Available Online at ESci Journals
International Journal of Entomological Research
ISSN: 2310-3906 (Online), 2310-5119 (Print)
http://www.escijournals.net/IJER

TRENDS IN DEVELOPMENT AND UTILIZATION OF SERICULTURE RESOURCES FOR DIVERSIFICATION AND VALUE ADDITION

[a]Zafar I. Buhroo, [b]Muzafar A. Bhat, [a]Manzoor A. Malik, [a]Afifa S. Kamili, [c]Nazir A. Ganai, [a]Irfan L. Khan

[a] Temperate Sericulture Research Institute,Faculty of Agriculture, Sher-e- Kashmir University of Agricultural Sciences and Technology of Kashmir, Srinagar, India.

[b] Proteomics and Genomics Laboratory, DOS in Sericulture Science, University of Mysore-Mysuru, Karnataka, India.

[c] Division of Animal Genetics and Breeding, Faculty of Veterinary Sciences and Animal Husbandry, Sher-e- Kashmir University of Agricultural Sciences and Technology of Kashmir, Srinagar, India.

A B S T R A C T

Sericulture is an activity where every part can be used for multiple purposes. Sericulture implies significant quantities of secondary and waste products such as perforated silk cocoons, *Bombyx mori* chrysalides, bedding left-over larval dejections and mulberry plant waste, superseded cocoons, surplus mulberry leaf, root and wood biomass, mulberry fruits, mulberry root biomass etc. Therefore, sericulture to produce only silk fabric can now be transformed into the functional industry by applying appropriate methods in processing the secondary and waste products from sericulture, which can double or even triple the farmers' income dramatically as obtained from the main activity of silk cocoon production. Thus, in order to ensure a profitable sericulture activity, it is necessary to process these secondary and waste products generated from different sericulture activities to obtain biologically active substances with important uses in: pharmaceutical, cosmetic, paper and cellulose, and organic agricultural food industries. Realizing the scope of utilizing by-products generated from different sericulture activities, in-depth research towards utility optimization is the prime need in placing the sericulture industry on a sound footing. The review is intended to focus on recent advances in comprehensive utilization, diversification and value addition of sericulture resources in broadening the sustainability of sericulture industry.

Keywords: Byproducts, Diversification, Resources, Sericulture, Trends, Utilization.

INTRODUCTION

Sericulture, an art of the rearing silkworms, is practiced at an economic scale in more than 25 countries all over the globe. Sericulture is an agricultural industry, yielding beside the main product (silkworm cocoons) a series of sub-products and secondary products having exceptional economic value if done properly. The main sericulture product is natural silk fiber. Silk cocoon production is the most important source for sericulture farmers and industries income. Silk Industry provides employment to 30 million families in countries such as China, India, Brazil, Bulgaria, Vietnam, Korea and Thailand (Kim *et al.*, 2010). The sericulture involves a large scale of interdependent technologies from which results differently by products and wastes. These ones may, however, be turned into new commercial products with a high use value. A major concern of the silk industry is the need to make the most efficient use of natural fibers, but also to utilize the waste products. Silk waste itself arises from damaged cocoons or from cocoons, which are difficult to unreel, together with waste fiber from the processes preparatory to spinning. Mulberry is an indispensable crop for silkworm production. The main use of mulberry globally is as feed for the silkworm but, depending on the location, it is also appreciated for its fruit (consumed fresh, in juice, alcoholic drink or as preserves), as a delicious vegetable (young leaves and stems), for its medicinal properties in infusions (mulberry leaf tea), for landscaping and as animal feed etc. In Japan, sericulture had been such an important industry that mulberry was not used for any

* Corresponding Author:
Email: mbhat.muzafar@gmail.com

other purposes. However, with the recent decline of sericulture industry, mulberry has been re-evaluated for other purposes, such as medicinal, fruit and animal production. (Singhal *et al.*, 2005). Currently, the importance of natural products is being revitalized to alleviate various health discrepancies. The link between health and diet is well documented and the consumers' trend reflects conscience towards their dietary habits. Probing these links has led to the emergence of functional, nutraceuticals and pharmafoods, now taking hold over the global nutrition market. Photochemicals in diet could provide protection against several threats like free radical formation, degenerative disorders and lifestyle related diseases but still the role of an array of active ingredients should be unveiled. It has a unique nutritional profile containing proteins, phenolics, flavonoids and anthocyanins that enhances its significance as promising nature's functional tonic. In many of the sericultural countries after the silk reeling, the pupae are thrown away without any utilization though they are rich in proteins (80%), fats, carbohydrates and vitamins. Literature reveals that some studies have been done on the utilization of by - products of the silk industry. However, not enough purposeful work has been carried out on the utilization of secondary wastes of the silk industry, which will definitely enhance the profit of silk industry (Majumder, 1997). From the available scientific studies from China, India and Japan, an attempt has been made to collect the information on the existing status of secondary waste products utilization and processing. Hence, it is necessary to describe an approach for proper utilization of secondary waste products of silk industry *i.e.*, sericin, pupae, moths, silkworm rearing wastes and silk fiber waste from all varieties of silk. The recent trends concerning the utilization of mulberry and silkworm resources for sustainable sericulture reveal the following aspects:

RESOURCES FROM MULBERRY

The mulberry *Morus alba* is renowned as the primary food source for silkworms and is widely cultivated in its native China. According to sources, white mulberry is the species that has been used exclusively in Chinese medicine since A.D- 659. The Morus plant is a rich source of natural isoprenoid substituted phenolic compounds including flavonoids. These compounds have been studied by many investigators with structural, biological and pharmacological interests. Mulberry species are sources of series of isoprenoid - substituted phenolic compounds such as Kwanon G and H which have attracted from researcher's biosynthetic point of view (Nomura and Hano, 1994). The methanolic extract of Morus species has anti-inflammatory, exudative, proliferative and anti-pyretic activities. The stem bark is used as purgative and vermifuge (Singh and Ghosh, 1992). Mulberry extracts or components especially flavonoids i.e. quercetin, rutin and isoquercitrin scavenge free radicals showing potential against oxidative stress. Presence of prenylated flavonoids further strengthened its antioxidant claims. Additionally, these antioxidants provide cardiovascular protection as these inhibit LDL oxidation and thus atherosclerosis. Likewise, some other components such as 1-deoxynojirimycin (DNJ) and Moran 20K have been reported to be effective against hyperglycemia and lipid peroxidation in diabetics. Mulberry leaves as a protein source in food formulations and neuroprotective functions can be used against neurodegenerative disorders such as Alzheimer and Parkinsonism. Furthermore, it also demands special consideration to improve skin tone. Chemopreventive potential has been highlighted in some studies but still, researchers should pay attention to validate the findings to enhance meticulousness.

MULBERRY LEAVES

Mulberry (*Morus spp*.) leaves have long been the traditional feed for the silkworm (*Bombyx mori*). There is evidence that sericulture started about 5000 years ago and hence the domestication of mulberry (Goldsmith *et al*., 2005).

Mulberry leaves as a source of tea: As health is of great concern for people nowadays, many natural ways to take care of one's health is gaining more and more popularity. One of these is having food and beverages made of herbs, and it has been scientifically proved that their equal or better than those made chemically, but have no side effects on health. Mulberry leaves are used for the preparation of decoction known as mulberry tea. Mulberry tea is a very common drink because of its antidiabetic and cholesterol reducing properties. A decoction of leaves is also used as a gargle in infection of the throat. Mulberry leaves used fresh or dried, causes dropping of the blood sugar level and reduction of arterial pressure. The leaves are diaphoretic and emollient. The mulberry crop could be well utilized for the preparation of mulberry tea. The corporate sectors manufacturing the commercial tea may find the possibilities of manufacturing and marketing mulberry tea which may add a new dimension to the sericulture industry.

Mulberry leaves as a source of juice: Mulberry leaves are used to obtain diverse food products (sweet products, bread, refreshment juices, and natural additives. Leaf juice keeps skin smooth, healthy and prevents throat infections, irritations and inflammations. The Leaf juice of Morus species has refrigerant and laxative properties. It is also used as a febrifuge, in diarrhoea, cold, endemic, malaria and amoebiosis (Venkatesh Kumar and Chuhan, 2008).

Mulberry leaves as a source of forage for live-stock: Mulberry has the potential to play a valuable role in world agriculture. It is an extremely versatile plant that can fulfil a number of roles in smallholder agricultural production. Its value is multifaceted and the potential for increasing and diversifying its use is enormous. Even though there have not been conducted any systematic researches on the use of mulberry leaves for the domestic animals feeding. There are many countries where mulberry is utilized traditionally as a feed in mixed forage diets for ruminants, such as in certain areas of India, China, Afghanistan, Bulgaria, Georgia, Azerbaijan etc. In Italy, there have been several studies on the use of mulberry for dairy cows and other domestic animals (FAO, 1993) and in France, a research project was undertaken to introduce mulberry in livestock production (Armand and Meuret, 1995). However, it was only in the 1980s that specific interest in the intensive cultivation and use of mulberry as animal feed started in Latin America. It is surprising that a plant that has been improved for leaf quality and yields to feed the silkworm, which has high nutritional feed requirements, has received such limited attention from livestock producers, technicians and researchers. Mulberry has been shown to have considerable potential for feeding goats, both from the biological and economic points of view since it is well accepted by these animals (Takahashi, 1998). The leaf of *Morus alba* contains 22 - 23% protein and yield leaf human nutrition (Singh and makkar, 2000). Mulberry leaves are relished by sheep and goats and have a high nutritive value with a protein content of about 20 percent of DM (FAO, 1998). Roothaert (1999) observed that dairy heifers had higher voluntary intake, and thus higher potential of milk production when consuming mulberry fodder rather than the cassava tree (*Manihot glaziovii*) and Leucaena (*Leucaena diversifolia*). Mulberry leaves could be considered as an appropriate supplement for sheep fed by a basal diet of ammoniated straw, replacing partially or totally the oilseed meals, which could then be used in monogastric diets. However, there is little information on this subject. The effect of supplementing mulberry leaves adlibitum to concentrate diets of Angora rabbits on wool production has been studied by Singh *et al*., 1984. The results indicated that mulberry leaves could be advantageously incorporated in the diets of Angora rabbits for wool production. Mulberry leaves can also be used in poultry rations. Incorporation of shade-dried mulberry leaves in layers' mash to the extent of 6 percent showed an increase in egg production with desirable yolk colour without any adverse effect on body weight and egg quality (Narayana and Setty, 1977). Mulberry leaves, owing to their high carotene content, can form a valuable source of vitamin A for the health of poultry birds and increased egg production.

