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Wild Yams (*Dioscorea* spp.) - a Potential source for plant based steroid drugs

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ABSTRACT

Wild yams contribute significantly as diets among the hill tribes of Asia and South West Africa. The nutritional compositions are similar to the cultivated yams except presence of high fibre content and acrid principle. In addition, wild yams are a source of steroid drugs. In the present paper, extraction and chemical structure of diosgenin, recent change in diosgenin based steroid industry, new sources of steroid, microbiological production of androstanes and chemical synthesis are discussed in addition to the distribution, botanical description, cultivation and economic uses. Conservation and use of genetic resources of wild yams in a sustainable manner has been emphasized.

Keywords: Wild yams, distribution, description, steroid drugs

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INTRODUCTION

World has witnessed an unprecedented growth of human population in the current century totalling to about 7.17 billion. Excessive population leads to poverty, malnourishment and shortage of basic needs like food, clothes, shelter and a quality of life and environment to live in. Population control and effective family planning seems to be the only alternative. To check faster growing population through avoiding unwanted pregnancy, millions of oral contraceptive pills are consumed every year. The pills are nothing but the steroid hormones. The base material for the steroid hormones is the “Diosgenin” which is extracted from wild yams (*Dioscorea* species). Wild yams make a significant contribution to diets of tribal people and the nutritional composition were similar to the cultivated yams except for the high value of crude fibre² *Dioscorea* is commonly known as yams and are used not only for medicinal properties but also used as the staple food among the hill tribes of Asia and South West Africa. Some wild species of *Dioscorea* tubers (*D. composita*, *D. floribunda*, *D. deltoidea* and *D. prazeri*) have gained a lot of attention of pharmaceutical companies due to the presence of a compound “Diosgenin” which is used as a principal base material for several steroid hormones ‘cortisone’ and ‘cortico-steroids’ and the production of steroid drugs is a large scale industry¹ Diosgenin is an active ingredient in oral contraceptive “pills”. for the first time indentified Diosgenin from Mexican *Dioscoreas* - a raw material identical with those obtained from progesterone and other mammalian sex hormones. Soon *Dioscorea* has emerged as an oral contraceptive “pill crop” and many companies were set up basing on diosgenin.

Distribution

The genus *Dioscorea* is pan tropical in distribution. It has 600 species distributed throughout the moist tropics of the world, pacific islands and warm temperate regions. In India, the genus is represented by 50 species, out of which only eleven are edible and the rest are in wild state. Yams are mostly cultivated in Assam, Bihar, Bengal, Madhya Pradesh, Odisha, Malabar and Coromandal Coasts. The wild yam species particularly *Dioscorea deltoidea* and *D. prazeri* occurs in wild state in India where as *D. composita* and *D. floribunda* both introduced from Central America has been successfully grown in Jammu conditions; Karnataka, Assam and Goa respectively. The distribution of *D. deltoidea* Wall. ranges from North Western Himalayas (Kashmir and Punjab) and extends up to Nepal and China and grown at an altitude of 900-3000 metres above sea level. *D. prazeri* occurs in Eastern Himalayas including North Bihar, West Bengal and Assam hills up to 5500 metres msl.

Botanical description

The genus *Dioscorea* was first included in the family Dioscoreaceae by Brown (1810) along with *Tamus*, *Rajania* and *Testudinaria*. Later, it was placed near to *Boarderea*, *Higinbothamia* and *Rajania*^{8,6}. The plants of *Dioscorea* are annual twining herbs with an underground stem and modified in the form of thick firm structure giving out aerial branches. Leaves predominantly alternate, simple or compound, entire or lobed or digitately 3-7 foliate. Inflorescence is a spike, paniced spike, or is in the form of cymes arranged in spicate manner. Flowers are small, bracteates, unisexual and dioecious. Male flowers green. Perianth persistent. Fruit in a three winged capsule. Seeds compressed often winged.

Dioscorea deltoidea Wall.

It is a climber growing up to 3 metre, unarmed stem twining to the left, stem glabrous, leaves glabrous, alternate, rhizome ligneous, horizontal and irregular, scattered roots, skin light brown. Rhizome is harvested after three years during December. Diosgenin varies from 2-5% on dry weight basis.

Dioscorea prazeri Prain & Burkill. –

A climber with smooth or slightly ridged, unarmed stem twining to the left. Leaves alternate or rarely opposite, rhizome short, stout, grey brown to nearly black, creeping horizontally. Diosgenin varies from 2-5% on dry weight basis.

Dioscorea floribunda Mart & Gal.

It is a perennial climber with simple alternate leaves, flowers cup shaped and arranged in racemes. Rhizome contains about 2-4 % diosgenin on dry weight basis.

