Moringa oleifera: Nutritional and Medicinal Properties for preventive health care

A. Padma*, A. Indhuleka, J. Janet and V. Ragavi

*padmasokki@gmail.com

Department of Science and Humanities, Sri Krishna College of Engineering and Technology, Coimbatore – 641008, Tamil Nadu, India

Abstract

Moringa oleifera, commonly known as “drum stick” or the “horse radish” is cultivated all over the country as it can withstand both severe drought and mild frost conditions. It is a good source of protein, vitamins, fatty acids, micro-macro minerals and other essential phytochemicals. Due to its high nutritional content, the extract of leaves of Moringa oleifera is used to treat malnutrition and supplement breast milk in lactating mothers. Because of its medicinal value, it is also used as anti-inflammatory, anticancer, antioxidant, antidiabetic, cardiovascular hepatoprotective, anti-ulcer, antimicrobial agent. The pharmaceutical effects of Moringa oleifera makes it useful in therapeutic remedy in traditional medicinal system. Each part of the tree is useful in one form or another due to high nutritional and medicinal value. This paper reports the results of the study made on how these can help boosting the immunity level in individuals.

Key words: Moringa oleifera, enriched nutrient supplement, preventive medical care.

1. Introduction

The Moringa genus comprises of 14 species namely Moringa arborea; Moringa longituba; Moringa borziana, Moringa pygmaea; Moringa hildebrandtii; Moringa drouhardii; Moringa longituba; Moringa peregrina; Moringa stenopetala; Moringa rivae; Moringa ruspoliana; Moringa Ovalifolia; Moringa Concanensis and Moringa oleifera (Rani et al., 2018). The scientific details are listed below:

| Scientific name: Moringa oleifera | Family: Moringaceae |
From the Moringaceae family, *Moringa oleifera* is the commonly known, studied and used species (Anwar 2005; Olson 2011) and it is also the most commonly cultivated plant. It is extremely nutritious with a variety of uses and it is an effective remedy for malnutrition. *Moringa oleifera* is an indigenous of Indian subcontinent and but now has become naturalized in many tropics and subtropics regions worldwide. *Moringa oleifera* is referred to as “The Miracle Plant or Tree of Life” (Palada, 1996; Fuglie, 1999). There are several reasons why the issues and challenges of malnutrition and under nutrition still prevail and unresolved. Reasons are many including food insecurity, lack of access and affordability to modern the health care, lack of availability of nutritional food supplements to certain class of people (West et al., 2006). One solution to resolve these issues is to find alternative and cost effective ways of producing nutritional food supplements. This could reduce the chances of people getting ill and thus reducing their expenses on medical treatments. The best choice for healthy and nutritional food is from fruits and vegetables. There are only few trees that grow in almost all climatic conditions, one such tree is *Moringa oleifera*. Almost all parts of moringa are used in diverse culinary ways (Chumark et al., 2008, Iqbal et al., 2006). This is used in different classes and society of people due to its nutritional value and medicinal properties (DanMalam et al, 2001; Dahiru et al, 2006).

Traditional healers and health consultants prescribe different parts of *Moringa oleifera* for treatment of skin diseases, respiratory illness, hypertension, diabetes, cancer treatment, ear and dental infections and have stimulated its use as a nutrient condensed food source (Anwar et al., 2007; Fuglie, 1999). All parts of the tree are rich in nutritional content and also have medicinal value (Adewumi et al., 2016). Leaves are used as forage, tree trunk is useful in making gums, flower nectar is beneficial for preparation in honey and seed powder for water purification (Fuglie, 1999).
Moringa *oleifera* leaf has been used as an alternative food source to combat malnutrition especially among children and infants (Anwar *et al*., 2007). Almost all parts of this plant, namely leaves, flowers, seeds, pods, bark and roots, have enormous nutritional content and are in traditional medicine to treat numerous pathologies. They are part of regular cooking in most of the areas. As Moringa *oleifera* can survive in all climates - humid or dry hot, and can grow even in poor soils, it is found in all regions irrespective of the climatic condition. (Anwar *et al*., 2007; Mainenti 2018). Moringa *oleifera*, a highly nutritious plant, helps to treat malnutrition in developing countries (Zongo 2013; Valdez-Solana *et al*., 2015; Gopalakrishnan *et al*., 2016; Debajyoti *et al*., 2017). This study is to focus on medicinal potential of this unique plant and its potential as a nutritional and medicinal benefits. The applications and the challenges of the tree is shown in Fig 1.

