



International Journal of Research in Agronomy

Value addition of mulberry fruits

Thanga Roja K, Saratha M, Bharath Kumar Neelaboina and Deepa P

DOI: <https://www.doi.org/10.33545/2618060X.2026.v9.i5Sc.5558>

Abstract

Mulberry belongs to the genus *Morus* and there are 24 species of *Morus* with at least 100 known varieties are available in the world. Botanically, the mulberry fruit is not a berry but a collective fruit is called as Sorosis. Mulberry tree is cultivated traditionally for feeding the silkworm, *Bombyx mori* L. However, due to its nutritive value, the mulberry fruit is now-a-days consumed in both fresh and processed forms such as juice, jams, syrups, beverages or dried fruits. Mulberry fruits contain considerable amounts of biologically active ingredients which are found to possess potential pharmacological activities such as neuroprotective, antitumor, anti-hyperglycemic, and anti-hypolipidemic activities and that are beneficial for human health (Zhang *et al.*, 2018). Anthocyanins are a group of naturally occurring polyphenols responsible for the colour in mulberry fruit. They are excellent antioxidants by their high radical scavenging ability towards DPPH.

Mulberry fruits contains high amount of natural anthocyanin dyes used for dyeing to increase colour strength and fastness of cotton fabric (Wang *et al.*, 2014). *M. nigra* possesses antibacterial activity, including 1-arylbenzofuran (Moracin M), stilbenoid oxyresveratrol, morusin, and kuwanon C. Due to these constituents, it act as anti-acne agent for facial skin treatment (Budiman *et al.*, 2017). Hence, more research studies are needed to be initiated for thorough exploitation of excellent characters of mulberry fruit for commercial utilization.

Keywords: Anthocyanins, *Morus*, mulberry fruit and pharmacological activities

Introduction

Mulberry (*Morus alba* L.) a generic name of *Morus* has been derived from Latin word “Mora”, which means delay (Janick and Paul, 2006) [33]. *Morus* genus has about 68 species of trees and shrubs throughout the world. This genus is widely distributed in Asia, Africa, Europe, South and North America. It is also widely found in hilly areas of Himalayas up to 3300 m elevation (Zafar *et al.*, 2013) [34]. Among various *Morus* species, *Morus alba* L. has been cultivated widely in Asia especially in China, Japan and India for rearing silkworms besides fruit purpose. Other species like *M. indica*, *M. serrata* and *M. laevigata* are also found in India (Ravindran *et al.*, 1997) [35].

Fruits of this species are long, ovoid or cylindrical, which are variable in colour like white, pink or purple to black. The fruit yield increases with tree size and a fully grown tree can yield between 10-15 Kg fruits (Sharma and Zote, 2010) [36]. Mulberry fruit is full of anti-aging properties and enriches the blood, protecting liver from damage, calms the nerves, balances internal secretions and enhances immunity. Only the scattered information is available in the literature and no systematic work has been done regarding the use of its fruits for the production of value added products. So keeping in mind its availability and importance with respect to various quality characteristics, this paper aims to summarize recent knowledge regarding the value addition and their health benefits of mulberry fruit. This review may be useful for predicting other health benefits and potential drugs and may encourage new research and relevant industries to more deeply explore mulberry fruit in the future.

E-ISSN: 2618-0618
P-ISSN: 2618-060X
© Agronomy
NAAS Rating (2026): 5.20
www.agronomyjournals.com
2026; SP-9(5): 240-245
Received: 17-02-2026
Accepted: 19-03-2026

Dr. Thanga Roja K
Scientist B, Regional Extension
Centre, Central Silk Board,
Palamner, Andhra Pradesh, India

Dr. Saratha M
Scientist B, Regional Extension
Centre, Central Silk Board,
Gobichettipalayam, Tamil Nadu,
India

Bharath Kumar Neelaboina
Scientist D and Head, Regional
Extension Centre, Central Silk
Board, Palamner, Andhra Pradesh,
India

