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## Review Article

# Agro-Based Sericulture Wastes for the Development of Rural Based Industry in India

**SK Nuri*[1], Somdip Majumdar[2] and Salil Raha[3]**

[1]Department of Sericulture, Raiganj University, Raiganj, North Dinajpur, West Bengal 733134

[2]Krishnath College, Department of Sericulture,University of Kalyani, Berhampore, Murshidabad, West Bengal 742101

[3]Departmentof Sericulture, Murshidabad University, Berhampore, Murshidabad, West Bengal-742101

*Corresponding author: sknuri007@gmail.com

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**Abstract**: Sericulture mainly aims towards the production of high quality silk yarn from mulberry and non-mulberry silkworms. These insects belong to two different families of the order Lepidoptera, named as *Bombycidae* and *Saturniidae* as per host plants concern. Commercial production of silk is dependent primarily on three major steps: the cultivation of larval food plants, rearing of silkworms for cocoon formations and reeling processes for obtaining raw silkyarn.To perform all these activities successfully and profitably thus obtaining a number of organic wastes commonly known as seri-wastes. It is interesting to note that any kind of sericulture practising wastes can be a part of valuable utilisation in our life and for which additional income sources have been secured to the sericulture farmers, reelers and weavers too. It is well established that wastes generated during various steps in sericulture can also be recycled and reused appropriately. Mulberry sericulture is managed by rural populations whereas non-mulberry sericulture is easily handled by tribal communities. So, both the agro based productive bioresources will definitely inspire to build rural based industries in our country for better livelihood in these areas. This article thus provides detailed information about sources and utilities of seri-wastes and advancing future researchers to explore more useful products.

**Keywords:** Economic gains, Industry development, Sericulture, Seriwastes, Utilities.

## Introduction

Silk and other sericultural wastes play a crucial role in the development of rural as well as tribal economics in the agriculture sector in India. Like all industries it also generates a lot of wastes. Sericulture is an agro-based labour-intensive industry for rural and semi urban areas. The sericulture industry provides employment to 30 million families in countries such as China, India, Brazil, Bulgaria, Vietnam, Korea and Thailand. In practising sericulture, it also makes a lot of waste in each and every step to produce the final product of silk thread (Kim *et al.*, 2010).

Waste is any substance object which the holder discards or intends to discover (The waste framework directive 75/442/EEC, 1975). Now-a-days numerous potential agro-based industrial wastes can be recycled to produce valuable commodities. Recycling is the process of retrieval of undesirable waste material into desirable material to meet customer demand to (REI reports, 2016). Further recycling was a very ancient concept of America where they reused the rock equipment (Blackman, 2004). Thus, to explain in another way recycling is one of the major steps in sustainable man material management. So, recycling of waste

can perform a potential economic scope in strengthening the social wealth and social activity at a large. Sericulture ideally involves the raising of food plants (Mulberry, Som, Saolu, Castor, Arjun etc) of silkworms, rearing of silkworms (*Bombyx mori, Antheraea assamensis, Phylosamiaricini, Antheraea mylitta* and other wild sericigenous insects)the production of cocoons and spinning and reeling of the cocoons for production of silk yarn. Each of these activities produce a large number of wastes popularly known as seri-waste. This study focuses on how these wastes can be put into good use as by-products of the sericulture industry.

