STUDIES ON THE CULTIVATION AND USES OF EVENING PRIMROSE (*OENOTHERA* SPP.) IN CHINA[1]

YU-CHENG DENG, HUI-MING HUA, JUN LI, AND PETER LAPINSKAS

Yu-Cheng Deng, Hui-Ming Hua, Jun Li *(Department of Plant Resources & Phytochemistry, Institute of Applied Ecology, Academia Sinica, PO Box 417, Shenyang 110015, Peoples Republic of China), and* **Peter Lapinskas** *(26 Deepdene Wood, Dorking, Surrey, RH5 4BQ, England; email Peter@Lapinskas.com; website www.Lapinskas.com).* STUDIES ON THE CULTIVATION AND USES OF EVENING PRIMROSE (*OENOTHERA* SPP.) IN CHINA. *Economic Botany 55(1): 83–92, 2001.* *Evening primrose originated in North America and became naturalized in the north-east of China about one hundred years ago, where it has been used as famine food and animal feed. New uses for the seed oil, which contains γ-linolenic acid (GLA), that have been developed in China and overseas since 1980 have created a much larger commercial demand for the seed. There are eight species of* Oenothera *L. growing wild in China, of which* Oenothera biennis *L. is preferred. The maximum annual production of wild evening primrose seed is estimated to be about 3000 tons but, since 1986, evening primrose has also been cultivated for its seed and oil using* O. biennis *(primarily in the provinces of Jilin, Liaoning, Hebei, and Shandong) to meet the increasing demand. New production techniques have been developed and disseminated, and reported seed yields range from 750 to 3000 kg ha^{-1}. Commercial production follows a cyclical pattern, with the largest harvest to date, in 1999, estimated at 16 000–19 000 tons of seed.*

During 20 years of research on a wide range of wild oilseed plants, Chinese scientists found that evening primrose oil was antiatherosclerotic, lowered hyperlipidemia and was antithrombotic. The oil was developed and licensed as a drug (which required work on processing technology, physicochemical characteristics, pharmacology, formulation, and clinical studies) and it has since been widely used in clinical practice. Further research work has been done on other bioactive properties of evening primrose oil, alternative sources of GLA, the concentration of GLA, the synthesis of prostaglandin E_1, and the development of health care drugs and cosmetics containing evening primrose oil. We believe that the prospects for the future development of evening primrose are good.

月见草（*Oenothera biennis* L.）原产北美，百年前传入中国东北。民间用作野菜、饲料等。八十年代，月见草油（富含 GLC）在国内外被开发为药用，其需求量猛增。月见草属植物中国有 8 种。野生月见草籽最高年产量为 3000 吨。1986 年以来，吉林、辽宁、河北、山东等省开展了月见草的栽培与培育工作，积累了高产经验，每公顷产籽 750-3000Kg。月见草籽的产量形成了周期性模式，高峰期为 1999 年，年产约 16-19,000 吨。中国科学家通过 20 年的野生油脂植物的研究，首次完成了月见草油作为抗动脉粥样硬化、降高血脂和抗血栓的药物研究与开发（包括月见草油的制备工艺、理化性质、药理、制剂和临床研究），该药广泛用于临床。此外，还开展了月见草油的其它生物活性、含 GLC 的新植物资源、GLC 的富集、PGE_1 的合成等研究，并开发了多种保健品和化妆品。我们相信月见草的应用前景十分广阔。

Key Words: evening primrose; *Oenothera* spp.; cultivation; oil; GLA; medicine; hyperlipidemia; China.

[1] Received 2 April 1999; accepted 14 July 2000.

Origin and Distribution in China

Oenothera biennis L. originated in North America and was introduced into China as a garden flower and as a weed before 1900, with the development of civilization and communications with Western countries. It then become naturalized in the eastern mountain areas of three provinces (Heilongjiang, Jilin, and Liaoning) of north-east China and Shandong province. It grows on the plains, lower mountains and hilly areas at an elevation of 50–300 m; on grassland, southern mountain slopes and wastelands; on the margins of fields, roads, and forests; and in sparse woods. It grows best and can turn into the dominant species on sunny fields and fertile, damp soil (Deng, Gao, and Li 1982; Deng, Hua, and Duan 1993; Li et al. 1994; Liu 1977; Zhu, Wu, and Li 1989), but it will also grow on slightly saline or alkaline soil.

There are at least eight species belonging to the genus of *Oenothera* L. that grow wild in China (Anonymous 1992a,b; Deng 1988; Deng, Gao, and Li 1982; Deng, Hua, and Duan 1993; Duan 1990; Li et al. 1994; Liu 1977; Liu, Wang, and Shan 1983; Zhu, Wu, and Li 1989). *O. biennis* is the dominant species and it is highly variable, both in terms of subspecies and races. Other species found in the wild include *O. glazioviana* Micheli (syn. *O. erythrosepala* Borb. and *O. lamarckiana* de Vries), *O. odorata* Jacq., *O. Oakesiana* Gray, *O. parviflora* L., *O. rosea* Ait., *O. stricta* Ledeb. and *O. villosa* Thunb.

At present, the species *O. biennis* is primarily used commercially. The seed oil contains an essential fatty acid, γ-linolenic acid (GLA) that is not found in the normal diet, yet it is an essential intermediate in human metabolism. The oil is therefore extracted from the seed to make medicine, nutrients, and health products in China and its seeds and oil are exported for use in pharmaceutical and health-food products overseas.