Mulberry leaves as a source of medicine: Mulberry leaf contains 13.53 % of protein, 3.53 % of fat and 13.73 % of fibre content. They also contain flavones protein concentration (5 - 6 g/100g fresh). The protein has future supplementary protein food sources for glycosides, astragalin, isoquercitrin, quercetin 3-o (6'- o-acetyl)-beta-D-glycoside. The health giving properties of the mulberry leaf are recognized for its diuretic, blood sugar and blood pressure reducing effects. New pharmacological benefits of the mulberry leaf against serious diseases like Alzheimer's disease, atherosclerosis, hyperlipidemia is reported. Mulberry leaf has sweet, bitter and cold properties (Kayo *et al*., 2000). In Chinese traditional medicine, its function is to clear lung heat (which is manifested as red, painful and watery eyes). It is also used to stop bleeding especially in patients who are vomiting blood. In addition, *in vitro* studies have shown that decoctions from fresh mulberry leaf can inhibit the progress of several bacteria including *Streptococcus aureus* and *Hemolytic streptococcus.* (Grover *et al*., 2002). Studies have reported that mulberry leaf extracts can also play a role in the management and treatment of diabetes. Mulberry leaves could be used for the production of tea and included in some medicines as well. Recent research has shown improvements in elephantiasis (enlargement and thickening of tissues) when treated with leaf extract injections and in tetanus (an acute infectious disease characterized by tonic spasm of voluntary muscles especially of the jaw and caused by the specific toxin of a bacterium (*Clostridium tetani*) which is usually introduced through a wound) following oral doses of the sap mixed with sugar. The leaves are antibacterial, astringent, diaphoretic (increase perspiration), hypoglycaemic (abnormal decrease of sugar in the blood), odontalgic (relating to or marked by toothache) and ophthalmic (relating to, or situated near the eye). They are taken internally in the treatment of colds, influenza, eye infections and nosebleeds. The 1-butanol extract of mulberry leaves inhibits the oxidative modification of low density lipoprotein and prevent against atherosclerosis. The active biomolecules which play a vital role in oxidative modification is Isoquercitrin. Another two new Diels Alder adduct were isolated from callus tissues of leaves of *M. alba* named as Mulberrofuran T and Kwanon E (Hano *et al*., 1989). The leaves of *Morus bombycis* also contain N-methyl- 1 – deoxynojirimycin which is used against diabetes mellitus. This compound also inhibits the infectivity of human immune deficiency virus (Asano *et al*., 1994). Leaf decoction of *Morus australis* is given as a gargle to soothe inflamed vocal cords (Jain and Fillips De, 1991). Evidence suggests that amyloidal beta-peptide (1-42) plays an important role in the aetiology Alzheimer's disease, forming plaques and fibrils disturbing the neuron network in the brain. The result suggests that mulberry leaf extract provides viable treatment against Alzheimer's disease through inhibition of amyloidal beta-peptide (1-42) fibril formation and attenuation of neurotoxicity induced by amyloidal beta- peptide (Iyengar, 2007). Harauma and his co-workers from Kyoto, Japan fed mulberry leaf powder to lipoprotein E-deficient mice. The mice were fed either normal or chow or a diet containing one percent mulberry leaf powder from six weeks of age. A significant increase in lag time of lipoprotein oxidation was detected in mulberry leaf group. The results confirm that mulberry leaf contains an anti-oxidative substance that might help prevent atherosclerosis (Iyengar, 2007). Studies have also shown that mulberry leaves have the potential of controlling Hyperlipidemia. Total flavonoids were isolated from mulberry leaves (MTF) and were evaluated on mice with high cholesterol (Hyperlipidemia) induced by a chemical triton WR-1339. After 12 h, serum lipid levels were reduced significantly. The triglycerides (TG), Total cholesterol (TC), low density cholesterol (LDL-C) were remarkably reduced to 388, 257 and 189 mg in mulberry leaves treated mice compared 540, 464, 299 mg/100ml respectively in the group treated triton WR-1339. The ratios of HDL -C /TC, HDL-C/ LDL -C were increased to 0.42 and 0.57 against 0.33 and 0.52 respectively (Iyengar, 2007). Mulberry 1-deoxynojirimycin (DNJ) is a potent source alpha-glycosidase inhibitor and helpful to establish greater glycemic control in type 2 diabetes. Young mulberry leaves taken from top part of branches in summer contains the highest amount of DNJ. In a human study, DNJ enriched powder of mulberry leaves significantly suppressed elevation of post-prandial glucose. Newly developed DNJ enriched powder can be used as a dietary supplement for preventing diabetes mellitus (Iyengar, 2007).

MULBERRY FRUITS

Mulberry is grown worldwide. Its leaves are used to feed the silkworms which in turn produce silk fiber. Besides using the leaves, mulberry bears sweet fruit. The full-bodied flavor of this fruit is a good balance of sweetness and tastiness with nutrient elements of vital importance for human metabolism. If these fruits are industrially exploited for various commercially valuable products, mulberry can become an important crop throughout the world. Mulberry can be used for making jam, jelly, pulp, fruit drink, fruit sauce, cake, fruit tea, fruit powder, fruit wine, food colourant, diabetes control agent and as ruminant livestock feed. It can also be used in the pharmaceutical industry. It opens a new vista for industrial exploitation of mulberry fruits worldwide. Such a use of the mulberry has been overlooked for the sake of using only mulberry leaf for the sericulture industry.

Chemical composition of mulberry fruit: Mulberry fruit is well known as an esteemed dessert fruit. It contains protein, fat, and minerals like calcium, iron, and potassium, iodine, phosphorous, besides different organic acids like malic acid, nimbic acid, pectin and also a colouring matter. A well ripened fruit has a mouth watering sweet taste with a pleasant flavour. Due to very high nutritional value, mulberry fruits are used for the health benefits of human beings (Singhal *et al*., 2003, 2005ab). Moreover, fruit contains nutrient elements of vital importance in human metabolism (Akbulut and Musazcan, 2009). In black mulberry (*M. nigra*) fruits, there is malic acid in the range of 35.4-198.5 mg/g followed by citric acid (5.5-23.4 mg/g). Tartaric acid, oxalic acid and fumaric acid were at a level of 4.16, 0.62

and 0.019 mg/g, respectively Koyuncu 2004. Analysis of mulberry fruit showed moisture content 8.75%, protein 1.5%, fat 0.4%, carbohydrate 8.3%, fiber 1.4%, mineral matters 0.9%, Calcium 80 mg, phosphorus 40 mg, iron 1.9 mg/100 g, carotene (as vitamin A) 1.74%, thiamine 9 ug, nicotinic acid 0.8 mg, riboflavin 184 ug and ascorbic acid 13mg/100g. The fruits also contain flavonoids, possibly eriodictyol.

Mulberry fruit in the preparation of jams, jellies and sweet products: Mulberry is basically a source of delicious fruit and popular among many countries of the world. Mulberry fruit contains high sugar content and hence used in the preparation of jams, jellies and other sweet products. In recent years, with considerable work on cultivating mulberry plants under various conditions, mulberry fruit juice has been commercially produced as a health beverage, and it has become very popular in China, Japan and Korea. Without adding preservatives, the original juice of mulberry fruit remains fresh under cold storage for 3 months, while the bottled beverage remains fresh at room temperature for about 12 months (Dharmananda, 2008). From one acre of mulberry tree cultivation; which has a spacing of 8 x 9' between tree to tree and row to row, about 1993 kg of fruit jam and 2794 liters of fruit pulp can be prepared in sub-tropical India. The market survey revealed an income of 1063.72 US $ and 1161.70 US $ from the sale of jam and pulp, respectively in Indian markets (Singhal *et al*., 2009ab). Mulberry fruits are used fresh, dried or frozen in the food industry to obtain different syrups, tonic wine, amaretto or vermouth wine, vinegar and different sweet products (marmalade, chocolate, frosting, jelly and fondant), oil from mulberry seeds. Mulberry fruit juice is also used as natural alcoholic extract additive for food and pharmaceutical industries. From the mulberry fruits after alcoholic fermentation and further distillation, it is made a perfect hard alcoholic drink. *Mouro* is the spirit beverage that comes from the distillation of fermented fruits of the mulberry tree (*Morus nigra* L.). *Mouro* is also the Greek common name of this fruit. Usually, it is used for the production of syrups, jams and jellies.

Mulberry fruit as a source of medicine: The mulberry fruits have a long history of medicinal use in old medicine. Sweet and sour in flavour, mild in nature, it is related to the liver and kidney channels. Moistens and tones liver and kidneys, nourishes blood, sharpens vision, produces fluids, quenches thirst, benefits vital energy and eliminates excessive fluids. Mulberry fruit is used for liver-kidney yin deficiency, ringing in ears, dizziness, insomnia, rheumatic pain, premature gray hair, constipation, diabetes. Mulberry fruit can be eaten raw, cooked or used in preserves. A delicious slightly acid flavour, it makes an excellent dessert fruit and can be eaten in quantity. The fruit is juicy and refreshing, though it must be used as soon as it is ripe (from mid-August to September) otherwise it will start to rot. The fruit can also be dried and ground into a powder. Mulberry fruit is rich in carotene, vitamins B1, B2 and C, glucose, sucrose, tartaric acid and succinic acid. The sole use of mulberries in modern medicine is for the preparation of syrup; to add flavours and natural colour in medicines (Singhal *et al*., 2001, 2003). The mulberry fruit is used for many medical purposes such as for balancing internal secretions and enhancing immunity (Venkatesh Kumar and Chauhan, 2008). It is used to treat urinary incontinence, tinnitus, dizziness, constipation, sore throat, depression and fever. The fruits of *Morus alba* have cooling and laxative property and are used in throat infection, dyspepsia and melancholia (Jain and De Fillips, 1991). The juice which is refrigerant is used as a drink in febrile diseases. It checks thirst and cools the blood. The fruit juice is commonly used for reducing high fever as a febrifuge. This is the first treatment normally given to any patient with symptoms of fever during endemic malaria (Shivakumar *et al*., 1995). It is mentioned by Singh (1997) that syrups and recipes prepared from fruits of *M. alba* are used against hyperlipidemia, constipation and insomnia, anti-aging, premonitory and apoplexy. It is further mentioned, that, decoctions prepared from fruits are used against cerebral arteriosclerosis, chronic nephritis, kidney asthenia, central retinitis and nasopharyngeal cancer. Ripened fruit works as a good appetizer and are carminative. Fruits are also used for loss of appetite, flatulence and for controlling intestinal parasites like a tapeworm. Fruits can nourish and promote the production of body fluid. As juice has a faint scent and sweet taste, it is suitable for people of all ages. The fruit of *M. alba* has a cooling and laxative property and are used in the treatment of throat infections, dyspepsia and melancholia. Ripe fruits are appetizer and carminative. Fruits are also used in loss of appetite, flatulence, constipation and intestinal worms like a tapeworm. Syrup of ripe fruits is useful in heart diseases, bleeding disorder, burning sensation, debility and anti-aging. The plant is also a part of the composite drug which is used for the treatment of tonsillitis. The fruits of *M. australis* are used to alleviate fever (Singh, 1997). The milky juice of the fruit of *Morus lavigata* is used as a plaster for sores and cools the blood. The fruits are rich in citrulline and hydroxyprolines. The seeds are rich source of free amino acids. The fruits of *Morus nigra* are one of the constituents of Unani medicine named "Tut- i-aswad" which is said to be against cancer (Ahmad *et al*., 1985). A new UK fruit juice company "Fairjuice" has launched a super fruit drink prepared from pure fresh pressed mulberry fruits which is full of antioxidants. It is also a source of resveratrol which is considered to be beneficial for heart health. It also suppresses the appetite, which is why it has been reported as a useful drink against obesity (Fairjuice, 2008). In Chinese markets, mulberry is often provided in the form of a paste called sangshengao. The paste is mixed in hot water to make a tea to improve the liver and kidney and sharpen the hearing and brighten the eyes. For this application, it is combined with the traditional formula Yiqi Congming Tang, which is used for deficiencies in hearing and vision. In Iran, dried mulberries are used as a sweetener in black tea. After a sip of tea, dried mulberry fruits are eaten to sweeten the mouth. Mulberry fruits can be dried and stored as a powder. About 10 g of dried fruits provides about 100 mg of anthocyanins. As it contains resveratrol, fruit powder works as an anti-mutagen which can inhibit the mutation of healthy normal cells into cancerous cells (Hou, 2003). It is believed to prevent heart disease, cancer and other diseases associated with chronic inflammation. The fruit powder has an anti-aging effect on cells because it combats free radical damage. Fruit powder promotes healthy cholesterol and controls carbohydrate digestion in the human body. Mulberry fruits are reported as antidiabetic with antioxidative properties (Kim *et al*., 1996, 1998). Hong *et al.* (2004) found that mulberry fruit strengthens the antioxidative defense system and reduces damaging oxidative substances in the erythrocytes of diabetes induced rats. The accumulation of a thiobarbituric acid reactive substance (TBARS) is checked.

