-methyl-sulfinylpentyl glucosinolates (glucoalyssine), p-hydroxybenzyl glucosinolates (glucosinalbine) m-hydroxybenzyl glucosinolates (tentative identification), pent-4-enyl glucosinolates (glucobrassicanapine), indolyl-3-methyl glucosinolates (glucobrassicine) and 4-methoxyindolyl-3-methyl glucosinolates (4-methoxyglucobrassicine). Muhammad et al. (2002) demonstrated the existence of macaridine (benylated derivative of 1,2-dihydro-N-hydroxypyridine) together with macamides (benzylated alkamides of N-benzyl-5-oxo-6E,8E-octadecadienamide and N-benzylhexadecanamide) and the acylic keto acid 5-oxo-6E,8E-octadecadienoic acid. Cui et al. (2003) isolated the new imidazole alkaloids lepidiline A (1,3-dibenzyl-4,5-dimethylimidazolium chloride) and lepidiline B (1,3-dibenzyl-2,4,5-trimethylimidazolium chloride) from an extract of maca (Fig. 9). Zhao et al. (2005) identified a range of alcamides (Fig. 10).

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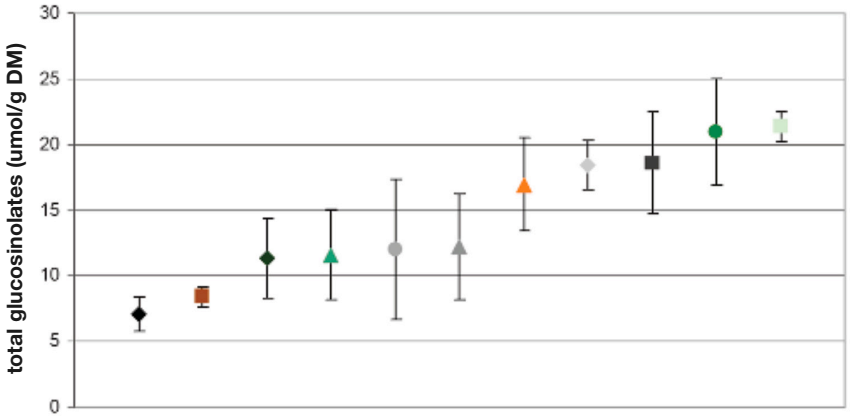

Figure 11.
Variation of total glucosinolate content in maca roots from 11 farms in Junin (Source: Locher 2006).

The above-mentioned studies are silent about which secondary metabolites are biologically active and therefore responsible for the reported pharmacological effects of maca in mammals. Johns (1981) suggested that the fertility-enhancing properties of maca may be due to isothiocyanates. Isothiocyanates have been shown to have antioxidant activities (Fahey and Talalay 1999) and anticarcinogenic properties (Rose et al. 2000).

Locher (2006) found that glucobrassicine, glucosinalbine, glucotropaeoline account for 90% of the total glucosinolate content of maca. Using roots from different localities in Junin, she showed that the total glucosinolate content varies enormously among different root colours and locations (Fig. 11). It is not clear whether this variation is due to environmental factors, genotype or the interaction of these factors. Obviously, this variation, and more importantly our ignorance about the factors causing it, could be an impediment to product standardization, for pharmacological or nutraceutical uses.

3.2 Traditional processing, culinary uses and intake levels

The overwhelming majority of maca roots are dried after harvest. In the cold, dry atmosphere of the puna the dried roots remain edible for several years. A minor proportion of the freshly harvested roots are roasted in *huatias*, earthen ovens that farmers build at the margins of fields during harvest. Both the drying and the heat treatment are

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Figure 12.
Winnowing dehydrated maca roots to remove soil. (Photo October 2006, photo courtesy Ms Céline Clément).

known to diminish pungency owing to the significant reduction of the content of glucosinolates.

The traditional drying of maca takes place on whatever flat surfaces are available to farmers (Fig. 12). The drying lasts for several weeks, during which time the roots are at risk of contamination by farm animals. Traditional drying, apart from reducing pungency, presumably converts some starch into free sugars and it also brings out the typical flavour of maca, which is peculiar and difficult to describe. One eager botanist likened the maca aroma to butterscotch (King 1988) but in our experience most maca novices do not find it at all attractive. Indeed, Torres (1984) showed that the acceptance of maca was very low in a focus group recruited from Lima with no previous exposure to this food. Maca quite obviously is an acquired taste, and this must have been a major use constraint and is likely to be one of the reasons for the failure of this crop to expand beyond its narrow geographic distribution in the past.

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Figure 13.
Dehydrated maca roots.

According to Locher (2006) farmers prefer small and medium sized roots for their own consumption; the bigger roots are reserved for sale since they fetch better prices. Smaller roots are quicker to boil, and are said to have less fibre and a sweeter taste. Some farmers prefer yellow-skinned roots, claiming these are the sweetest, while black roots may be employed in the preparation of maca liquor. However, these preferences are not pronounced and no particular maca landraces are recognized for particular culinary qualities (as is the case for potatoes, maize and many other Andean crops). Locher (2006) reports that product developers from processing companies confirmed that there are no notable difference in taste and quality between different maca morphotypes (mainly based on their skin colour). Her own research remained inconclusive in that regard.

Except when baked in *huatias* (see above), for which freshly harvested roots are used, maca recipes require dehydrated roots. These are

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Figure 14.
Dehydrated (left) and rehydrated maca roots (right).

typically rehydrated overnight (Fig. 14) before being boiled and then blended into a range of dishes or potions to which the maca imparts a characteristic flavour. Soups and blended beverages seem to be the most popular local recipes in which maca is used, but the cooked roots are also used in jams, empanadas (stuffed pastry), alcoholic cocktails, etc. Maca blended into coffee, milk or juice is popular for breakfast.

The dehydrated maca can also be ground into flour for use in the making of bread, cakes, pancakes or as a thickening agent in mazamorras (a sweet porridge, for which usually starch is used). Locher (2006) also recorded the contemporary use of roasted, milled maca roots as a coffee surrogate.

Locher (2006) found that a producer family will nowadays typically consume maca one to three times a week. She estimated consumption per family at about one kilogramme of dehydrated maca roots per week. This coincides with the assessment of Javier Castillo Güere (personal communication, 2006), a native of Junin and president of the local maca producer association, who estimates that maca was consumed traditionally two to three times per week. Farmers still take maca to work in the field, as it is said to help them resist the cold for the whole day. Locher (2006) estimated the intake of dehydrated maca to be around 50–100g per person per meal.

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3.3 Indigenous knowledge associated with maca use

There are very few references pre-dating the maca boom of the 1990s that provide authentic information on the indigenous knowledge surrounding the use of maca. We must assume that later reports of farmers' 'indigenous knowledge' are not necessarily genuine but rather contaminated by press reports and the hype associated with Internet claims (see Section 7.1.3.) and maca product promotion, especially when they relate to the 'immune system', better 'concentration and memory', etc. (Locher 2006).

Leon (1964b) says that maca is "now eaten by Indian and white women who want to have children". Those early reports stress maca and fertility, but do not portray it as an aphrodisiac. This is confirmed by our interviews with knowledgeable Junin residents, such as Javier Castillo Güere, who told us in 2006 that maca was never consumed as a libido stimulant, but rather for its allegedly invigorating effect. Locher (2006) also found farmers making references to better physical stamina, and strength for work as a consequence of maca consumption. Fifty eight per cent of the maca farmers in Pasco interviewed by Locher believed in the fertility enhancing effects of maca, but a further 40% regarded it as a myth or claimed no experience in that regard. On the other hand, the Peruvian writer Luis Gallegos provides us with the anecdote of a hot maca potion on sale in 1947/1948 in the mining town of La Oroya next to a brothel and eagerly consumed by the establishment's visitors (personal communication, 2003).

In any case, the sparse indigenous knowledge available to us from the literature seems always to have been in the public domain and was not owned by a particular ethnic group.

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4 Domestication and pre-contact distribution

The earliest evidence of maca as an edible food plant comes from Pearsall's stratigraphic analysis of archaeological plant remains recovered from the midden of Panaulauca Cave, a rock shelter occupied by humans from 7700 BC to 1200 AD and located at 4140 m altitude, near Atocsayco in the Department of Junin (Pearsall 1989). Maca roots first appear in excavated horizons dated between 1900 BC and 1600 BC, at a time when quinoa also becomes more abundant, at the expense of more 'primitive' gramineous seeds that must have served as food (e.g. *Festuca* spp.).

Initially the size of the thin tuberous taproot of what Pearsall refers to as a contemporary wild *Lepidium* species found around Panaulauca, the excavated maca roots increase in size after 1600 BC reaching a maximum in the horizons corresponding to the period 1000–300 BC. By 1200 AD, at the end of the archaeological record at Panaulauca cave, the average size of maca is similar to the lower range of modern maca cultivars. Concomitantly with the increase in root size, there is also increasing abundance of maca at 1000–300 BC (Pearsall 1989).

Pearsall (1989) concludes that the increase of size and abundance in the maca roots is suggestive of incipient maca cultivation (tending) and domestication. This appears to coincide with the domestication of camelids at the site. Indeed, Pearsall speculates that herding may have favoured maca domestication. Corralling animals and grazing may have provided the disturbed habitat that this herbaceous species requires. However, given abundant evidence for the use of camelids, deer, and a variety of small animals at Panaulauca, it seems unlikely that plant-derived food sources, including maca, played a dominant nutritional role in the diet of Panaulauca's occupants.

Apart from Panaulauca, we are unaware of other archaeological maca remains. Pearsall's extensive list of archaeological plant remains

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(Pearsall 1992) from excavations in the Peruvian and Bolivian Andes, the Peruvian coast and the Chilean coast and Sierran oases of the Atacama desert, is silent on maca remains, while a wide range of root and tuber as well as seed and fruit crops is well documented for most archaeological sites. This is all the more remarkable since the dried maca roots preserve much better than similarly fleshy plant products. Pearsall concludes from these findings that maca "never spread far from the Central Andes but formed a component of the puna system of llama herding and root crop cultivation" (Pearsall 1992). In this context it is interesting to note that no phytomorphic ceramics representing maca have been documented in the ancient Peruvian pottery that is otherwise so rich in representations of cultivated plants (Leon 1964a, b).