Early Uses

O. biennis was introduced into China about a century ago. From then on, in famine years, local farmers living in the eastern mountain areas of the three provinces in North-East China gathered the tender roots and leaves of *O. biennis* as an edible wild vegetable, crushed its seeds with a stone roller and baked cakes (with wheat flour added), or squeezed oil from the seeds for use as a salad oil or drying oil (Anonymous 1960; Deng, Gao, and Li 1982; Zhu, Wu, and Li 1989). The decoction of its roots simmered in water has been used as a folk oral remedy for the common cold and for laryngitis (Anonymous 1992a,b). Some local farmers used the whole plants as pig feed, and the seeds as bird and poultry feed. Some primary school students even gathered the seeds to exchange for pencils and paper.

In addition, an infusion of the roots of *O. glazioviana* soaked in wine has been used as an oral folk remedy for rheumatism and bone and muscle aches (Anonymous 1992a,b).

However, over the last 20 years, evening primrose seeds have been produced on a much larger scale. Now they are mainly purchased by the rural native product corporations for export, and by local pharmaceutical and oil processing factories.

Commercial Production in China

China is now the major producer of evening primrose seed in the world, with an estimated 90% of total supply, which it has been able to achieve through the combination of low-cost hand labor, and growing conditions that are ideally suited to the crop. Commercial production began with seed harvested from the wild (primarily *O. biennis*) for export as "wild sesame" in the 1970s (Fedeli, Paganuzzi, and Tiscornia 1976), with the first shipments for health-food use leaving in 1980. The maximum annual production level for wild seed, of about 3000 tons, was reached in 1985, so cultivation as a crop (using wild-collected seed) began in 1986 to meet the escalating demand that resulted from the launch of a Chinese medicine for lowering hyperlipidemia and the continuing growth of demand in export markets where the oil was sold as a health-food supplement. For example, by 1988, in Yanbian area of Jilin Province, it was planted on about 2000 ha., and the output of seeds was about 2000 tons. Although global demand for the oil has been reasonably consistent, and growing since 1985, the supply (and hence the price) has fluctuated dramatically. This is primarily because, although there is some contracted production, there are also a large number of speculative crops sown by individual small farmers. Because they have no knowledge of the world market situation, they tend to base their planting decision on the price obtained for the previous year's harvest. Thus, when seed is short

and prices high, too many farmers sow the crop, driving the market into surplus the following year, forcing down prices to uneconomic levels. As a result, most of them drop out, leading to a shortage the year after, and the cycle begins again. In fact, because of the possibility of biennial crops, and various market factors, the peak-to-peak cycle time seems to be about five to seven years. Thus there were market surpluses from the harvests in 1986, 1991, 1992, and 1999, and corresponding shortfalls in between.

In terms of volume, in the production peak of 1992, in Liaoning and Jilin provinces, the output of seeds was about 10 000 tons (Wu et al. 1994), and in Shandong Province, evening primroses were planted on 430 ha. from which 500 tons of seeds were produced (Li et al. 1994), yet the export market was estimated to require only around 2500–5000 tons (J. X. Tang pers. comm.) and the domestic market 800–2400 tons of seed equivalent (assuming an average of 8 tons of seed for 1 ton of oil).

The surplus from the 1999 harvest has been particularly severe as it followed two years of shortage (and hence high prices) because of a large number of climate-induced crop failures. Current export demand is usually estimated to be running at 1000–1200 tons of oil per year (8000–9500 tons seed-equivalent) and the total yield in 1999 is generally estimated to have been double this. (Hard data on yields is not available because of the fragmented and secretive nature of the market.)

Development of Evening Primrose Cultivation in China

The rapid increase in demand for evening primrose seed up to 1986 resulted in severe seed shortages and high market prices which aroused the interest of many institutes and farms who began to research and disseminate the methods of cultivation and breeding of evening primrose.

The following description of the main techniques and points for attention is a summary of the practice in the five provinces of Jilin, Liaoning, Hebei, Shandong, and Jiangsu (located at north latitude between 32° and 45°, and at east longitude between 115° and 130°) (Anonymous 1992c; Deng, Hua, and Duan 1993; Duan 1990; Li et al. 1994; Liu, Wang and Shan 1983; Sun 1990; Wu et al. 1994; Yu 1982; Zhang 1994; Yu and Tian 2000).

Life Cycle

Evening primrose is sown between 15 March and 15 April. Polyethylene sheeting is used in some areas to warm the soil. The seedlings emerge after six to 13 days. In areas of lower temperature, the seeds are sown in a greenhouse, and the resulting seedlings are transplanted. They flower from June to September. The capsules ripen from the middle of August through to the first 10 days of October. The reproductive cycle is about 125 days in Jilin, 150 days in Hebei, 180–200 days in Shandong. The height of the plants normally varies from 1.0 to 1.5 m but can reach 1.75 m. Plants which are sown after the middle of May mostly become rosettes (literal translation "lotus thrones") and neither bolt nor flower during that year. Biennial evening primrose is sown between July and September, is cut down by the frost over winter, and starts to regrow from the root crown in the following March, ripening in September.