**Applications**
- Food
- Nutritional Supplement
- Therapeutics
- Bioremediation

**Challenges**
- Change of quality due to environmental factors
- Lack of efficient propagation method
- High susceptibility to plant pathogens
- Variability in metabolites

![Fig 1: Applications and challenges of Moringa oleifera](image)

2. **Nutritional Properties of Moringa Oleifera**

Moringa *Oleifera* tree is rich in a number of nutrients such as proteins, fibre, minerals, flavonoid content and essential phytochemicals present in its leaves, pods and seeds (Jongrungruangchok *et al*., 2010, Moyo *et al*., 2011) that play important role in human nutrition and cosmetic industry. Moringa is found to have higher level of nutrients compared to the costly counterparts. For instance, when compared to other plants, from 100 g of dry leafs of Moringa *oleifera* has 7 times more vitamin C than oranges, 10 times more vitamin A
than carrots, 17 times more calcium than milk, 9 times more protein than yoghurt, 15 times more potassium than bananas and 25 times more iron spinach (Oduro et al., 2008; Rockwood 2013; Saini et al., 2016) as shown in Fig 2. As *Moringa oleifera* is easily cultivable and cheaper supplement compared to other products, it becomes a sustainable remedy for malnutrition (Kasolo et al., 2010).

Fig 2: Comparison of nutrient value of *Moringa oleifera* with other food items

The nutrients present in different parts of Moringa have made it useful in treatment of various diseases. Due to rich iron content, more than the content in Spinach, Moringa powder are used in the treatment for anemia (Fuglie, 1995).

The bioactive flavonoids in the leaves of Moringa *oleifera* have excellent anti-viral and anti-estrogenic activities that makes it an appropriate for nutritional and pharmaceutical supplementation (Havsteen, 2002; Miean et al., 2001 and Middleton et al., 2000). The reported facts are supported by the reports of World Health Organization (WHO) which has studied the use of *Moringa oleifera* as a low cost supplement enhancer in the poorest countries around the world especially in countries suffering from malnutrition (WHO Readers). Earlier researchers have reported that moringa seed oil contains around 76% PUFA. PUFAs are linoleic acid and oleic acid that have the ability to control cholesterol. Hence moringa is an ideal substitute for olive oil (Lalas et al., 2002).

2.1 The leaves
The leaves of *Moringa oleifera* are used in traditional food as vegetables in almost all parts of the world. It is consumed either in fresh or powder form, allowing conservation for use in the later period (Moyo 2011; Olson *et al.*, 2016). Studies show that nutritional value of *Moringa oleifera* does not reduce. The study on the nutrient content of these leaves showed that they are a valuable source of both macro-and micronutrients. In addition to these nutrients, they also have significant amounts of vitamins like beta-carotene of vitamin A, vitamin B such as folic acid, pyridoxine and nicotinic acid, vitamin C, D and E (Hekmat *et al.*, 2015, Mbikay, 2012). *Moringa* oleifera leaves are also rich in phytonutrients such as carotenoids, tocopherols and ascorbic acid (Saini *et al.*, 2014b, Saini *et al.*, 2014d). These nutrients when combined with a balanced diet may have immunosuppressive effects (DanMalam *et al.*, 2001). Moringa leaves also have low calorific value and can be used in the diet of the obese.

![Fig 3: Moringa Leaves](image)