Obregon (1998) refers to several Peruvian authors who observe that toponyms consisting of, or containing 'maca' occur in in the departments of Arequipa, Cajamarca, Cusco, Puno, and even beyond Peru (Argentina, Bolivia, Chile, Colombia Ecuador), i.e. outside the historically confirmed area of maca cultivation. This is often taken as evidence that maca cultivation in pre-Spanish historic times must have been much more widespread across Peru and neighbouring countries than historical sources and the available archaeological record suggests. To assess the linguistic validity of this argument is beyond the scope of this paper, but whether the etymology of toponyms can be derived from simple phonetic similarities appears highly debatable.

5 Distribution and use in colonial times

The texts of some Spanish chroniclers as well as records by the colonial administration in the 16th and 17th centuries mention maca and provide hints as to its distribution, its significance compared to other crops and its uses.

In his description of Lake Junin (written around 1550), Pedro Cieza de Leon, a Spanish conquistador and author of *La Crónica del Perú*, briefly refers to the cultivation of roots at Lake Junín as the predominant agricultural activity apart from livestock herding[6]. In 1562, Iñigo Ortíz de Zúñiga, in his account of travel to the province of 'León de Huánuco', mentions the use of maca as barter among the Yaros population of Chinchaycocha (areas surrounding Lake Junin)[7]. As quoted in Obregon (1998), the Archivo General de Indias de Sevilla contains a document, dated 1583, which describes the payment of an annual tribute of approximately 15–18 t of maca by the district of Chinchaycocha to the encomendador Juan Tello de Sotomayor, giving rise to speculation that the Spanish might have used maca to maintain fertility in their domestic animals (Obregon 1998). Sánchez (1996) hypothesizes that the Spaniards might have learned from the local population about maca's nutritious and fertility-enhancing properties, as they were concerned about the fertility of their horses, which in fact is reduced at higher altitudes (Clegg 1978, Rostworoski 1975).

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[6] Cieza de Leon 1988, p. 200, cap. LXXXIII (De la Laguna de Bombón y cómo se presume ser nacimiento del gran río de la Plata): "Dase poco maíz en esta parte, por ser la tierra tan fría como he dicho; pero no dejan tener otras raíces y mantenimientos, con que se sustentan."

[7] Guillen 1972: "...Y tienen tierras para sus sementeras para pastos de su ganado y que en su tierra cogen maiz y papas y quinoa y taures y olluco y maxua y oca y frijoles y maca: Y no otra cosa y que estas sementeras hacen en andenes porque es tierra de sierra..."

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Felipe Guaman Poma de Ayala, writing in 1615, refers to the invigorating effect of maca[8]. In 1630, Antonio Vásquez de Espinosa, in his *Compendio y descripción de las indias occidentales* mentions maca as a unique crop of the cold Junin highlands, and makes reference to the need for long fallow periods to maintain maca productivity[9]. Writing in 1653, the Jesuit Bernabé Cobo gives the most detailed account of maca, again for Chinchaycocha, with a reference to the reputed fertility-enhancing effects of the plant[10]. Obregón (1998) refers to a document in the Archivo Arzobispal of Lima, dated 1650, which describes the use of maca, maize and potatoes in rites practiced in Junin. Finally, in 1777, the botanist Ruiz records the cultivation of maca in the villages of Ondores, Pampa de los Reyes, Carhuamayo and Ninacaca in what is today the department of Junin (Barreiro 1940).

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[8] Guaman Poma de Ayala 1615, p. 119: "Y se purgaua cada mes con tres pares de *bilca tauri* [purgante de *Tawri*] y otro tanto que pesase de maca y tomaua por la boca la mitad y la mitad se echaua melecina; con esto aumentó salud y uida. Hasta treynta años no tenía muger ni marido ni cargo y ací tenían muy mucha fuerza."

[9] Quoted in Obregón 1998, p. 47: "La provincia de Chinchaycocha es muy fría tanto que en toda ella no se da un tan solo arbol, ni se cria maiz ni trigo; sino solo se da una rrais de hechura de navo como hogasuela que los indios llaman macas sola esta se da en esta provincia y tiene en si tanto fuego, que me certificaron los indios, que donde se siembra dexa esterilizada la tierra por 30 años que no queda de provecho para poderla sembrar…".

[10] Cobo 1958 (Lib. 4,Cap. XVIII): "En la sola provincia de Chinchaycocha, diocesis de Lima, se halla la raiz llamada maca en la lengua de los naturales de aquella tierra. Nace esta planta en lo mas áspero y frío de la Sierra, donde no se da otra planta alguna de las que se cultivan para sustento de los hombres; que parece proveyó Dios a los indios de aquella provincia de esta raíz para que no quedasen sin tener en la tierra algún mantenimiento natural de ella. Sírvele de pan, verde y seca, como la guardan, para todo el año. La planta es pequeña, que no se levanta del suelo más que un palmo; la hoja muy menuda y la raíz es del tamaño y forma de una pera cermeña, blanca como nabo por dentro, y después de seca queda mucho menor y muy parecida a las perillas secas; es dulce y de buen gusto; cómese así pasada, cocida y asada. Tiene una extraña propiedad, que doquiera que se siembra un año, abrasa la tierra de tal manera, que en más de diez años no se puede volver a sembrar en ella; y para que no se hiele con las contínuas nieves y heladas que siempre hay donde se siembra la suelen cubrir con paja hasta que llegue a sazón de cogerla. Su temperamento es muy caliente, y es común opinión que, con ser la Provincia de Chinchaycocha, donde se da esta raíz, muy estéril y de tan frío y áspero temple, por mantenerse sus naturales con esta raíz no solo van a menos, como en las demás provincias del Perú, sino que se multiplican cada día más, para lo cual dicen tener virtud esta raiz".

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These accounts are frequently interpreted as evidence for great significance of maca in Peru during Inca rule and in the two centuries following European contact (Obregon 1998). A frequently quoted legend, according to which Inca troups in Cusco were supplied with maca (Antunez de Mayolo 1981), seems to support this notion. Many authors state that maca cultivation may have extended beyond Lake Junin and Huancayo to Cusco and even to the land around Lake Titicaca (Quiros & Aliaga 1997, Johns 1981) and eventually declined to its modern pre-boom distribution in a reduced number of localities in the departments of Junin and Pasco.

However, the above quoted literature clearly points to the areas surrounding Lake Junin (=Chinchaycocha) as the only area of maca cultivation in colonial Peru. We were unable to find a reference to a single historical source to suggest other locations. If indeed important and traded beyond Chinchaycocha prior to European contact, the long lasting dried maca roots would most likely have been found in excavated archaeological material, or be represented in phytomorphic pottery. Based on the historical and archaeological records we therefore conclude that maca, in pre-contact and well into colonial times, was restricted to the area identified by Pearsall (1989) as the crop's likely place of domestication. The view of maca's highly localized economic significance is also supported by the fact that Inca Garcilaso de la Vega, writing in the mid 16th century, is silent on maca in his chapter XXV on edible roots, while he provides detailed descriptions of potato, sweetpotato, oca, añu and the elusive cuchucho root (Garcilazo de la Vega 1982, p. 97–99).

6 Modern expansion of use and market development

6.1 Humble beginnings (until about 1990)

We are unaware of any mention of maca cultivation in the literature of the 19th and early 20th century. Even Weberbauer (1911), in his extensive monograph on the Andean Flora of Peru, fails to mention cultivated maca (although he records a wild *Lepidium* species occurring in Moquegua, Southern Peru). Perhaps, this is an indication of the decline of the maca area during that period in the wake of the general decline of Peruvian highland agriculture. This decline was caused by the expansion of wool production and mining that provided much local employment and income opportunities owing to the increasing demands for raw materials of the British metal and textile industry (Morlon 1992).

The first newspaper articles on maca appear in the 1960s, such as Pulgar's piece in 1960, which mentions maca's positive effects on reproductive fertility. Chacon, in her pioneering thesis on maca (1961) reports on trials with rats suggesting accelerated maturation of Graaf follicles and the enhanced production of sperm in rats.

In 1964, Leon introduces maca to an international audience in his article in Economic Botany (Leon 1964b). In this first survey on the cultivation and use of maca, he confirms the Junin area as maca's habitat, but notes that maca is also grown near Huancayo.

In the 20 years that pass after the appearance of Leon's article, not much change appears to occur in terms of the area cropped to maca, and the economic significance of the crop. Vílchez (1999) estimates that in 1980 maca was grown only around Lake Junin and Yanacancha, a community close to Huancayo. Maca was cultivated mainly for self-consumption, and occasionally, it was used during local festivities in the Junin area. He estimates that the area of land under maca cultivation at that time (1980) was around 15 hectares,

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an area so small as to raise concern that the the crop might become extinct (IBPGR 1982).

In the late 1970s and early 1980s, different local actors start to promote maca on the grounds of its locally perceived health benefits. For example, Pulgar (1978) disseminates information through national newspaper articles, referring also to his own experiments, which he claims show how maca-supplemented feed helps boost the fertility of heifers. A key person in the promotion campaign is Timotea Cordova, the owner of a beverage shop in Junin, on the road between Lima and Huanuco. In 1980, she successfully begins to offer a maca beverage that is highly appreciated by her clients. Truck drivers and travellers enjoy the fortifying hot drink, said to be good also for sexual stamina and fertility. Over the following years, Timotea's store becomes 'the place' from where the news about maca spreads to other parts of the country, in particular to the nearby capital city of Lima. To this day, the little store serves the hot maca beverage to travellers, and numerous postcards on display—profusely thanking Timotea for restored marital lives and the arrival of desperately wanted children—are testimony to the almost magical powers ascribed to maca (Vilchez 1999).