Persistence

The evening primrose that has formed the shape of lotus throne (rosette) by autumn can survive through the winter even with temperatures as low as −22°C. It has strong resistance to drought, diseases, and insect pests. On the other hand, wet and hot conditions in the rainy (summer) season, long-term accumulation of water, and overcrowded plants may bring about root rot, leaf blight, and loss of leaves. Sometimes insect pests appear, such as *Agrotis ypsilon, Acherontia lachesis, Cryptothelea pryeri, Ectomyclois ceratoniae* and *Gryllotalpa unispina* (Zhang 1994).

Cultural Technique

The soil is carefully prepared and fertilizer (farmyard manure and/or chemical fertilizer) applied. The row spacing used is in the range 33–60 cm, the drill being irrigated before sowing and the seed covered with soil to the depth of 0.4–0.5 cm, pressed slightly and irrigated again if necessary. The sowing rate used is between 3.0 and 9.5 kg/ha. The average weight of 1000 seeds is 0.373 g (0.236–0.535 g), and the optimum germination percentage is 80–98%. Before sowing, the seeds are normally soaked in water at 40°–50°C for 24–48 hours, or put into oven at 25°C to hasten germination (Li et al. 1994). In North-East China the seed may be vernalized by soaking it in water or mixing it with wet soil

and then burying it in the frozen soil in early spring (Anonymous 1992c; Zhu, Wu, and Li 1989). In some areas, the seed is sown into frozen ground in the Autumn, so that it can become fully vernalized over winter *in situ* to give an early germination and establishment the following spring. The crop is weeded two to four times during the growing season by hand hoeing. The plants are thinned and finally singled two to three times in June to give a density of 75 000 plants per hectare in Shandong (Li et al. 1994), 210 000 in Liaoning (Anonymous 1992c), and 300 000 in Jilin (Wu et al. 1994). Densities which are too high result in over-tall crops with weak stems which are prone to disease and lodging. The fields are irrigated if necessary. The plants are gathered when two-thirds of capsules have become ripe, and stacked in sheaves for threshing. After threshing (by hand, or mechanically using animal drawn sledges or wheeled vehicles) the seed is dried in the sun, and stored in a dry well-ventilated warehouse, free from mice, and sheltered from the sun. The yield of seeds is generally between 1125 and 1530 kg/ha, and in some better situations, may reach 1875 kg/ha in Beijing (Duan 1990) and up to 2700 kg/ha in Jilin (Anonymous 1992c; Wu et al. 1994). In 1992, the yield reached 3000 kg/ha in the experimental fields in Qingyuan County. In 1993, in the experimental field of 0.15 ha in Rizhao City of Shandong Province, an even greater yield, equivalent to 3750 kg/ha of seeds, was recorded (Zhang 1994).

In Shandong Province, evening primrose is either intercropped with peanuts, soybeans, medicinal herbs, or saplings, or grown on sandy wastelands (Li et al. 1994; Zhang 1994).

Experiments on the cultivation of *O. biennis* have also been carried out in Jilin City of Jilin Province and Dongtai City of Jiangsu Province in order to extract a volatile oil and a concentrated solvent-extract (gum) from plant tissues (Li et al. 1994; Sun 1990).

Cultivation of the evening primrose crop not only provides raw material for the medical industry and export trade, but also contributes to a diversified economy in the countryside, the increase of economic income, the conservation of water and soil and the beautification of the environment. In the future, further research is needed for the production of improved varieties with more flowers and a higher yield of seeds (Anonymous 1992c; Duan 1990; Wu et al. 1994; Zhang 1994; Zhao and Wu 1993; Zhao et al. 1994), higher content of seed oil and GLA (the GLA of some varieties has reached 12.0%) (Duan 1990), and a more consistent maturation period. In addition, some research is needed on the photoperiodic response for bolting (Zhao and Wu 1993) and on tissue culture (Gu 1989).

The Physicochemical Constants of Evening Primrose Oil

As an example, the following data were obtained on oil processed from the seeds of wild *O. biennis* collected in Fengcheng County of Liaoning Province. The percentage of oil in the seeds was 26.4%. The oil was deep yellow, with a refractive index (20°C) of 1.4770, specific gravity (20°C) of 0.9310, iodine value of 139.7, saponification value of 188.2, acid value of 2.8, aceto value of 24.9, thiocyanogen value of 83.9, and unsaponifiable matter of 1.1%. The fatty acid composition of the oil (expressed as the percentage of total fatty acids) was reported as 0.8 caprylic acid, 0.4 capric acid, trace lauric acid, 0.4 myristic acid, 6.1 palmitic acid, 1.8 stearic acid, trace arachidic acid, trace behenic acid, 7.7 oleic acid, 73.4 linoleic acid, and 9.2 γ-linolenic acid (Deng 1987, 1988; Zhu et al. 1980).

The oil percentage and the composition of the main fatty acids in seeds of eight species of evening primrose grown in Beijing are shown in Table 1 (Deng 1988; Deng, Hua, and Duan 1993; Duan 1990).