Dr. Deepa P
Director, CSRTI, Central Silk
Board, Mysuru, Karnataka, India

Corresponding Author:
Dr. Thanga Roja K
Scientist B, Regional Extension
Centre, Central Silk Board,
Palamner, Andhra Pradesh, India

Physico-chemical characteristics of mulberry fruit

1. Physical characteristics

Characteristics	Content		Reference
Fruit weight	<i>Morus alba</i>	0.66 - 3.49 g	Iqbal <i>et al.</i> 2010; Zengin <i>et al.</i> 2012 ^[10, 32] .
	<i>Morus nigra</i>	1.13 - 5.67 g	Koyuncu <i>et al.</i> 2004; Dwivedi and Pathak 2012 ^[12]
Seed	<i>Morus nigra</i>	3.90%	Dwivedi and Pathak 2012 ^[12] .
Colour	Variable in colour (white, pink, red, blue, purple and black)		Kumaresan <i>et al.</i> 2008 ^[13]
Size	Diameter (cm)	Length (cm)	Pathade <i>et al.</i> 2009; Iqbal <i>et al.</i> 2010 ^[10, 19]
	0.94-2.06	1.41-7	

2. Chemical characteristics

Chemical Composition	<i>Morus alba</i>	<i>M. nigra</i>	<i>M. rubra</i>
Lipid (%)	1.10	0.95	0.85
Linoleic acid (%)	57.26	61.85	43.39
Palmitic acid (%)	22.42	12.06	24.79
Oleic acid (%)	10.49	14.75	-
Protein (%)	10.15-13.33	8.9-10.85	-
P (mg/100g)	247	232	226
K (mg/100g)	1668	922	834
Ca(mg/100g)	152	132	132
Mg(mg/100g)	106	106	115
Fe(mg/100g)	4.2	4.2	4.5
Na (mg/100g)	60	59	61
Mn (mg/100g)	3.8	4.2	4.0
Zn(mg/100g)	2.8	3.2	3.2
Cu (mg/100g)	0.5	0.4	0.4
Se(mg/100g)	0.005	0.008	-
Vitamin C (mg/100g)	22.4	21.8	19.4

3. Phytochemical Compounds

Phytochemicals	<i>M. alba</i>	<i>M. nigra</i>	<i>M. rubra</i>	References
Total phenolics (mg GAE/100 g)	181	1422	1035	Ercisli <i>et al.</i> 2007 ^[8]
Total flavonoids (mg GAE/100 g)	29	276	219	Ercisli <i>et al.</i> 2007 ^[8]
Cyanidin-3-O-glucoside(C3G)(mg/g)	ND	8.22	-	Chen <i>et al.</i> 2017 ^[4]
Cyanidin-3-O-rutinoside(mg/g)	ND	2.86	-	Chen <i>et al.</i> 2017 ^[4]
Pelargonidin-3-O-glucoside(mg/g)	ND	0.25	-	Chen <i>et al.</i> 2017 ^[4]
Total phenolics (mg GAE/100 g)	181	1422	1035	Ercisli <i>et al.</i> 2007 ^[8]
Total flavonoids (mgGAE/100 g)	29	276	219	Ercisli <i>et al.</i> 2007 ^[8]
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Cyanidin-3-O-rutinoside(mg/g)	ND	2.86	-	Chen <i>et al.</i> 2017 ^[4]
Pelargonidin-3-O-glucoside(mg/g)	ND	0.25	-	Chen <i>et al.</i> 2017 ^[4]
Quercetin-3-O-rutinlside(mg/g)	0.08	0.45	-	Chen <i>et al.</i> 2017 ^[4]
Quercetin-3-O-rutinlside(mg/g)	0.08	0.45	-	Chen <i>et al.</i> 2017 ^[4]