It is well established from the beginning that sericulture practise is broadly classified as mulberry and non-mulberry sericulture. In mulberry sericulture the worm *Bombyx mori* feeds on the food plant *Morus sp.* The whole procedure for commercial output is the indoor process. In contrast to this, non-mulberry sericulture involves mainly four types of silkworm rearing, viz. Muga Culture, Eri Culture, Tropical Tasar Culture and Temperate Tasar Culture. Peculiarity is that most of the non-mulberry insects are polyphagous i.e., they can devour many plants. Muga Culture is the rearing of the worm *Antheraea assamensis*which feeds on leaves of som and soalu plants. Eri culture is the rearing of *Philosamiaricini* which feeds on leaves of castor plant. It is the only domesticated non-mulberry culture. Tropical Tasar culture in the rearing of *Antheraea mylitta,* feeds on the leaves of Arjun plant. The Temperate Tasar or Oak Tasar feeds on Oak plants. The characteristics of the worm, rearing pattern, reeling and spinning process etc are different in mulberry and non-mulberry sericulture, so wastes generated during both processes are different in some ways. Like mulberry seri-wastes, non-mulberry seri-wastes have so many applications like compost preparation, biomedical applications, pupal oil preparation and other so many by-products. The matured, damaged, dried mulberry leaves can be harvested to produce a semi synthetic or artificial diet of the silkworm (Manoon*et al.,* 2016). Mulberry leaves contain high amounts of nitrogen, as per many reports use of mulberry plant residue in compost preparation will increase the quality of the compost. Mulberry fruit extract is effective in lowering the blood pressure (Sang Woong Park *et al.,* 2018). Mulberry fibres can be used in paper production (Kaustubha 2016). The mulberry silkworm rearing waste include mainly the excreta (60%of ingested food), leftover leaves (20-30%), harvested leaves (10-20%), exuvia of the moulted larvae and weak, unhealthy, or diseased or dead rejected larvae. Silkworm faces contain 83.77-90.44% of organic matter and 16.23-9.56% of Ash, thus it is used in biogas plants (Bergman,1934). Reeling waste mainly include pupae, pelade layer, and reeling water containing sericin protein of silk filament. Pupal oil is used in preparation of soaps glycerine cosmetics (Priyadarshini *et al.*,2021). Sericin that is found dissolved in the waste reeling water, has the ability to check for clonal cancer (S. Zhaorigetu*et al.,* 2007). Non-mulberry sericulture is mainly performed outdoors, that's why the waste generated during the cultivation of the food plant, rearing process and reeling waste are lesser than mulberry sericulture. It had been reported that many by-products of Non-Mulberry with various uses, as in case of mulberry sericulture. For example, as per reports, *Terminalia arjuna, the* food plant of *Antheraea mylitta, has* had various biomedical applications in India more than 3000 years ago. It had been used for curing asthma, problems related to hearts and for patients suffering from bile duct disorder. So, here in this article our prime aim is to present valuable notes on seri-wastes obtained from both types of sericulture and to encourage future research workers in exploring more useful commodities.

## Utilisations of mulberry seri wastes

### From Mori culture

The soul food plant of domesticated silkworm *Bombyx mori* is Mulberry or various species of *Morus* genus. The cultivation of Mulberry for silkworm rearing is known as Mori culture. During the years, various parts of mulberry are treated as seri-wastes and are used these as by-products of sericulture in many ways.

Among these credible products of mulberry plants, use of medicines is prime since remote time in our life. A

**Table 1.** Utilisation of various parts of Mulberry plants parts.

| Mulberry plant part | Application as a byproduct of Sericulture | Source |
|---|---|---|
| **Leaves** | • An artificial and semi synthetic diet of silkworms can be produced by using the mature and unused mulberry leaves. | • (Kaustabha *et al.,* 2016) |
| | • Mulberry tea is rich in antioxidants and is useful in reducing the blood pressure (arterial pressure) and for controlling blood sugar). | • (Arabshahi *et al.,* 2007) |
| | • Leaves are rich in vitamins and proteins, so intact leaves can be used as a food for cattle, rabbits and pigs. | • (Srivastava Sarita *et al.,* 2006) |
| | • Mulberry leaves can be used in compost preparation and also be used as poultry feed. | • Annual report of ICAR (Directorate of poultry research) (2017-2018) |
| **Fruit** | • Mulberry fruit is rich in carotene thiamine, nicotinic acid, riboflavin and vit-c, so this fruit juice can be used as a natural tonic vitamin supplement. According to the trait mulberry fruit is laxative in nature. Thus it is very effective in dyspepsia and melancholia and it has many applications in pharmaceuticals. | • (Yuan Qingxia *et al.,* 2017), |
| | • Besides all these, it is also used for pickle and jam preparations. Due to antioxidant and anti-wrinkle properties of mulberry fruits many uses have been noted in cosmetic industries and gained wide acceptance | |
| **Stem** | • Mulberry stem contains tannin and pigment, for this it is used in manufacturing industries. The bark of the Mulberry stem can be used in the paper industry and mulberry fibres are possible to use as supplementary cotton fibre used in spinning of jute. The bark of the Mulberry stem contains alpha -amylase, for this it is suitable for designing in the textile industry. | • (Kaustabha *et al.,* 2016) |
| **Root** | • Black mulberry root has DNJ (Alkaloid Deoxynojirimycin) compounds which can inhibit the glycosidase and have potential against AIDS. | • (Reddy *et al.,* 2010) |

large number of publications have been appeared in regard to the medicinal importance of mulberry plant from time to time and thus detailed pharmacological updates are now available (R. Singh *et al.,* 2013). The notable medicines have been used in curing diabetes, stress, cardiac symptoms, nervous disorder etc. Mulberry leaves, stems and roots are still now using for some rapid mechanism of action in some pathological conditions and this area of study.