In 1981, Vílchez starts to offer dried maca roots to several local markets in Central Peru (Vilchez 1999). He produces the first printed leaflets on maca promoting the health attributes of this crop to a wider audience. With expanding demand and the product still in short supply from a small cropping area, maca prices for the first time increase beyond its traditional low levels, and incentives are thus provided for a slight expansion of local production. From 1987 onwards, Vílchez also sells maca sporadically at different natural food fairs in Lima. The interest of two national newspapers and a television channel covering his activities help familiarize many more people with a plant still largely unknown to most Peruvians. It is also at this time that the first convenience products containing maca begin to appear, using the root at lower concentrations or with ingredients that mask its strong flavour, thus improving its acceptance among urban consumers (Torres 1984, Vílchez 1991).

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During this same period in the 1980s, the first foreigners 'discover' maca. For instance, in 1982, two US students visit Junin to survey the economic botany of maca (Balick and Lee 2002). In the 1980s, Johns publishes his thesis and publications on the ethnobotany and phytochemistry of maca and añu (*Tropaeolum tuberosum*) (Johns 1980, 1981, 1986).

The 1980s also put maca on the political agenda of the Peruvian government. Under the umbrella of a new law, ratified in 1986 to promote Andean crops, maca is introduced to other parts of the Peruvian Andes, with the stated aim of overcoming malnutrition in poor communities (Obregon 1998). However, the lack of maca seed and growing insecurity owing to the insurgency of the Shining Path Maoist guerrilla organisation get in the way of these activities and finally curtail the project's completion (Castro 1990).

6.2 Expansion of demand and production (from 1990 onwards)

The 1990s see an unprecedented expansion of the production of maca. Since 1991, and with the Shining Path insurgency subsiding, the Peruvian government finally follows through with its plans to promote maca production in different parts of the country through its agricultural research and extension program (INIA) (Vílchez 1991). As illustrated in Fig. 15, the area under maca grows manyfold from 1983 to 1993. This Figure also shows that, by 1983, maca had been reported only from the traditional maca growing districts in the departments of Junin and Pasco in Central Peru. Ten years later, in 1993, MINAG agricultural census data record maca also in high altitude districts of the departments of Ancash, Apurimac, Arequipa, Ayacucho, Cajamarca, Huanuco and Cusco. In 2003, however, maca areas appear to be contracting again in the non-traditional areas of Apurimac, Cajamarca and Huanuco. In Ancash and Cusco, the crop has disappeared again in 1993. Puno and La Libertad start to grow maca only after 1993. According to Roberto Valdivia (personal communication, 2007), maca is no longer grown in Puno, perhaps because of poor adaptation to a climate that is much drier than the climate of the traditional maca growing areas in Central Peru. It

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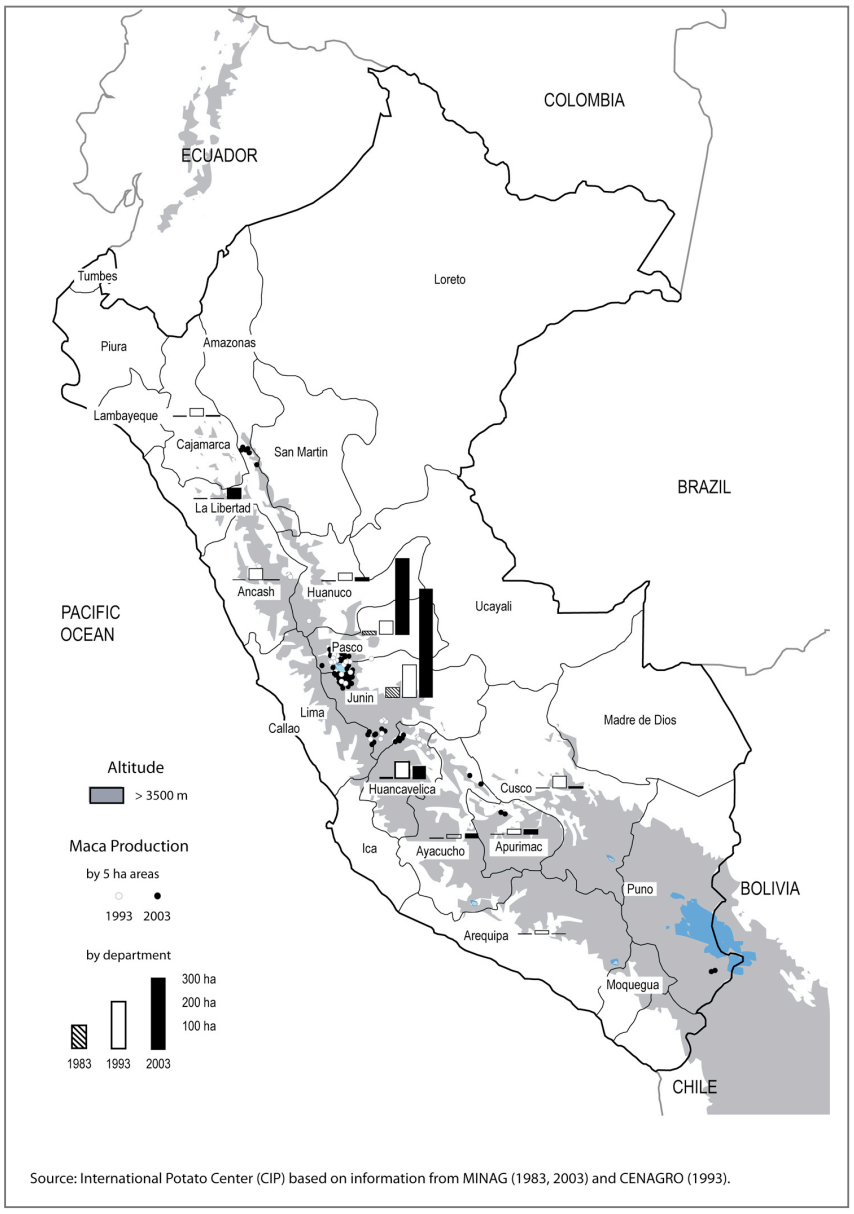

Figure 15.
The evolution of maca production in Peru from 1983 to 2003. Source: GIS Unit, International Potato Center, based on information from MINAG (Ministry of Agriculture) and CENAGRO (Censo Nacional Agropecuario).

seems that maca cultivation requires particular growing conditions that are met in the Central Peruvian puna only, and give that region an absolute advantage over other high-altitude areas within the Andes and other mountain areas.

In the 1990s, academic interest in maca also increases considerably as indicated by the number of university theses and publications, which exceed by a factor of 3–4 the number of all publications in previous years (Table 2). Publications initially cover agronomic subjects, but

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increasingly deal with maca food composition, product development and animal studies, reflecting the needs of market development and attribute substantiation. A large share of theses is conducted at Peruvian universities. Some of these claim to substantiate traditional beliefs in the capacity of maca to increase fertility. For instance, feeding maca as a supplement to sheep (Cóndor 1991) is shown to increase the heat symptoms of female animals, improving reproduction performance. Similar results are presented for cattle by Matos (1995), who also finds increased sperm count and motility in bulls' semen. Data presented by Lock and Apumayta (1993) suggest accelerated sexual maturity in maca-fed female rats. Alvarez (1993) and Meza (1995) find that the fertility of female guinea pigs as well as the survival of their offspring is positively related to maca intake.

Table 2: Growth of maca literature recorded at the library of the International Potato Center (1960–2006)
(Data courtesy Cecilia Ferreyra)

Time Period	1960–69	1970–79	1980–89	1990–99	2000–06	Total
Journal articles	1	1	7	39	68	116[a]
Theses	1	0	3	13	32	49[b]
Other publications	-	-	-	-	-	165[c]

[a] of which 55 are in English, 57 in Spanish, 4 in other languages.
[b] of which 46 were defended at Peruvian universities.
[c] of which 146 are in Spanish, 17 in English and 2 in other languages.

Beginning in the early 1990s, the governments of Germany and Switzerland support over a period of 15 years (1990–2004) the Lima-based International Potato Center (CIP) and its public sector partners in Peru to improve the conservation and use of nine neglected and underutilized Andean root and tuber crops. The Programme generates and documents a considerable body of knowledge on maca and does some scientific groundwork for enhanced conservation methods and use strategies (Tello et al. 1992, Quiros et al. 1996, Toledo et al. 1998).

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Figure 16.
Leading Peruvian brands of maca nutraceuticals (Maca Andina, Maca Forte) on display in a pharmacy in Lima, 2003.

It is impossible to determine the extent to which CIP has contributed to the expansion of maca, but CIP is recognized in Peru for making significant contributions for more than a decade to public awareness, and information dissemination. In particular, CIP's library has built up an impressive collection of literature on maca, including grey literature, which has been instrumental in providing information to private sector players.

In 1995, Química Suiza, a Peruvian pharmaceutical company became interested in maca. Over the following years the company invested more than one million USD in the development and branding of the nutraceutical Maca Andina®, tablets containing crude maca flour (Chauvin 1999). Launched in the Peruvian market in 1998 (Química Suiza 1998), Maca Andina became the flagship maca nutraceutical in Peru and, encouraged by its success, several Peruvian companies ventured into similar products (Fig. 16).

