



**Review Article**

## Phyto-characteristics, Cultivation and Medicinal Prospects of Chinese Jiaotou (*Allium chinense*)

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### ABSTRACT

Chinese jiaotou (*Allium chinense* G. Don) is a commercially important plant species. Historically, it has been used in Asia and elsewhere mainly as vegetable and for controlling various diseases and stresses like heart problems, headache, worms and tumors. Several types of glycosides and other medicinal compounds have been isolated from this plant. In China, the largest areas of its cultivation are situated in Jiangxi, Yunnan, Hubei and Zhejiang provinces, where efforts are being made for improving their cultivation techniques. Four major cultivars are now grown in China viz. large leaved, pumilum, long sheath, and pearl Chinese jiaotou. Its plants are considered to be autotetraploids. Conventional breeding method (bulb propagation) has limited the breeding program and genetic researches on this crop. Jiaotou multiplies by vegetatively and each plant producing nearly thirty bulbs, which are harvested and stored between 4 to 18°C. Low propagation rate and high rate of virus infection during vegetative propagation are the limiting factors for its cultivation. Due to the medicinal importance, we also describe the phytochemical constituents of Chinese jiaotou bulbs. Plants of the genus *Allium* are known for their creation of steroid saponins, as well as organosulfur compounds. Steroid saponins have been found to have some fascinating biological and pharmacologic actions including antifungal, antibacterial, antiinflammatory and hypocholesteremic influences. However, a variety of steroid saponins from *Allium* spp. are being increasingly recognized for their importance in biological processes. Chinese jiaotou bulbs give the following percentage, based on fresh weight; protein, 2.2; fat, 0.3; carbohydrate, 13.1; and ash, 3.8. These data also give some information about their quality and importance. In this review, we provide background for and insight into body of literatures on Jiaotou bio-ecology, agricultural techniques to motivate the interest in this crop, which is very importance in China as well as in south-east Asia. © 2012 Friends Science Publishers

**Key Words:** Chinese jiaotou; Distribution; Herbal medicines; Nutrition; Production

### INTRODUCTION

Jiaotou with synonyms *Allium bakeri* Regel and *Caloscordum exsertum* (Lindley) belongs to genus *Allium* and is placed in the Alliaceae family as described previously (Allardice, 1997). *Allium* has 750 species all over the world. As described previously (Anonymous, 1985), it is the largest genus of petaloid monocotyledons except orchid. Its common names in different regions are; Chinese jiaotou or 'ch'iao 'ou' (in China), jiaotou (in Japan), Japanese scallion, Japanese bunching onion and Welsh onion as described previously (Anonymous, 1986). Jiaotou is categorized with onion, chives and garlic as the edible Alliums, which have

been used for their typical flavour and broad medical-therapeutic effect since ancient times. Indians mostly use it as vegetable and condiment for making pickle. Its bulbs or cloves are pickled, while leaves and flowers are employed as flavor in different food items e.g., soups and curries as described previously (Araki *et al.*, 1981). Jiaotou plant is also known for insects and moles repelling characteristics, while its extract is used for moth control (Brewster, 2008).

It has particular significance due to its high vitamin, mineral and dietary fiber contents. In China, Jiaotou has been used as spice, food and traditional Chinese medicine for over 2000 years as described previously (Chittendon, 1956; Chen & Snyder, 1989; Chen *et al.*, 2000). In Chinese

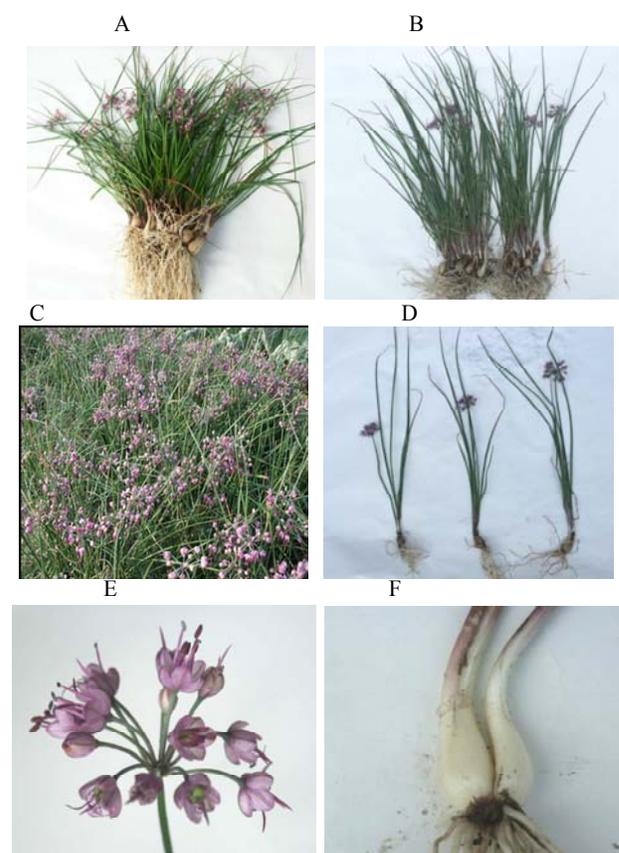
traditional medicine, plant bulbs of Jiaotou are reputed to cure mental stress, heart problems, and tumors etc., and are also incorporated in several medicinal preparations as previously described (Cooper & Johnson, 1984). A Chinese crude drug 'Xiebai' is made from this plant to treat stenocardia, heart asthma, and stagnant blood as demonstrated by (Davies, 1992).