Though the main target of Mulberry globally is to produce silk, in some countries, fruits of mulberry are also favoured. Mulberry fruit has a good nutritional value containing proteins, flavonoids and anthocyanin which increase its effectiveness as a promising natural tonic. An artificial and semi synthetic diet of silkworms can be produced by using the mature and unused mulberry leaves (Kaustabha*et al.*,2016). Mulberry tea is rich in antioxidants and is useful in reducing the blood pressure (arterial pressure) and for controlling blood sugar (Arabshahi*et al.,* 2007). Leaves are rich in vitamins and proteins, so intact leaves can be used as a food for cattle, rabbits and pigs (Srivastava Sarita *et al.*, 2006). Mulberry leaves are diaphoretic in nature; thus, it will be effective against gram positive bacteria and yeast in checking their populations build up on the host's body. Mulberry leaves can be used in compost preparation and also be used as poultry feed (Annual report of ICAR Directorate of poultry research, 2017-2018). Mulberry fruit is rich in carotene thiamine, nicotinic acid, riboflavin and vit-c, so this fruit juice can be used as a natural tonic vitamin supplement (Yuan Qingxia*et al.*,2017). According to the trait mulberry fruit is laxative in nature. Thus, it is very effective in dyspepsia and melancholia and it has many applications in pharmaceuticals. Besides all these, it is also used for pickle and jam preparations. Due to antioxidant and anti-wrinkle properties of mulberry fruits many uses have been noted in cosmetic industries and gained wide acceptance. Mulberry stem contains tannin and pigment, for this it is used in manufacturing industries. Bark of the Mulberry stem can be used in the

paper industry and mulberry fibres are possible to use as supplementary cotton fibre used in spinning of jute (Kaustabha *et al.,*2016). The bark of the Mulberry stem contains alpha-amylase, for this it is suitable for designing in the textile industry. Steroid saponins present in mulberry stems which are active against gram positive bacteria and Yeast. In addition, stems contain some bio molecules which are very effective in hair and fur growth. Black mulberry root has DNJ (Alkaloid Deoxynojirimycin) compounds which can inhibit the glycosidase and have potential against AIDS (Reddy *et al.,* 2010).

## From silkworm rearing

During rearing of silkworm, huge amounts of wastes are generated, which included leftover mulberry leaves, larval litters, dead and diseased larva, excuavae of the moulting larva and these seri-wastes have many notable applications which have been described in the Table-2.

Mulberry leftover leaves from the rearing bed are a necessary material for compost preparation (Khurheed Wani *et al.,* 2019). Silkworm larval stages contain nitrogen, potash and phosphoric acid and direct application of fresh larval instars to the field can be reason for spreading diseases, so it can be used only as compost (Singh *et al.,* 2002). The manorial value of bio digested cow dung plus silkworm larval litter slurry is given in Table 3.

Silkworm litter mixed with leftover mulberry leaves can be used as poultry food. Growth hormone, extracted from silkworm litter that can be used in making paints, pencil covers, plastic carbon and activated carbon of good quality for commercial purpose (Reddy *et al.*,2010). Excreta of silkworm litters, chlorophyll can be extracted and this chlorophyll can be used in medicine and cosmetic industry. Cow dung along with silkworm larvae together are good raw materials for biogas plants and phytol and carotene can also be extracted from silkworm larvae are being used to develop Gan Xue Bao a new drug for hepatitis and leukaemia (Wani Khursheed *et al.,* 2020). The medicine already developed from silkworm excrement has an efficiency rate of 95.6% due to chemotherapy and radiotherapy. Triacontanol is extracted also from larval