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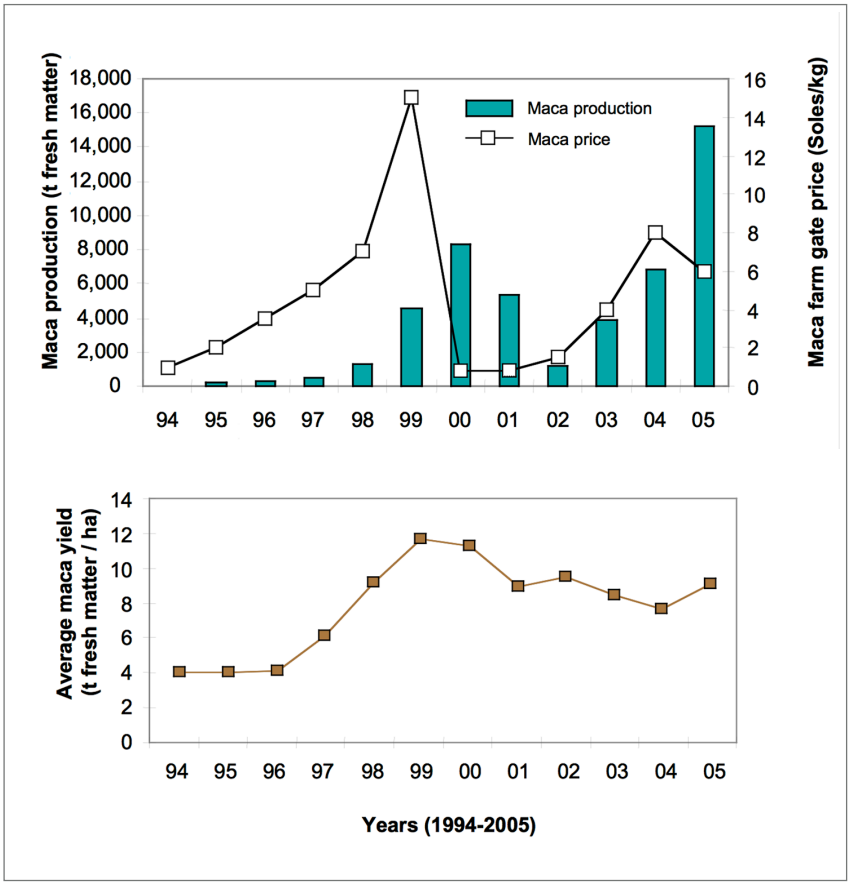

Figure 17.
Evolution of maca production and prices in Junin from 1994 to 2005. (Source of data: Ministry of Agriculture [production], personal information from Javier Castillo, maca producer in Junin [prices], Junin Office of Ministry of Agriculture [yield]).

6.3 Crash and consolidation (2000–2006)

As consumers and the private sector become increasingly interested in maca during the late 1990s, both demand for maca and producers' prices rise drastically (Fig. 17). High prices, in combination with expectations to export maca in large quantities to Japan, the USA, and Europe (Chauvin 1999) provide further incentives to producers to enhance maca production. Expanding production is also stimulated by a government campaign to finance the cultivation of an additional 800 hectares of maca in the Junin area. Peru's president at the time, Alberto Fujimori, made considerable publicity for maca in Japan from 1998 to 2000, which led to inflated expectations as to the export demand of maca. The increment of maca production was driven by high market prices during these years, provoking both an expansion of the cultivated area and the intensification of maca cultivation, notably through the use of mineral fertilizers, which resulted in a significant increase of area yields (Fig. 17).

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The resulting drastic expansion of production in 2001 and 2002, however, resulted in oversupply of dehydrated maca, which was not absorbed by the market (Fig. 17). Gomez (2002) estimated that, in 2002, 2000 t of dried maca were stored in the Junin area alone. The Peruvian company *Quimica Suiza* had gathered huge stockpiles of maca for which the company had no use (Andrés Vázquez, personal communication, 2001). Consequently, prices collapsed and many farmers were ruined as they were not able to pay back their loans.

Consequently, the abundant availability of dried maca at a low cost attracted new companies to enter the maca business, targeting with their products the national and international market. In the year 2000, there were already 15 formal companies processing and commercializing maca as food or pharmaceutical preparations (Vilchez 1999).

The low maca prices also favoured the market entry of many informal players. In contrast to the formal companies, these informal (and smaller) processors and traders tended to avoid taxation and registration systems. They targeted the large number of less wealthy consumers, especially in Lima, who account for a growing share of the purchasing power in urban areas of Peru but favour lower product prices. In this informal setting, price pressure and strong competition led to the adulteration of maca with wheat flower, causing market distortions, insecurity, and confusion among consumers (Gómez 2002).

This informality continues to affect export practices. Without scientific evidence about the efficacy and appropriate dosage of maca, many exporters, or their collaborating overseas distributors, position maca as an over-the-counter substitute of Viagra, a drug used to treat erectile dysfunction in humans (see Section 7.2.1.). This tendency goes hand in hand with Internet information and newspaper articles that reinforce the notion that maca is a natural Viagra or ‘Andean Viagra’ (e.g., Chauvin 1999).

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It was also in the early 2000s that the first peer-reviewed scientific papers seeking to substantiate product claims appeared in international journals (see Section 7.4.1.). Such information was picked up by many companies, who used it in product promotion.

Because of the lack of coherent, scientific information about maca, European food safety legislation also began to pose a serious problem for exports in 2002 (see Section 7.2.2.). The confiscation in Japan of maca contaminated with pesticide residues was widely observed and attributed to the intensification of cultivation and unscrupulous use of pesticides. This provided incentives to return to the traditional ecological production of maca, and led some companies to seek organic certification for production, which they source increasingly through contract farming. In 2006, the share of organically certified maca reached 15%.

In recent years, the increased competition has led to tensions between the main producer groups of Junin and Pasco. For example, they no longer conduct a shared maca trade fair, but have opted for separate individual fairs. There are even reports about quarrels between the two groups concerning the establishment of product norms (Mr Magno Meyhuay, personal communication, 2007).

Interest in maca continues to grow unabatedly, although export figures from the years 2003 to 2005 suggest that export demand was stagnating in that period. Currently most products on the market are for human consumption, but there could be market opportunities for greater maca use in feed supplements for intensive production systems, such as for chickens, pigs, fish, especially for juvenile animals where boosting growth rates and curtailing mortality strongly affect net gains.

6.4 Maca production outside Peru

Experimental plantings of maca outside Peru, in which storage root formation has been observed, have been reported from northern California (Mediterranean winter conditions; Quiros & Aliaga 1997), Czechoslovakia (Valentová & Ulrichová 2003) and in greenhouse experiments conducted by Quirós et al. (1996). It is not clear from

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these reports whether commercially relevant yields competing with those common in the Central Andes can be obtained. Outside of Peru, we are aware of limited commercial maca cultivation in Bolivia only.

Maca seeds are occasionally on offer in seed catalogues for sale in small quantities to what are presumably hobby gardeners (e.g. Horizon Herbs, US). There are also several eBay records (2006–2007) of the sales of small batches of maca seeds (15–100) from sellers in the US, Australia and Bolivia.

7 Analysis of factors affecting maca market development

7.1 Demand expansion

7.1.1 Product innovation and diversification

Torres (1984) showed that the acceptance of maca is low among people with no previous exposure to this food. His results suggest that maca is an acquired taste, which is probably one of the reasons for this crop failing to expand beyond its narrow geographic distribution in the past.

Product development and diversification have been key in the expansion of maca demand, particularly the development of convenience products for urban consumption that mask the maca flavour, typically by limiting its share of total product weight to under 20%. Today, there is a plethora of maca products available on the Peruvian market. They include breakfast cereals, biscuits, alcoholic and non-alcoholic beverages, jams, soluble instant flours, spray-dried extract, candies and gelatine capsules filled with maca flour (Fig. 18).

Some of the main processed products are described below.

Maca flour: Dehydrated maca roots are milled to produce flour. The dehydrated roots are either obtained by traditional drying as described under Section 3.2. or by oven-drying the freshly harvested roots. The latter method yields flour which is higher in glucosinolates.

Extruded maca flour: Extrusion of raw maca flour from conventionally dried roots results in the gelatinization of starch. The extruded product is then finely milled and becomes largely water-soluble. Extruded maca flour is an attractive product for use in milk or breakfast cereals, upon which it imparts a unique flavour at low concentrations.

Pills: Raw flour from freshly harvested maca can be mixed with excipients and pressed into pills.

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Figure 18
Range of maca products available in Peru, 2003 (Photo courtesy: Ivan Manrique).

Alcoholic extract: Alcohol can be used as solvent to extract pharmacologically active substances from sliced roots or coarsely milled maca. Evaporation of the alcohol leaves an aqueous solution of maca solids.

Table 3 shows the value added through processing from crudely processed to final consumer products.

Table 3. Average free-on-board (FOB) value per gross weight of exported maca products (2001–2005)

Type of exported maca product	FOB (US$/kg)
Dried roots	3.1
Crude flour	6.2
Fine flour	7.2
Gelatinized flour	13.5
Capsules	27.5
Maca extract	67.0

Source: Calculated from export data provided by PROMPEX (Comisión para la Promoción de Exportaciones, Peru)

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7.1.2 Supply chain diversification

Although dozens of companies are currently exporting maca products (see Section 7.1.4.), few enterprises have their own processing facilities. In fact, most companies subcontract services from bigger companies with the equipment to produce gelatinized flour, capsules or liquid extracts. Castillo (personal communication, 2006), for instance, mentions that in Junin, only two enterprises have processing facilities for maca, and both are linked to farmer groups with organic certification. Most companies acquire maca through a number of intermediaries who exploit the need of individual farmers for cash by negotiating very low prices.

Castillo mentions that in total, there are at least 10 maca farmer associations in Peru: Junin (4), Cerro de Pasco (4), Carhuamayo (1), Huancayo (1). However, farmers do not always respect their contractual obligations with the associations and, at times of high maca demand, tend to sell their produce to the highest bidder. Except for organically certified maca, supply contracts between enterprises and farmers are rare. Moreover, they provide little supply security for enterprises.

Castillo estimates that currently 10–15% of the total maca area is organically certified. The certification is typically owned by companies commercializing maca and also by individual farmers who act as intermediaries. The fact that farmers are not owners of the certification is due to the high cost of the certification.

In the Lima wholesale market, the most important market for maca in Peru, a few traders dominate the turnover of fresh maca, which is of great relevance to smaller enterprises and retailers. Actually, the most important wholesaler is called the 'King of Maca'. Although there is also maca flour on sale, many smaller processors favour the purchase of whole maca roots, thus avoiding the risk of obtaining adulterated flour.

The local promotion of maca is based on brands and driven by the commercial interest of a few companies with enough economic strength to invest in publicity for their products. Given the confusing messages consumers have received about maca during the last

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years, these companies are very careful in how they sell their maca products nowadays. Currently, all important and formal maca publicity in Peru targets consumer segments interested in maca as a natural energy enhancing food supplement.