Oil Processing Technology and Quality Standards

There are at least 10 factories producing evening primrose oil from seed in China. In 1986, the oil factory of the Institute of Applied Ecology, Academia Sinica (IAE), formerly known as the Institute of Forestry and Soil Science, Academia Sinica, began to extract the oil with mechanical screw presses using the following process (Deng, Hua, and Duan 1993). The seeds are winnowed to remove foreign substances. The seed skins are softened using steam and the oil extracted without additional heat using a spiral oil press. After filtering, the oil is refined by neutralizing with alkali, deodorizing with steam, and decoloring by charcoal filtration. It is then dried, and filtered again to give the final product. Vitamin E is added to the oil. The oil is poured into drums which are purged with nitrogen,

TABLE 1. THE OIL PERCENTAGE AND THE COMPOSITION OF THE MAIN FATTY ACIDS (% OF TOTAL FATTY ACID METHYL ESTERS) IN SEEDS OF 8 SPECIES OF EVENING PRIMROSE GROWN IN BEIJING (DUAN 1990).

Species	Oil and fatty acid (%)					
	Oil percentage in seed	Palmitic acid 16:0	Stearic acid 18:0	Oleic acid 18:1 (9c)	Linoleic acid 18:2 (9c, 12c)	GLA 18:3 (6c, 9c, 12c)
19 samples of *O. biennis* growing wild in Liaoning and Jilin Provinces	19.0–30.1	5.0–6.7	1.1–2.9	4.7–10.7	73.5–81.9	6.8–9.4
O. biennis	24.7	5.97	1.52	11.16	73.13	8.20
O. erythrosepala	17.4	7.45	1.64	6.58	75.48	8.85
O. glazioviana	19.9	5.31	1.36	12.93	73.19	7.18
O. lamarckiana	7.0	7.89	1.62	5.94	75.26	9.32
O. odorata	24.4	10.76	2.42	6.46	76.93	3.30
O. parviflora	26.6	4.79	3.06	13.54	67.92	10.15
O. rosea	13.4	8.97	1.58	6.33	83.11	trace
O. villosa	23.9	6.21	1.90	6.82	76.03	9.02

sealed, and stored under refrigeration. In China, oil is also extracted by means of solvent (normally hexane) and, to a small extent, with supercritical CO_2 (Yu et al. 1992).

The refined evening primrose oil produced by IAE is pale yellow and transparent, with a moisture content of less than 0.2%. Its specific gravity (25°C) is 0.915–0.935. The acid value is typically 0.3 mg KOH per gram of oil (the standard set by the Chinese pharmaceutical administration is below 2.5), the peroxide value is 0.03% (the standard is below 0.15%). The GLA percentage averages 9.1% (the standard is above 7.0%). There are no organic solvent residues, arsenic, cadmium, lead, mercury, or residues of agricultural insecticides. The content of GLA is determined with gas chromatography (Anonymous 1987; Deng, Hua, and Duan 1993). Product specifications for the content of GLA vary between suppliers; 10%, 9–10%, and 8–9% are all quoted.

Over the last five years, several joint ventures with experienced foreign partners have been established in China for the local extraction and processing of evening primrose oil. It is likely that this injection of capital and expertise will further improve the quality of the oil.

EVENING PRIMROSE OIL AS A MEDICINE

Evening primrose seed oil has been widely studied in the West since the 1970s as a potential treatment for a large number of medical conditions, including eczema, mastalgia, diabetic neuropathy, cancer, multiple sclerosis, rheumatoid arthritis, and elevated blood cholesterol levels. Pharmaceutical licenses for products containing evening primrose oil for the treatment of eczema and mastalgia have been granted in the United Kingdom and several other countries. The work performed in the West is well known and has been substantially reviewed elsewhere (Horrobin 1990a,b, 1992, 1994, and 2000; Huang and Mills 1996; Fan and Chapkin 1998).

The work performed in China during this period is, however, less well known in the West, as it has been largely published in Mandarin. In fact, thorough studies on evening primrose oil and GLA started independently in China in 1980. Researchers in the Department of Phytochemistry of the IAE began a study into the oil chemistry and possible applications of wild oil plants in 1962 (Deng 1982, 1987, 1988; Li et al.

1983; Zhu et al. 1980). After completing the determination of fatty acids in the seed oils of 350 plant species, they engaged mainly in research on the wild plant *O. biennis,* from 1981 to 1985. The areas covered included: its availability as a raw material (Deng, Gao, and Li 1982; Deng, Hua, and Duan 1993; Liu 1977; Zhu, Wu, and Li 1989); pharmacognosy studies (Gao, Xu, and Deng 1983); the separation and identification of γ-linolenic acid (Gao et al. 1982); the determination of fatty acids of seed oil from different species and areas; the technology of extracting, processing and refining the oil (Deng, Hua, and Duan 1993); the formulation of a quality standard and tests of stability for the oil (Deng, Hua, and Duan 1993; Wang, Zhu, and Li 1989; Zhu and Li 1988); studies on the formulation as a drug; the pharmacodynamics of the oil (including its action in atherosclerosis; lowering triglyceride, cholesterol, and β-lipoprotein; and reducing liver lipoidosis) (Wang and Xu 1984); toxicity testing (acute and subacute tests); mutagenicity (tests of accumulative toxicity, Ames, marrow cellular, and micronuclei); and teratological effects (test of sperm malformation) (Deng 1988; Deng, Hua, and Duan 1993).