Mulberry fruit in the preparation of wine: Mulberry fruit is having a high content of vitamin C hence is commonly used for the preparation of special wine and beer in most of the temperate countries. Over-ripened and sour fruits can be converted into mulberry wine (Ehow, 2009). The wine has a sweet and sour taste. A glass of mulberry wine a day helps get rid of impurities and coprostasis (fecal residue in the intestines) in the body which can help make the body slim. The wine made by immersing the mulberry in rice wine or grape wine works as medicine for weakness after diseases that can also be used to notify masculine vitality and benefit overall vitality. In Azerbaijan, Georgia and Armenia, a potent liqueur "Tut araghi" made from mulberry fruit juice is very popular. It is one of the national Azerbaijani versions of vodka. It is believed that a small dose of the drink protects against stomach and heart diseases (Alakbarov and Aliyev, 2000). In Greece, mulberry fruits are used for the production of the traditional aromatic mouro distillate. Soufleros *et al*. (2004) standardized the production process of mouro distillate for its safe use as an alcoholic beverage. Mulberry fruit wine is very popular among ladies as a ladies drink in Europe.

Mulberry fruit as a natural food colourant: Mulberry fruits are rich in anthocyanins and deserve to be exploited for the industrial production of natural colour to be used in the food industry. In particular, it is known to contain cyanin, which contributes to the red pigment that gives the fruit a red to purple colour. The major anthocyanins found are cyaniding-3-glucoside and cyaniding-3-rutinoside. These pigments hold potential for use as dietary modulators, of mechanisms for various diseases, and as natural food colourant (Wrolstad, 2001). As synthetic pigments are unsafe, there is a demand for natural food colourants in the food industry. Since these are water-soluble, they are easily extractable and incorporated into the aqueous food systems. A cheap and industrially feasible method to purify anthocyanins from mulberry fruit has already been established (Liu *et al*., 2004), which could be used as a fabric tanning agent or food colourant of high colour value. It is found that out of 31 Chinese mulberry cultivars tested, the total Anthocyanin content varies from 148 mg to 2725 mg per liter of fruit juice. Total sugars, total acids and vitamins remain intact in the residual juice which can be used for pulp and wine preparation. However, Anthocyanin content depends upon the climate of the area of cultivation. Anthocyanin content is particularly high in dry regions. Tropical sericulture countries could make quite a good profit with the industrial production of anthocyanins from mulberry fruits.

Mulberry fruit as a feed supplement to livestock: Habib (2004) has reported that a multinutrient feed block prepared from mulberry fruits has increased milk production from 30% to 50% in livestock with low disease incidence. It is found that a farmer can earn about the US $ 17-26 per month during the mulberry season from a commercial preparation of mulberry fruit blocks. It is mentioned that the technology of utilizing mulberry fruits as feed blocks for animals can be exploited as an income-generating microenterprise.

MULBERRY ROOTS

The *Morus* species is known especially for the utilization of leaves in sericulture as well as for the utilization of different organs as a prime source for obtaining some of the active pharmacological products. In conformity with plant organs, the chemical composition of vegetal material is different. Mulberry root bark is used in traditional medicine, especially in Asian regions. Modern medicine has confirmed the therapeutic potential of the products obtained from mulberry root bark, products which have a specific pharmaceutical activity. The studies from the last years present the identification and isolation from the mulberry root bark of many chemical compounds of different classes with pharmaceutical activity, which can be used in therapeutics.

Isolates from *Morus alba* root bark: The root bark of *M*. *alba* is a traditional Chinese medicine which is used as medical treatment for cough, asthma and other diseases. The ethanolic extract from the bark displayed activity against HIV which contains flavonoids like Morusin, Mulberrofuran D, G, K and Kuwanon G, H., of which Morusin and Kuwanon H showed positive activity against HIV (Shi *et al*., 2001). A novel stilbene glucoside was isolated from the root bark of *M*. *alba* along with Mulberroside A, Cis-mulberroside A and Oxyresveratrol (Feng *et al*., 1996). Kuwanon G was isolated from ethyl acetate fraction of methanolic extract of *M. alba* which showed antibacterial activity against *Streptococcus mutans, Streptococcus sobrins* and *Streptococcus sanguis* (Park *et al*., 2003). Four new antifungal phytoalexins-Moracin E, F, G and H, Kuwanon D, E, F were isolated from root bark of the host plant and this mulberry plant. The root bark of *M*. *alba* contains Sanggenon alkaloid which inhibited plaque formation. Morusin 4'- glycoside and Kuwanon H show positive activity against HIV. The root bark also contains an alkaloid, Deoxynojirimycin- 1 inhibited glycogenolysis, glycoprotein, processing and saccharide hydrolysis enzymes whereas its derivatives have great therapeutic potential for the treatment of viral infections, diabetes, obesity and cancer (Hughes and Rudge, 1994). *Morus alba* cortex is also one of the constituents of herbal mixture named 'Jiang Qi Ding Chuan San' which has a longer and better bronchodilatory effect in asthmatics. *M. alba* root bark has been found to have an immunomodulating activity. The polyphenols which has been isolated from *M. Alba* root bark with pharmacodynamic activity are: mulberroside C with weak antiviral activity for the virus Herpes simplex type 1; oxyresveratrol with inhibitory effect for enzymes such as cyclooxygenose-2 or mulberroside A with ant oxidative activity. From variety Ichinose root bark have been isolated two polyphenols from the water soluble fractions: ethyl β-resorcylate with antimicrobial activity for all type of fungus and plant's pathogen bacteria and 5,7-dihydroxychromone with selective antimicrobial activity. root of *M. alba* is astringent, and bark is anthelmintic (Bhattari, 1992).

Isolates from *Morus australis* root bark: The roots of *Morus australis* are astringent and anthelmintic whereas the bark is purgative. The plant extracts of *M. australis* were very effective in inhibiting the growth of serotypes C and D of *Streptococcus mutants* and gram + ve bacteria (Chen *et al*., 1989). A new prenylflavonoid australone A (1), triterpenoid 3 beta- [(m-methoxy benzoyl) oxy] urs-12- en-28- oic acid (2), morusin (3), Kuwanon C(4), betunilic acid, beta- amyrin, quercetin ursolic acid, of which Morusin (3) showed a significant role in arachidonic acid, collagen and prenylflavonoid induced platelet aggregation. Mulberrofuran D and phenolic constituents like Sanggenols N and O were isolated from root bark of M. *australis* (Shi *et al*., 2001).

Isolates from *Morus bombycis* root bark: From root bark of *Morus bombycis* was isolated chemical compounds with nitrogen such as polyhydroxylated alkaloids: polyhydroxylated piperidine, polyhydroxyl-non-tropane and polyhydroxy-pyrrolidine alkaloids: 1-deoxynojirimycin which can prevent diabetes and obesity; and glycoproteins such as moron 20K which contains 20% serine and cysteine, the same as insulin. The antioxidant activity and liver protective effect of *Morus bombycis* Koidzumi were investigated. Aqueous extracts of *M. bombycis* Koidzumi had higher superoxide radical scavenging activity than other types of extracts. Mulberry root biomass is a valuable raw material for the pharmaceutical industry, due to its high flavones and phenol content. Root bark having a bitter acid taste possessed cathartic and antihelmentic properties. Root is one of the constituents of the drug named, "Glucosidase" which is used in high blood pressure. Root juice agglutinates the blood and is very useful in killing the worms in the digestive system (Shivkumar *et al*., 1995). The Root is one of the constituents of Chinese drug named "Sohaku-hi" which reduces the plasma sugar level in mice (Hikino *et al*., 1985). The root bark of *Morus bombycis* contains quinones named as Kuwanons G and H with hypotensive activity, phytoalexins like Moracin A-Z and Albanins A -H with anti-microbial activity. From water extract of root bark of *Morus bombycis* koidz, seven compounds namely gamma-amino butyric acid, L-asparagine, L-arginine, L- lysine, choline etc were isolated which are active against microbial and hypotensive activity (Daigo *et al*., 1986).

Isolates from *Morus rubra* root bark: The roots of *Morus rubra* are cathartic or emetic and are used as ant bilious and by a human when passing yellow urine. The bark has antidysenteric, laxative, purgative and vermifuge properties and is used for urinary problems and weakness (Duke, 1992). Four new flavones namely rubraflavones A, B, C and D isolate (Rastogi and Mehrotra, 1990).

Isolates from *Morus nigra* root bark: Root bark of *Morus nigra* contains calcium malate; the bark contains tannins, phytobaphenes, sugar, phytosterol, ceryl alcohol, fatty acids and phosphoric acid. The root bark of *M*. nigra is purgative and vermifuge. Root has an effect on pancreas and glycogenylsis while its juice reduces the blood sugar level in the diabetic patient. The root bark extract contains Deoxynojirimycin (DNJ), an alkaloid which is said to be active against AIDS virus. An infusion of leaves causes a drop in blood sugar (Singh and Ghosh, 1992), sometimes diuresis and a reduction of arterial pressure.

Isolates from *Morus serrata* root bark: The bark of *Morus serrata* contains beta- Amyrin acetate, betunilic acid, cerylalcohol, quercetin and morin (Chemical Abstracts, 1979). Also, there have been isolated, physical-chemical described and pharmacological tested many flavonoids, compounds with classic flavonic structure, such as isoquercitrin, quercetin and morin, or with much more complex structure, such as: phenyl flavonoids, morusin from *Morus nigra*, with analgesic properties, kuwanon G and H, with hyposensitive activity, kuwanon G has also a strong antimicrobial activity for caryogenic bacteria: *Streptococcus sorbinus, S. sanguis* or *Porphyromonas gingivalis*.

Isolates from *Morus macroura* root bark: *Morus macroura* belongs to economically and medically important genus of Morus. Previously, many novel compounds, which were regarded biogenetically as Diel Alder adducts of dehydroprenylphenol and chalcone Cathayanon B which were also isolated from *M. alba*, *M. bombycis* and *Morus lhou*. About 9 compounds have been isolated from its ethanolic extract against oxidative and inflammatory effects which are named as Guangsangons A, B, C, D and E along with four known compounds - Albafuran C, Kuwanon X, P, Y from *Morus macroura*, of which compound Guangsangons A, Albafuran C, Kuwanon X showed good anti-oxidative activity while Guangsangons A, B, D, showed activity against inflammation (Yu- De-Quan *et al*, 2004a). Five Diels Alder Type Adducts named Guangsangons F, G, H, I and J along with two known compounds Mulberrofuran J and Kuwanon J were isolated from ethanolic extract of stem bark of *Morus macroura* which exhibits potent antioxidant and anti-inflammatory activities (Yu De-Quan *et al*., 2004b). The ethanolic extract of stem bark of *M. macroura* results in isolation of Diels Alder Type Adducts Guangsangons K-N together with Mulberrofuran G and K. The new isolated structures showed good anti-oxidant activity (Yu De-Quan *et al.*, 2004c).

Isolates from *Morus cathayana* root bark: *Morus cathayana* the Chinese mulberry tree have several compounds that are actively participating for curing the disease hypertension. On further examination of root bark of *M.cathayana*, five new flavonoids Sanggenols F, G, H, I, J etc. was isolated. The other two new Diel- Alder type adduct, Cathayanon. A and B which resembles compound sanggenon C and O which were also isolated from root bark of *M. cathayana* that plays a vital role in anti-inflammation (Rui-Chao and Lin Mao, 2001). Another four new prenylated flavones namely Sanggenols F-K was isolated from root bark of *M. cathayana* (Toshio *et al*., 1998).