7.1.3 Promotion on the Internet

Since the early 1990s, maca products, principally gelatine pills filled with the ground flour of the roots, have been advertised on the Internet. Fig. 19 shows screenshots of websites touting maca as an alternative to Viagra. Many sites refer to maca as the 'female' Viagra, the 'Peruvian Ginseng', a rejuvenating tonic, or a 'feel good' product.

Figure 19. Screenshots of websites (2003) praising maca as a 'safe' or 'natural' alternative to Viagra.

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In April 2007, a Google search for the term 'maca' yielded 4 260 000 hits, and in combination with the term '*Lepidium*' still 226 000 hits. Overwhelmingly, websites featuring maca have commercial purposes, and much of the information on maca is incorrect and misleading. The lack of readily available authoritative information on maca is all too apparent.

7.1.4 Exports

Statistics based on export records of the Peruvian tax authority SUNAT (Fig. 20, upper graph) show that the first maca exports took place in 1995, and have since grown steadily and vigorously, except for the year 2000 when the international maca demand dropped by approximately one third relative to the previous year (concomitantly with the worldwide stockmarket crash and ensuing recession). Until 1999, sales to the US accounted for most exports, but beginning in 2000, Japan took over as the most important international maca buyer, with a share accounting for about half of all sales between 2001 and 2005. By 2005, total maca exports from Peru had grown to a total free-on-board (FOB) value of approximately US$ 3.7 million. This represented 0.28% of Peru's total agricultural export value. Maca export figures are dwarfed by the export value of grapes, mangoes, asparagus, paprika and native products such as cacao and tara from Peru in the same year (Table 4). Importers in countries of the European Union (Italy, Spain) were among the first to buy maca from Peru, as early as 1996, but the EU share of total maca exports has in most years remained significantly less than 20%.

The importing countries reported together in Fig. 20 under the category 'Other Countries' include Australia, Brazil, Canada, China, Switzerland, Taiwan, each with a share of between 0.5–2.0% of total maca FOB value in the period 1995–2005.

Figure 20.
Evolution of exports of maca products according to country destination, product type and gross weight. (Source of data: Biocomercio - PROMPEX. Note that for 2005 only the total FOB value of maca exports is available.)

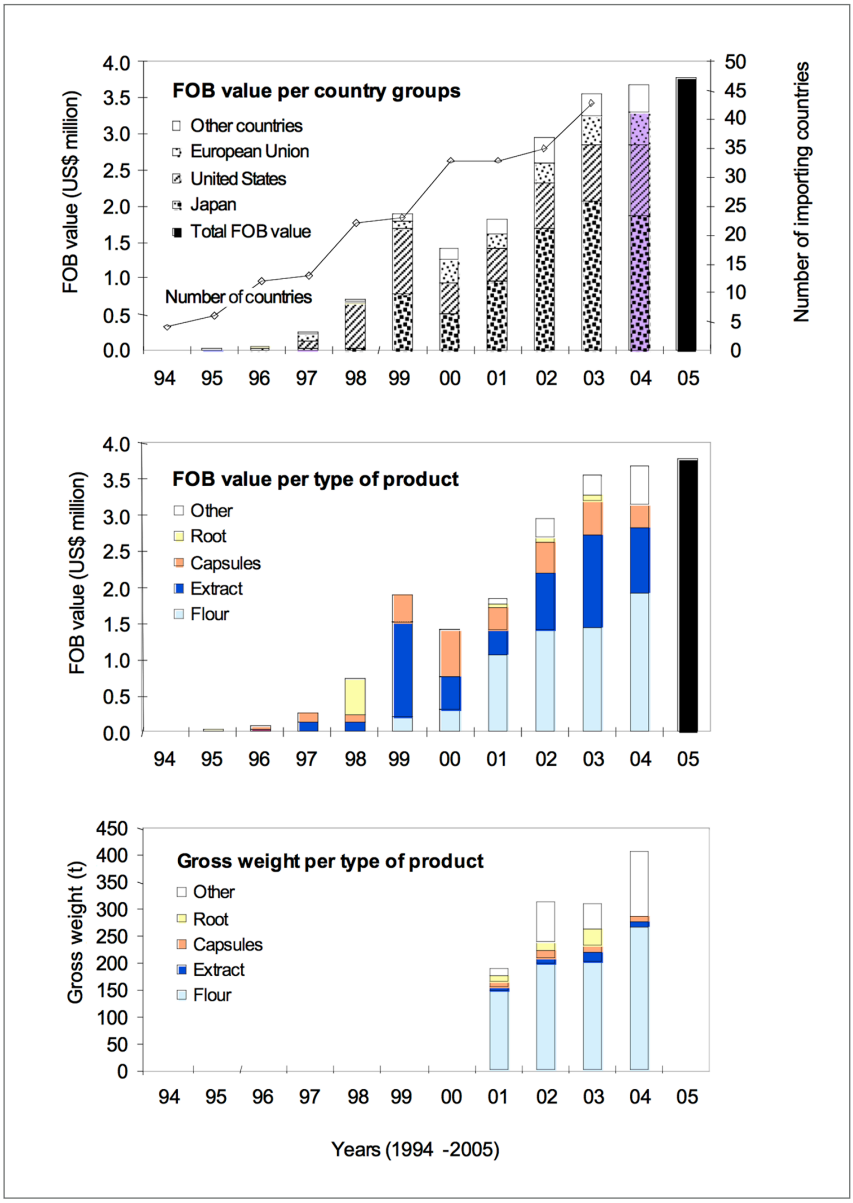

Fig. 20 (middle graph) shows the evolution of maca export value by product type. SUNAT records upon which this graph is again based, are almost certainly flawed owing to confusion by customs officers and declaring exporting companies over the meaning of categories 'flour' and 'extract' and erroneous application of respective tariff codes ('partidas arancelarias'), especially in the early years of product innovation. However, Fig. 20 clearly shows that overwhelmingly the export revenue throughout the years has been generated by products

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with medium added value (flour) and high added value (extract and capsules) (see also Table 3), thus countering the widely held notion of maca being exported as primary material only, as argued by Peruvian media and politicians to eventually misguide policy decisions. As a matter of fact, exports of the dried, unprocessed, roots (the product type with the lowest added value) accounted for a major share of total export value only in 1998, but were of negligible importance in all other years.

Table 4: Export free-on-board (FOB) value of maca compared to other agricultural products from Peru

Product	Value FOB (US$ million)
Introduced crops	
Asparagus	263
Paprika	95
Artichokes	49
Mangoes	43
Citrus fruits	19
Olives	16
Native American crops	
Cocoa	29
Avocadoes	24
Tara (*Caesalpinia spinosa*)	11
Maca	3.7
Total agricultural exports	1340

Source: Peruvian customs, ADEX, PROMPEX, 2005.

SUNAT statistics also reveal that in the five years to 2005, a total of 220 companies exported maca at some time or other (Fig. 21). However, only 31 companies (14%) managed to complete at least one maca export transaction in each of the 5 years. These companies accounted for 70% of the total export value (US$ 11.03 million), with an average of US$ 71 154 per year per company. By contrast, 105 companies were recorded as exporters in only one of the 5 years; these accounted

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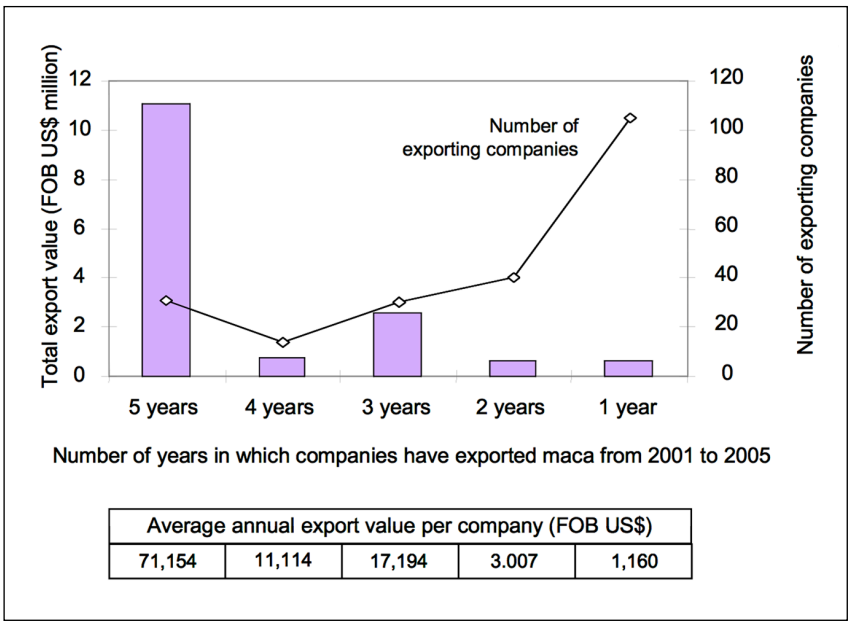
Figure 21.
Consistency of maca exporting activity during 2001 to 2005.



Average annual export value per company (FOB US$)				
71,154	11,114	17,194	3.007	1,160

for only 4% (US$ 610000) of the total FOB value, with an average of US$ 1160 per year per company. These figures demonstrate that only a small number of companies have emerged as significant maca suppliers for export markets, while a much larger number of companies is involved in minor and occasional sales to external clients, with some companies never progressing beyond the dispatch of product samples.

7.2 Maca encountering barriers on international markets

7.2.1 The problem of unsubstantiated health claims

The frivolous Internet marketing of maca as a libido booster that began in the mid-1990s, quickly propelled it to international notoriety. As exports picked up from 1997 onwards, maca pills containing the crude flour or hydro-alcoholic extracts became increasingly available in Europe by mail and over the counter, and were openly touted for their alleged pharmacological effects and often on sale in red light districts, or advertised on webpages linked to adult material.

The fact that none of these products had gone though internationally accepted registration procedures mandated for pharmacological

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products did not escape the attention of the regulatory entities in target markets. Particularly in the EU, an increasing number of maca shipments were confiscated in the 1990s and maca marketing became increasingly limited to informal distribution channels including sales through the Internet.