Dioscorea composita Hemsl.

Plant is quite hardy and vigorous which completes its life cycle in 1-5 years. Rhizome contains about 2-4 % diosgenin on dry weight basis.

Cultivation

The yams are preferably grown in deep and well drained soils and are chiefly propagated through underground tubers or by aerial bulbils. They are planted in the month of March-April and exhibit vigorous growth during the onset of monsoon from June to September and stop abruptly at the beginning of autumn. The vines are given support for optimum yield. Tubers are harvested during December or January. The size and shape of tubers varies considerably from large cylindrical to globose or depressed-globose of small or large size tubers. Tubers are either solitary or clustered together at the base of the plant. Yield ranges of 2-14 tons per acre have been recorded for cultivated yams (recorded an average of 7 and 8 tons for *D. alata* and *D.*

esculenta respectively).

Economic Uses

Yams constitute a cheap source of carbohydrate food for the hill tribes of Africa and Asia. These are of great potential value during famine or periods of scarcity. For use as food, yams are washed, cut into slices and cooked or baked to eliminate alkaloid (Dioscorine) or other poisonous principles. When eaten raw, Yams cause irritation or a feeling of discomfort in the throat. The cultivated types, *D. aculeata*, *D. alata*, *D. bulbifera* and *D. esculenta* are comparable to potatoes in quality and taste (Table 1). Yams are also used for the extraction of starch and alcohol on a commercial scale. Some species are also rich in vitamins, B₁, B₂ and B₆. *D. hispida* when used in large quantities cause paralysis and respiratory troubles. Some poisonous species like *D. pistacorum* and *D. prazeri* are used for stupefying fishes and killing head lice respectively.

Table 1. Comparison of nutritive value of Yams and Potatoes (Per 100 gm of food material)

Nutritional component/Crop	Yam	Potato
Sodium (mg)	14.0	11.0
Iron (mg)	0.5	0.7
Phosphorous (mg)	31.0	40.0
Magnesium (mg)	29	20
Calcium (mg)	16	10
Mineral (gm)	0.8	0.6
Vitamin C (mg)	-	1.7
Nicotinic acid (mg)	0.7	1.2
Niacin	0.3	0.4
Riboflavin (mg)	0.01	0.01
Thiamine (mg)	0.08	0.1
Vit. A. I.U.	1.30	40.0
Total Calories (gm)	79	97
Fibre (mg)	0.1	0.4
Fat (mg)	0.5	0.1
Protein (mg)	1.8	1.6
Carbohydrate (mg)	18.4	22.6
Moisture (%)	79.6	74.7

Source: Gopalan, C. *et al.*, *Nutritive value of Indian foods*, National Institute of Nutrition, Hyderabad, India

As oral treatment, wild yam is used as an alternative for estrogen replacement therapy, postmenopausal vaginal dryness, premenstrual syndrome, menstrual disorders, infertility, osteoporosis, increasing energy and libido in men and women, and for breast enlargement. Wild yam is also used orally for treating diverticulosis, gall bladder colic, painful menstruation, cramp, rheumatoid arthritis, and for increasing energy. As topical treatment, wild yam is used for

menopausal vasomotor symptoms such as hot flashes, menstrual disorders, and infertility. In manufacturing steroidal drugs, the constituent of wild yam root, diosgenin, is used as a precursor for commercial chemical synthesis of human steroidal hormones. The tubers of *D. composita*, *D. floribunda*, *D. deltoidea* and *D. prazeri* possess 2 – 5% of diosgenin.

Extraction and Chemical structure of diosgenin

The wild species of *Dioscoreas* like *D. composita*, *D. floribunda*, *D. deltoidea* and *D. prazeri* contain diosgenin a base material for steroid industry. The procedure for extraction is as follows: The dried powder of yams is mixed with hydrochloric acid (1:10 ratio) and incubated for six hours, hydrolysed product filtered with sodium bicarbonate and washed with water till free from acid or any colouration. The residue is dried and extracted with petroleum ether (40-60⁰ c) hexane in soxhlet apparatus for 10 hours. The petrol ether/ hexane extract on concentration yields steroidal sapogenin. This extract on repeated washing with cold petroleum ether produces diosgenin.

D. composita and *D. floribunda* contains highest amounts of diosgenin (10-13%). The diosgenin content also varies depending upon the size of planting material, time of harvesting and fertilizer application.

The chemical structure of diosgenin and related steroids are given in Figure. 1. The production of various other steroidal compounds from a single source *i.e.* from diosgenin is also possible as given in Figure. 2. Thus, compounds like testosterone, progesterone and estrogens become available at a low cost from a single versatile compound “diosgenin” relatively easy to extract from abundantly available natural sources.