MULBERRY TWIGS BRANCHES AND WOOD STEM

A lot of mulberry branches are left after silkworm rearing. This can be composted successfully, independently or together with other remnants from silkworm rearing and can be used as good organic fertilizer. One of the main sources of non commercial fuel for sericulture farmers are dry mulberry branches after silkworm rearing and mulberry tree wood (Krishna *et al*., 1932). In India near 64 % of generated energy is used for family purposes and part of non commercial fuel is covered by mulberry branches (Chinnaswami and

Haripriprasad, 1995). Mulberry twig branches and wood stem are used in cosmetics – for hair lotions; moisture products for skin, in the paper industry, in the wood processing – for furniture, as fuel, in the food industry – for natural colouring, alcohol ennobling and in the textile industry – for making the so called "artificial cotton". Because tyrosinase catalyzes melanin synthesis, tyrosinase inhibitors are important in cosmetic skin-whitening. Oxidative stress contributes to skin aging and can adversely affect skin health, which means antioxidants active in skin cells may support skin health. The thick stem of mulberry can be used as materials for the preparation of pens and can be used as medium grade fuelwood in rural areas. Thin and soft twigs can be used to prepare baskets; dried twigs along with dried leaves are used in compost. The milky juice exuded by the mulberry is effective against the action of certain bacteria and yeast. Mulberry has the fibre in the part of the bark, the farmers often used instead of rope. The stem bark is used for paper pulp especially in China and Europe. The bark is digested with 14 % caustic soda and 5 % bleaching powder gives a product pulp obtained as white and soft fibre suitable for use in the textile industry. It is the blast fibre of phloem available in the bark, which consists of cellulose, lignin and pentosoan and used in the manufacture of fibre. The bark is used as a parzetive and hermitage as it contains sugar, phytosteros, Cheryl, fatty acids and phosphoric acid. A study was carried out using the appropriate production methods of technical textile from mulberry fiber, the transformation of technical textile from mulberry fiber into lamp products to study the customers 'satisfaction in lamp products. The study revealed that the characteristics of technical textile were good level according to the community products standard and most of the customers were highly satisfied in lamp products of weaving method (Pholam *et al*., 2012). Thus, adding value of the mulberry branches waste by development into textile product such as technical textile from mulberry fiber for art and artifacts. It is the job creation and increases the incomes for the farmers. And it is an approach to the development of new fiber in the textile industry. The mulberry wood is valued mainly for the manufacture of sports goods because of its elasticity and flexibility. The wood piece of mulberry is used in antiseptic treatment, it is compared with teak wood in regard to its resistant ability, strength, hardness, etc. The timber is used to produce hockey sticks, tennis rackets, squash rackets, cricket stumps and bats etc. Wood is also suitable for house construction, agriculture implements, furniture and farmers especially in preker's arms, tools, handles etc. Mulberry woods are also in use to produce tea boxes and toys. The wood is suitable for low grade plywood and for panelling, carving and turnery. Mulberry wood is also used for the construction of small boats and large ships owing to its strength, elasticity, flexibility and durability besides being free from defects. The extracts prepared from mulberry wood are considered suitable for tanning and colouring.

MULBERRY IN PHYTO REMEDIATION

The development of moriculture as an ecological landscape technology shall be an important approach for the sericulture re-launch. There have been put the beginning of using the mulberry for phytoremediation of heavy metal polluted soils. It was detected that regardless of the high contents of lead and zinc estimated in the food, excrements and silkworm body as a whole the contents of heavy metals in the cocoon shells and silk were negligible. Therefore it is concluded that the mulberry silkworm producing system could be used as a biological method of cleaning and utilization of heavy metal polluted soils. There were made researches regarding mulberry plants utilization for phytoregenerable activity (environment decontamination, polluted with traffic Pb), phytopharmaceutical (therapeutic products obtained from mulberry roots, fruits and leaves), agro alimentary production (semi-finished sugar product from mulberry fruit and proteic concentrate out of mulberry leaves). Lately, it was evaluated the economic potential of Morus plants as a regenerable energy source, for an intensive cultivation system.

MULBERRY IN BIOGAS PRODUCTION

Studies have been conducted on the characterization of mulberry leaves for biogas and comparison of these values with other tree foliages (Devarajan, 1999). Degradation of biogas was studied by the *in vitro* gas production technique (Menke *et al*., 1979) showed that the potential biogas production in young leaves was 60.6 ml/200 mg while the rate of degradation was 0.0703. The corresponding values for the mature leaves were 35.4 ml and 0.0624 respectively, indicating the fall in fermentability with maturity. The potential gas production for the young leaves was highest among the forages studied and the rate of biogas production lower compared with only *Moringa oleifera*, suggesting high nutritive value of the young leaves. The fermentability of the mature leaves was also high and comparable with *Leucaena* leaves. The high rate of biogas production for mulberry indicates high intake potential of this forage (Tanase *et al*. 2008).

RESOURCES FROM SILKWORM

SILKWORM EGGS

The silkworm eggs contain 56% albumin, 19.2% fats, 7.7% sugars. They are used as they are, by eating, serving as male sexual stimulator (in popular tradition) as extract, rich in proteins, embryo inductors, glycoprotein's, B1 and B2 vitamins with energizing and hepatic protector action, hypolipidic and hypoglycemic effect. This extract is sold in Romania as the Human fort B product. Silkworm's eggs processed into proteic extract used in the pharmaceutical industry with hepatoprotean action, and also in the food industry. It is believed that the silkworm eggs, if eaten by heavy alcohol drinkers they give up drinking completely because they start feeling alcohol disgust. However, this fact has not been proved scientifically.

SILKWORM LARVAE

The silkworm larvae are used for feeding young animals, reptiles, as proteic flour having the role of dietary supplement; also, as etheric extract having a high bombycisterol (a cholesterol isomer) content; the Florence lily, used as surgical thread. Silkworm larvae from different evolution stages are used as a total proteic extract in the pharmaceutical industry (anti diabetic action) or in the food industry as supplementary nutraceuticals. Traditionally, silkworm has been utilized as a diabetic medicine in oriental countries such as China, Korea, and Japan, and recently many studies have proved the blood glucose-lowering effect of the silkworm. However, a diverse research is urgent to maximize the medicinal effect of the silkworm. Silkworm powder can be easily digested and absorbed by human bodies. It also can promote the physiological functions of the gastrointestinal tract. Furthermore, silkworm powder plays an excellent role in lowering blood-glucose levels. (Ryu *et al*., 1997). The result showed that the maximum blood-glucose lowering effect of the silkworm can be obtained when the silkworm was prepared at the 3rd day of the fifth instar, manufactured by freezing dry method and taken in the form of powder rather than others. Although the powdery silkworm has been proved in its pharmacological mechanism, no study has yet illustrated the major components in the silkworm and their content, which exerts blood glucose-lowering effect, until recent past. However, now the substances are turned out to be the poor blood glucose-lowering substances as well as the major component, DNJ (1-deoxynojirimycin), which are nitrogen compounds. It was also found that the silkworm contains the highest content per gram of DNJ among per gram of silkworm, mulberry leaves, and mulberry fruit, syncarp, suggesting that high concentration of DNJ is accumulated in the silkworm body.

SILKWORM EXTRACT

Silkworms have long been associated with mankind. It is a common fact that the much coveted silk is made from the cocoons of silkworms, which are the larvae of the moth named *Bombyx mori*. In Latin, *Bombyx mori* means silkworm of the mulberry tree. The origin of silk has been traced back to ancient China. It is believed that the source of this fabric was kept a secret by the Chinese people for around 2000 years. (Goldsmith *et al*, 2005). Now, it is no longer a secret and silk is produced in various parts of the world. While most of us are aware of the fact that silk is produced from silkworms, very few know that these larvae have also been used for its so-called health benefits. In fact, silkworms have been used in traditional Chinese medicine for a very long time. This extract is said to contain unsaturated fatty acids, vitamins, proteins, amino acids, cephalic and various other beneficial compounds. It is said to contain male hormones too. All these components make this extract useful in nourishing the endocrine as well as the reproductive system of males. This preparation is said to be effective in boosting sexual desire, especially in males. Silkworm extract is also said to work wonders in treating conditions like migraine, carpal tunnel syndrome, osteoarthritis, rheumatoid arthritis and fibromyalgia. As it is believed to help in retention of moisture by the skin, this extract is also used for curing skin lesions. It is also claimed to be beneficial in treating prostate hyperplasia. Even erectile dysfunction is said to be cured with this product (Qian, 1997). Today, silkworm extract is found as an ingredient in various health supplements. Silkworms are used in medicine in the dried form or as extracts. Such extract has been used in China for a very long time and is said to be prepared through fermentation of silkworm larvae. The moths that emerge from cocoons are also used for preparing silkworm moth extract. Male silk moths are separated from the females, as soon as they emerge from the cocoons. This is done to prevent copulation, which is said to lower the effectiveness of these moths as an aphrodisiac. These male moths are dried, before preserving in alcohol. Later, the extract is prepared from them. These extracts are used as such or in combination with other such supplements like ginseng and cordyceps. The enzyme found in the intestine of silkworms is also said to have numerous health benefits. It is said that this enzyme, named serrapeptase, is good for enhancing blood circulation and in treating arterial plaque. The enzyme is said to act on non living tissues and so, is believed to be beneficial for breaking down arterial plaque, scar tissues, blood clots and cysts. Serrapeptase is claimed to be beneficial for treating inflammatory conditions too (Feng, 2004). In short, extract made from silkworms is claimed to be effective for treating various health problems. However, it is widely known for its aphrodisiac properties. But, so far, there is no conclusive evidence to prove silkworm extract benefits or safety. Most of these products are not reviewed or approved by the FDA. So, it will be always beneficial to seek the opinion of your doctor, before using this product. Another point to note is to use this extract, as per the instructions of a qualified Chinese medical practitioner.

SILKWORM AS A MEDICINE SOURCE

Traditional Chinese medicinal preparations consist of various ingredients, mainly plants and herbs. However, you may also come across some strange ingredients like certain fungi, powdered centipede, cow's gallstones, tiger penis or rhinoceros horn. You may get surprised to know that silkworms are also included in this long list of materials that are said to have medicinal properties (Chen *et al*, 2002a). Dried silkworm larvae (died of white muscardine disease) are used for treating spasms, flatulence and various other conditions. It is said that silkworms that feed on mulberry leaves are found to be have more health effects than the others. While, the extracts from silkworm cocoons are used for medicinal purposes, even the enzymes released by the bacteria that are found in the gut of these larvae are said to be beneficial for treating various health problems. Extracts made from male silk moths is also said to be effective as an aphrodisiac (Chen *et al.*, 2002b).

SILKWORM PUPAE

Pupal protein is a complete protein and the amino acids compositions are with appropriate proportions in line with FAO/WHO standards (Xia and Zhao, 2003; Chen *et al.*, 2002a,b). Moreover, some unsaponifiable ingredients, including b-sterol, cholesterol and campesterol, make up approximately 1% of silkworm pupal fat. Silkworm pupae are an extraordinarily valuable edible animal protein resource.