Peruvian exporters and their EU importer counterparts reacted by toning down advertisements and/or by removing health claims from their product labels, but this invariably resulted in reduced demand (Mr Gmür, personal communication, 2001). It was also at this time that a sense of the need for scientific substantiation of maca's 'invigorating' effects became commonplace leading to research that was eventually published in university theses and in peer-reviewed journals from 1999 onwards (see Section 7.4.1.).

7.2.2 European food safety legislation

Some maca suppliers, however, began to pursue a different marketing strategy aimed at the promotion of maca as a food or food ingredient consistent with the root's traditional use in its native area in the Lake Junin area. This strategy was beset with two major difficulties. One was the *de facto* positioning of maca as a drug in the Internet, which was further accentuated by the appearance of science papers suggesting the efficacy of maca's action on reproductive parameters in animals and humans. This necessarily led to concerns about possible toxicological effects at the much higher doses implied in consumption of maca as a food. A second problem of this approach consisted in the fact that maca suppliers were unprepared to respond adequately to food safety concerns, particularly those embodied by EU Regulation No 258/97[11] also known as the Novel Food Regulation (NFR).

[11] Regulation (EC) No. 258/97 of the European Parliament and of the council of 27 January 1997 concerning novel foods and food ingredients. Official Journal L 043 , 14/02/1997 p. 0001 – 0007 (accessed 27 Dec. 2006), Available from http://eur-lex.europa.eu/LexUriServ/site/en/consleg/1997/R/01997R0258-20040418-en.pdf.

This regulation requires food safety assessments of traditional foods (viewed as novel from a European perspective) for pre-market approval. Its stated objective is to protect public health by ensuring food safety. The NFR arbitrarily defines *novel food* as food or food ingredients that were not used for human consumption to a significant degree *within the EU before 15 May 1997*. The NFR calls for anyone wishing to place a food product on the EU market to first evaluate whether the food was used prior to 1997 and to present evidence to support the case. If the food in question can be shown to have been used within the EU before 15 May 1997, it is viewed as *not novel*, and it may be placed on the market. An assessment under the NFR is then not required. If market presence for the food can not be demonstrated for the time before 15 May 1997, it is viewed as *novel*, and an assessment of the food's safety under the NFR is required. Scientific evidence of the highest standards with regard to food composition, suggested intake levels, toxicological assessments and allergenic potential need to support the application. Member states can and do raise objections against the submitted evidence and applicants may be asked to present additional evidence to address such objections.

In 2002, the first reports of the seizure of maca consignments by EU country authorities became known, hitting maca exporters and importers fairly unprepared. Most had not heard about the NFR, and since maca was an age-old crop plant in the Andes, was it not safe for consumption by Europeans as well? In March 2002, the German customs withheld a consignment of maca flour referring to the potential status of maca as a novel food under the NFR (Guillerm, personal communication, 2002).

A letter dated 27 September 2002, by José Urrutia, Ambassador of the Peruvian Mission to the EU, directed to the Directorate General for Health and Consumer Affairs of the European Commission (DG SANCO), expressed concern about the denying of market access to maca as a food in the EU. It referred specifically to section 1.2.1 of the NFR, which appears to exempt food products derived from traditional propagation procedures, but is contradicted by the prevailing practice of the NFR.

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In October 2002, the Danish Veterinary and Food Administration Division for Nutrition stated that raw maca flour was not considered safe for human consumption and that it was not legal to sell it in Denmark, relative to the Danish Food Act, § 7 (Mr Guillerm, personal communication, 2004). Reasons for this decision included:

- Uncertainty about maca's composition owing to the lack of appropriate literature.
- Presence of alkaloids (as reported by Dini et al. 1994).
- Uncertainty about the appropriate processing of maca for food uses, based on the observation that reports of consumption in the Andes quote the use of heat-treated maca products only (boiling), while the use of the raw root flour was suggested in products destined for consumption in Europe.
- Two refereed journal articles (Zheng et al. 2000 Cicero et al. 2001) suggesting that the dried tuber or an extract derived from the dried tuber had an effect on mating behaviour and increased locomotion of mice and rats, giving rise to concerns that similar (recommended) intake levels would likely pose risks to the hormone system of humans.
- In order to assess food safety risks, there was a need for more information on 1) harvest periods, 2) product standardization, 3) traceability of the botanical identity of maca at all supply chain stages.

In November 2002, the office of consumer protection in the German town of Regensburg obliged the natural products distributor Compendium to withdraw several maca products, in reference to the NFR. In June 2002, Schiphol airport customs (Netherlands) confiscated a shipment of maca pills, also quoting concerns related to the NFR.

In May 2003, the food safety authority in the Netherlands seized a consignment of maca flour, and issued two warning notifications banning

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maca flour ('crushed root') as a non-authorized novel food from entry to EU markets under references 2003.AZW and 2003.AZ (along with a variety of chemically and microbiologically contaminated food items). The notification was published in the weekly Rapid Alert System for Food and Feed (RASFF), a newly created instrument to assist authorities with the rejection of incriminated foods at the EU's external borders or with the removal of such foods from the market. However, a few months later, the owner of the consignment had produced statistics from the Peruvian tax authority (SUNAT) revealing for 1996 maca shipments to Italy and Spain worth some US$ 5200. This was taken as proof for the use of maca in the EU prior 1997 (when the NFR came into force) and the consignment was returned to the importer.

In March 2004, a letter from DG SANCO, signed by Guido Mattera Ricigliano and addressed to the Embassy of Peru in Brussels, confirmed that a final agreement had been reached among member states to consider maca as *not novel* referring to its acknowledged history of consumption before May 1997. The letter goes on to say: "Therefore, according to Regulation 258/97/EX, these food stuffs [=roots of maca] shall not be considered novel and do not require an authorization under this Regulation before placing them on the market, *provided that they comply with other legal and safety requirements of the EU"* [authors' italics].

Yet, concern about these safety requirements figured prominently in a decision issued in September 2004 by AFSSA (Agence Française de Sécurité Sanitaire des Aliments), denying market authorization for maca flour in France, and reiterated in March 2005. While confirming DG SANCO's interpretation of maca not falling under the remit of the NFR, AFSSA raised the following food safety concerns:

- The presence of alkaloids in maca roots.
- The need for more information about the composition of maca, particularly about the possible presence of other potentially toxic compounds.

- Libido enhancing effects observed in rats at intake rates equivalent to those recommended for humans.

It appears likely that the cases listed above, in which the NFR has challenged the importation and distribution of maca, are probably only the tip of the iceberg of a phenomenon that has discouraged investment in maca supply chains, and particularly in product and market development. We have interacted with a number of companies intrigued by the marketing potential of maca, who eventually shied away from investment because of uncertainties surrounding the food safety assessment of maca in the context of the NFR.

7.3 Maca supply chains and government policies

Using fairly ambiguous language, in early 1999, Peru's government under Alberto Fujimori, issued a presidential decree (Decreto supremo No 025-99-AG), which prohibited "the export of specimens, products and sub-products of maca in a natural state or obtained through primary mechanical transformation, so that its exportation be with higher added value". This decree appeared to be motivated by the desire to halt the flow of maca germplasm to Bolivia and Ecuador, countries which had (exaggeratedly) been portrayed in press reports as emerging producers of maca from illegally obtained Peruvian seed. The decree was also issued in response to the perception of maca being exported as a low value commodity, while added value was claimed to accrue mainly in importing countries. Indeed, in 1998, over half a million US$ worth of unprocessed maca roots accounted for the lion's share of that year's total maca exports (see Fig. 20). The decree effectively brought exports of unprocessed maca roots to a halt, while in the following two years, the export of maca flour gained momentum, despite the fact that at least the fraction of crude milled flour would have fallen within the decree's definition of 'primary mechanical transformation'.

In June 2001, the Government issued another decree (No. 035-2001-AG), which suspended decree 025-99-AG thus effectively allowing again the export of crude and unprocessed maca. This

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decree was based on the fallacy that restricting maca exports to added-value products was crippling export opportunities and had lead to a decline in maca prices, when indeed maca revenues were increasingly obtained from higher value products (Fig. 20) and were in 2001 reaching 1999 levels again after the global economic downturn that had temporarily depressed international maca demand. More importantly, however, the drastic decline in farm-gate maca prices was the consequence of increasing stockpiles and over-supply of dried maca produced in 1999 and 2000. High farm-gate prices in the late 1990s and the administration's supply push (as described in previous paragraphs), at a time when it should have cautioned exuberant maca producers about the limits of maca demand had finally resulted in the collapse of maca production and the disillusionment of many poor producers.

The value of maca exports nearly doubled in the year following decree 035-2001-AG, but not as a consequence of resuming exports of the unprocessed roots, but rather owing to the growth of international demand for products with medium and high added value (Fig. 20). The export of unprocessed roots accounted for only a tiny proportion of overall exports from 2001 to 2003.

Still, in 2003, under a new administration, the presidential decree No. 039-2003-AG marked another change of mind among Peruvian policy makers, reverting to their original position of prohibiting the export of maca products of primary processing (as specified in article 1[12]), in accordance with the original decree 025-99-AG. The flour obtained by milling the roots clearly falls under the decree's export restrictions,

[12] El Peruano, p. 256756, 8 December 2003, Decreto Supremo No. 039-2003-AG, Articulo 1: 'Prohíbase la exportación de semillas botánicas, vegetativas, especimenes, productos y subproductos de la maca *Lepidium meyenii (Lepidium peruvianum)* al estado natural o con proceso de transformación primaria, a efectos de promover su exportación con mayor valor agregado. Entiéndase por Proceso de Transformación Primaria, todo aquel que implique la limpieza, clasificación y envasado de raíces, tallos, hojas, flores, frutos y semillas, así como, la molienda, picado, pelado, chancado, y otro proceso físico similar, aplicado a hojas, flores, frutos, semillas y raíces."

but it continues to be exported to a large extent (Fig. 20). This same decree also prohibits the export of maca seeds but to our knowledge, the Peruvian government has never investigated the issue of maca production in Bolivia from seed that has almost certainly come from Peru through informal channels, thus challenging Peru's ownership of maca genetic resources.