Inspite of several leaves consumed as food, studies have shown that Moringa *oleifera* leaves are extremely high in protein and iron. There may be slight variations in the nutritional value of *Moringa Oleifera* of different cultivar and source (Jongrungruangchok *et al.*, 2010, Teixeira *et al.*, 2014, Moyo *et al.*, 2011). Yang *et al.* (2006) has reported that among *all species of Moringa*, Moringa *oleifera* has the highest amount of β-carotene, ascorbic acid (Vitamin C), α-tocopherol (Vitamin E) and iron. Fresh leaves of Moringa *Oleifera* have been found to be good sources of carotenoids such as trans-lutein (approx. 37 mg/100 g), trans-β-
carotene (approx. 18 mg/100 g) and trans-zeaxanthin (approx. 6 mg/100 g) and high amounts of ascorbic acid (271 mg/100 g) and tocopherols (36.9 mg/100 g) (Saini et al., 2014d). Studies have showed that Moringa oleifera leaves contain significant amount of essential amino acid, alpha linoleic acid and a wide range of dietary antioxidants (Moyo et al., 2011, Moyo et al., 2012, Qwele et al., 2013, Saini et al., 2014d, Saini et al., 2014e, Yang et al., 2006). According to Yang et al. (2006), Moringa oleifera leaves have significantly higher antioxidant contents when compared to fruits such as strawberries that are known for high antioxidant contents. (Saini et al., 2014b, Saini et al., 2014d). Other studies have showed that Moringa Oleifera plant improve meat quality in terms of chemical composition, colour and lipid stability (Qwele et al., 2013, Nkukwana et al., 2014a, Nkukwana et al., 2014b, Nkukwana et al., 2014c ).

Experimental studies have proved that leaves of Moringa oleifera contain a high amount of polyunsaturated fatty acids and low saturated fatty acids content (Moyo 2011). Studies have proved that these fatty acids in the leaves along with diuretic and lipid help in maintenance of cardiovascular health (Anwar et al., 2007). The blood pressure lowering properties of leaves and pods also aids good cardiovascular health. Phytosterols from Moringa oleifera increase estrogen production that enhance the activity of the mammary glands ducts (Gopalakrishnan 2016). It is found that adding fresh or dried leaves to the feed of milk cows increased milk production by 43 and 65% respectively (Bhargave 2015). Moringa oleifera can also help lactating mothers produce more milk and help to treat malnutrition in young children. Studies carried out on mice by adding Moringa oleifera in doses of 0.042 mg/g of body weight resulted in increased milk production. The presence of antioxidants and flavonoids enhances the nutritional value of the foods/snacks with Moringa oleifera. (Ellis 2011; Jung 2016). Studies were carried out on animals with cerebrovascular diseases by adding Moringa oleifera in their daily feed and found to have promoted memory, learning and cognitive
functions (Vauzour et al. 2008). Due to high iron content, Moringa *Oleifera* can overcome iron deficiency and modulate the expression of iron-responsive genes better than conventional iron supplements and leaves can be a potential source of dietary folate. (Saini *et al*., 2014b).

Moringa leaves have antioxidants (260 mg/100 g) along with polyphenol contents (260 mg/100 g), quercetin (100 mg/100 g), Kaempferol (34 mg/100 g) and B-catotene (34 mg/100g). A complete list of nutrients available in leaves (Fresh & Dry), leaf powder, seeds and pods are shown in Table 1 (Fuglie L.J, 1999). It is noted that nutrient content is more in dry leaves than in fresh ones.