Preliminary clinical observations began in 1982 on 88 patients with hyperlipidemia. From 1984 to 1985, the formal clinical observation of 425 cases of this disease were carried out in the Shenyang Military Region General Hospital of the Peoples Liberation Army (Tong, Jiang, and Zhou 1988), Liaoning Province Hospital, Beijing Tiantan Hospital, the First Subsidiary Hospital of Beijing Medical University, and Beijing Friendship Hospital (Deng 1988). Patients were selected for the study on the basis of having two or more of the following blood indices above normal levels: cholesterol, triglyceride, low-density lipoprotein, and high-density lipoprotein. All patients had blood cholesterol levels greater than 5.2 μmol/l. The patients were randomized to the active and placebo groups The active group of 350 patients took soft gelatin capsules containing four grams of evening primrose oil daily, the control group of 75 patients took 200 mg of vitamin E daily, both for 90 days. The parameters were measured at the end of the treatment phase and again 30 days later. Patients in the active group were aware that they were taking the experimental substance. There was no change in the diet or exercise treatment for either group. The results are shown in Table 2. In addition, 57% of the subjects on the active treatment lost 2–8 kg in body weight with no signs that this might be attributable to toxicity; there was no overall weight loss in the placebo group.

In the spring of 1986, this drug (Capsulae Oenotherae Biennis Olei, Soft Capsules of Evening Primrose Oil) was appraised and approved by the Western Medicine Branch of Liaoning Province Drug Evaluation Committee as a new medicine (Category 2). The quality standards of the medicine and the corresponding oil have been adopted by the medicine administration departments in other areas of China. The research project on this drug was awarded the second prize of Liaoning Province Science and Technology Advancement in 1988. More than 20 factories have put it into production including at least nine registered pharmaceutical factories (Deng 1988; Deng and Wei 1986; Ma 1985). They mainly use the Type II soft-capsule-making machines by the Spaceflight Ministry of China. The IAE oil factory has generated substantial funds for research work through the manufacturing and sale of the oil. They also sell an enriched evening primrose oil with 25% GLA. At present, the Department of Phytochemistry is engaging in research on soft capsules of evening primrose oil (Hua et al. 1994) in combination with other compounds.

The research workers of Bethune University of Medical Sciences in Changchun City also worked on research into the use of GLA in evening primrose oil as a medicine (γ-Evening Primrose-E Soft Capsule) from 1984 to 1985. Their work included biochemical experiments on the inhibition of aggregation of platelets and the synthesis of TXA_2 by platelets (Fu, Wu, and Gu 1987). The clinical observation of 228 cases in which each subject took 1.2–2.7 g of oil daily was carried out. The drug was approved in Jilin in 1985 and put on the market. This project won second prize for Science and Technological Advancement from the Chinese Ministry of Public Health in 1987. There were therefore two independently developed licensed drugs using evening primrose oil available in China by 1986, although it was not until 1988 that an equivalent product (Epogam®, developed by Scotia Pharmaceuticals Ltd. for the treatment of eczema) was licensed in a Western country. Since 1989, the Shenyang College of Pharmacy together with others, has developed an oil emulsion product (Yao and Ren 1987; Yu et al. 1986). This

TABLE 2. THE EFFECT OF EVENING PRIMROSE OIL ON HYPERLIPIDAEMIA. THE FIGURES IN THE PLACEBO AND ACTIVE COLUMNS REFER TO THE PERCENTAGE OF PATIENTS FOR WHOM THE IMPROVEMENT IN THE MEASURED PARAMETER HAS EXCEEDED THE LEVEL GIVEN IN THE CRITERIA COLUMN. T REPRESENTS THE TIME (90 DAYS) AT WHICH TREATMENT WAS STOPPED (DENG 1988).

	Time of measurement	Criteria	Placebo (Vitamin E) (n = 75)	Active (EPO) (n = 350)	Probability (χ^2)
Serum cholesterol (reduce)	T	≥10%	39.8%	68.2%	<0.001
	T + 30 days		35.7%	63.8%	<0.001
Serum triglycerides (reduce)	T	≥15%	17.9%	64.5%	<0.001
	T + 30 days		40.8%	81.5%	<0.001
Low density lipoprotein (reduce)	T	≥10%	31.4%	58.4%	<0.001
	T + 30 days		33.3%	64.8%	<0.001
High density lipoprotein (raise)	T	≥10%	50.0%	63.5%	N.S.
	T + 30 days		75.0%	74.5%	N.S.

was introduced as a medicinal product (Evening Primrose Oil Emulsion) in 1991 in Chongqing City of Sichuan Province, and increased the range of indications to include diabetes and premenstrual syndrome.

GLA in evening primrose oil has also been studied in treating inflammatory diseases (Sun et al. 1986), lowering blood lipids (Guo et al. 1987; Shi, Liu, and Shi 1990), reducing body weight in obesity (Du and Wang 1988), and treating nephrosis (Liu 1994).

OTHER RESEARCH AND APPLICATIONS RELATING TO EVENING PRIMROSE OIL IN CHINA

ALTERNATIVE SOURCES OF GLA

There are about 10 families of higher plants containing GLA of which Onagraceae, Boraginaceae, and Saxifragaceae have some potential for use. The oil containing GLA from the seeds of *Ribes* sp. is used as health-care medicine in Harbin City and Changchun City. The researchers of Plant Resource Department of IAE studied the relationship between GLA in 13 species plants of currants (*Ribes*) and their plant taxa. The Tree Physiology Department of IAE investigated the cultivation of borage (*Borago officinalis* L.) which yielded about 375 kg/ha of seed containing 34% oil, of which 22% (expressed as a proportion of total fatty acids) was GLA.