**Table 2.** Utilisation of Seriwastes from Mulberry Silkworm rearing.

| Types of Seriwates of Silkworm rearing | Its utilisations | Source |
|---|---|---|
| **Leftover Mulberry Leaves** | • Mulberry leftover leaves from the rearing bed is a necessary material for compost preparation. Silkworm larval stages contain nitrogen, potash and phosphoric acid and direct application of fresh larval instars to the field can be reason for spreading diseases, so it can be used only as compost. | • (Khurheed Wani *et al.,* 2019) |
| **Larval Stage** | • Growth hormone, extracted from silkworm litter that can be used in making paints, pencil covers, plastic carbon and activated carbon of good quality for commercial purpose. | • (Reddy *et al.*, 2010) |
| | • From the Excreta of silkworm litters, chlorophyll can be extracted and this chlorophyll can be used in medicine and cosmetic industry. As per report of, phytol and carotene can also be extracted from silkworm litter, which are used in the pharmaceutical industry. | • (Singh *et al.,* 2002) |
| | • According to the studies of the Zhejiang Academy of Traditional Chinese Medicine chlorophyll extracted from silkworm litter is being used to develop Gan Xue Bao, which is a medicine for hepatitis and leukaemia. | • (Zhejiang Academy of Traditional Chinese Medicine) |
| **Dead Larva** | • Silk glands of mature larva are used to make absorbable suturing materials in surgery | • (Gregory H Altman *et al.,* 2003) |

**Table 3.** Manorial value of biodigested cowdung plus Silkworm larval litter slurry.

| Types of Manure (in %) | Nitrogen | Phosphorous | Potassium |
|---|---|---|---|
| Cow dung | 1.65 | 0.70 | 0.67 |
| Silkworm larval litters | 2.67 | 0.92 | 1.36 |
| Cow dung + silkworm larval litters | 2.01 | 0.93 | 1.04 |
| Silkworm larval litters + Old slurry | 2.56 | 0.95 | 1.07 |
| Cow dung + Old slurry +Silkworm larval litters | 2.18 | 0.97 | 1.12 |

**Table 4.** Nutrients content of Silkworm pupae.

| Pupa | Water (%) | Fat (%) | Protein (%) | Glycogen (%) | Chitin (%) | Ash (%) | Others (%) |
|---|---|---|---|---|---|---|---|
| Dried | 7.18 | 28.57 | 49.98 | 4.65 | 3.73 | 2.19 | 3.70 |
| Squashed | 6.32 | 15.20 | 60.77 | 5.78 | 4.63 | 2.73 | 4.57 |
| Fat free | 5.49 | 0.47 | 75.82 | 6.92 | 5.55 | 3.27 | 5.48 |

stages which is useful as growth promoter for mulberry plants. Silkworm larvae can be used in mass cultivation of potential biopesticide, *Bacillus thuringiensis* (Patil *et al.,* 2013).

**From Grainage Activities:** Grainage operations generate seri-wastes like defected cocoons (Pierced cocoons, stained cocoons, flossy cocoons etc), waste moths etc. The pupa is accepted as very nutritious food in many parts of the world though it is excreted in huge amount during the grainage as well as reeling activity in sericulture. The nutritive content of pupae is given in the Table 4.

Cake made from pupa is fed to rabbits, hens, pigs and fowls for its high nutritive quality and pupal cake is also used for the preparation of pet biscuits (U.I. Seikh , 2018). It has been estimated that pupa content oil up to 25% to 30% of its dry weight which can be extracted and used for burning lamps. A mixture of pupal oil and linseed oil in the proportion of 25: 75 used in the jute industry to soft and jute fibres (Ramamoorthy*et al.,* 2015). Cut cocoons get good value from the spun silk industry. From Brazil cut cocoons are exported to Italy to produce spun silk. Defected cocoons are used for making handicrafts.

## From Reeling Activity

Reeling is the process of unwinding of the filament from cooked and brushed cocoons with the help of reeling machines to obtain raw silk of desired thickness. Reeling involves cooking and unwinding. In cooking, the cocoon dissolves its glue protein of silk, sericin in the hot water as waste and the unwinding generates pelade layers, pupa within it. Sericin protein is discarded as waste during the reeling. Sericin actually is that gummy protein which is responsible for the formation for the erect structure of cocoon. It can be extracted from reeling waste water by hollow fiber nanofiltration membrane integrated process, (Lie *et al.*, 2015). Sericin protein is nowadays becoming one of the most important biomolecules for its potential uses in pharmaceutical and cosmetics uses (Lalit *et al.,* 2015). Pelade layer is generated during the reeling process as a waste. This is now used to make silk fibre with the help of new technology. The uses of these wastes have been elaborate in table-5.