**Table 1. The Nutritional analysis of Fresh and Dry leaf powder, seeds and pods per 100 g of edible portion.**

<table>
<thead>
<tr>
<th>Nutrients</th>
<th>Fresh leaves</th>
<th>Dry leaves</th>
<th>Leaf powder</th>
<th>Seed</th>
<th>Pods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calories (cal)</td>
<td>92</td>
<td>329</td>
<td>205</td>
<td>–</td>
<td>26</td>
</tr>
<tr>
<td>Protein (g)</td>
<td>6.7</td>
<td>29.4</td>
<td>27.1</td>
<td>35.97 ± 0.19</td>
<td>2.5</td>
</tr>
<tr>
<td>Fat (g)</td>
<td>1.7</td>
<td>5.2</td>
<td>1.9</td>
<td>35.21 ± 0.01</td>
<td>0.1</td>
</tr>
<tr>
<td>Carbohydrate (g)</td>
<td>12.5</td>
<td>41.2</td>
<td>38.2</td>
<td>8.67 ± 0.12</td>
<td>3.1</td>
</tr>
<tr>
<td>Fibre (g)</td>
<td>0.9</td>
<td>12.5</td>
<td>19.2</td>
<td>2.87 ± 0.03</td>
<td>4.8</td>
</tr>
<tr>
<td>Vitamin B1 (mg)</td>
<td>0.06</td>
<td>2.02</td>
<td>2.64</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>Vitamin B2 (mg)</td>
<td>0.05</td>
<td>21.3</td>
<td>20.5</td>
<td>0.06</td>
<td>0.07</td>
</tr>
<tr>
<td>Vitamin B3 (mg)</td>
<td>0.8</td>
<td>7.6</td>
<td>8.2</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>Vitamin C (mg)</td>
<td>220</td>
<td>15.8</td>
<td>17.3</td>
<td>4.5 ± 0.17</td>
<td>120</td>
</tr>
<tr>
<td>Vitamin E (mg)</td>
<td>448</td>
<td>10.8</td>
<td>113</td>
<td>751.67 ± 4.41</td>
<td>–</td>
</tr>
<tr>
<td>Calcium (mg)</td>
<td>440</td>
<td>2185</td>
<td>2003</td>
<td>45</td>
<td>30</td>
</tr>
<tr>
<td>Magnesium (mg)</td>
<td>42</td>
<td>448</td>
<td>368</td>
<td>635 ± 8.66</td>
<td>24</td>
</tr>
<tr>
<td>Phosphorus (mg)</td>
<td>70</td>
<td>252</td>
<td>204</td>
<td>75</td>
<td>110</td>
</tr>
<tr>
<td>Potassium (mg)</td>
<td>259</td>
<td>1236</td>
<td>1324</td>
<td>–</td>
<td>256</td>
</tr>
<tr>
<td>Copper (mg)</td>
<td>0.07</td>
<td>0.49</td>
<td>0.57</td>
<td>5.20 ± 0.15</td>
<td>3.1</td>
</tr>
<tr>
<td>Iron (mg)</td>
<td>0.85</td>
<td>25.6</td>
<td>28.2</td>
<td>–</td>
<td>5.3</td>
</tr>
</tbody>
</table>
Studies have demonstrated that regular consumption of Moringa oleifera leaf tea changes blood circulating neutrophils and helps in ease of stress (Drue et al., 2018). Previous studies fed mouse with acute lung inflammation with dried Moringa leaves tea and showed that mice that had decreased lung inflammation marked by alterations in cytokine production, leukocyte migration, and neutrophil apoptosis (McKnight et al., 2014). It is proved by the animal study carried out on Swiss albino mice that ethanolic extract of Moringa leaves has anti-anxiety effect (Bhat 2014).

2.2 The Flowers

Moringa oleifera flowers are consumed directly as part of the diet, but also to make infusions which have hypocholesterolemic properties (Gopalakrishnan et al., 2016). The flowers can also be a cause of nectar and are used to produce honey and in transepidermal water loss letting to increase hydration (Ali et al. 2013a, b, c) (2). A methanol extract of Moringa oleifera flowers is proved to have anti-cancer properties by inhibiting growth of PC3 cells in a dose-dependent manner, while not affecting the feasibility of normal cells (Inbathamizh 2013). Several researchers have reported on the medicinal value of Moringa oleifera flower, especially their anti-microbial and anti –tumour properties (Fahey (2005, 2017), (Divya et al., (2019), (Delaveau Boiteau 1980; Hameed et al., 1998; Faizi et al., 1998; Fuglie 1999, Guiger et al., 2016; Gopalakrishnan et al., 2016)

Moringa flowers are found to have significant amount of amino acids and substantial quantity of calcium and potassium. Due to this reason, it is prescribed for lactating mothers as nutrient supplement. The flowers also produce good honey and honey clarifier (Jahn, 1984).
Moringa flowers contained both sucrose and D-glucose and it is mostly used in treatment of tumors. The flower juice of Moringa *peregrine* is useful for urinary problems (Moustafa AA, et al., 2020).

![Moringa Flowers](image)

**Fig 4: Moringa Flowers**

Recent studies on laboratory rats have shown that extracts from the moringa flower can be used to reduce inflammation and muscle spasms. Owed to the diuretic effects of moringa flower extract, it is use to help the body heal after an injury or illness. Moringa *oleifera* flowers have sufficient amount of vitamin A to boost the immune system and protect vision. As the flowers are rich in calcium, they are used to strengthen bones. Its high vitamin C content helps to reduce. (Adewumi, 2016) Moringa flower contains sucrose, D-glucose, nine amino acids, alkaloid, wax, calcium and potassium. The antibiotic property of pterogosperm in present in Moringa flower is highly effective in the treatment of cholera. They are also noted for their quercetin, flavonoid with hepatoprotective activity.