Nutritional and medicinal importance as well as good economic returns has forced the commercialization of jiaotou to meet the needs of increasing domestic and foreign markets as demonstrated by (Facciola, 1990). Although evidence exists that jiaotou can play an important role in generating income and curing some diseases; however, little attention has been given to this unique plant species. Jiaotou mostly grows wild and is cultivated occasionally. Therefore, it might become endangered or could have the possibility of genetic devastation due to over-exploitation or habitat destruction in the realm of development as described previously (Araki *et al.*, 1981). This situation necessitates understanding its ecological needs, cultivation practices and conservation strategies. Most of the scientific information on jiaotou is scattered and incomplete. This review paper comprehensively gives the insights into Chinese jiaotou. We systematically organized the latest and empirical knowledge on its botanical, ecological, physiological and agronomic aspects, which would be valuable to scientific community in developing the strategies for judicious exploitation of this plant.

**Botanical and morphological characteristics:** Jiaotou is a perennial plant and a member of Alliaceae family, which includes herbaceous perennial flowering plants distributed throughout the world in most of the temperate regions. Its plant is autotetraploid as demonstrated by (Chen & Snyder, 1989; Fereol *et al.*, 2005) with  $2n = 32$  chromosomes (Freeman & Whenham, 1975). *Allium* genus contains about 750 species as described previously (Anonymous, 1985) that exhibit great diversity in various morphological characters particularly in life form (rhizomes or bulbs) and habitat as demonstrated by (Fritsch & Friesen, 2002).

Chinese jiaotou plant produces leaves all the year but flowers in summer during August and September (Fig. 1). Plant height is up to 0.5 m and producing evergreen bulbs. It has hollow bright green leaves, grows in clumps and forms many well developed bulbs as described previously (Fritsch & Friesen, 2002). Leaves are slender and thin-walled, 3 to 5 angled (not round) and less stiffly erect (Anonymous, 1986), having solid seed stalk (scape) as described previously (Hanelt, 2001). Its flowers are lavender in color with long pedicels, thick perianth segments and long-exserted styles and stamens. Inflorescence bears umbel reddish purple flowers on a stalk 40-60 cm long. Unlike other *Allium* crops, it is on the side of the main growing shoot, not emerging from its centre as demonstrated by (Hashimoto *et al.*, 1984). Generally, the umbel consists of about 5 to 25 flowers, which are hermaphrodite. The plant root can reach 45 to 55

**Fig. 1: Jiaotou plant A-B; C: Flowers in the field; D: The umbel of Jiaotou; E: Plant of Jiaotou; F: The bulb of Jiaotou**



cm depth and possesses a spherical bulb derived from a valve stem.

Bulb is formed in autumn after summer dormancy with oval shape about 4 to 5 cm in diameter after the second or third year of growth as demonstrated by (Havey, 1995). Grey-white or purple, with a thin transparent skin, it has an excellent crispy texture that covers its white meat, which has a strong onion flavor at maturity. Approximate nutritional composition of bulb is: carbohydrates 18.3%, total protein 3.1%, fats 0.12% and ashes 0.7% (Jorge *et al.*, 2001).

There is large number of jiaotou cultivars in both China and Japan. Recognized cultivars can be divided in two groups, according to bulb size. Majority of the large-bulb cultivars originated from Japan, and most of them are quite similar. Descriptions of some small and large-bulb cultivars grown in Japan are as demonstrated by Hashimoto *et al.* (1984).

“Tama jiaotou” is the representative of small-bulbed group, which was introduced in Japan from Taiwan. The plant is short, and leaves are thin and curled. Ten to 25 bulblets (1.5 to 3.0 g) are produced from mother bulb. Bulbs color is white, soft and almost odorless. The plants are highly susceptible to *Rhizoglyphus* mite. “Rakuda” is the

representative of large-bulbed group (4 to 10 g) cultivated in Japan. Rakuda plants are strong, develop large foliage and produce 6 to 9 bulbs per year as demonstrated by (Yukio *et al.*, 2005). “Yatsufusa” is very suitable for processing and pickles, but it matures earlier with low yield and quality.

In China local strains are common but the cultivated varieties (cultivars) are rare. Four major cultivars of Chinese jiaotou currently grown in China are: Large-leaved, Pumulim, Chang bing (Long sheath) and Pearl.

**Distribution and ecology:** Geographically, the domestication and cultivation of Jiaotou have been in Eastern Asia as described previously (Fereol *et al.*, 2005; Mukhopadhyay *et al.*, 2005). While important as vegetable in the Orient, Jiaotou is seldom grown in many parts of the world (Hanelt, 2001). It has been grown in China since ancient times and from there it spread to other areas in Asia (e.g., Japan, Korea), at the term of the first millennium A.D as demonstrated by (Kameoka *et al.*, 1984). It is also cultivated in Vietnam, Indonesia and other countries of south-east Asia as a minor or moderately important crop, and can be grown wild on the field borders as demonstrated by (Kik *et al.*, 2001). In Indian Himalayan region, wild species of *Allium* take up a significant position in hill agriculture as they are used there as vegetable, spices, condiment, medicine and ornamental (Araki *et al.*, 1981; Kunkel, 1984). In China, jiaotou is cultivated in the south-eastern parts (Jiangxi, Yunnan, Hubei & Zhejiang province), and its wild types are scattered along rocky hills of Chiansu and Zhejiang provinces.