With the increase in maca trade and consumption both within Peru and abroad, the lack of product standards together with the incoherent and even confusing use of product names, widely varying product quality and frequent adulteration (especially at times of low supply) has become a problem and has been perceived as compromising the reputation of maca, increasing transaction costs and putting food safety at risk. Recognizing these problems, in 2004, the Sociedad Nacional de Industriales de Junin, Junin's Regional Office of the Ministry of Agriculture, and a group of maca producers approached INDECOPI[13] requesting the establishment of technical product norms for maca. Calling upon government institutions, producer organizations, private companies, universities, the International Potato Center and independent experts, INDECOPI established three committees to focus on consumption, production and technical aspects (Mr Magno Meyhuay, Ministry of Agriculture, DGPA, personal communication, 2006).

In 2006, INDECOPI's Comisión de Reglamientos Técnicos y Comerciales published drafts of three technical product norms for public consultation, with the intention of ratifying them in 2008. The norms concern dehydrated roots (PNTP 011180, *maca seca*), toasted flour (PNTP 011181, *harina de maca tostada*), and gelatinized flour (PNTP 011182, *maca gelatinizada*). These norms provide glossaries of accepted terms and define physical product properties, acceptable ranges of product composition and microbial contamination, and describe appropriate processing procedures. Drafts of three additional norms are in preparation, for crude flour, liquor, and nectar.

[13] Instituto Nacional de Defensa de la Competencia y de la Protección de la Propiedad Intelectual

In summary, Peruvian government policies have had a mixed record in terms of support to maca supply chains. Ill-informed and politics-driven activities promoted maca production without complementary market development interventions. The decrees limiting exports of crudely processed maca probably generated more damage than benefits to farmers and other supply chain actors. However, the recent support of INDECOPI in the establishment of maca product norms in consultation with a wide range of maca stakeholders, is an encouraging development for the regulatory role of this public agency. These product norms are expected to contribute to consumer safety and the proper functioning of maca marketing, making the sector more competitive.

7.4 Supporting product innovation

7.4.1 Scientific substantiation of maca attributes

Since 1999, a growing number of scientific papers seeking to substantiate the efficacy of maca consumption on male fertility, sexual performance and physical stamina have appeared in peer-reviewed journals (Table 5). The paper by Zheng in the journal Urology (2000) has been particularly influential and is widely referred to as proof of maca's aphrodisiac effect. Zheng presented data suggesting that oral administration of a proprietory extract obtained from maca (see 7.4.2.) enhanced the sexual function of mice and rats in terms of increased frequency of intromissions, the increased number of sperm-positive females, and a decrease in the latent period of erection in male rats with erectile dysfunction.

Aphrodisiac or fertility-enhancing effects in animal models are typically observed at consumption levels that are several orders higher (≈1g per kg body weight) than those recommended in commercial maca nutraceuticals, casting doubt on the efficacy of commercial products. Some authors speculate that maca's elevated content of glucosinolates is responsible for fertility enhancement but this has not yet been confirmed.

Unfortunately, some authors of the peer-reviewed articles in Table 5 fail to disclose the private sources of funding for their research and the links of their work to commercial product development and related intellectual

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Table 5: Reported pharmacological effects of maca to support health claims

Year	Author(s)	Organism	Reported pharmacological effects	Supported health claim	Document*
1961	Chacón	Rats	Enhanced maturation of Graaf follicles and production of sperms	Fertility (male and female)	Thesis (S)
1991	Cóndor	Sheep	Improved heat symptoms and other reproduction parameters	Ferility (female)	Thesis (S)
1993	Alvarez	Guinea pigs	Improved reproduction with higher birth weight and decreased risk of death at birth	Ferility (female)	Thesis (S)
1993	Lock and Apumayta	Rats	Enhanced sexual female maturity	Ferility (female)	Thesis (S)
1995	Matos	Cattle	Higher number of ejaculated sperms with increased motility	Fertility (male)	Thesis (S)
1995	Meza	Guinea pigs	Improved reproduction with higher birth weight and faster growth of newborns	Fertility (female), Growth	Thesis (S)
1997	Beltrán et al.	Rats	Non-toxicity at lethal dose (DL 50)	Non-toxicity	Document (S)
1999	Miura et al.	Rats	Improved energy response in hypoglycemic conditions	Stress recovery	Journal article (E)
2000	Tapia et al.	Rats	Improved stress resistence and recuperation from stress	Stress resistance and recovery	Journal article (S)
2000	Zheng et al.	Rats	Improved sexual performance and decrease of sexual dysfunction of male rats	Sexual performance (male)	Journal article (E)
2001	Cicero et al.	Rats	Improved sexual performance	Sexual performance (male)	Journal article (E)
2001	Menaldo et al.	Human	Improved fertility in intrauterine insemination	Fertility (female)	Journal article (E)
2002	Sandoval et al.	None	Capacity to protect cells against oxidative stress	Prevention of cancer	Journal article (E)
2002	Cicero et al.	Rats	Improvements in sexual performance with hexanic maca	Sexual performance (male)	Journal article (E)
2001a	Gonzales et al.	Rats	Invigorated spermatogenesis in male rats	Sexual performance (male)	Journal article (E)
2001b	Gonzales et al.	Human	Improved sperm production and sperm motility	Sexual performance (male)	Journal article (E)
2002	Gonzales et al.	Human	Improved sexual desire in men	Sexual desire (male)	Journal article (E)
2003a	Gonzales et al.	Rats	Onset and progression of spermatogenesis activated	Sexual performance (male)	Journal article (E)
2003b	Gonzales et al.	Human	No effect on serum reproductive hormone levels	Sexual performance (male)	Journal article (E)
2004	Gonzales et al.	Rats	Higher epididymal sperm count than at sea level without treatment	Sexual performance (male)	Journal article (E)
2004	Lee et al.	Trout	Improved growth and reduced mortality in trout alevins and juveniles	Growth, stress resistence	Journal article (E)
2004	López et al.	Rats	Alleviation of stress-related symptoms and improvment in stress resistance	Stress resistance	Journal article (E)

* E = in English, S = in Spanish

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property claims. A recent survey[14] has shown that industry-backed scientific papers on the health effects of food products were seven times as likely as publicly funded research to produce a conclusion favouring a company's product. This begs the question whether research on the efficacy of maca consumption is affected by the same phenomenon.

In a thesis that did not rely on private sources of funding, Locher (2006) found that a maca feeding trial with breeding bulls, lasting 84 days (average 0.23 g per kg body weight) produced no statistically significant effects on ejaculate volume, sperm count and motility.

7.4.2 Maca patents

In 2001 and 2002, the United States Patent and Trademark Office granted Pure World Botanicals Inc. patents protecting the "extract of *Lepidium meyenii* roots for pharmaceutical applications" (US patent 6,267,995) and the "treatment of sexual dysfunction with an extract of *Lepidium meyenii* roots" (US patent 6,428,824). These inter-related patents basically claim novelty for an alcoholic extraction procedure employed in the standardization of a commercial product, claimed to contain novel amides (by the commercial name *macamide*). The patents also seek to protect the concept of the use of this extract for the treatment of sexual dysfunction and cancer. Another less publicized patent is held by Biotics Research Corporation (US patent 6,093,421) and claims novelty for the combined use of maca and antler for augmenting testosterone levels.

News of the patents unleashed a storm of protest in Peru amongst farmers' rights and biodiversity advocacy groups (e.g. press release by ETC Group, 3 July 2002[15]), accusing the companies who had filed the patents of engaging in flagrant biopiracy. Shortly afterward it became apparent that the patents do not result in a monopoly on the growing and marketing of maca, or on the use of maca genetic

[14] PLoS Medicine, DOI: 10.1371/journal.pmed.0040005

[15] http://www.etcgroup.org/en/materials/publications.html?pub_id=194

resources. Nor do the patents preclude the protection and marketing of other extracts, but the outrage over what was perceived as the appropriation of common maca knowledge through patents lingered on and culminated in Del Castillo's paper on maca and biopiracy (Del Castillo 2004). Clearly, Pure World Botanicals Inc. had not shown sensitivity towards the economic needs of indigenous maca farmers, with whom it might have sought an agreement on a profit-sharing mechanism, nor did the company have the vision that a fair profit-sharing agreement might have been a powerful marketing instrument paying handsome dividends.

Public sentiment did not approve of the company's desire to protect what it claimed was a novel extraction method, for which the Peruvian companies claiming to be using it already might have pursued patent protection as well. Moreover, campaigners did not appreciate that regulators will not allow the use of indigenous knowledge in product advertisements and labelling unless there is scientific evidence backing it up. Thus, companies investing in the scientific substantiation of indigenous knowledge face difficult trade-offs between the need for product protection and the reputational risks of biopiracy accusations. As a matter of fact private investors can make an important contribution (for admittedly selfish reasons) to the recognition and economic valuation of indigenous knowledge by providing scientific substantiation, but are forced to protect themselves through patents or other IPR mechanisms against free-riders unwilling, or unable, to make such investments.

In hindsight, the publicity surrounding the patents may actually have promoted maca, and Zheng, Pure World Botanicals' chief scientist, is quoted in a 2007 Associated Press release[16] as saying that his company's research efforts were instrumental in popularizing maca as a world-wide Peruvian export, a claim not easily dismissed in view of the frequent citation of Zheng's research paper (see Section 7.4.1.), also in connection with Internet advertisements of maca

[16] www.washingtonpost.com/wp-dyn/content/article/2007/01/05/AR2007010500807.html

products of the firm's competitors! The same source also quotes Naturex, the company now owning PureWorld patents, as willing to "grant free licenses to Peruvian companies to use MacaPure [the product obtained through the proprietary extraction protocol] in their products".