**Table 5.** Utilisation of reeling wastes from Mulberry Sericulture.

| Wastes | Utilisation |
|---|---|
| Sericin Protein | • Sericin protein is discarded as waste during the reeling process. Sericin protein is nowadays becoming one of the most important biomolecules for its potential uses in pharmaceutical and cosmetics uses. (Jia Liua *et al.*, 2022) |
| Pelade Layer | • Pelade layer is generated during the reeling process as a waste. This is now used to make silk fibre with the help of new technology. |

## Utilisation of nonmulberry Sericulture

Non mulberry sericulture is globally known as Wild or Vanaya sericulture. Tropical Tasar, Temperate Tasar, Muga, Eri, Anaphe and many more are the sources of non-mulberry silks. Tasar is produced 95% nearly in the non-mulberry silk production. As mostly in the non-mulberry sericulture is performed outside the wastes are much less in comparison to mulberry wastes.

## Waste from tropical Tasar culture

### From food plants

Tasar culture is regarded as a symbol of tribal culture. Indian Tasar mainly belongs to the Adivasi or aboriginal peoples (Santhal, Kol, baiga, Telega, Ho etc.) in the dense humid tropical forest of central and south part. Tropical Tasar is a polyphagous insect that can feed on leaves of *Terminalia arjuna*, *Shorea robusta*, *Terminalia tomentosa* and more. From these food plants we can also benefited with many by-products mainly used in pharmaceuticals. Bark of *Terminalia arjuna* plant is used in production of a powder (an indigenous drug) and used in the treatment of blood sugar, cholesterol and HDL-cholesterol. The result showed fairly effective in patients with symptoms of stable angina pectoris. However, it has a limited role in unstable angina. Bark of *Tarminalia arjuna* are responsible for its anticancer properties because the barks contain Tanin and flavonoids (Ahmad *et al.*, 2014). *Terminalia arjuna* also can be considered as a cardioprotective drug with immense therapeutic potential (Kapoor *et al.,* 2014). *Terminalia arjuna* has antioxidant constituents to improve endothelial dysfunction in smokers (*Bharani et al.,* 2004) Leaf of *Terminalia arjuna* can be used in compost preparation in addition. The young leaf extract of *Shorea robusta* is effective in wound healing (Mukherjee *et al.,* 2013). *Shorea robusta* resin dissolved in water applying at two different doses 150mg and 300mg/kg body weight was responded effectively on ethanol and pyloric ligation induce gastric ulcer models in rats. Thus, it suggested that *Shorea robusta* resin possesses gastroprotective activity for curing ailments occurring in alimentary canal (Kumar *et al.,* 2012). The methanol extract of dried leaves of *Shorea robusta* was investigated for antinociceptive use. Anti-obesity effect of hydro-alcoholic extract of *Shorea robusta* was found on monosodium glutamate induced obesity in albino rat models. Anti-pyretic activity of *Shorea robusta* resin also supports the traditional therapeutic use in face. The aqueous extract of floral part of *Shorea robusta* was prepared with cold water maceration and well diffusion method was employed to determine the effect of antibacterial potential against gram positive bacteria. The aqueous methanol, petroleum and benzene extract of oleoresin of *Shorea robusta* were tested in several cases and are found to inhibit the growth of microorganisms like *Bacillus coagulans*, *E. coli*, *Bacillus cereus* including slightly on *Salmonella typhi*. The bark of *Terminalia tomentosa* contains tannin and non-tannin content was found to be suitable as a cheap dye for cotton, silk, wool, and jute fabrics as well as for pulp and paper (M.G. *et al.,* 1970). *Terminalia tomentosa* possesses significant anti-inflammatory activity and pronounced effects on adjuvant arthritis as well (Jitta *et al.*, 2019) . The methanolic extract of *Terminalia tomentosa* treated group shows a significant anticonvulsant activity (Shaik Gouse Pasha *et al.,* 2014). Thus, it can be used as a natural supplentary remedy for the treatment for the treatment of convulsion. Some uses of the wastes generated while Tasar sericulture is performed have been described in the Table 6 and 7.