Jiaotou grows on wide range of soil types but well drained, loamy and slightly acidic/alkaline soils are most satisfactory. It prefers moist soil, and does not grow well in the shade. Jiaotou grows in temperate as well as in tropical zones. There are few reports on the effects of environmental requirements on the commercial yields of jiaotou. Differences in the environmental conditions greatly affected the yield reported by (Takeuchi *et al.*, 1983). Environmental factors that affect the yield are air and soil temperatures, relative humidity and light intensity. Toyama *et al.* (1995) also examined the effects of light intensity and temperature on photosynthesis and transpiration of jiaotou in controlled environment. Photosynthesis decreases as the temperature increases from 15 to 35°C, but transpiration increases.

Because of its vigorous growth habit and strong ability to absorb nutrients, jiaotou produces high yields of good quality small bulbs even in poor soils. These characteristics make jiaotou a suitable crop for reclaimed soils and sand dunes. Jiaotou requires well drained soil. In fertile soil such as a clay loam or volcanic ash, the yield increases but the bulbs become too large; and therefore, have lower market value. Moreover, these bulbs are too soft and are much inferior in the quality to those grown on sand dunes.

**Cultivation:** Jiaotou cultivation is relatively easy because the plant is hardy, and it can grow in a broad range of agro-

ecological conditions even in poor soils as previously described by (Havey, 1995). However, it performs very well on light well-drained soil and in sunny position (Li *et al.*, 1989). Jiaotou seedlings usually die-back in hot summer and recover growth in late summer, and flowers set in the autumn examined by (Havey, 1995). In China, mother bulbs are generally grown in September and thus cooled during the winter and offspring bulbs are usually reaped during the succeeding June as described previously (Liu *et al.*, 2005). The best germination of most taxa within the subgenus *Allium* occurs at 16°C within 30 days; whereas, lower and higher temperatures reduce the germination significantly (Mann & Stream, 1960).

An area of 667 m<sup>2</sup> may require approximately 120-150 kg of jiaotou bulbs. Generally, bulbs are planted just below the soil surface, 5 to 8 cm apart, and covered with a thin layer of soil (Li *et al.*, 1989). The planting is performed by hand in 1 m beds, each with two rows which are distant of 30 to 36 cm. Bulbs if planted upside-down in the soil may result in poor growth or no growth at all. Fertilization would depend on the nutrients available in the soil. It is recommended that 10 to 15 kg of urea per 667 m<sup>2</sup> be applied from mid December to late January.

Sato and Tanabe (1970) investigated the change in mineral content of jiaotou with growth. Nitrogen, potassium, magnesium and phosphorous uptake rates of shoot are high in the spring and early summer, especially in May and June. Nitrogen, magnesium and particularly potassium are accumulated in the roots in autumn and winter, but at slower rate. Although this mineral intake is not accompanied by an increase of leaf biomass, it probably has an important role, since the root system is developed in these cold months; and thereafter, it promotes vegetative growth in the spring. In spring, the mineral content of roots declines sharply, but that of bulbs increases as it swells.

Jiaotou is tolerant to drought and can be grown with no irrigation. It is almost impossible to obtain good growth in the dry months from May to September in sand dune fields as in Japan. Sato and Tanabe (1972) showed that spring irrigation in sand dune fields resulted in an increase of both bulb weight and yield. Autumn irrigation promotes mainly lateral bud formation and growth. Ueda (1981) repeated these experiments and showed 20 to 30% increase in bulb yield following spring and autumn irrigation on sand dune fields.

Jiaotou takes about 300 days to mature. It is ready to be harvested when the leaves are partially dry and stoop to the ground. The bulbs are pulled either manually or mechanically. In areas of rainfall or dew, the bulbs should be protected from moisture. In early summer, the leaves wither and the plants become dormant; during this period (May to August) the crop is harvested in Japan. For consumption, jiaotou bulbs can be kept for several months at ordinary temperatures, but for prolonged storage they should be held at nearly 0°C and under 60% RH. The cloves sprout quickly when stored at 5°C; so, storage under

temperatures near this point should be avoided. As with onions, bulbs can be kept at temperature above 25°C, but shrinkage may occur at this temperature. For planting stock, bulbs should be kept between 5 and 10°C but not below 4 or above 18°C.

**Propagation and genetic improvement:** Jiaotou plants possess rhizomes and false bulbs developed from leaf sheaths. During the course of normal growth, plant subdivides continuously by making a thick clump of shoots (Freeman & Whenham, 1975). Jiaotou is propagated normally through seeds as well as bulb divisions. Seed cultivation is done in spring by sowing the seeds in a cold frame. When the seedlings attain a suitable large size enough to handle, they are pricked out into individual pots. It is recommended to plant three seedlings in each pot for quick development of clumps. These are grown preferably in greenhouse during the first winter for proper growth, and then are pricked out for permanent planting in spring. Secondly, cultivated jiaotou is propagated through bulb divisions as the flowers lack seed setting (Hashimoto *et al.*, 1984). The divisions are planted directly into the pots or field at any time in growing season where they grow successfully.

Tissue culture is an alternative method of vegetative multiplication. Direct shoot regeneration using stem disc has been carried out successfully in this crop (Chittendon, 1956; Negi, 2006). However, shoot propagation from callus still needs to be developed. Induction of regenerated plant through indirect organogenesis is one prospective way to contribute to Chinese jiaotou genetic improvement, because there are some advantages of shoot induction from callus over direct shoot regeneration. A callus phase is generally included in tissue culture protocols with the goal of generating variability to introduce new desirable traits and generating transgenic plants to introduce traits such as pest resistance in *Allium* crops (Ohwi, 1965; Oboh, 2006; Pandey *et al.*, 2008). Moreover, callus induction is also a requisite approach for obtaining protoplasts used in protoplast fusion, a useful implement in genetic advancement of vegetatively propagated *Allium* spp. for introducing useful genes or producing new crops as described previously (Peng *et al.*, 1996a & b). According to the above reports it seems likely that *in vitro* vegetative multiplication through tissue culture and regeneration from explants would be an efficient alternative for obtaining elite clones of jiaotou (Miao *et al.*, 2009). Thus, utilization of genetic engineering and identification of genetic diversity patterns could improve the breeding program of new cultivars (Reid, 1977).