GLA also exists in some species of alga, fungus, bryophytes, and pteridophytes. In 1987, the Shanghai Institute of Industrial Microbiology acquired a strain of *Mucorales* which contains 7–9% GLA (Lin and Zhang 1994). In 1989, the Microbiology Department of IAE screened the C8761 and T8765 strains containing 12–18% and 22–24% GLA, respectively (Zhao et al. 1991).

CONCENTRATION OF GLA

Workers at the Beijing Teachers University extracted the principal GLA-containing triglyceride (containing one-third GLA) from evening primrose oil to produce a 90.9% pure triglyceride oil by freeze crystallization. The concentration of GLA was thereby raised by a factor of four- to five-fold (Xiao and Yan 1986). GLA contents of up to 80% were achieved in a hydrolyzed mixture of free fatty acids by one inclusion of the urea adduct method (Song and Hong 1988). GLA methyl esters can be further

purified up to 98% by $AgNO_3$ column chromatography (Song and Hong 1990).

Semisynthesis of PGE_1

In 1982, the Phytochemistry Department of IAE proposed that PGE_1 could be prepared from the substrate gamma-linolenic acid in evening primrose seed oil through dihomo-gamma-linolenic acid with sheep seminal vesicle enzyme (Liu, Zhu, and Cai 1975; Struijk et al. 1966). This research was carried out together with Shenyang Pharmaceutical University (SPU), and Bethune University of Medical Sciences in 1983 (Chen, Hong, and Gao 1986; Deng 1988; Gu et al 1985). The pharmaceutical factory of SPU has put the method into production in small batches.

Commercial Development of Evening Primrose Oil Products in China

There are at least 10 different types of products in which evening primrose oil is the main component that are sold in China, in the nutritional, medical, anti-obesity, and cosmetic markets. Products containing evening primrose oil have been licensed for sale for medicinal purposes in the following regions: Hebei, Jiangsu, Zhejiang, Fujian, Guangxi, Jiangxi, Hubei, Guizhou, Sichuan, Xinjiang, and Inner Mongolia. The products are made in pharmaceutical factories, institutes, or pharmaceutical colleges in a range of locations, including Changchun, Shenyang, Beijing, and Shanghai City. Other components which are added to the evening primrose oil include soybean phospholipids, flavonoids, vitamins, trace elements, and amino acids. The seed oil of *Perilla frutescens* (L.) Britt. is also used as main component of combination health products. This oil contains 51.1–63.8% of alpha-linolenic acid which belongs to ω-3 family of fatty acids (Deng 1987). Some products include fish oil containing EPA (eicosapentaenoic acid) and DHA (docosahexaenoic acid) (Deng, Hua, and Li 1998; Wang 1995). These products can take many forms, including capsules, emulsions, poultices, and creams.

Conclusion

We believe that evening primrose oil and GLA have an important role to play in human nutrition, health care, and cosmetics, and especially in relation to a variety of common diseases, which are otherwise difficult and complicated to treat. In addition, commercial development in this area could lead to important social and economic benefits, so we hope that this work will be continued both in China and overseas (Deng, Hua, and Li 1995; Deng et al. 1998; Horrobin 1995; Wang 1995; Zhang and Xiao 1997).

Literature Cited

Anonymous. 1960. *Oenothera biennis* L. Pages 24, 115, and 443 *in* Economic flora of Liaoning Province, Liaoning Press, Shenyang.

———. 1987. Oenotherae Biennis Oleae. Pages 371–372 *in* Medicine standard of Liaoning Province. Liaoning Science Press, Shenyang.

———. 1992a. *Oenothera erythrosepala* Borb. Page 477 *in* A great dictionary of traditional Chinese medicine. Shanghai Science and Technology Press, Shanghai.

———. 1992b. *Oenothera biennis* L. Page 1697 *in* A great dictionary of traditional Chinese medicine. Shanghai Science and Technology Press, Shanghai.

———. 1992c. The main cultivation techniques of evening primrose. Leaflet published by Science and Technology Committee of Qingyuan County, Liaoning Province, 7 February.

Chen, G. W., Y. Hong, and Y. Q. Gao. 1986. The synthesis of a PGE_1 precursor: all cis-8,11,14-eicosatrienoic acid. Journal of the Shenyang College of Pharmacy 3(1):47–50.

Deng, Y. C. 1982. Discussion on a survey of the resources and application of oil plants in North-East China. Natural Resources Research 1:41–47.

———. 1987. Evening primrose (*Oenothera biennis* L.). Pages 25, 27, and 410–411 *in* L. Z. Jia, and J. Zhou, eds., The oil plants of China. Science Press, Beijing.

———. 1988. Studies on evening primrose (*Oenothera biennis* L.) oil as a treatment for hyperlipidaemia. Natural Resources Research 1:71–73.

———, **Y. Q. Gao, and X. B. Li.** 1982. Wild evening primrose (*Oenothera biennis* L.) in North-East China will be a new medicinal plant worthy of attention. Natural Resources Research 4:34–37.

———, **H. M. Hua, and J. X. Duan.** 1993. Evening primrose (*Oenothera biennis* L.). Pages 317–324 *in* R.H. Zhou, ed. Resource science of Chinese medicinal materials. Chinese Medicinal Science and Technology Press, Beijing.