Chemical composition of silkworm pupa: Pupa contains crude 50 - 60% proteins, 25 - 35% fats, 5-8% free amino acids, 8 – 10% sugars, E, B1, B2 vitamins, calcium, phosphorous, 100 g of dried silkworm pupae can provide 75% daily protein requirement of human individual (Singh and Suryanarayana, 2003). The vitamins like pyridoxal, riboflavin, thiamine, ascorbic acid, folic acid nicotinic acid, pantothenic acid, and minerals like calcium, iron copper, selenium and phosphorus make the pupae more nutritive and also found used for better lactation in tribal women (Koundinya and Thangavaleu, 2005; Roychoudhury and Joshi, 1995; Singh and Suryanarayana, 2003). The silkworm pupae due to their high fat content (over 30%), are used as chrysalis oil to obtain cosmetic products (cream, soap, lotion, emulsion) and as proteic powder for valuable animal's fodder. From the pupae, the following products are obtained. Pupal oil, used in the pharmaceutical industry (anti-inflammatory, anti-tumefying effect, lymphatic circulation stimulant, used in the treatment of sinusitis, otitis, bronchitis, asthma, tuberculosis, urinary infections and in post-surgery situations. In Japan, a product based on chrysalis oil is called Serratiopeptidase; while in China a product is called Gan Mo Le. From the same chrysalis oil, superior sodium and potassium soaps are obtained; varnishes and dyes used in the textile and tannery industry, lubricants, printing inks, plasticizer for PVC are amongst its other uses. The residue formed during the chrysalis oil's extraction is used as natural organic fertilizer and as food for poultry, pigs, and fish and fur bearer animals.

Silkworm pupae as a nutritious and delicious human food: In some Asian countries like Korea, China, Japan, Thailand etc. the silkworm pupae are used as delicious human food. The characteristics like refractive index-1.47 at 30^{o}C, acid value-67.37, safonification value-150.88, iodine value-174.91, cholesterol %- 0.36 of pupa oil made its utility as great prospect in food industry (Choudhury, 2003). Pupal protein is used as raw material for preparing amino acids and flavored products with high nutritive value (Aruga, 1994). In terms of protein, fat, vitamins and calories the silkworm pupae are equal to meat and better than the protein of soya bean, fish or beef and has been found used for better lactation in tribal women (Koundinya and Thangavaleu, 2005; Roychoudhury and Joshi, 1995; Singh and Suryanarayana, 2003). The exoskeleton of pupae contains large amounts of crunchy chitin, which can supplement the cereal diet of rural people. The use of pupae in chocolates, chilli sauce has vast potential for commercializing the concept. Silkworm pupae were eaten by Chinese as food (Roychoudhury and Joshi, 1995) and Pectin, the pupal byproduct used as a thickener in candy, jelly, jam, fruit juices and ice creams (Raju, 1996). Chitin, a component of pupal skin used in different applications like an additive to increase the loaf volume in wheat flour bread and in Japan cakes are prepared and sold as silkworm pupal cakes due to their high nutritive value (Majumder, 1997). In Hong-Kong, China, Korea and Japan the healthy silkworm pupae are sterilized, vacuum dried and sold as commercial food and the cocoon Palade powder was used in soups and sauce preparations (Ramakanth and Raman, 1997). The delicious fry, pakori, chop and cakes are prepared from the eri pre pupae and pupae (Singh and Suryanarayana, 2003). The free amino acids extracted from the cocoon Palade has wide utility in food industries as a cheap source of raw material and the Shinki fibroin, the hydrolyzed by-product from waste silk fiber consumed with milk or coffee (Ramesh *et al.*, 2005). In Africa, the mature larvae of Saturniids used as a garnish in raw, dried and powdered form for human consumption and the roasted pupae, the dried product of pupae, the peaggie are consumed as food in Western United States. The silk protein has wide applications as food and drinks (Kumaresan *et al*., 2007) and could be converted to diet for the crew of Control Ecological Life Support [CELIS], one of the most advanced and complicated closed ecological systems in the world (Dandin and Kumar, 2007).

Diet problems in the space during the extended residence in the space are the key issues. Recent studies have confirmed that silkworm food can provide better nutritional requirements to astronauts during their long term missions in the space owing to its high quality protein content, appropriate proportions of amino acids, unsaturated fatty acids and essential nutrient elements for humans (Yang *et al*., 2002). Japan Aerospace Exploration Agency [JAXA] has released a pupal recipe during 36th Scientific Assembly of the Committee on Space Research [COSPAR] as astronaut food (Velayudhan *et al*., 2008).

Silkworm pupae in bio-medical and pharmaceutical industry: Chitin, a component of pupal skin used in post operational treatments such as conchotomy, deviatory, polypectomy because of its easy usability, less hemophase, greater pain relief and fastens healing of wounds. Chitin found as potent anti-microbial agent against Staphylococcus aureus, Klebsiella pneumoniae, Asppergillus niger etc., anti-fungal against Trichophyton equinum, its buffering activity against acids, as food additive to control carcinogenicity of food stuffs. Chitin also used as immuno-adjuvant (antiviral agent), bacteriostatic, fungistatic, anti-sordes agents in preventing carcinogenic bacteria from teeth and bio-compatible membrane to check bleeding in major surgeries (Katti *et al*., 1996). Silkworm proteins in the form of Serrapeptidase is used in pharmaceuticals for anti-inflammatory, anti-tumefacient action of acute sinusitis, tonsiloctomy, oral surgery, during filling, cleaning and taking out teeth. The artificial fibres and membranes are prepared from pupal proteins are of good use in the medical field (Majumder, 1997). Certain proteins of silkworm and pupae used as special diets for cardiac and diabetic patients because they are easily digestible and reduces cholesterol and blood sugar by providing additional energy (Ramakanth and Raman, 1997). Serrapeptidase, an enzyme derived from silkworm protein was used as non-steroidal anti-inflammatory agents for treating rheumatoid arthritis. The glucosamine extracted from silkworm pupae can be used for treating osteoarthritis (Datta *et al*., 2007). The pupae were used in medicinal wine since ancient days and for lowering fat, BP, blood sugar levels. They also used for treating liver hepatitis, pancreatitis, leukocytopenia, neurological, ophthalmic, anti-bacterial, anti-histaminic, gastric ailments and in preparation of vitamins A, E and K (Velayudhan *et al*., 2008). The silk pupae are the potential base for culturing highly valuable mushrooms fighting cancer with strengthening the immune system and silk fibers can be used for making bioactive textiles due to their anti-bacterial activity (Koundinya and Thangavaleu, 2005). More than 30% of pupae oil is linolenic acid which is the raw material of human DHA exerting an important effect on human intellect and memory improvement, sight-protection and is a precaution chemical against hyperlipoidemia (Lu *et al.,* 1998).

Silkworm pupae in cosmetic and chemical industry use: The silkworm pupae due to their high fat content (over 30%), are used as chrysalis oil to obtain cosmetic products (cream, soap, lotion, emulsion). Pupal skin protein derivative, chitin found used in cosmetic preparations and the absorbent/ resilient hybrid silk films used in wound healing and in de-scarring (Dandin and Kumar, 2007; Katti *et al*., 1996). The silkworm pupal fat and oil is useful in soap/cosmetology industries and found working in anti-aging, darkening gray hair and body weight reduction. The silkworm pupal oil is used in cosmetics like hair oil, face powder, creams and body deodorants (Velayudhan *et al*., 2008). The silkworm pupae oil has got wide uses in oleo chemical and food processing industries. Pupal fat is good raw material in soap, glycerin, cosmetic industries and fertilizer can also be generated from the pupa and pupal excreta. The n-triacontanol, a plant growth promoter is found in good quantities and being extracted from the silkworm. The pupal skin which is available abundantly in the reeling and grainage sectors as waste can be utilized as commercial raw material for various industries (Han *et al*., 2002; Katti *et al*., 1996).

Silkworm pupae as a source of animal feed: Waste silkworm pupae (SWP) generate vast resources of nutrients for livestock and poultry. SWP is one of the unconventional top class protein (65-75%) and lipid. Among many alternative protein sources, SWP are considered as an important dietary protein source for poultry after proper processing at a reasonable cost (Iyengar, 2002). Pupae and silk waste are being used as poultry or fish feed (Iyengar, 2002). The de-oiled pupae fed hens improved their egg laying capacity with impact on the colour of the egg yolk and the fat free pupae used as feed of carps and fish for better yields (Aruga, 1994). Silkworm pupae were used as food in piggery, poultry, and pisciculture and as dog feed due to their richness in protein and fatty acids. The silkworm pupae fed to hybrid magur fish has significantly enhanced growth to fetch 4~5 times more profit and this escalated the dried pupal cost to Rs.13~ 15 per kg from Rs. 2~ 3 (Ghosh, 2005,). The dried pupal feed has enhanced growth rate and egg quality in hens and improved survival rate, feed conversion rate and specific growth rate in fish. The deoiled feed of pupae made rabbits to gain better weight and growth of fur (Velayudhan *et al*., 2008).

SILK MOTHS

The *Bombyx mori* species, result during the technological flux of obtaining silkworm eggs; they are used to prepare pharmaceutical products for trauma and convalescence recovery or to strengthen the masculine functions (by fermentation or extraction of silkworm oils). The butterfly oil contains 75% fatty oils, from which more than 50% are unsaturated fatty acids, having a boiling point of 201°C, iodine index of 132 and volumetric weight of 0.928. The silkworm moth oil can be used to obtain textile dyes and superior soaps. (Gui and Zhuang, 2000). The extraction residue can be used in obtaining of monosodium glutamate or as fodder. The butterflies can also yield Cellular Cytochrome- C for pharmaceutical use, uric acid or hormones and sex messengers of the PTTH (hormone of the central nervous system) and DH type sexual hormone (Gui *et al*., 2001).

SILKWORM LITTER

The remaining materials from silkworm rearing include left over mulberry leaves, twigs and silkworm excreta that can give a very good support to farming community by way of recycling it to high class organic manure and biogas (Sharma and Madan,1992). The silkworm excreta, containing: 7.35% water, 13.88% crude protein, 1.44% raw fats, 15.41% raw cellulose, 47.15% substances without nitrogen; it can be used as organic fertilizer, as chlorophyll source (by alcoholic extraction) or as drug for heart diseases in the traditional Chinese medicine. The silkworm litter is used for the purpose of manure for the ornamental plants in the gardens of Japan. The residuum of silkworm rearing composed of vegetable mulberry remnants and excreta can be used as organic fertilizer (as compost) or in biogas production or fodder for animals during winter. This method is largely used in Japan for feeding sheep, goats and cattle.

SILK PROTEINS -SERICIN AND FIBROIN

Recently, silkworm is being used as biofactory for the production of useful protein using the silk gland, which has promoted the technological development in sericulture. The silk is used in anti-hay fever masks, gauze pads, bandages to treat dermatological disorders, as artificial skin, blood vessels, tendons, ligaments, contact lenses, catheters for surgical procedures and anti-coagulants. Scientists in Korea and Japan have made innovative research on application of silk proteins as basic research material in biological and biomedical fields. The silk and its proteins sericin and fibroin are the highly promising silk proteins, potentially used as bandages to promote wound healing, potential material to fight diabetes, impotence, sinusitis, arthritis, edema, cystitis, epididymitis, tissue regeneration, cancer, post-surgical trauma and used as anti-oxidative, bioadhesives, ultra-violet screens, and moisturizing, anti-wrinkle, anti-aging and bio-active textiles (Dandin and Kumar, 2007). Silk proteins are natural polymers and are biodegradable with reactive functional groups that open up the possibility to be cross linked with other polymers to be used in controlled delivery. Like other common biomedical textiles such as polyester, silk contains various polar functional groups that might enhance antibiotic absorption. The silk derivatives have diversified applications in epidermal recovery, bone formation, drug delivery systems and also in veterinary pharmaceuticals. The silk bio-polymer is used in manufacturing contact lenses, tissue regeneration for treating burn victims and matrix of wound dressing (Ramesh *et al*., 2005). With the above background, silkworm can be classified as a value added biomaterial for medical application, application of silk protein fibroin and sericin as a biomaterial and other seri-byproducts.