**Pests and diseases:** In nature, jiaotou is attacked by many organisms including bacteria, mites, thrips and aphids, which generally occur 10 days following planting when temperatures and RH are higher. Onion thrips are one of the main pests attacking the crop. Cutworms can damage or cut off young plants at the base, while nematodes attack the roots. Leek maggots infest the bulbs. Downy mildew and

anthrax are the serious diseases of jiaotou. Yellow dwarf, an aphid-transmitted viral disease, causes chlorotic streaking, stunting and distorted flattening of leaves (Fritsch & Keusgen, 2006). Soft rot is caused by bacteria, which appears as water-soaked areas in the bulb tissue and then becomes odorous and soft. Leek yellows viral disease caused by putative luteovirus with yellowing symptoms in phloem cells has also been observed as phloem necrosis in Jiaotou as described previously (Saghir *et al.*, 1964). *Sclerotium cepivorum* and *Fusarium* sp. are the germplasm transmitted fungal pathogens which occur frequently in the vegetative parts of *A. chinense* (Riotte, 1978).

**Nutritional composition and volatile compounds:** Interest in cultivating jiaotou is partly due to its nutritional aspects. This species is commonly cultivated for its leaves and edible bulb. It is found mostly in the tropical and sub-tropical regions of China and many other areas of eastern Asia as previously described by (Saghir *et al.*, 1964; Sato & Tanab, 1970; Chen *et al.*, 2000).

Its bulb contains approximately 0.12% fat, 3.1% protein, 18.3% carbohydrate and 0.7% ash (Jorge *et al.*, 2001). The nutritional composition of jiaotou (Table II) varies according to cultivation areas as previously described (Sato & Tanab, 1972). A 100 g of jiaotou contains approximately 87.9 g water, 8.0 g carbohydrates, 1.6 g protein and 1.2 g cellulose (Table I). It also contains high levels of calcium, magnesium and phosphorus; while, iron, copper, manganese, strontium and zinc are present as trace elements. Other components including proteins, carotene, vitamin C, 16 amino acids, garlic sugars, acid, volatile oil, which are known for its unique flavor. Its onion-like flavor is due to sulfur compounds.

The volatiles are formed by enzymatic splitting of the nonvolatile precursors, *S*-alk(en)yl-L-cysteine sulfoxides, when the plants are crushed. These sulfoxides are odourless, non-protein sulfur amino acids specifically existing in members of the family Alliaceae. They are precursors to the lachrymatory and flavour compounds detected in the agronomical important genus *Allium*. According to (Jorge *et al.*, 2001) the volatile compounds in jiaotou are divided into the following groups: sulfides, disulfides, trisulfides, tetrasulfides, pentasulfides, oxygenated compounds and terpenes. Sulfur and oxygenated compounds constitute 94 and 2.3%, respectively of the total volatiles in jiaotou. These include ethyl propionate and 2,3-dihydro-2*n*-octyl-5-methylfuran-3-one in jiaotou. Saghir *et al.* (1964) analyzed jiaotou and found that volatile compounds of the plant mainly consisted of methyl propyl disulfide, dimethyl disulfide and alkyl methyl disulfide, while Jorge *et al.* (2001) reported methyl propyl trisulfide (9.9%), dimethyl disulfide (7.3%), dimethyl trisulfide (6%) and methyl propyl disulfide (5.5%) as major volatile compounds.

Freeman and Whenham (1975) reported approximately equal level of alkenyl groups, and Kameoka *et al.* (1984) related dipropyl disulfide as important volatile

**Table I: Original places and agricultural characteristics of the main cultivars of Jiaotou**

Cultivar	Growing areas (province)	Height (cm)	Leaf characters	Bulb size (cm) (L × W)	Bulb weight (g)	Growing period(days)	Yield (kg per 667 m <sup>2</sup> )
Large leaved	Hubei	45-55	Rough long, 30-50 cm, short stalk	4 × 2	8-10	300-320	2000~2500
Pumilum	Jiangsu, Zhejiang, Guizhou	35-45	Fine short/long, 25~35 cm, short stalk	3.5 × 2	8-12	290-310	1000~1500
Chang bing (long sheath)	Hunan	40-50	Medium, long, 40~60 cm, long stalk	4.0 × 2.5	12-16	290-310	1500~2500
Pearl	Zhejiang Jiangxi Yunnan	30-45	Slender, long 30~35 cm, short stalk	2.5 × 1.0	6-9	280-300	800~1000

**Table II: Nutrition contents in Jiaotou adopted from (Li *et al.*, 1989)**

Nutrient component	Contents (%)	Nutrient component	Contents (%)
Water content	73.52	Aspartyl acid threonine	0.132
Protein	1.71	Arginine	0.127
Sugar	11.51	B acid serine	0.130
Water soluble sugar	4.20	Glutamate	0.071
Vitamin B1	8.66	Alanine	0.094
Vitamin C	0.16	Methionine	0.027
Lysine	0.160	γ-aminobutyric acid	0.124
Asparaginase valley	0.191	Leucine isoleucine	0.104