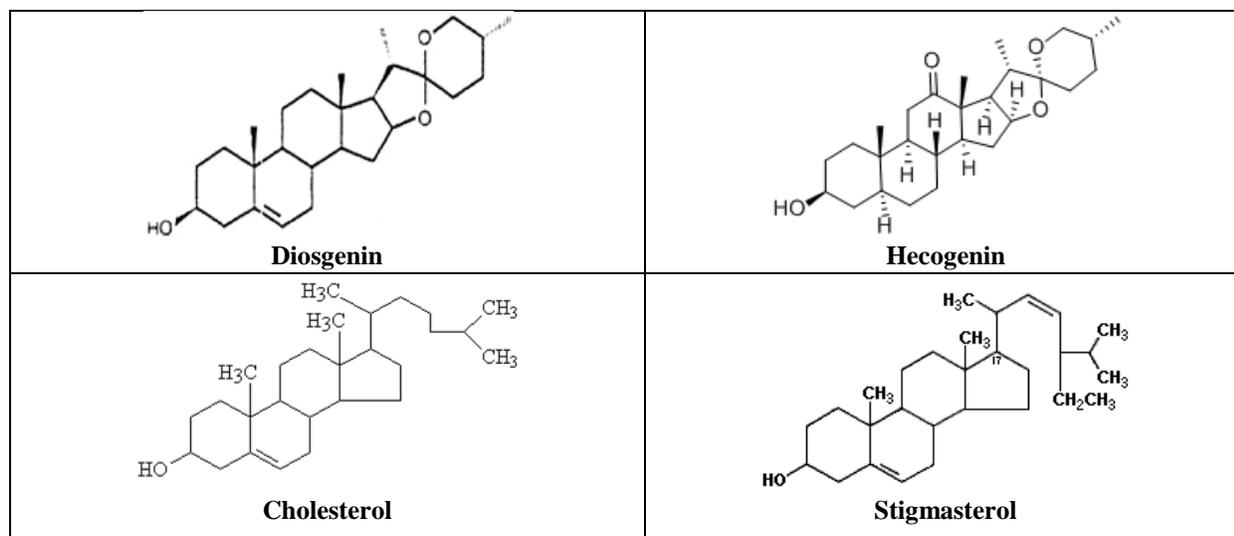


Figure. 1 Chemical structure of Diosgenin and related Steroids

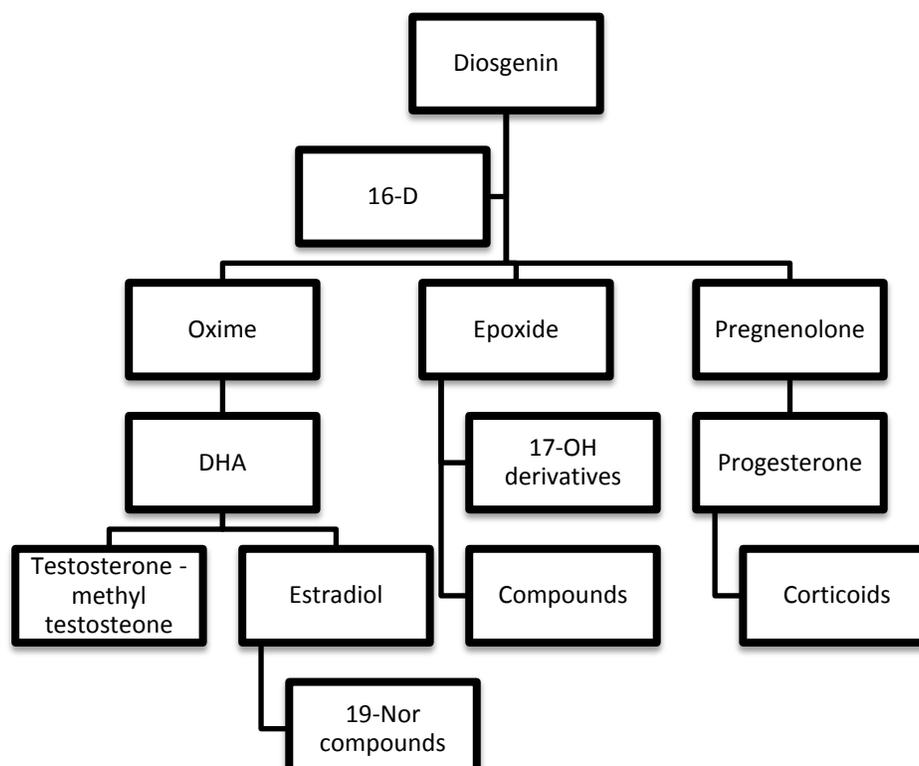


Figure.2. Conversion of Diosgenin into various steroidal compounds

Use and mode of action of oral contraceptive pills

The use of pill in birth control is common among the women of cities as well as villages. Pills contain either as estrogen and progesterone or in combination. Initially daily dose was 10 g, later it was reduced to 0.35 mg. Currently, a wide spectrum of pills has been developed depending upon the content of active principle, frequency of administration, safety and choice of particular types to suit to individuals. They are 1. The combined type pill, 2. The sequential pill. 3. The mini pill. 4. The morning after pill and 5. The combined once-a-month pill. The trade names for above types of pills are Norinyl, Norlestrin, Ovral; Norquen, Sequelen, Sinovula; Femulen, Norgest, Microvula; Pimolut N and mestranol quinestrol, respectively.

The action of oral contraceptive pills is brought about by action of estrogen and progesterone at hypothalamohypophyseal. These hormones inhibit secretion of gonadotropin releasing hormones (LH-RH and FSH-RH) and also block synthesis and /or release of LH (Luteinizing hormone) responsible for maturation of ovum and ovulation. These pills either inhibit ovum transport through the oviduct or interfere normal functions of corpus luteum or prevent mid cycle thinning and other changes in cervical mucus. It may prevent pregnancy through their effects on the endometrium. Thus the pills, in addition to their action at hypothalamo- hypophyseal complex, also interfere directly or indirectly with the normal functioning of tubal motility, function of

corpus luteum, cervical mucus and endometrial cycle.

Recent developments

China is a major producer of diosgenin in the world market but it uses most of its raw material for its own industry and consumption. Next to China; India, Mexico, Guatemala and Costa Rica are the producers of diosgenin though to a lesser extent. In India, uncultivated *Dioscorea* grows in the northeastern Himalayas. *D. composita* and *D.floribunda* are being attempted in Indian Institute of Horticultural Research (IIHR), Wylth laboratories (Goa), CIBA GEIGY (India), CIPLA, Bangalore, and CIMPO, Lucknow, CIPLA has programme of plantation in Coory and in Andamans. IIHR, IARI & NBRI, Lucknow grow *D. floribunda* with high yielding strains for providing tubers to commercial grower. Cultivation of *D. composita* has been taken up by cinchona department of Tamil Nadu, in Anamalai hills and Directorate of Cinchona, medicinal plants by Govt. of West Bengal in Darjeeling hills. Attempts are being made for the micropropagation of *Dioscoreas* and biosynthesis of diosgenin in cell and tissue culture, which is an alternative biotechnological method for rapid propagation and future exploitation of Indian *Dioscoreas*.