Nutraceutical and Medicinal Properties

Sr. No.	Biological activity	Findings	References
1	Anti-diabetic activity	Ethyl acetate-soluble extract of mulberry showed decrease in the fasting glucose and glycosylated serum protein levels of diabetic rats (fed for 2 weeks). Mulberry anthocyanin extract (50 and 125 mg/kg body weight per day) fed for eight weeks was effective in reducing the fasting blood glucose levels of male C57BL6/J genetic background type-II diabetic mice Diabetic rats fed with Mulberry Fruit Polysaccharide-MFP50 and MFP90 ethanol Extract for seven weeks showed 26.5% and 32.5% decrease in serum insulin levels respectively. Significant decrease in levels of fasting glucose and serum insulin, and triglyceride was observed.	Yan, Dai and Zheng, 2016 Jiao <i>et al.</i> , 2017 Wang, Xiang, Wang, Tang, 2013 ^[11, 31]
2	Hypoglycemic activity	Mulberry Fruit Polysaccharide i.e. MFP3P-Se (selenide of Polysaccharide) had more significant hypoglycemic effects than MFP3P through promoting pancreatic cell proliferation and increasing glucose metabolism and insulin secretion	Chen <i>et al.</i> , 2016 ^[4]
3	Hyperglycemic activity	Mulberry fruit extract was found more effective among bilberry and blackberry fruit extracts in decreasing the glucose level when given to	Ștefănuț <i>et al.</i> , 2013 ^[24]

		Diabetic rats in drinking water for five weeks.	
4	Anti-obesity action	High- fat diet-induced obese mice fed with a combination of mulberry leaf extract and mulberry fruit extract at low and high doses (133 mg MLE and 67 mg MFE/kg/day) and (333 mg MLE and 167 mg MFE/kg/day) respectively for 2 weeks significantly showed anti-obesity action as it resulted in decrease in body weight gain, fasting plasma glucose and insulin, adipocyte size. Mulberry water extract (MWE) showed anti- obesity action on male hamsters by lowering the high-fat diet-induced body weight, visceral fat, serum and liver lipids. The MWE maintains lipolysis and lipogenesis thus helps in weight loss. Mulberry anthocyanins were introduced in Daily diet of mice fed with high fat diet, Showed inhibition in weight gain, reduced the adipocytes size and impaired lipid accumulation.	Peng <i>et al</i> , 2011 Wu <i>et al</i> , 2013 Lim <i>et al</i> , 2013 ^[16, 20]
5	Hyper-lipidemic action	Water extracts showed lipid lowering effects by diminishing its biosynthesis and increasing the LDLR gene.	Liu <i>et al</i> , 2009 ^[17]
6	Antioxidant activity	Destruct the damaging oxidative substances in RBC. 70% ethanol extract was successful in giving the protective results in the protective action of mulberry fruit in H ₂ O ₂ - induced oxidative injury of pancreatic MIN6N beta-cells at a concentration of 400µg/mL. Mulberry Fruit Polysaccharide i.e. MFP3P-Se (selenide of Polysaccharide) exhibited higher peroxyradicals-scavenging capacity than MFP3P <i>in vitro</i> .	Yan and Zheng, 2017 Hong <i>et al.</i> , 2004 ^[30]
7	Hypolipidemic activity	5% or 10% mulberry powder was supplemented with high fat diet oral showed significant increase in the HDL levels thereby decreasing the LDL, liver triglyceride and total cholesterol levels. This is due to the presence of high linoleic acid and dietary fiber content in the fruit. High cholesterol diet with 0.5% and 1.0% mulberry fruit (water extract) was given to New Zealand white rabbits, significantly decreased cholesterol (total and LDL) levels, triglycerides and reduced severe atherosclerosis. 45 g freeze-dried mulberries were consumed by hyper-cholesterolemic Adults (30-60yrs), after 6 weeks they showed lower levels of cholesterol (total and LDL).	Yang, Yang and Zheng, 2010 Chen <i>et al.</i> , 2005 ^[4, 31]
8	Vaso-active action and neuroprotective effect	Plasma peroxide levels elevation was inhibited by the fruit juice and possess anti-stress action. Fruit extract prevents the cerebral ischemic damage caused due to oxygenglucose deprivation in PC12 cells	Sakagami <i>et al.</i> , 2006 Kang, Hur, Kim, Ryu and Kim, 2006 ^[21]
9	Anticancer action	Anthocyanin-rich mulberry fruit extract given to male bal b/c nude mice for seven weeks, showed inhibition in atypical glandular cells (AGS) tumour xenograft growth thus preventing gastric Carcino maformation	Huang, Chang, Wu, Hung and Wang, 2011 ^[3, 9]
10	Nephroprotective action	Butyl pyro glutamate, a bioactive compound was extracted from mulberry fruit has a protective effect against cisplatin-induced kidney cell damage	Lee <i>et al.</i> , 2018 ^[14]
11	Anti viral activity	0.005% and 0.25% mulberry juice was found effective on reducing the infectivity of murine norovirus-1 (MNV-1) and feline calicivirus-F9 (FCV F9) respectively. 0.1% juice was effective enough for inhibition of viral replication (60% reduction).	Lee, Bae, Oh, Kim and Chung, 2014 ^[15]
12	Cytoprotective action	Polysaccharides extracted from fruit protects the cells of the pancreas by inactivation of certain components such as Bcl-2, Bax, JNK, p38, and caspase-3 responsible for causing apoptosis.	Jiao <i>et al.</i> , 2017 ^[11]