### From Silkworm (*Antheraea mylitta)* rearing of tropical Tasar

From the grainage activity, where the Tropical Tasar silkworm eggs are produced, the rearing and reeling generate various kinds of wastes, which can be used in many ways for extra economic benefits to the farmers. Defected cocoons can be used to make handicrafts, flower vase, garland, dolls, jewellery, wall hangings, greeting cards etc. Sericin, one of the most important proteins, can also be extracted from reeling water and silk glands and cocoons. As per the reports the dead pupae which remain after reeling are very rich in protein (63-65%), oil (20-25%), carbohydrate (10%) and minerals (7-8%). The pupal oil can be used as a cleansing ingredient in soap manufacturing. Pupal powder is very nutritive in nature and it contains 80% protein, so it is used in making protein rich biscuits. Pupa are also used by many people as the source of protein.

## Wastes from temperate Tasar

Temperate Tasar or Indian Oak Tasar is produced by a hybrid of Chinese *A. pernyi* and Indian *A roylei*. It feeds on the leaves of the Oak tree of the genus *Quercus*. It is outdoors reared in the Himalayan borders.

**Table 6.** Utilisation of Tasar Food plants Rather than Sericulture.

| Food plants | Utilisation of Rather than Sericulture | Sources |
|---|---|---|
| **Arjun (*Terminalia arjuna)*** | • Bark of *Terminalia arjuna* plant is an indigenous drug,produced in the form of powder and used in the treatment of blood sugar, cholesterol and HDL-cholesterol. The result showed fairly effective in patients with symptoms of stable angina pectoris. However it has a limited role in unstable angina. | • (Dwivedi *et al.,* 2007) |
| | • The bark of *Tarminalia arjuna* are responsible for its anticancer properties because the barks contain Tanin and flavonoids. | • (Ahmad *et al.*, 2014) |
| | • *Terminalia arjuna* also can be considered as a cardioprotective drug with immense therapeutic potential. | • (Kapoor *et al.,* 2014) |
| | • *Terminalia arjuna* has antioxidant constituents to improve endothelial dysfunction in smokers. Leaf of *Terminalia arjuna* can be used in compost preparation in addition. | • (Bharani *et al.,* 2004) |
| ***Shorea robusta*** | • The young leaf extract of *Shorea robusta* if effective in wound healing. | • (Mukherjee *et al.,* 2013), |
| | • Ethanolic extract of *Shorea robusta* was responsible alleviate pain and gastroprotective potential of *Shorea robusta* resin dissolved in water applying at two different doses 150mg and 300mg.kg body weight was responded effectively on ethanol and pyloric ligation induce gastric ulcer models in rats. Thus it suggested that *Shorea robusta* resin possesses gastroprotective activity for curing ailments occurring in alimentaly canal. | • (Kumar *et al.,* 2012) |
| ***Terminalia tomentosa*** | • In the back of *Terminalia tomentosa,* tannin and non-tannin content was found to be suitable as a cheap dye for cotton,silk, wool, and jute fabrics as well as for pulp and paper. | • (M.G. *et al.,* 1970). |
| | • Recent studies, *Terminalia tomentosa* possesses significant anti-inflammatory activity and pronounced effects on adjuvant arthritis as well. | • (Jitta *et al.,* 2019) |
| | • The methanolic extract of *Terminalia tomentosa* treated group shows a significant anticonvulsant activity. | • (Shaik Gouse Pasha *et al.,* 2014), |

**Table 7.** Utilisation of Defected Cocoons & Pupae from Tasar Culture.

| Wastes | Utilisation |
|---|---|
| **Cocoons** | • Defected cocoons can be used to make handicrafts, flower vase, garland, dolls, jewellers, wall hangings, greeting cards etc. |
| | • Sericin, one of the most important proteins, can also be extracted from reeling water and silk glands and cocoons. |
| **Pupae** | • As per the reports the dead pupae which remain after reeling are very rich in protein (63-65%), oil (20-25%), carbohydrate (10%) and minerals (7-8%). This pupal oil can be used as a cleansing ingredient in soap making. |
| | • Pupal powder is very nutritive in nature. It contains 80% protein, so it is used in making protein rich biscuits. |
| | • Pupa are used by many people as the source of protein. |