———,———, **and J. Li.** 1995. The researches and applications of evening primrose in China. Pages 27–28 *in* Abstracts, National Symposium on Plant Resources and Phytochemistry, Hongzhou, China, October 1995.

———,———, **and** ———. 1998. Inquiry into the function and utilisation of essential fatty acids of the n-6 and n-3 series. Pages 539–540 *in* Proceedings of the 65th Anniversary Meeting of the Bo-

tanical Society of China, Chinese Forestry Press, Beijing.

———, **and Y. C. Wei.** 1986. Evening primrose oil soft capsules are put onto the market. Chinese Science News, Beijing, 13 September.

Du, X. Y., and Y. M. Wang. 1988. Effects of evening primrose oil on monosodium glutamate induced obese rats. Pharmacology and Clinics of Chinese Materia Medica 4(2):9–13.

Duan, J. X. 1990. Introduction and cultivation of *Oenothera.* Plant Introduction and Acclimatization 7: 79–89.

Fan, Y. Y., and R. S. Chapkin. 1998. Importance of dietary gamma-linolenic acid in human health and nutrition. Journal of Nutrition 128(9):1411–1414.

Fedeli, E., V. Paganuzzi, and E. Tiscornia. 1976. Chemical composition of Chinese oenotera (*Oenothera biennis* L.) oil. La Rivista Italiana delle Sostanze Grasse 53(2):25–32.

Fu, F. H., D. Y. Wu, and Y. Q. Gu. 1987. Inhibitory effect of evening primrose oil and dihomo-γ-linolenic acid on platelet aggregation and thromboxane A_2 biosynthesis. Journal of the Norman Bethune University of Medical Sciences 13(1):1–5.

Gao, Y. Q., X. B. Li, L. S. Hu, and T. R. Zhu. 1982. Studies on the active principles of evening primrose (*Oenothera biennis*)—I. Isolation and identification of γ-linolenic acid. Chinese Traditional and Herbal Drugs 13(9):1–2, 12.

———, **C. Q. Xu, and Y. C. Deng.** 1983. Pharmacognosy studies on evening primrose (*Oenothera biennis*). Chinese Traditional and Herbal Drugs 14(10):34–36.

Gu, H. F. 1989. Preliminary studies on tissue culture of evening primrose and two medicinal plants. Chinese Medicinal Materials 1:15.

Gu, Y. Q., X. H. Yang, G. R. Chen, R. Zhao, H. L. Yang, and R. J. Fan. 1985. Biosynthetic preparation of prostaglandin E_1 from seed oil of the evening primrose. Journal of the Norman Bethune University of Medical Sciences 1:5–8.

Guo, S. Z., Y. Wei, M. S. Gu, and H. Xu. 1987. Biological activity of evening primrose oil and safflower oil in China. Modern Applied Medicine 10:8.

Horrobin, D. F. 1990a. Gamma linolenic acid. Reviews in Contemporary Pharmacotherapy 1(1):1–45.

———, ed. 1990b. Omega-6 essential fatty acids: pathophysiology and roles in clinical medicine. Alan R. Liss Inc., New York.

———, ed. 1992. Treatment of diabetic neuropathy: a new approach. Churchill Livingstone, Edinburgh.

———, ed. 1994. New approaches to cancer treatment: unsaturated lipids and photodynamic therapy. Churchill Communications Europe, Edinburgh.

———. 1995. Medical roles of metabolites of precursor EFA. Inform 6(4):428–435.

———. 2000. Essential fatty acid metabolism and its modification in atopic eczema. American Journal of Clinical Nutrition 71(1 Supplement):367S–372S.

Hua, H. M., J. Li, B. Z. Yang, and Y. C. Deng. 1994. Research and advances in the application of evening primrose oil. Page 57 *in* Report of the Foundation Meeting of the Committee for Young Academic Exchanges, Chinese Nutrition Society and First Young Nutritionalists Symposium, Lanzhou, China, October 1994.

Huang Y.-S., and D. E. Mills. 1996. γ-Linolenic acid metabolism and its roles in nutrition and medicine. AOCS Press, Champaign, Illinois.

Li, B. H., S. J. Xing, H. F. Shang, P. C. Sun, and Y. Q. Qin. 1994. Evening primrose. Pages 106–137 *in* Plants of Wasteland Reclamation in Seaside. Shandong Science and Technology Press, Jinan.

Li, X. B., Y. C. Deng, Y. Guo, and Y. C. Wei. 1983. Studies on plant oils from North-East China—fatty acid composition of seed oil of 157 species. Collected Papers of Institute of Forestry and Soil Science (Academia Sinica) 6:159–168.

Lin, F., and Y. Zhang. 1994. Studies and applications of γ-linolenic acid. Chinese Pharmaceutical Journal 29(5):263–268.

Liu, C. Z. 1994. Effects of evening primrose oil on human renal function—with clinical observation of 8 patients. Chinese Traditional and Herbal Drugs 23(7):346–348.

Liu, S. E. 1977. *Oenothera* L. Pages 155–157 *in* Flora Plantarum Herbacearum Chinae Boreali-Orientalis 6, Science Press, Beijing.

Liu, Y. S., Y. G. Wang, and Y. N. Shan. 1983. New oil crop—evening primrose (*Oenothera lamarckiana*). Chinese Oil Crop 1:5–6.