Potential applications of silk sericine: Silkworm silk fibers have been the primary silk- like material used in biomedical applications, particularly as sutures. During decades of use, silk fibres have proven to be effective in many clinical applications. Tasubouchi (1999a) developed a silk fibroin-based wound dressing that could accelerate healing and could be peeled off without damaging the newly formed skin. The non-crystalline fibroin film of the wound dressing had a water content of 3-16% and a thickness of 10- 100 μM. Subsequently, the wound dressing was made with a mixture of both fibroin and sericin (Tsubouchi, 1999b). The silk protein, sericin due to its saturation, revitalization and UV ray's absorption properties has got potential as skin moisturizer, anti-irritant, antiwrinkle and sun protector in addition to shaping the hair by making soft and flexible (Kumaresan *et al*., 2007). Silk protein can be made into a biomaterial with anticoagulant properties, by a sulfonation treatment of sericin and fibroin (Tamada, 1997). Kato *et al*. (1998) provided the first evidence of antioxidant action of the silk protein by showing that sericin suppressed in vitro lipid peroxidation. Furthermore, sericin also found to inhibit tyrosinase activity. These results suggested that sericin is the valuable natural ingredient for food and cosmetics. The biopolymer sericin has a strong affinity to keratin. Excessive transepidermal water loss (TEWL) is one of the causes of dry skin and skin moisturizers have been used to overcome it. The silk sericin has resemblance with the natural moisturizing factor (NMR). Sericin gel is prepared by using sericin solution with pluronic and carbopol as a stabilizer to prevent water loss from the upper layer of the skin. It forms a moisturizing, semi-occlusive, protective, antiwrinkle film on the skin surface imparting an immediate, long lasting, smooth, silky feeling (Padamwar *et al*., 2005). The configuration of sericin is very close to the one of human beings. That is why sericin can naturally saturate into skin and revitalize cells. It is discovered that sericin can restrain the functions of active-oxygen (major factor of aging), which brings wrinkles and dark spots. The use of oxygen-permeable membranes from silk fibroin and silk sericin, containing about 60% water for contact lens, artificial skin, etc. The other uses of sericin includes, as a soil conditioner, coagulant for purification of waste waters, hygroscopic moisture-releasing polyurethane foams and their manufacture for furniture and interior materials, as additives for health foods to prevent colon cancers, medical composites of sericin, additives to rice cooking, fabric care compositions, light and sunscreen compositions, foam-forming aerosol shaving gels, sericin-coated powders for cosmetics, as dermatitis inhibitor, as wound prot film, nail cosmetics, and chewing gums (Gulrajani, 2005).Environment - friendly biodegradable polymers can be produced by blending sericin with other resins (Annamaria *et al*.,1998). The Polyurethane foams incorporating sericin are said to have excellent moisture absorbing and desorbing properties (Minoura *et al*., 1995). The moister absorption/desorption rate of the sericin containing polyurethane form is two-to five fold greater than that of control. Other procedures have also been reported for producing sericin-containing polyurethane with excellent mechanical and thermal properties (Hatakeyama, 1996). A membrane composed of sericin and fibroin is an effective substrate for the proliferation of adherent animal cells and can be used as a substitute for collagen. Minoura *et al*., (1995) and Tsukada *et al*., (1999) investigated the attachment and growth of animal cells on films made of sericin and fibroin. Cell attachment and growth were dependent on maintaining a minimum of around 90% sericin in the composite membrane. The film made of sericin and fibroin has excellent oxygen permeability and is similar to the human cornea in its functional properties. It is hoped that the sericin- fibroin blended film could be used to form article corneas (Murase, 1994). A novel mucoadhesive polymer has been prepared by template polymerization of acrylic acid in the presence of silk sericin (Ahn *et al*., 2001). Sericin- coated film is used on the surface of refrigeration equipment because of its anti-frosting action (Tanaka and Mizuno, 2001). Use of the coated sericin film is an effective anti-frosting method that can be widely applied to refrigerators, deep freezers and refrigerated trucks and ships. Moreover, the use of coated film on roads and roof can prevent frost damage. Sericin protein can be coated on surfaces of various durable materials to enhance functionality (Li, 1996). Sericin can be used in the preparation of art pigments and for surface protection of articles. The material coated the sericin have excellent weather ability, good permeability and do not warp on drying. Sericin blends with water-soluble polymers, especially with polyvinyl alcohol (PVA). A blended hydrogel made of sericin and fibroin and PVA is said to have excellent moisture absorbing and desorbing properties and elasticity (Yoshii *et al*., 2000). The hydrogel can be used as a soil conditioner and in medical materials and wound dressing.

Potential applications of silk fibroin: Fibroin has been explored as biomedicine for various applications. Fibroin powder was processed in such a way to retain its natural, optical beauty. A unique property of this silk powder is its ability to hold and release moisture depending on the temperature and humidity of the surroundings. The extremely fine powder (11.3 O sizes) is particularly ideal for applications in pressed powders, blusher, eye makeup, lipstick and nail enamel. Sericin and fibroin have been recently explored in the field of drug delivery systems. Wu *et al*., (1996) studied the properties and application of wound protective membrane made by silk fibroin. It is concluded that the fibroin membrane has good wound healing properties. The fibroin hydrogels prepared either by treating a 2% (w/v) silk fibroin aqueous solution at 4 °C temperature or by adding 30% glycerol could be used as scaffolds able to promote *in situ* bone regeneration (Matta *et al*., 2004). Using fibroin controlled release tablets, gels and mesosphere have been prepared. The applicability of fibroin, a major silk protein, to controlled release type dosage tablets is investigated *in vitro* and *in vivo*. The sulfated silk fibroins have anti-HIV-1 activity in vitro, apparently due to interference with the adsorption of virus particles to CD4+ cells, and completely blocked virus binding to the cells at a concentration of 100 micro gm/ml (Gotoh *et al*., 2000). The silk fibroin can be used as the substratum for the culture of animal cells in place of collagen (Inouye *et al*., 1998). Aslani and Eral, (1994) investigated the uranium recovery from dilute aqueous solutions using silk fibroin. The aqueous solution of fibroin is used to prepare a membrane for immobilization of Aspergillus niger glucose-oxidase and Pseudomonas fluorescens lyophilized cells (Demura *et al*., 1989). Yoshimura *et al*., (1989) reported that the fibroin membrane is used to immobilizing coenzed insect cell culture as a vaccine. Hu, (2006) reported that the Recombinant human-like collagen (RHLC) is blended with fibroin to prepare a novel biocompatible film as a scaffold material for hepatic tissue engineering applications. Solution blending is used to incorporate RHLC with silk fibroin to enhance the blend films biocompatibility and hydrophilicity while maintaining elasticity. Soluble fibroin enhances Insulin sensitivity and glucose metabolism in 3T3-L1 Adiposities. The fibroin protein is one kind of biological materials used for artificial skin and others medical application. Silk fibroin membrane supports the application as photo sensor for hydrogen peroxide analysis. Silk protein sericin, suppress DMBA-TPA induced mouse skin tumorgenesis by reducing oxidative stress, inflammatory responses and endogenous tumor promoter TNF-alpha (Zhaorigetu *et al*., 2003). The insolubilized silk fibroin membrane could be used to separate the mixture of water and alcohol (Chisti, 1998). The silk fibroin peptides are used in cosmetics due to their glossy, flexible, elastic coating power, easy spreading and adhesion characters (Dandin and Kumar, 2007).

SUB PRODUCTS FROM SILK MANUFACTURE

Represented by silk residues, non-usable cocoons or lint. From these, there can be obtained wool and thread of camelhair type (spun silk). silk powder for cosmetic products or for pharmacological amino-acids (glycine, alanine, serine, tyrosine, aspartic acid, glutamic acid). Silk wastewater from the reeling mill, containing soluble silk (sericine). By products and waste resulted in the eggs production and silk cocoons proceeding may be used in textile, leather, pharmaceutical, cosmetics as food industries as a proteic, atomizated or lyophilized powder (Singh and Benchamin. 2001). From these silk residues, the raw materials obtained are: proteic gels; proteic precipitates with inorganic salts; microfibers; atomized proteic powders; lyophilized proteic powders; proteic agents used for textiles and leathers' finishing;

hydrolyzed silk protein (as polypeptide is used for cosmetic ingredients; they excellent perform as moisturizer, smoother and protector for both skin and hair, applied technology of hydrolyzed protein up to now).

SILK COCOONS IN ART CRAFT USES

The eye catching art of cocoon craft is one of the very interesting utility of by-products which will give scope to develop human skills in addition to generating self employment and revenue. The value addition in post cocoon sectors is estimated to generate income ranging from 10 to 25% in total returns. Different articles like garlands, flower vase, wreath, pen stand, dolls, jewellery, wall hangings, wall plates, clocks, bouquets and greeting cards are being prepared using the waste silk cocoons (Vathsala, 1997). In Japan some laboratories have produced silk paper in different colours for making craft articles like flowers and lamp stands. The silk leather, a paint containing silk powder is used to decorate plastics, steel and fabrics. The hybrid silk, net raw silk, silk tow and silk wave were produced in Japan for making undergarments, jackets, sweaters, carpets and furnishings (Singh *et al*., 2002).

CONCLUSION

Proper utilization of secondary and waste products of sericultural industry can generate extra income in addition to the silk, the main output. The major wastes and by products of sericulture are sericin, pupae, moths, silkworm excreta, silk fiber waste and mulberry leaves, fruits and roots. The effective utilization of these waste products for value addition is a must for placing sericulture on sound footing. The new commercial products have been obtained from these raw materials with the valuable destination for pharmaceutical (antidiabetic, antiviral, hypoglycemic, hypotensive, antibacterial and antivirus products), cosmetic (skin and hair products), zootechnic (fodder for rabbits, goats, poultry, swine, sheep and fur animals), foodstuff (oil, juice, marmalade, wine, fruit distillate, vinegar, dried fruit powder, natural colouring) and ecological (landscape, phytoremediation) importance. Mulberry tree forage is well accepted by ruminants, pigs, poultry and rabbits. There is a dire need for systematic research on the optimization of the use of this tree forage and for developing strategies for its optimum supplementation under different feeding situations. The promotion of mulberry should be viewed in the context of a holistic farming systems approach with the aim of increasing farmers' incomes, generating employment and conserving the environment. This is also an attractive option to achieve an integration of silk production and livestock rearing. Acceptance of these strategies could reduce the need for land clearing and pasture establishment in the fragile areas of the world that are prone to erosion following clearing. It is evident that a large number of active biomolecules that are present in different species of mulberry provides an altogether new world for life enhancement as they possess a high degree of health and therapeutic values. Thus, mulberry could be explored and exploited further for enhancing the life potential among all. The high protein content and carbohydrate contents of mulberry leaves and protein and oil content of silkworm pupae have proved to be the best source of diet supplement for both human and livestock. To develop the technique for utilizing of silkworm protein as livestock or poultry feed would partly meet the protein deficiency in the country. Considering the high potential of utilizing the sericulture resources, the research institutions in sericulture advanced countries should pay more attention in doing research in this field in order to create new valuable items, utilizing the vast available mulberry and silkworm germplasm resources. The development of sericultural in this direction may be considered as an alternative way to solve partly the problem with the decline of silk production and the efficient utilization of the existing sericultural human capacity, research and production facilities.

REFERENCES

Ahmad, J., A.H. Farooqui and T.O. Siddiqui. 1985. *Morus nigra*. Hamdard Medicine: 15: 76-78.

Ahn, J.S., H.K. Choi, K.H. Lee, J.H. Nahm and S. Cho. 2001. Novel mucoadhesive polymer prepared by template polymerization of acrylic acid in the presence of silk sericin. *Journal of Applied Polymer Science*. 80: 274–280.