In the last two decades there have been many exciting events in the contraceptive steroid field. i) The number of users grew at a fantastic rate ii) The requirement of progestagen rose from kilos to tons. The world requirement of diosgenin during 1985 was 200-500 tonnes costing about 1,250 billion dollars and the demand increased at least by 10 per cent every year. India's annual requirement was 60 tonnes and is expected to increase further to a level of 100 tonnes with the increase in family planning programme⁵ With the increasing demand of diosgenin, the raw material soon gets diminished at a fast rate. Because of a) insufficient supply of diosgenin intermediates, b) increase in cost of materials c) and uncertainty in supply or cost of the material there has arisen a need for search towards the alternate sources of diosgenin.

New sources of steroid

Plant source - Diosgenin can also be made from *Solanum* steroids, fenugreek, *Balanites*, *Kalstroemia pubescens* and *Costos speciosus*. Among them solasodine is an attractive competitor for diosgenin since it possesses the same versatility and can be grown rapidly in areas of cheap labour.

Microbiological production of androstanes

The microbiological processes for degradation of cholesterol and sitosterol to androsterone leading to androgens, estrogen, progestagens and spironolactone were put into industrial production by Mitsubishi Chemical Industries (MCI) Japan.

Chemical synthesis

Chemical synthesis of norethindrone to various steroid compounds has been tried by different laboratories of France, Germany, Switzerland, China and U.S.A. However since total synthesis of corticosteroids is not feasible with the existing methods, natural material remains the major source of steroid production.

CONCLUSION

The exploitation of Indian wild yams is suffering a heavy loss because of large scale denudation and exploitation by pharmaceutical companies. Better clones are diminishing at a fast rate. Unless strict regulations are formulated the potential raw material will soon be exhausted from our environment. In spite of the developments of alternate sources of diosgenin, the supply of diosgenin from wild *Dioscorea* towards meeting steroidal requirement will be at the top level. The genetic resources of wild yams need to be conserved for sustainable use by future generations and pharmaceutical industry.

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