Economic uses of 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 colorant, 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.

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) ^[5]. 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.*, 2009a b) ^[22]. 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 it 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 in the preparation of wine

Mulberry fruit is having 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) ^[7]. 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 small dose of the drink protects against stomach and heart diseases. In Greece, mulberry fruits are used for the production of the traditional aromatic mouro distillate. Soufleros *et al.*, (2004) ^[23] 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. 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 small dose of the drink protects against stomach and heart diseases. In Greece, mulberry fruits are used for the production of the traditional aromatic mouro distillate. Soufleros *et al.*, (2004) ^[23] 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 colorant

Mulberry fruits are rich in anthocyanins and deserve to be exploited for the industrial production of natural color to be used in the food industry. In particular, it is known to contain cyanin, which contributes the red pigment that gives the fruit a red to purple color. The major anthocyanins found are cyaniding-3-glucoside and cyaniding-3-rutinoside. These pigments hold potential for use as dietary modulators, mechanisms for various diseases and as natural food colorant (Wrolstad, 2001) ^[28]. As synthetic pigments are unsafe, there is a demand for natural food colorants 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) ^[17] which could be used as a fabric tanning agent or food colorant of high color 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 multi-nutrient 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 US\$17-26 per month during the mulberry season from 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 micro enterprise.

Dyeing cotton fabric with anthocyanin dyes from mulberry

Fruits: The natural anthocyanin dyes (mainly consisting of cyanidine 3-glycoside) extracted from mulberry (*Morus rubra*) fruits has been successfully used to dye cotton fabric, with a dyeing property performance good enough for potential commercial applications. In this study, succinic acid was firstly incorporated into cotton fabrics by esterification to the hydroxyl groups of cellulose, forming an anionic site for the dyes. The anthocyanin extracts from mulberry fruits were used to study the dye ability of the control and modified cotton fabrics. Red and deep purple (aubergine) are two main shades of cotton fabrics dyed with mulberry fruit extracts. The colour strength of dyed cotton fabric was improved from 2.7 to 5.3 in the case of dyeing without mordants, and from 3.2 to 6.9 in the case of dyeing with tin mordanting. Meanwhile, the colour fastness was improved by 0.5-2 grades with increasing succinic acid concentration in the finish solution.

The colour fastness to perspiration, crocking, light, and washing of fabric dyed with simultaneous tin mordanting and modified with 30g of succinic acid was found to be acceptable, with a grey scale grade of at least 3. As for home laundering, neutral soapy solution was more acceptable than alkaline soapy solution.