The flowers were believed to be beneficial and effective for helping to let go of traumatic memories that obstructed the mind, guilt, emotional wounds and phobias. Moringa *oleifera* flowers are said to encourage positive thinking and to renew the view on life, bringing light to the spirit (Warrier 2010).

### 2.3 The Pod
Pods of Moringa oleifera have β-carotene and vitamin A and C support in the induction of antioxidant and anti-inflammatory profiles (Bharali et al., 2003; Praengam et al., 2014). They act as potent inhibitors on the formation of reactive oxygen intermediates, a pre-requisite for tumorigenesis (Gupta et al., 2010; Kraiphet et al., 2018).

![Fig 5: Moringa Pods](image)

The pods are highly nutritious containing all the essential amino- acids (Ramachandran et al., 1980, Makkar et al., 1996). Pods of Moringa contain high amount of Ca, Mg, K, Mn, P, Zn, Na, Cu, and Fe (Aslam et al., 2005).

### 2.4 The seed

Seeds, collected from pods, can be eaten raw or cooked. Moringa oleifera seed oil or Behen/Ben oil is produced through the cold pressing of its seeds. Moringa oleifera oil has several uses such as cooking oil, preparation of biodiesel, as lubricant and in the cosmetic industry (Rashid et al., 2008). The oil contains behenic acid, which has more resistance to oxidative degradation compared to other vegetable oils. The constituents of Ben oil is oleic acid (up to 76%), palmitic (6.54%), stearic (6%), behenic (7%), and arachidic (4%) (Anwar 2005). It is used in preparation of cosmetic cream because of its nourishing, moisturizing, antioxidant and protective properties. It is also a good skin cleansing product (Nadeem and Imran 2016).

Moringa oleifera seeds help reducing the blood glucose level and its anti-diabetic activity is proved by carrying out several studies on rats by treating with 50 or 100 mg of Moringa
Moringa oleifera seeds powder/kg body weight for 4 weeks (Al-Malki and El Rabey, 2015). It also showed that ingestion led to an increase in antioxidant enzymes and compound contents such as glucomoringin, phenols, and flavonoids. This study also demonstrated the significant improvement in the kidney function. Treatment with Moringa oleifera seeds also changed oxidative stress in relation to its anti-inflammatory activity. Histopathological observations showed mild or less infiltration of lymphocytes, angiogenesis and synovial lining thickening. Seeds also have applications in industries. Seed powder has the capability to purify water and remove heavy metals and organic compounds (Sharma et al., 2006) through low molecular weight cationic proteins arbitrated precipitation (Kansal and Kumari 2014). A significant reduction of 80–99.5% in the turbidity of the water and 90–99.99% of bacterial reduction was observed (Bhargave 2015; Lea 2014). The left over paste after the oil extraction has the same flocculation properties (Lea 2010).

The seeds of Moringa were found to increase immunity. Due to the present pandemic situation, these seeds were widely used and given especially to people who are isolated in home to increase the immunity in their body (Moustafa AA et al., 2020).

![Moringa Seeds](image)

**Fig 6: Moringa Seeds**

Moringa seed oil is rich in unsaturated fatty acids like oleic acids and is more stable against oxidative rancidity and ensures low risks of coronary diseases. Seed oil from Moringa contains high amount of tocopherol (Vitamin E) indicates the higher level of antioxidant activity.
The seeds were considered notifying and were believed to renew the spirit and strengthen the body, as well as the mind and emotions (Warrier 2010).

3. **Medicinal Properties**

In traditional medicine, a paste made of leaves is applied externally in wounds (Siddhuraju and Becker 2003). Aqueous leaves extract increased human dermal fibroblasts proliferation and lead to faster wound healing (Muhammad et al., 2013). *Moringa oleifera* leaf extract with addition of ethyl acetate, in low concentration (12.5-50 µg/ml), exhibited in vitro effect in skin healing (Gothai et al., 2016). A hydro alcoholic extract of *Moringa oleifera* leaves used in a cream showed anti-aging characteristics due to phenolic compounds (Baldisserotto et al., 2018). Application of such cream is found to reduce sebum production and in transepidermal water loss permitting to increase hydration. (Ali et al., 2013a, b, c).