**Table III: Volatile compounds in Chinese chive and rakkyo adopted from (Jorge *et al.*, 2001)**

2,3-dihydro-2 <i>n</i> -octyl-5-methylfuran-3-one	Dimethyl trisulfide	Methyl <i>cis</i> -1-propenyl trisulfide
Alkyl <i>cis</i> -1-propenyl disulfide	Dipropyl disulfide	Methyl pentyl tetrasulfide
Alkyl methyl disulfide	Dipropyl tetrasulfide <sup>f</sup>	Methyl propyl disulfide
Alkyl methyl trisulfide	Dipropyl trisulfide	Methyl propyl trisulfide
Alkyl propyl tetrasulfide	Ethyl <i>cis</i> -1-propenyl disulfide	Methyl <i>trans</i> -1-propenyl trisulfide
Alkyl <i>trans</i> -1-propenyl disulfide	Ethyl <i>cis</i> -1-propenyl sulfide	Propyl <i>cis</i> -1-propenyl disulfide
Butyl methyl disulfide	Ethyl methyl disulfide	Propyl <i>cis</i> -1-propenyl trisulfide
Butyl methyl trisulfide	Ethyl methyl trisulfide	Propyl <i>cis</i> -1-propenyl pentasulfide
Diallyl disulfide	Ethyl propionate	Propyl <i>cis</i> -1-propenyl tetrasulfide
Diallyl sulfide	Ethyl propyl disulfide	Propyl methyl pentasulfide
Diallyl trisulfide	Ethyl <i>trans</i> -1-propenyl disulfide	Propyl <i>trans</i> -1-propenyl disulfide
Dimethyl disulfide	Limonene	Propyl <i>trans</i> -1-propenyl trisulfide
Dimethyl tetrasulfide	Methyl <i>cis</i> -1-propenyl disulfide	Propyl <i>trans</i> -propenyl tetrasulfide

compound. Quantitative variation of volatiles might be due either to the part of the plant, which were analyzed or the genetic and environmental factors affecting the plant. Among the 34 sulfur compounds identified by Jorge *et al.* (2001) in jiaotou, were not previously reported in this plant. They include some novel sulfide and polysulfides with ethyl, butyl and pentyl groups. Table III shows the volatile constituents identified in jiaotou (*A. chinense*) and Chinese chive (*A. tuberosum*). Kameoka *et al.* (1984) and Hashimoto *et al.* (1984) identified some thioethyl and thiopentyl compounds in *A. fistulosum* and *A. grayi*. This finding indicates the possibility that *S*-alkyl-L-cysteine sulfoxides also occur in jiaotou. The bulb of jiaotou is reported to have some saponins compounds, as isolated and characterized by (Kuroda *et al.*, 1995). These components are reputed to be effective as a heart failure cure in Chinese medicine and are included in some traditional Chinese preparations as previously described (Cooper & Johnson, 1984).

In addition, two new furostanol saponins, named chinenosides II and III, have been extracted from Jiaotou bulbs. Structures of chinenosides II and III are: 26-O-β-glucopyranosyl 3β,26-dihydroxy- (25R)-5α-furost-20(22)-

en-6-one 3-O-β-xylopyranosyl-(1→4)-[α-arabinopyranosyl(1→6)]-β-glucopyranoside, and 26-O-β-glucopyranosyl 3β,26-dihydroxy-(25R)-5α-furost-20(22)-en-6-one 3-O-α-arabinopyranosyl(1→6)-β-glucopyranoside, respectively (Takeuchi *et al.*, 1983).

**Culinary aspects, processing and medicinal use:**

Nutritional ingredients in edible parts of jiaotou are listed in Table II. The content of crude protein (protein conjugated with other compounds) in all parts of the plant is similar, ranging from 15 to 18%, but the content of true protein in the bulbs is lower as compared to other parts. The highest values of crude fiber (40%) are found in roots and the lowest (3%) in bulbs. Bulbs have the highest content both of N-free extract (71%) and pentosan. Soluble sugars are high in both the bulbs and in middle leaves. They divide equally between reducing and non-reducing sugars. Most of the reducing sugars are glucose and fructose. The non-reducing sugars are fructo-oligosaccharides and fructans, all of which are characteristics of *Allium* spp. Alkyl sulfides are the main source of characteristic odor of jiaotou mush as in other *Allium* spp. The steam vapor volatiles of jiaotou include thiolanes, alcohols, ketones and the oily

compounds 2, 3-dihydro-2-hexyl-5-methyl-furan-3-one and others.

Much of the jiaotou is consumed as pickles and the quality pickles are made from small bulbs. The bulbs are usually first steeped in brine for several days before being transferred to vinegar, sake and sugar to produce sweet pickle or vinegar and salt to produce sour pickle. Soy sauce may be added to produce an amber-colored pickle. The pickles are transported in bulk in barrels and they may then be bottled or canned and sterilized. Pickled jiaotou is exported from Japan to many countries, particularly to USA and to Southeast Asian countries.

*Allium* spp. have been used traditionally in Asia, Europe and America as folk medicines for the remedy of various human diseases. Since antiquity, *Allium* plants have been considered to be beneficial for human health. High contents of organo-sulfur compounds (*S*-alk[en]yl-Cys sulfoxides & products of their conversions) are known to be responsible for the therapeutic effects of *Allium* plants in the treatment and prevention of numerous diseases and infections such as: tumors, pathogenic infections and cardiovascular disease according (Toyama *et al.*, 1983).