Liu, Z. Y., L. Z. Zhu, and Z. H Cai. 1975. Pages 33–58 *in* Prostaglandins. Shanghai People's Press, Shanghai.

Ma, C. Y. 1985. A good advance in studies on the evening primrose oil in China. Chinese Science News, Beijing, 29 September.

Shi, K. Q., Z. Z. Liu, and S. H. Shi. 1990. Treatment for hyperlipidaemia with evening primrose oil capsules. New Drug and Clinics 9(1):8.

Song, H. R., and Y. Hong. 1988. Evening primrose oil and gamma-linolenic acid. Journal of the Shenyang College of Pharmacy 5(1):64–68.

———, **and Y. Hong.** 1990. The preparation of pure γ-linolenic acid and its derivatives. Journal of the Shenyang College of Pharmacy 7(3):202–204, 211.

Struijk, C. B., R. K. Beerthuis, H. J. J. Pabon, and D. A. van Dorp. 1966. Specificity in the enzymic conversion of polyunsaturated fatty acids into prostaglandins. Recueil 85:1233–1249.

Sun, X. B., C. C. Zhou, H. B. Gao, Y. C. Deng, and Y. Q. Gao. 1986. Anti-inflammatory effects of evening primrose oil. Chinese Traditional and Herbal Drugs 17(6):39.

Sun, X. Z. 1990. The cultivation techniques for even-

ing primrose in Dongtai City of Jiangsu Province. Information on Traditional Chinese Medicine, 10 March.

Tong, M., L. Jiang, and J. Zhou. 1988. Treatment for hyperlipidaemia with evening primrose oil capsules. Chinese Association of the Integration of Traditional and Western Medicine 8(8):469–471.

Wang, H. D., D. Zhu, and X. B. Li. 1989. Preliminary examination on stability of evening primrose seed oil. Food and Oil 4:45–47.

Wang, Y. M., and C. H. Xu. 1984. Studies on the anti-hyperlipidaemia and anti-atherosclerosis effects of evening primrose oil. Chinese Pharmacology Communication 4(1):100–102.

Wang, Z. 1995. The function of n-3 series unsaturated fatty acids on atherosclerosis. Pages 226–250 *in* W. Z. Chang, X. Cheng, Q. D. Han, and D. F. Su, eds., Advances in cardiovascular disease pharmacology. People's Health Press, Beijing.

Wu, G. L., X. J. Wang, J. Li, and X. S. Wei. 1994. Development and outlook for evening primrose. Agriculture and Technology of Jilin Province 4:19–21.

Xiao, W., and M. H. Yan. 1986. Concentration of active components in evening primrose oil. Chinese Traditional and Herbal Drugs 17(9):16–17.

Yao, C. S., and X. Ren. 1987. Inspection on the stability of the emulsion of evening primrose (*Oenothera*) oil. Chinese Traditional and Herbal Drugs 18(12):11–13.

Yu, D. J. 1982. A new oil crop—evening primrose. Plants 2:28–29.

Yu, E. P., K. Y. Xia, M. W. Shi, R. N. Yan, and Z. R. Fang. 1992. Study on supercritical CO_2 extraction of evening primrose oil. Chinese Traditional and Herbal Drugs 23(7):346–348.

Yu, S. Q., and Y. Q. Tian. 2000. Development of studies on breeding, growth and cultivation of evening primrose in China. Chinese Traditional and Herbal Drugs 31(1):70–72.

Yu, Q. H., Y. Y. Guo, L. B. Zou, and G. E. Gao. 1986. Anti-lipid peroxidation of emulsion of complex *Oenothera biennis* oil. Journal of the Shenyang College of Pharmacy 3(3):178–180.

Zhang, G. L., and Z. C. Xiao. 1997. Plant sources of gamma-linolenic acid, their use and exploitation. Chinese Wild Plant Resources 14(10):5–10.

Zhang, T. Y. 1994. Cultivation techniques for evening primrose. Chinese Forestry 6:10.

Zhao, F. L., and G. L. Wu. 1993. Preliminary study on photoperiodical response of a common evening primrose. Page 337 *in* Reports and Abstracts of the 60th Anniversary (1933–1993) of the Botanical Society of China, Beijing.

Zhao, Z. Y., L. J. Zhou, Q. L. Ma, and L. S. Hu. 1991. Studies on microbiological production of γ-linolenic acid. Journal of Microbiology 11(2):44–46.

———, Y. B. He, Y. B. Feng, Y. G. Hong, and S. H. Liang. 1994. Brief report on the breeding of a new strain of *Oenothera biennis* L. Chinese Wild Plant Resources 2:36.

Zhu, D., and X. B. Li. 1988. Studies on the stability of evening primrose oil in capsules. Food and Oil 3:33–35.

Zhu, T. R., Y. C. Deng, X. B. Li, Y. Guo, Y. C. Wei, and H. D. Wang. 1980. *Oenothera biennis* L. Pages 86–87 *in* North-East Chinese oil plants and analytical method of lipid composition. Liaoning Press, Shenyang.

Zhu, Y. C., D. C. Wu, and J. F. Li. 1989. Evening primrose (*Oenothera biennis* L.). Pages 777–779 *in* Plantae Medicinales Chinae Boreali-Orientalis. Heilongjiang Science and Technology Press, Harbin.