Recent utilization of mulberry fruit products

S. No	Mulberry fruit products	Key findings
	Wine	Various mulberry accessions were used for wine production. MI- 497 was best suited mainly because of its deep red color and retained physicochemical and sensory properties (Yadav, Garg, & Kumar, 2017) ^[29] .
2.	Jelly	Jelly was prepared by using various juice-sugar combinations and the best-suited combination was of 50% juice and 45%. Most of physiochemical, quality and sensory characteristics were retained in this particular combination at refrigerated condition (Thakur, 2016) ^[26] .
3.	Biscuit and Bread	Dry fruit and fruit powder (colouring agent and to enhance anthocyanin content) of <i>Morus nigra</i> was used for the preparation of biscuits and breads at different levels. The best-suited level of dry fruit and powder was for biscuits 15% and 2%, respectively. Biscuits were kept for evaluation (18 days) and retained texture for 10 days and off flavour was sensed on 14th day of evaluation. The best suited level of dry fruit and powder for bread was 15% and 4%, respectively. Bread was kept under observation for 6 days and was evaluated at 2 days-intervals. Due to moisture loss, hardening occurred on 4th and dryness on the 6th day (Nayak, Jamuna and Chandru, 2013) ^[18] .
4.	Appetiser	Different juice and TSS combinations were tried for preparing mulberry appetizer (spiced squash) and the one with 40% juice and 40°B TSS was best suited combination with highest sensory attributes (Hamid and Thakur, 2017) ^[25] . Squash - Combination of 30% juice and 45 ° B was rated best based on sensory, physiochemical and quality attributes (Thakur and Hamid, 2017) ^[25] .

5.	Yoghurt	Fruit flavoured yogurt was prepared using different concentration (2.5 to 10%) mulberry pekmez (conc. juice) Mulberry pekmez-based yogurt showed higher whey separation, low acid development and low viscosity than the controlled samples (Celik & Bakirci, 2003) ^[2] .
6.	Jam	Jam was prepared from black mulberry fruit and changes were observed in the physiochemical properties due to processing of fruit into jam. Fruit processing resulted in a significant loss of anthocyanin content, polyphenols, flavonoids and antioxidant capacity of mulberry-based jam (Tomas <i>et al.</i> , 2017) ^[27] .
7.	Vinegar	Vinegar from different fruits was prepared but vinegar prepared from mulberry was high in succinic and lactic acid over other fruit vinegars (Chang <i>et al.</i> , 2005) ^[3] .
8.	Cosmetic Cream	Concentrated mulberry extract (4%) was used in the whitening cream that showed a decrease in the melanin and erythema content (Akhtar <i>et al.</i> , 2012) ^[1] .

Traditional mulberry fruit products in other countries

Traditional mulberry fruit Product details and cost	Country
Apotent liquour “tutaraghi” made from mulberry fruit juice is very popular. Mymouné mulberry syrup (\$ 15.00).	Azerbaijan, Georgia and Armenia
Mulberry fruits are used for the production of the traditional aromatic “Mouro” distillate - 5,35 €	Greece
Mulberry Pestil with Walnut Marasbazaar.com; are liable wholesaler in turkey	Turkey
Mulberry Molasses (Dut Pekmezi) by Koska- 380gr £3.95- £6.95	Turkey
Turkish Churchkhela (Köme) made mulberry with Walnut/Pikola by Kral 350 gr -US \$12.99 Approximately EUR 11.57	Turkey
In Traditional chinese medicine, Sang Shen (Mulberry fruit) bulk herbis used in the daily dosage of 9 to 15 g. In most cases, bulk herbs are cooked in boiling water to make tea or soup for consumption - \$19.98	China
Mulberry Fruit Juice, Premium 100%Natural - Japan origin beverages - A powerful, anti-oxidant and anti-aging drink: a booster of health -SGD 39.25 - (Rs. 1998.38)	Japan

Conclusion

Sericulture is such an activity which can be used for multiple purposes. It implies significant quantities of secondary and waste products such as perforated silk cocoons, Bombyx mori chrysalides, larval dejections, mulberry plant waste, superseded cocoons, surplus mulberry leaf, root and fruits biomass etc., Therefore, silkworm rearing can now be transformed into the functional industry by processing the secondary and waste products which increase farmer's income. In order to ensure a profitable activity, it is necessary to process these secondary and waste products to obtain biologically active substances with important uses in various industries. For utilization of by-products generated from sericulture, in-depth research towards utility and optimization is the prime need in placing this industry on a sound footing. This 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.

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