Interest in the cultivation of jiaotou is also due to its medicinal properties as evident by its active compound as previously described (Su, 1977; Takeuchi *et al.*, 1983). Some of These active components have been isolated and characterized according for several medicinal properties (Su, 1977; Toyama *et al.*, 1985; Stearn, 1992). It has beneficial effects for treating bronchitis, pleurisy, angina pectoris, chest pain, stuffiness sensation, tenesmus and diarrhea by (Toyama *et al.*, 1990). Generally, jiaotou is very healthy addition to the diet and if used regularly, it reduces cholesterol levels in blood, improves digestive system and strengthens circulatory system. For instance, dry jiaotou bulbs are very efficient against stenocardia, heart asthma and platelet aggregation.

Besides its medical importance, jiaotou is also reported to have positive and negative interactions with both plants and animals. It has an inhibitory effect on the growth of legumes by (Brewster, 2008); but vegetates well to most crops, particularly roses, carrots, beet and chamomile. When it is associated with alfalfa each species affects on the other as previously described (Ueda, 1981). Consumption of certain members in this genus by some mammals causes poisoning; especially dogs are susceptible (Wang *et al.*, 2002). Besides these aspects, the juice of the plant or the plant itself is repellent to insects and moths in particular by (Bianchini & Vainio, 2001).

**Future research and commercial aspects:** The premise of this review paper is to promote the potentials of jiaotou as a valuable crop, thereby contributing to food security and health. For this, we need to know the extent to which this plant is important, especially on nutritional and medicinal basis.

Almost all of the herbaceous parts of jiaotou viz. bulb, leaves, flowers and young seed pods can be consumed (Yamaguchi, 1993; Xu *et al.*, 2008). In fact, nutritional benefit is not the single positive aspect of jiaotou. Researchers have now become interested in the chemical components of *Allium* vegetables and their pharmacologic properties, with particular regard to their effects in the prevention of cancer and on the cardiovascular system as described previously by (Yamashita *et al.*, 2002). As in most members of the genus *Allium*, active components that can cure a number of diseases are present in jiaotou (Su, 1977; Toyama *et al.*, 1983; Stearn, 1992). For instance, addition of this plant extracts in our meals greatly aid to reduce cholesterol levels in blood. The intake of meals mixed with such extracts also confers tonicity to the digestive and the circulatory tracts. Dry bulbs are efficient against stenocardia, asthma and platelet aggregation. Further evidence for the medical importance of jiaotou is provided by (Yeung, 1985) who reported analgesic property and usefulness against pleurisy, angina pectoris, bronchitis, diarrhea and tenesmus. Although Jiaotou is used for treating several diseases, however like garlic, its excessive and unregulated intake can damage the cells through free radicals production in the body (Yang *et al.*, 2006).

The work of Riotte (1978) is of particular importance, showing evidence that jiaotou has insecticidal properties against moths. Larvae of these lepidopterans are the major group of pest insects in agriculture (Yeung, 1985) and their control with existing tools has limited success. Moths control through toxic organo-chemical-based insecticides used to be the primary strategy for reversing their impacts, but environmental and human health concerns combined with insecticide resistance, limit their usefulness. In the quest of finding non-toxic insecticides which could eventually substitute toxic insecticides and at the same time overcome the limitations caused by the existing bio-insecticides. Jiaotou may be a valuable material on the search of compounds, which could be used for the development of new insecticides and antimicrobials. *Pseudomonas aeruginosa* and *Aspergillus niger* have already been found susceptible to the diluted essential oil of *A. sphaerocephalon* L. subsp. *Sphaerocephalon* (Zhang, & Dai, 2010). It could be attributed to the presence of large amounts of antioxidants in *Alliums* spp. (Zheng, 2005; Lazarević *et al.*, 2011).

Jiaotou cultivation has good economic returns. Recent, it has been commercialized as a mixture with salted products to respond to the increased demand of the domestic and international markets. This mixture has been accepted by consumers in some south Asian countries. This crop has an important economic value in east Asia, notably Japan, Korea and China. Annual Japanese production of jiaotou is about 30,000 tones, most of which is being used to produce high value pickles by (Brewster, 2008). In South China, it is exported to the South Sea Islands from Amoy and Swato,

while in central China it is sold raw or for manufacturing. In California, pickled jiaotou is sold in all towns or cities having oriental populations, not only in Chinese and Japanese stores but in many supermarkets as well by (Mann & Stearn, 1960).