Akbulut, M and M. Musazcan. 2009. Comparison of mineral contents of mulberry (Morus spp.) fruits and their pekmez (boiled mulberry juice) samples. *International Journal of Food Science and Nutrition* 60: 231-239.

Alakbarov, F and I. Aliyev. 2000. Silk Road – The origin of the mulberry trees. *Azerbaijan International* 8: 3.

Annamaria, S., R. Maria, M. Tullia, S. Silvio and C. Orio. 1998. The microbial degradation of silk: a laboratory investigation. *International Biodeterioration and Biodegradation*. 42: 203– 211.

Armand, D. and M. Meuret. 1995. Selection and utilization of cultivated fodder trees and shrubs in Mediterranean extensive livestock production systems. *Avignon, France, Institutitute National de la Recherche Agronomique.* Rapport Final (1991-1994).

Asano, N., E. Tomioka, H. Kizu and K. Matsu. 1994. *Carbohydrate Research*. p. 253.

Aslani, M.A. and M. Eral. 1994. Investigation of uranium recovery from dilute aqueous solutions using silk fibroin. *Biological Trace Elements Research*. 43: 737-743.Bhattari, N. K. 1992. Folk anthelmintic drugs of central Nepal. *International Journal of Pharmacognosy*. 30:145.

Chemical Abstracts. 1979. 91: 35740.

Chen, C.P., C.C. Lin and T. Namba. 1989. Screening of Taiwanese crude drugs for antibacterial activity against Streptococcus mutans. *Journal of Ethnopharmacology.* 27(3):285-95.

Chen, Y.G., M. Zi, L.N. Hai and Y. Zhang. 2002b. Analysis of amino acids from silkworm chrysalis. *Yunnan Chemical Technology*. 6:22–23.

Chen, Z., S. Liao, Q. Li, L. Chen, Y. Wu and X. Yao. 2002a. Study on multivoltine yellow blood silkworm for edible and medicine utilization. *Silkworm Science*. 28: 73–76.

Chinnaswami, K and K. Haripriprasad. 1995. Fuel energy potentiality of mulberry. *Indian Silk*, 8: 15-17.

Chisti, Y. 1998. Strategies in downstream processing; in Bioseparation and bioprocesssing: a handbook. G. Subramanian (ed). New York: Wiley-VCH. pp. 3–30.

Daigo, K., Y. Inamori and T. Takempto. 1986. Studies on constituents of water extract of root of mulberry tree Morus bombycis. *Chemical Pharmaceutical Bulletin*. 34(5): 2243.

Dandin, S.B. and S.N. Kumar. 2007. Bio-medical uses of silk and its derivatives. *Indian Silk*. 45(9): 5-8.

Datta, R.N., A. Sarkar and S. K. Das. 2007. Glucosamine from Eri silkworms. *Indian Silk*. 46(2): 22.

Demura, M., T. Asakura and T. Kuroo. 1989. Immobilization of biocatalysts with *Bombyx mori* silk fibroin by several kinds of physical treatment and application to glucose sensors. *Biosensors*, 4: 361-372.

Devarajan, S. 1999. Effect of tannins on the ruminal degradation kinetics of locally available tree forages. Izatnagar, India I. RI Deemed University.

Dharmananda, S. 2008. Fruit as medicine – Morus fruit (Mulberry). Institute for traditional medicine, Portland, Oregon, USA, pp. 1-7.

Duke, J.A. 1992. Handbook of edible weeds, CRC Press Inc, USA. p. 128.

Ehow 2009. How to make mulberry wine. Food and Drink. www.eHow.com.

Fairjuice. 2008. Superfruit mulberry juice. *Food and Beverage International* 13: 4.

FAO. 1993. Possibility of combined utilization of *Morus alba* and *Trifolium subterraneum* in the Tuscan Maremma (Italy). In Management of mediterranean shrublands and related forage resources. *REUR Technical Series Rome* .28: 206-209.

FAO. 1988. *Mulberry cultivation*. *FAO Agricultural Services Bulletin Rome*. (73/1):27.

Feng, P. 2004. The study of structure and edibility of silk protein. Food Research Development. 25: 51–54.

Feng, Q., K. Kenchi, K. Kanko, S. Kenchi, Y. Xinsheng and K. Yoshihro. 1996. A Novel Stilbene Glucoside, Oxyresveratrol 3′ -O-β-Glucopyranoside, from the Root Bark of Morus alba. *Plant Medica*. 62(06): 559-561.

Ghosh, M.K. 2005. Utilization of silkworm pupae in pisciculture. *Indian Silk*. 44(6): 11.

Goldsmith, M.R., T. Shimada, and H. Abe. 2005. The Genetics and Genomics of the Silkworm, *Bombyx mori*. *Annual Reviews Entomology* 50: 71-100.

Gotoh, K., H. Izumi, T. Kanamoto, Y. Tamada, H. Nakashima. 2000. Sulfated fibroin, a novel sulfated peptide derived from silk, inhibits human immunodeficiency virus replication in vitro. Bioscience *Biotechnology Related Articles, Books Biochemistry*. 64: 1664-1670.

Grover, J.K., S. Yadav and V. Vats. 2002. Medicinal plants of India: *A review Journal of Ethnopharmacology* 81(1):81-100.

Gui, Z. and D. Zhuang. 2000. Study on the silkworm powder and its physiological functions. *China Sericulture*. 2: 53–54.

Gui, Z., Chen, J., Chen, W and Zhuang, D. 2001. Effect of silkworm powder (SP) lowering blood-glucose levels in mice and its mechanism. *Science Sericulture.* 27: 114–119.

Gulrajani, M.L. 2005. Sericin: A Bio-molecule of value. *Souveni 20th congress of the international sericultural commission*, Bangalore, India 15-18th December 2005. pp. 21-29.

Habib, G. 2004. Mulberry fruit based feed blocks – a key supplement for livestock in mountainous regions.

Mountain Research Development. 24: 106-109.

Han, S.M., Y.S. Suk, H.J. Baek, H.R. Park and M.S. Han 2002. Effects of silkworm extract on streptozotocin – induced diabetic rats. *International Journal of Industrial Entomology*. 5:201-204.

Hano, Y., T. Nomura and S. Ueda. 1989. Two new diels alder type adducts Mulberrofuran T and Kwanon E from callus tissue of *Morus alba*. *Heterocycle.,* 29: 10.

Hatakeyama, H. 1996. Biodegradable sericin-containing polyurethane and its production. *Japan Patent* 08-012738A.

Hikino, H., Mizuno, T., Oshima, Y., Konno, C., 1985. Isolation and hypoglycemic activity of Morans A, a glycoprotein of Morus alba root barks. *Planta Medica* 51:159–160.

Hong, J.H., J.M. Ahn, S.W. Park and S.J. Rhee. 2004. The effects of mulberry fruit on the antioxidative defense systems and oxidative stress in the erythrocytes of streptozotocin-induced diabetic rats. Nutritional Science. 7: 127-132.

Hou, D.X. 2003. Potential mechanisms of cancer chemoprevention by anthocyanins. Current. Molecular Medicine. 3:149-159.

Hu, K. 2006. Biocompatible Fibroin Blended Films with Recombinant Human-like Collagen for Hepatic Tissue Engineering. *Journal of Bioactive and Compatible Polymers*. 21: 23-37.

Hughes, A.B and A.J. Rudge. 1994. Deoxynojirimycin: Synthesis and Biological actitivity *Natural Product Reports* p 135.

Inouye, K., M. Kurokawa, S. Nishikawa and M. Tsukada. 1998. Use of *Bombyx mori* silk fibroin as a substratum for cultivation of animal cells. *Journal of Biochemical and Biophysical. Methods*. 18:159-164.

Iyengar, M.N.S. 2002. Recycled silk wastes as feed integrated for poultry. *Indian Silk*. 41(5): 30.

Iyengar., M. N. S. 2007. Research Beliefs. Indian silk, July, 29.

Jain., S.K and A. De Fillips. 1991. Medicinal plants of India, Reference Publication, Inc., Algonac Michigan. 2: 438.

Kato, N., S. Sato, A. Yamanaka, H. Yamadam, N. Fuwam and M. Nomura. 1998. Silk protein, sericin, inhibits lipid peroxidation and tyrosinase activity. Biosciences Biotechnology and Biochemistry. 62: 145–147.

Katti, M.R., R. Kaur and S. Gowri. 1996. Pupa skin – A useful waste. *Indian Silk*. 35(4&5): 5-8.

Kayo, D., K. Takashi and F. Yasuo. 2000. Mulberry Leaf Extract Inhibits the Oxidative Modification of Rabbit and Human Low Density Lipoprotein. Biological and Pharmaceutical Bulletin. 23(9):1066-71.

Kim, K.Y., P.D. Kang, K.G. Lee, K. Hyung, M.J. Kim, K.H. Kim, S.W. Park, S.J. Lee, B.R. Jin and I. Kim. 2010. Microsatellite analysis of the silkworm strains (*Bombyx mori):* high variability and potential markers for strain identification. *Genes & Genomics* 32: 532-543.

Kim, S.Y., K.J. Park and W.C. Lee. 1998. Anti-inflammatory and antioxidative effects of Morus spp. fruit extract. *Korean Journal of Medicinal Crop Sciences*. 6: 204-209.

Kim, T.W., Y.B. Kwon, J.H. Lee and I.S. Yang. 1996. A study on the antidiabetic effect of mulberry fruits. *Korean Journal of Sericulture* Science. 38: 100-107.

Koundinya, P.R. and K. Thangavaleu. 2005. Silk proteins in biomedical research. *Indian Silk*. 43 (11): 5-8.

Koyuncu, F. 2004. Organic acid composition of native black mulberry fruit. *Chemistry of Natural Compounds* 40: 367-369.

Krishna, P., S. Banna and T. Gusheelama. 1932. Calorific value of mulberry shoots. Indian Journal of agriculture. 2: 36-40.

Kumaresan, P., R.K. Sinha and S.R. Urs. 2007. Sericin – A versatile by-product. *Indian Silk*. 45(12):11-13.

Li, X. 1996. Usages of sericin in durable material. *China patent*.1116227A.

Liu X., G. Xiao, W. Chen, Y. Xu and J. Wu. 2004. Quantification and purification of mulberry anthocyanins with macroporous resins. *Journal of Biomedicine and Biotechnology*. 5: 326-331.

Lu, P., B.S. Lai and X.L. Yan. 1998. Purification and determination of a-Linolenic acid in silkworm pupa by urea adduction fractionation method. *Chinese Journal of Pharmaceutical Analysis*. 18 (6), 390–393.

Majumder, S.K. 1997. Scope for new commercial products from sericulture. *Indian Silk*. 35(12):13-18.

Matta, A., C. Migliaresi, F. Faccioni, P. Torricelli, M. Fini and R. Giardino. 2004. Fibroin hydrogels for biomedical applications, preparation, characterization and in vitro cell culture studies. *Journal of Biomaterial Science Polymer Edition*. 15:851-864.

Menke, K.H., L. Raab, A. Salewski, H. Steingass, D. Fritz and W. Schneider. 1979. The estimation of the digestibility and metabolizable energy content of ruminant feedstuffs from the gas production when they are incubated with rumen liquor *in vitro. Journal of Agriculture Sciences*. 92: 217-222.

Minoura, N., S. Aiba, Y. Gotoh, M. Tsukada and T. Imai.

1995. Attachment and growth of cultured fibroblast cells on silk protein matrices. *Journal of Biomedical Material Research*. 29: 1215-1221.

Murase, M. 1994. Method for solubilizing and molding cocoon silk, artificial organ made of cocoon silk, and medical element made of cocoon silk. *Japan Patent* 06- 166850A.