![Fig 7 Medicinal value of Moringa oleifera](image)

### 3.1 Anti-inflammatory activity

*Moringa* plant parts have substantial anti-inflammatory activity. The root extract exhibits anti-inflammatory activity in carrageenan induced rat paw oedema (Ezeamuzie et al., 1996; Khare et al., 1997). As the seeds of *Moringa oleifera* contains n-butanol, it shows anti-inflammatory activity against ovalbumin-induced airway inflammation. This is confirmed as result of studies on guinea pigs. Treatment with *Moringa oleifera* seeds also altered oxidative stress in relation to its anti-inflammatory activity. Histopathological observations showed mild or less infiltration of lymphocytes, angiogenesis and synovial lining thickening.
(Mahajan et al., 2009). The anti-inflammatory activity of Moringa oleifera bioactive compounds could cure inflammation related chronic diseases (Muangnoi et al., 2011). Due to the anti-inflammatory activity of Moringa plant, it has beneficial effects on asthma, pain, and other resultant symptoms.

3.2 Protection against microorganisms

Antimicrobial components of Moringa oleifera have been proved to be inhibitory against several microorganisms. Research studies have shown that aqueous extracts of Moringa oleifera was found to be inhibitory against many pathogenic bacteria, including Staphylococcus aureus, Bacillus subtilis, Escherichia coli, and Pseudomonas aeruginosa and Mycobacterium phlei and B. subtilis and the growth of fungi Basidiobolus haptosporus and Basidiobolus ranarums (Saadabi and Abu Zaid, 2011, Eilert et al.,1981, Nwosu and Okafor, 1995).

Study conducted on antimicrobial activity of seed extracts against bacteria (Pasturella multocida, E. coli, B. subtilis and S. aureus) and fungi (Fusarium solani and Rhizopus solani) showed that P. multocida and B. subtilis were the most sensitive strains. Moringa oleifera flower and leaves are also capable of scheming parasitic worms. (Bhattacharya et al., 1982).

3.3 Antipyretic properties

Due to anti-inflammatory action of Moringa bioactive constituents, the antipyretic activity can be hypothesized. A study carried out on rats to assess antipyretic effect of ethanol, petroleum ether, solvent ether and ethyl acetate extracts of Moringa oleifera seeds using yeast induced hyperpyrexia method. Paracetamol was used as control in the study. Ethanol and ethyl acetate extracts of seeds showed significant antipyretic activity (Hukkeri et al., 2006). From all above observations, it can be concluded that the seeds possess promising antarthritic property (Mahajan et al., 2009).

3.4 Use in treatment of asthma
Moringa plant alkaloid relaxes bronchioles and hence are used in the treatment of asthma (Kirtikar and Basu, 1975). The seed kernels of Moringa *oleifera* significantly decrease in the severity of asthma symptoms and also improves the respiratory functions (Agrawal and Mehta, 2008).

### 3.5 Significance in cure for diabetics

Several medicinal plants have been valued for their potential as therapeutic agent for diabetes. Moringa *oleifera* is also an important component in this category. As a mechanistic model for antidiabetic activity of moringa, it has been shown that dark chocolate polyphenols and other polyphenols are responsible for hypoglycemic activity. (Grassi *et al*., 2005)

### 3.6 Use in treatment of ophthalmic diseases

Moringa *oleifera* leaves and pods are rich source of vitamin A. This helps in preventing night blindness and eye problems in children. The leaves of moringa enhance vitamin A nutrition and slow down the growth of cataract (Pullakhandam and Failla, 2007).

### Conclusion

The study on nutrients present in Moringa has demonstrated its medicinal properties. These properties make it a promising plant for cure of various diseases such as malnutrition, ophthalmic diseases, asthma and related inflammatory diseases etc. Almost each and every part of the tree is edible consisting of larger amount of proteins, vitamins and carbohydrates compared to other nutritional products. There are number of food preparation which can be made from a single tree using various parts. Moringa is popularly referred as Miracle Tree having many benefits and can be grown at large scale without much of water and good soil requirements.

### Acknowledgements

This study was carried out as part of the project (TIDE SEED/ TITE/2019/77) financially supported by Department of Science and Technology. Authors wish to acknowledge
Department of Science and Technology for their financial support extended for the project and management of Sri Krishna College of Engineering and Technology for the support extended to carry out the project in the campus.

References