## REFERENCES

- Allardice, P., 1997. A-Z of companion planting. In: Fern, K. (ed.), *Plants for a Future: Edible, Medicinal and Useful Plants for a Healthier World*. Cassell Publishers Limited, UK
- Anonymous, 1985. *The Dictionary of Chinese Drugs*, Vol. 1, p: 226. Shogakukan Tokyo
- Anonymous, 1986. *Oriental Herbs and Vegetables*, p: 39. Brooklyn Botanic Garden Record
- Araki, M., S. Yamashita, Y. Doi and K. Yora, 1981. Leek yellows virus. *Ann. Phytopathol. Soc. Japan*, 47: 138
- Bianchini, F. and H. Vainio, 2001. *Allium* vegetables and organosulfur compounds: do they help cancer? *Environ. Heal. Perspect.*, 109: 893–902
- Brewster, J.L., 2008. *Onions and Other Vegetable Alliums*. 2<sup>nd</sup> edition, pp: 1–26. CABI, Oxfordshire, UK
- Chen, S. and J.K. Snyder, 1989. Diosgenin-bearing, molluscicidal saponins from *Allium vineale*: an NMR approach for the structural assignment of oligosaccharide units. *J. Org. Chem.*, 54: 3679–3689
- Chen, X., S. Liang, J. Xu and M.N. Tamura, 2000. *Liliaceae in Flora of China*, Vol. 24. In: Wu, Z.Y. (ed.), *Raven (Flagellariaceae through Marantaceae)*, Vol. 24, pp: 73–263. PH. Science Press, Beijing, China
- Chittendon, F., 1956. *RHS Dictionary of Plants Plus Supplement*. Oxford University Press, UK
- Cooper, M. and A. Johnson, 1984. *Poisonous Plants in Britain and their Effects on Animals and Man*. HMSO, London
- Davies, D., 1992. *Alliums - The Ornamental Onions*. BT Batsford Ltd., London
- Facciola, S., 1990. *Cornucopia: A Source Book of Edible Plants*. Kampong Publications, California, USA
- Fereol, L., V. Chovelon, S. Causse, D. Triaire, I. Arnault, J. Auger and R. Kahane, 2005. Establishment of embryogenic cell suspension cultures of garlic (*Allium sativum* L.), plant regeneration and biochemical analyses. *Plant Cell Rep.*, 24: 319–325
- Freeman, G.G. and R.J. Whenham, 1975. A survey of volatile components of some *Allium* species in terms of S-alk-(en)yl-L-cysteine sulphoxides present as flavor precursors. *J. Sci. Food Agric.*, 26: 1869–1872
- Fritsch, R.M. and N. Friesen, 2002. Evolution, domestication and taxonomy. In: Rabinowitch, D. and L. Currah (eds.), *Allium Crop Science: Recent Advances*, pp: 5–30. CAB International, Wallingford
- Fritsch, R.M. and M. Keusgen, 2006. Occurrence and taxonomic significance of cysteine sulphoxides in the genus *Allium* L. (Alliaceae). *Phytochemistry*, 67: 1127–1135
- Hanelt, P., 2001. Alliaceae. In: Hanelt, P. (ed.), *Mansfeld's Encyclopedia of Agricultural and Horticultural Crops (Except Ornamentals)*, pp: 2250–2269. Springer Verlag, Berlin
- Hashimoto, S., M. Miyuzawa and H. Kameoka, 1984. Volatile flavour components of *Allium grayi* Regel. *J. Sci. Food Agric.*, 35: 353–356
- Havey, M.J., 1995. Onion and other cultivated alliums. *Allium* spp. (Liliaceae). In: Smartt, J. and N.W. Simmonds (eds.), *Evolution of Crop Plants*, 2<sup>nd</sup> edition, pp: 344–350. Longman Scientific and Technical, Harlow, UK
- Jorge, A.P., F. Victor and T.C. Margarita, 2001. Volatile constituents of Chinese chive (*Allium tuberosum* Rottlex Sprengel) and rakkyo (*Allium chinense* G. Don). *Agric. Food Chem.*, 49: 1328–1330
- Kameoka, H., H. Iida, S. Hashimoto and M. Miyazawa, 1984. Sulphides and furanones from steam volatile oils of *Allium fistulosum* and *Allium chinense*. *Phytochemistry*, 23: 155–158
- Kik, C., R. Kahane and R. Gebhardt, 2001. Garlic and health. *Nutr. Metab. Cardiovasc. Dis.*, 11: 57–65
- Kunkel, G., 1984. *Plants for Human Consumption*. Koeltz Scientific Books, Koeningstein, West Germany
- Kuroda, M., Y. Mimaki, A. Kameyama, Y. Sashida and T. Nikaido, 1995. Steroidal saponins from *Allium chinense* and their inhibitory activities on cyclic AMP phosphodiesterase and Na<sup>+</sup> / K<sup>+</sup> ATPase. *Phytochemistry*, 40: 1071–1076
- Lazarević, J.S., A.S. Đorđević, B.K. Zlatković, N.S. Radulović and R.M. Palić, 2011. Chemical composition and antioxidant and antimicrobial activities of essential oil of *Allium sphaerocephalon* L. subsp. *sphaerocephalon* (Liliaceae) inflorescences. *J. Sci. Food Agric.*, 91: 322–329
- Li, H.Z., X.L. Xiao and X. Zhou, 1989. Nutrition component analysis. *J. Human Agric. Coll.*, 15: 118–130
- Liu, J., X. Xu and X. Deng, 2005. Intergeneric somatic hybridization and its application to crop genetic improvement. *Plant Cell Tissue Organ. Cult.*, 82: 19–44
- Mann, L.K. and W.T. Stearn, 1960. Rakkyo or Ch'iao T'ou (*Allium chinense* G. Don, syn. *A. bakeri* Regel) a little known vegetable crop. *Econ. Bot.*, 14: 69–83
- Miao, M.Y., X. Chan, H. Chun, C. Yeong, A.A. Bah and D.P. Guo, 2009. Effects of explant type, culture media and growth regulators on callus induction and plant regeneration of Chinese jiaotou (*Allium chinense*). *Sci. Hortic.*, 123: 124–128
- Mukhopadhyay, M.J., P. Sengupta, S. Mukhopadhyay and S. Sen, 2005. *In vitro* stable regeneration of onion and garlic from suspension culture and chromosomal instability in solid callus culture. *Sci. Hortic.*, 104: 1–9
- Negi, K.S., 2006. *Allium* species in Himalayas and their uses with special reference to Uttaranchal. *Ethnobotany*, 18: 53–66
- Oboh, G., 2006. Tropical green leafy vegetables prevent garlic-induced hepatotoxicity in the rat. *J. Med. Food*, 9: 545–551
- Ohwi, J., 1965. *Flora of Japan (English Ed)*, p: 1066. Smithsonian Institution, Washington DC
- Pandey, A., R. Pandey, K.S. Negi and J. Radhamani, 2008. Realizing value of genetic resources of *Allium* in India. *Genet. Resource Crop Evol.*, 55: 985–994
- Peng, J.P., X.S. Yao, Y. Tezuka and T. Kikuchi, 1996a. Furostanol glycosides from bulbs of *Allium chinense*. *Phytochemistry*, 41: 283–285
- Peng, J.P., X.S. Yao, Y. Tezuka and T. Kikuchi, 1996b. New furostanol glycosides, chinenoside IV and V, from *Allium chinense*. *Planta Medica*, 62: 465–468
- Reid, B.E., 1977. *Famine Foods of the Chiu-Huang Pen-t'ao*. Southern Materials Centre Taipei Taiwan
- Ritotte, L., 1978. *Companion Planting for Successful Gardening*. Garden Way, Vermont, USA
- Saghir, A.R., L.K. Mann, R.A. Bernhard and J.V. Jacobsen, 1964. Determination of aliphatic mono- and disulphides in *Allium* by gas chromatography and their distribution in the common food species. *Proc. American Soc. Hortic. Sci.*, 84: 386–389
- Sato, I. and K. Tanabe, 1970. Studies on growing Baker's garlic (*Allium bakeri* Regel) in a sand dune field. II Changes of mineral contents following the growth. *Bull. Sand Dune Res. Inst. Tottori University*, 9: 9
- Sato, I. and K. Tanabe, 1972. Studies on growing Baker's garlic (*Allium bakeri* Regel) in a sand dune field. IV Effect of irrigation in autumn and spring on growth and yield. *Bull. Sand Dune Res. Inst. Tottori University*, 11: 11
- Stearn, W.T., 1992. How many species of *Allium* are known? *Curtis's Bot. Mag.*, 9: 180–182
- Su, J., 1977. New Medical College - Dictionary of Traditional Chinese Crude Drugs. Shanghai Scientific Technologic. *Shanghai*, 2: 2642–2643
- Takeuchi, Y., M. Toyama, O. Nishiyama and K. Sugimoto, 1983. Relationship between meteorological conditions and yield of rakkyo (Baker's garlic, *Allium bakeri* Regel) in sandy fields. *Bull. Sand Dune Res. Inst. Tottori University*, 30: 276–282
- Toyama, M., Y. Takeuchi and O. Nishiyama, 1983. Meteorological conditions which affect to the yield of rakkyo (Baker's garlic, *Allium*