Narayana, H. and S.V.S. Setty 1977. Studies on the incorporation of mulberry (*Morus indica*) leaves in layers mash on health, production and egg quality. *Indian Journal of Animal Science.* 47: 212-215.

Nomura, T. and Y. Hano. 1994. Isoprenoid subsituted Phenolic compounds of Moracious plants. *Natural Product Reports*. p.205.

Padamwar, M.N., A.P. Pawar, A.V. Daithankar and K.R. Mahadik. 2005. Silk sericin as a moisturizer an in vivo study. *Journal of Cosmetics and Dermatology*. 4: 250-257.

Park, K.M., J.S. You, H.Y. Lee, N.I. Baek and J.K. Hwang. K. 2003. Kuwanon G: an antibacterial agent from the root bark of Morus alba against oral pathogens. *Journal of Ethnopharmacology*. 84(2-3):181-5.

Pholam, K., C. Sakorn and K. Uraiwan. 2012. Development of transformation textile products from mulberry fiber. RMUT*P* International Conference: Textiles & Fashion. July 3-4, 2012, Bangkok Thailand.

Qian, J. 1997. The chemical constitution and utilization of silkworm pupae. *Science Technology and Food Industry*. 5: 42–43.

Ramakanth and K.V.A. Raman. 1997 Cocoon Pelade for better health. *Indian Silk*. 35(8&9): 35.

Ramesh, S., C.S. Kumar, S.V. Seshagiri, K.I. Basha, H. Lakshmi, C.G.P. Rao and Chandrashekaraiah. 2005. Silk filament its pharmaceutical applications. *Indian Silk*. 44(2): 15-19.

Rastogi, K. and M. Mehrotra. 1990. Compendium of Indian medicinal plants. PID, New Delhi, 1: 280.

Roothaert, R.L. 1999. Feed intake and selection of tree fodder by dairy heifers. *Animal Feed Science. Technology*. 79(1-2): 1-13.

Roychoudhury and K.C. Joshi, 1995. Silkworm pupae as human food. *Indian Silk*. 34(3): 10.

Rui, C.S and L. Mao. 2001. Diels Alder Type Adducts from Morus cathayana *Phytochemistry*. 57:1231.

Ryu, K.S., H.S. Lee and R.W. Choue. 1997. An activity of lowering blood-glucose levels according to preparative condition of silkworm power. *Korean Journal of Sericulture Sciences*. 39:79–85.

Sharma, S and M. Madan, 1992. Optimal utilization of ericulture waste. Resource Conservation. And Recycling. 7: 295–304.

Shi, Y.Q., T. Fukai, H. Sakagami, W.J. Chang, P.Q. Yang, F.P. Wang and T. Nomura. 2001. Cytotoxic flavonoids with isoprenoid groups from Morus m ongolica. *Journal of Natural Products*. 64: 181–188.

Shivakumar, G.R., K.V. Anantha Raman, S.B. Magadum and R.K. Datta. 1995. Medicinal values of mulberry. *Indian Silk* 34: 15-16.

Shivkumar, G.R., K.A. Raman, S.B. Magadum and R.K. Datta. 1995. Medicinal value of mulberry. *Indian Silk*, 34: 15-16.

Singh K. P, Ghosh PL (1992). Methanolic extract of Morus species. *Indian silk*. 31:16.

Singh, K.P., P.L. Ghosh. 1992. Mulberry cultivation under agro forestry and land management, *Indian silk.* 31:16.

Singh, B. and H.P.S. Makkar. 2000. The potential of mulberry foliage as feed supplement in India. In: Mulberry for animal production (Ed. M. D. Sanchez). Animal Health and Production Paper No. 147. FAO, Rome, Italy. pp. 139-153.

Singh, B., G.C. Goel and S.S. Negi. 1984. Effect of supplementing mulberry (*Morus alba*) leaves *ad libitum* to concentrate diets of Angora rabbits on wool production. *Journal of Applied Rabbit Research*, 7: 156-160.

Singh, K.C. and K.V. Benchamin. 2001. Eri: Product diversification pays. *Indian silk*. 40(1): 11-15.

Singh, K.C. and N. Suryanarayana. 2003. Eri pupae A popular cuisine too. *Indian Silk.* 41(12): 57-58.

Singh, K.P. 1997.Medicinal properties of mulberry: a review. Indian Drugs 34:488-492.

Singh, R., G.V. Kalpana and T. Yamamoto. 2002. Modern trends in Japanese sericulture research. *Indian Silk*. 40(12): 17-20.

Singhal, B.K., A. Dhar, B.B. Bindroo, P.M. Tripathi, S.M.H. Qadri and M.M. Ahsan. 2003. Medicinal utilities of mulberry and non-mulberry food plants of the silkworm. In: Recent Progress in Medicinal Plants, Vol. 8, Phytochemistry and Pharmacology II. Studium Press LLC, USA, pp. 477-500.

Singhal, B.K., A. Dhar, M.A. Khan and B.B. Bindroo. 2005a. Utilization of sericultural byproducts as urgent need for sustainable sericulture. In: Govindan R., Ramakrishna Naika, Sannappa B. and Chandrappa D. (eds), Progress of Research in Organic Sericulture and Seri byproduct Utilization, *Seri Scientific Publishers, Bangalore*, pp. 211-226.

Singhal, B.K., A. Dhar, A. Sharma, S.M.H. Qadri and M.M. Ahsan. 2001. Sericulture by-products for various valuable commercial products as emerging bio science industry. *Sericologia* 41: 369-391.

Singhal, B.K., M.A. Khan, A. Dhar and B.B. Bindroo. 2009b. New vistas for industrial exploitation of mulberry fruits in horticulture industry. Paper presented in International Conference on Horticulture (ICH-2009), PNASF, VEGINET, UAS, Bangalore, India, Abst. 1.4-O6, p. 249.

Singhal, B.K., A. Dhar, M.A. Khan, D. Sengupta and S.L. Dhar. 2005b. Mulberry by-products utilization for sustenance of sericulture industry of Jammu and Kashmir. Proc. The 20th Congress of the International Sericultural Commission, Central Silk Board, Bangalore, pp. 152-156.

Singhal, B.K., A. Dhar, M.A. Khan and B.B. Bindroo. 2005a. Utilization of sericultural byproducts as urgent need for sustainable sericulture. In: Govindan R., Ramakrishna Naika, Sannappa B. and Chandrappa D. (eds), Progress of Research in Organic Sericulture and Seri byproduct Utilization, Seri Scientific Publishers, Bangalore, pp. 211-226.

Singhal, B.K., A. Dhar, B.B. Bindroo, P.M. Tripathi, S.M.H. Qadri and M.M. Ahsan. 2003. Medicinal utilities of mulberry and non-mulberry food plants of the silkworm. In: Recent Progress in Medicinal Plants, Vol. 8, Phytochemistry and Pharmacology II. Studium Press LLC, USA, pp. 477-500.

Singhal, B.K., A. Dhar, M.A. Khan, B.B. Bindroo and R.K. Fotedar. 2009a. Potential economic additions by mulberry fruits in sericulture industry. *Plant Horticulture Technology*. 9: 47-51.

Soufleros, E.H., A.S. Mygdalia and P. Natskoulis. 2004. Characterization and safety evaluation of the traditional Greek fruit distillate "mouro" by flavor compounds and mineral analysis. *Food Chemistry* 86: 625-636.

Takahashi, R. 1998. Sericicultura: Amoreira (*Morus alba* L.) Bicho da Seda (*Bombyx mori* L.). Jaboticabal: FCAV UNESP, 135 p. (Apostila).

Tamada, Y. 1997. Anticoagulant and its production. *Japan Patent* 09-227402A.

Tanaka, K. and S. Mizuno. 2001. Homologues of fibroin L-chain and P25 of *Bombyx mori* are present in Dendrolimus spectabilis and Papilio xuthus but not detectable in Antheraea yamamai. *Insect Biochemistry and Molecular Biology*. 31: 665-677.

Tanase, D., C. Glavan, M. Constantinescu, E. Pau, C. Ungureanu. 2008. The SWOT method for energetic potential of Morus biomass plants. *International conference, Bucharest*, July, 2008.

Toshio, F., Y.H. Pei, N. Taro, C.Q. Xu, L.J. Wu and Y.J. Chen. 1996. Components of the root bark of Morus cathayana. 1. Structures of five new isoprenylated flavonoids, sanggenols A - E and a diprenyl-2-arylbenzofuran, mulberrofuran V. Heterocyles. 43(2): 425-436.

Tsubouchi, K. 1999a. Wound covering material. *US patent* 5951506.

Tsubouchi, K. 1999b. Occlusive dressing consisting essentially of silk fibroin and silk sericin and its production. *Japan Patent* 11-070160A.

Tsukada, M., S. Hayasaka, K. Inoue, S. Nishikawa and S. Yamamoto. 1999. Cell culture bed substrate for proliferation of animal cell and its preparation. *Japan Patent* 11-243948A.

Vathsala, T.V. 1997. Creativity in cocoon crafts. *Indian Silk*. 36(2): 17-22.

Velayudhan, K., N. Balachandran, R. K. Sinha and C. K. Kamble. 2008. Utility of silkworm pupae: A new dimension as food and medicine. *Indian Silk*. 47(1): 11-18.

Venkatesh Kumar, R. and S. Chauhan. 2008. Mulberry: Life enhancer. *Journal of Medicinal Plant Research*. 2: 271-278.

Wrolstad, R.E. 2001. The possible health benefits of anthocyanin pigments and polyphenolics, Linus Pauling Institute, Oregon State University.

Wu, C.Y., B.Z. Tian, D. Zhu, X.M. Yan, W. Chen and G.Y. Xu. 1996. Properties and application of wound protective membrane made from fibroin. *In International silk congress, Suzou Institute of silk technology,* Suzou, China, 25-28th October. pp 79-87.

Xia, W. and D. Zhao. 2003). The chrysalis of silkworm synthesizes to develop the present condition and technique. *Journal of Shaanxi Normal University* (Natural Science Edition) 31: 265–269.

Yang, H.X., X.R. Zhu and Z.M. Fang. 2002. Research progress of the exploitation and utilization of the silkworm's excretion. *Bulletin of Sericulture* 3: 9–13.

Yoshii, F., N. Kume, K. Makuuchi and F. Sato. 2000. Hydrogel composition containing silk protein. *Japan Patent* 06-017373A.

Yoshimura, T., Y. Shimizu, W. Kurotani, R. Yamaoka and K. Hayashiya. 1989. Application of fibroin membrane to immobilizing coenzed insect cell culture for use as vaccine. *Agriculture and Biological Chemistry* 52: 3201-3202.

Yu, D.Q., S.J. Dai, Z.B. Ma, Y. Hiu and R.Y. Chen. 2004b. Guangsangons F-J, antioxidant and anti-inflammatory Diels- Alder Type adducts, from Morus macroura. *Phytochemistry*. 65(3):135.

Yu, D.Q., S.J. Dai, Z.B. Ma, Y. Hiu and R.Y. Chen. 2004a. New Diels alder type adducts form Morus macroura and their anti-oxidant activities. *Chemical Pharmaceutical, Bulletin.* 52(10):1190.

Yu, D.Q., J. Kang and Y. Ruo. 2004c. Bioactive Diels Alder Type Adducts from Stem bark of Morus macroura. *Planta Medica*. 70:758.

Zhaorigetu, S.N., M. Sasakim, H. Watanbe and N. Kato. 2003. Silk protein, sericin, suppresses DMBA-TPA induced mouse skin tumorigenesis by reducing oxidative stress, inflammatory responses and endogenous tumor promoter TNF-alpha. *Oncology Reports*. 10: 537-543.