## From food Plants

The wastes generated during the culture of Oak Tasar have many applications. Bark of the *Quercus sp*. has antibacterial properties (Elansary *et al.,* 2019). So, it can be used as an antibiotic in Ayurveda. Oak wood is very resistant to insect and fungal attack, as it contains high tannins. Therefore, it is very good material for furniture making mentioned that due to the high content of tannin, it is used tanners for tanning leathers (Falcão *et al.,* 2018). Oak galls harvested at a specific time of year were used for centuries as a main ingredient in iron gall ink.

## From Silkworm (*Antheraea pernyi*) rearing

Defective cocoons are used in making handicrafts. Pupa is used as food and Pupal oil is used in soap making. Pupal powder which is rich in protein content, is used in making protein rich foods. Sericin can also be extracted from the

waste reeling water. This sericin can be used in many pharmaceuticals and cosmetic industries.

### Wastes from Muga culture

The lustrous golden yellow muga silk is produced by *A. assamensis*. It is the unique mono culture of India and adjoining hills of Assam. The silkworm *A. assamensis* feeds on Som (*Machilus bombycina*) and Soalu (*Litsea monopetala*). Rearing is done mainly outdoors and for the young worm rearing short time practicing in the rearing room. The muga culture produced various by-products from the food plant as well as from the rearing.

### From food Plants

The silkworm *Antheraea assamensis* is fed on leaves of Som (*Machilus bombycina*). The waste leaves mixed with cow dung in compost preparation. Leaves of *Machilus bombycina* have the important contents to cure the pimples and rheumatism. *Machilus bombycina* is used in Ayurveda for its antimicrobial, antioxidant and antifungal properties (Ali Mohammad *et al.,* 2017). Leaves of *Machilus bombycina* give a clean and sweet smell, so it is used in cosmetics as scented oil. Leaves of *Litsea monopetala* are used in treatment of arthritis. The oil from the seed of Soalu (*Litsea monopetala*) is used in Ayurveda and the wood is used for making furniture. The extract of leaves is used as an ingredient in commercial cosmetic preparations as a skin conditioner.

### From Silkworm (*Antheraea assamensis*) rearing

Muga Silkworm larvae mixed with the leaves of the food plant and can be used as in ingredient for compost preparation. Pupa is used as food for its high protein content. Pupal oil is extracted and is used in soap making and Pupal powder is also used in many industries. Defective Cocoons can be used to make handicrafts like flower vase, greetings card, wall hanging etc. Sericin extracted from the reeling water has many uses as antibacterial and antioxidant.

### Wastes from Eri culture

*Philosamia ricini* is also called Castor silkworm for its food plant. It is domesticated non-mulberry insect The Eri culture includes the planting of Castor food plants (*Ricinus communis)* and rearing of Eri silkworm (*Philosomia ricini*) and there are various by-products obtaining in Eri sericulture. Dead larvae are used to prepare compost, defected cocoons are used to make handicrafts, pupal oil used in cosmetic making, pupal powder is used to make protein biscuit and pupa itself can be used as food for cattle, fish, poultry etc.

### Conclusion

Nowadays, mulberry as well as non-mulberry sericulture industry govern useful conversion of many by-products, a prospective role in the development of rural and tribal people as a whole. By performing sericulture in rural areas, a good number of people will have the opportunities to manufacture useful items from the both village-based sericulture practice. To enjoy more socio-economic advantage the inhabitants of rural and tribal areas may involve in making remarkable conversion of necessary by-products with the development of available processing techniques. The various utilization of newly produced products as well as blended by-products like Hai silk, new towel, high valued fancy jackets carpets etc. have gained worldwide acceptance. Thus, it is expected that in the field of pharmaceutical, biomedical, cosmetics industrial sections, the importance of these by products from both animal and plant origin will create a fabulous demand and thus to encourage a strong rural based employment generating industry for overall benefits. We are hopeful the review of the present paper will inspire new entrepreneurs and industrialists to take the initiative for their lucrative venture. The production and proper utilization of these precious bio-resources will not be harmful for our environment and may establish also old and new trends in this traditional agro-based fields.

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