- Regal) cultivated in sandy filed. *Bull. Sand Dune Res. Inst. Tottori University*, 22: 47–53
- Toyama, M., Y. Takeuchi, N. Kuroyanagi and K. Sugimoto, 1985. Relationship between photosynthesis, transpiration, water use efficiency, air temperature, relative humidity and light intensity. *J. Japan. Soc. Hortic. Sci.*, 53: 444–452
- Toyama, S. and I. Wakamiya, 1990. Rakkyo *Allium chinense* G. Don. In: Brewster, J.L. and H.D. Rabinowitch (eds.). *Onions and Allied Crops*, pp: 197–218. CRC Press, Boca Raton, Florida, USA
- Ueda, H., 1981. Irrigation and soil management in rakkyo fields, preparation of ground basis and introduction to the fields in Futube Sand Dune. *Fields Soil*, 13: 103
- Wang, F.Y., J.M. Yang and C.H. Chen, 2002. Study on the cultural practices of Xie (*Allium chinense*). *China Veg.*, 1: 33–34
- Xu, Z., Y.C. Um, C.H. Kim, G. Lu, D.P. Guo, H.L. Liu, A.A. Bah and A. Mao, 2008. Effect of plant growth regulators, temperature and sucrose on shoot proliferation from the stem disc of Chinese jiaotou (*Allium chinense*) and *in vitro* bulblets formation. *Acta Physiol. Plant*, 30: 521–528
- Yamaguchi, M., 1993. *World Vegetables: Principles, Production and Nutritive Values*, pp: 202–203. AVI. Publication Co. Inc. Westport, Connecticut, USA
- Yamashita, K., Y. Hisatsune, T. Sakamoto, K. Ishizuka and Y. Tashiro, 2002. Chromosome and cytoplasm analyses of somatic hybrids between onion (*Allium cepa* L.) and garlic (*A. sativum* L.). *Euphytica*, 125: 163–167
- Yang, R.Y., S.C.S. Tsou, T.C. Lee, W.J. Wu, P.M. Hanson, G. Kuo, L.M. Engle and P.Y. Lai, 2006. Distribution of 127 edible plant species for antioxidant activities by two assays. *J. Sci. Food Agric.*, 86: 2395–2403
- Yeung, H.C., 1985. *Handbook of Chinese Herbs and Formulas*. Institute of Chinese Medicine, Los Angeles, California, USA
- Yukio, N., M. Saito, and H. Komori, 2005. Breeding of Autumn-flowering Interspecific Hybrids of *Allium*. *Acta Hort.* 673: 141–147
- Zhang, L.J. and S.L. Dai, 2010. Genetic variation within and among populations of *Orychophragmus violaceus* (Cruciferae) in China as detected by ISSR analysis. *Genet. Resour. Crop Evol.*, 57: 55–64
- Zheng, S.J., B. Henken, R.A. de Maagd, A. Purwito, F.A. Krens and C. Kik, 2005. Two different *Bacillus thuringiensis* toxin genes confer resistance to beet armyworm (*Spodoptera exigua* Hubner) in transgenic Bt-shallots (*Allium cepa* L.). *Transgen. Res.*, 14: 261–272

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