An INDECOPI-led delegation of Peru-based research institutions, private sector and advocacy groups eventually brought the issue of maca patents to the attention of the World Intellectual Property Organization (WIPO), who published the delegation's position paper in 2003[17]. In it, Peru presents a thorough technical and legal analysis of the maca patents to WIPO's Intergovernmental Committee on Intellectual Property and Genetic Resources, Traditional Knowledge and Folklore. The paper argues that some of the claims by the US patents which they analyzed do not meet the requirement of novelty, particularly regarding the extraction procedure. It notes also that the biological activity of the isolated compounds has not been demonstrated and thus does not appear to meet the requirement of industrial applicability, putting the patents in doubt from a legal point of view.

In the paper the authors lament that, while there is a great deal of literature and information on maca, access to this information is difficult. This would explain why patent offices from third countries generally fail to revise documents and literature which could refer to ancestral uses of agrobiodiversity by indigenous peoples or to indigenous knowledge. The authors conclude that these difficulties constrain rigorous and comprehensive examinations of patent applications, giving rise to the granting of rights of doubtful legitimacy.

The report also points out the need for documenting indigenous knowledge in a national database accessible to the main patent offices in order to conduct searches and examinations of the data. It also proposes that Peru should be more proactive about research

[17] www.wipo.int/documents/en/meetings/2003/igc/pdf/grtkf_ic_5_13.pdf

into and development of plant and other biological materials and seek benefits from these products but notes that Peru still requires a national legal regime to generate incentives for cooperation in research and development.

Finally, the paper observes the “enormous difficulties” encountered by Peru when challenging or questioning the United States or European patents of this nature, in particular the prohibitive costs and need for specialized advice. Indeed, no information on action by the Peruvian Government following up on the complaint to WIPO is available to us.

8 Impact of the expansion of maca production

Our assessment of the impact that the expansion of maca production and trade has had on rural welfare, the environment and maca diversity on farm is entirely based on circumstantial and anecdotal evidence. We are unaware of much quantitative data in this connection.

8.1 Impact on rural welfare

Castillo (personal communication, 1996) mentions that half the total area cultivated with maca is produced by small-scale farmers (1–3 ha of maca). To date, maca remains an important crop for Junin, because the roots can be stored and sold for cash, providing more income security to farm households, which, in fact, have very few income options.

With farm-gate prices over 3 Soles (ca. one US$) per kilogramme of dehydrated maca roots for several years (Fig. 17), and conservatively estimating average dry matter yields of one tonne per hectare, the revenue from a two-hectare field of maca (typical of a smallholding), is likely to have exceeded US$2000 in most years. This is by far more than farmers could expect from any other agricultural activity under the harsh conditions of the Puna, and significant income effects must have occurred as a consequence of the growing demand for maca. In Huancayo (Yanahuanca), some farmers created considerable wealth in the late 1990s when maca prices soared, and a large part of the proceeds were used to buy houses, trucks, and to pay for school fees (Martin Lara, unpublished rural survey, 2003). Farmers chosing to re-invest profits in the expansion of cultivation were badly hit at the turn of the century as described in Section 6.3.

In her survey in Pasco, Locher (2006) confirmed that maca growing had become a source of self-employment and income for the rural poor. Half of the farmers had only started growing maca during the Fujimori administration (1990–2000) and said they no longer needed

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to work in mines due to the alternative income generation option of maca cultivation.

Especially in Junin, the expansion of maca production has triggered the development of a number of small-scale businesses related to maca processing and commercialization, some of which are benefiting from the strategic location on the road connecting Lima with the tropical lowlands. This has allowed farmers to set up family businesses allowing them to diversify activities, and thus lowering income risks. At the same time, important new skills have been gained along maca supply chains, related to product development and marketing. Those skills have raised the competitiveness and the attractiveness of Junin as a market place in general.

One important effect on rural welfare is the self esteem of the native population. In contrast to the past, rural producers take pride in all the external interest in maca.

8.2 Impact on on-farm diversity of maca

There is no meaningful baseline data on the genetic diversity of maca at the beginning of the crop's renaissance over one and a half decades ago, or in the current situation, and it is therefore impossible to determine how the expansion of maca production has affected the on-farm diversity of the crop. In each growing season many maca seed lots are being moved across the crop's geographical range through informal seed supply systems, and no pressures favouring particular morpho- or chemotypes have become evident. Moreover, local traders may blend produce from different locations and years of production.

Companies recognize the need for raw material standardization and uniformity (Locher 2006, Li et al. 2001), and breeding work at the Universidad Nacional Daniel Alcides Carrion in Cerro de Pasco is aiming at producing varieties of maca with higher yields and a less variable chemical composition, but no formally released and uniform seeds have become available. Thus, there is currently no replacement of farmer seed with 'improved varieties'.

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9 Conclusions

Although the case of maca described here is unique, some general conclusions for the market development of minor or neglected and underutilized species (NUS) can be drawn.

As for many NUS, the market development for maca has in the past been constrained by a lack of demand, rather than by supply limitations. In the case of maca, the major demand constraint is the low acceptability of the product's flavour. In addition, maca's restricted geographic distribution made it 'invisible' to most consumers and resulted in a lack of familiarity even among most Peruvians with the product and its uses. These demand constraints were overcome by the promotion of maca and, more importantly, by the development and diversification of convenience products that mask the maca taste and make them suitable for urban and export markets. The discussion surrounding market prospects of NUS typically concentrates on their value attributes and how these can be used in promotion, when indeed the identification of crop (=supply) or demand constraints would be equally rewarding.

The maca case shows that the identification of a key product attribute (effectiveness as a libido stimulant) and the focused and sustained communication of that attribute, despite a lack of scientific substantiation, has allowed a strong positioning of the product on the market and in the minds of consumers. Similarly, the effective marketing of a single important attribute, namely the nutritionally relevant content of oligofructose, also propelled yacon (*Smallanthus sonchifolius* (Poepp. & Endl.) H. Robinson), another Peruvian root crop, from obscurity to hugely expanded use, in even fewer years than maca. These experiences suggest that the often blurred and unfocused messages to consumers associated with the 'multipurpose functions' of some NUS are much less effective for the positioning of a 'new' crop.

The re-appraisal of maca was initially a domestic Peruvian development, however quickly growing interest from export markets and related Internet promotion provided important feedback to domestic market

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development in terms of increased consumer awareness and maca demand in Peru, greater entrepreneurial interest, incipient policy making in support of native agrobiodiversity and investment in the substantiation of economic product value attributes. While the prospects of greater opportunities in export markets as opposed to national or regional markets prompted many supply chain actors to invest in maca production and marketing, they underestimated the need for a coherent marketing approach, and for responsible product claims. Maca's success in export markets has been astonishing, but growth has been curtailed by the inability of maca marketers to effectively deal with market access barriers such as European food safety legislation.

When underutilized crops are promoted, strong price fluctuations must be anticipated. Growing consumer demand for a crop with marginal production will quickly outstrip supply and this will raise producer prices. Small-scale farmers face constraints (e.g., lack of seed, access to land and labour) that cannot be overcome in the short term and they cannot therefore keep up with the growth of demand. The case of maca shows that the resulting high farm-gate prices provide strong incentives for farmers to further invest in the crop, but that also non-governmental and governmental institutions tend to jump on the bandwagon of a newly expanding crop.

Eventually, however, high prices will lure farmers into over-production and the inevitable price collapse comes at considerable social costs for rural areas. Therefore, strategic alliances between producers, processors, and traders in a given supply chain are crucial. Yet, in practice, such strategic alliances between farmer groups and enterprises are difficult to build in boom-and-bust cycles, because initial high farm-gate prices provide no incentive for farmer collective action. Farmers tend rather to negotiate independently with the many clients eager to buy their produce. Consequently, they will not be prepared to react in an organized manner once prices crash, and companies begin to set the price and purchasing conditions.

In the case of maca, indigenous knowledge associated with the crop's use provided an important pointer for product and market

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development. The sensationalist and irresponsible use of indigenous knowledge in the Internet paid quick dividends for some companies, but it eventually brought maca into ill repute, particularly in the EU, where regulators have banned maca from the market because of food safety concerns.

Unfortunately, indigenous knowledge is not recognized in the documentation of food safety, health and nutrition claims. Regulators will allow its use in product claims, say for pharmacological effects or nutritional properties, only if it has been substantiated by scientific methods. Substantiation is cumbersome and expensive, and companies engaging in it understandably seek intellectual property protection (e.g., through patents) against competitors for their investment, a legitimate need they need to balance with reputational risks arising from biopiracy accusations.

A widely-held opinion in Peru about the US patents filed for maca is that these do not meet the requirements of novelty and industrial applicability, and that the patent offices examining the applications had insufficient access to the documentation of traditional uses of native biodiversity. This suggests that coordinated efforts to systematize information on NUS are necessary, e.g. on traditional intake levels, processing methods, anecdotal information on food hazards. Such information should ideally be available from public databases and authoritative crop and product monographs. Defensive publishing could also be a means to protect traditional knowledge. Defensive publishing could also be used to suggest product concepts not substantiated by experimental data, in order to prevent companies from staking out claims.

The state and public sector have important roles to play to support NUS supply chains through regulatory frameworks and research unaffected by particular private sector interests. The design of policies in Peru in support of maca supply chains has in general been poorly informed and implemented. However, the recent public sector initiatives to support maca product norms, and to challenge the maca patents granted in the US, are an encouraging sign of future

developments. Much more needs to be done by the public sector in order to ensure an enabling environment for the market development of NUS, such as geographic indication protection, and more peer-reviewed research on NUS.

Government agencies and R&D institutions also play a key role in helping build strategic alliances between farmers and commercial companies by providing information on prices, diseases, technologies and potential markets and by providing contacts to research and credit institutions, certifying companies and so on. Government agencies might also stimulate rural development through local capacity building that enhances farmers' organizations and local processing.

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ANNEX

Bibliography on maca available at CIP

The following is an exhaustive list of bibliographic references on maca, including URL addresses for electronic versions, as recorded at the library of the International Potato Center (CIP), Lima, Peru, as of March 2007 (Courtesy Cecilia Ferreyra, CIP). Literature listed in the section "References" has been excluded here.

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