International Journal of Scientific Research Updates

Journal homepage: https://orionjournals.com/ijsru/

ISSN: 2783-0160 (Online)

(REVIEW ARTICLE)

Review on jute leaf: A powerful biological tool

Zakaria Ahmed * and Shuranjan Sarkar

Technology Wing, Bangladesh Jute Research Institute, Manik Mia Avenue, Dhaka, Bangladesh.

International Journal of Scientific Research Updates, 2022, 04(01), 064–085

Publication history: Received on 19 June 2022; revised on 23 July 2022; accepted on 22 July 2022

Article DOI: https://doi.org/10.53430/ijsru.2022.4.1.0088

Abstract

The increasing proliferation of diseases, with the associated drug resistance, has underscored the need for new drug development. Plant-derived natural products possess diverse pharmacological activities and consequently are an attractive resource for the development of advanced chemotherapeutics to treat a wide range of disease conditions, including microbial infections. Jute leaves rich with active diterpenoids for the potential discovery of new drugs and boost up the immune system. It is commonly used for its anti-inflammatory, antineoplastic, antipyretic, anti-hypertensive, antidiabetic, cytotoxic and antipyretic effects and immune-boosting properties. Therefore, in the search for economically feasible with better efficacy and low toxicity, plant sources are highly prioritized. The present review deals to provide extensive knowledge on the different activities of jute leaves and its extracts based on the available scientific literature.

Keywords: Jute; leaves; Antioxidant; Antimicrobial

1. Introduction

Corchorus spp. (jute) is a native plant of tropical Africa and Asia, and has since spread to Australia, South America and some parts of Europe. The golden fiber and one of the main cash crops of Bangladesh is *Corchorus capsularis* (white jute). These leaves not only make great ingredients but they have also been found to have numerous medicinal benefits. Jute leaf is rich in secondary metabolites and is used in folk medicine in jute-producing communities [1].

2. Constituents and physical properties of jute leaf

More than 80 compounds, including glycosides, triterpenes, ionones, phenolics, phytosterols, organic acids, lignins, alkaloids have been isolated and identified from jute plant [2, 3]. Leaves of jute plants are 6-10 cm long and 3.5-5 cm broad. Leaves alternate, simple; stipules narrowly triangular with long point; petiole 1–7 cm long; blade narrowly ovate, ovate or elliptical, 4–15 cm × 2–5 cm, cuneate or obtuse and with setaceous appendages up to 2.5 cm long at base, acuminate to acute at apex, margin serrate or crenate, almost glabrous, usually shiny dark green, 3–7 veined from the base. Inflorescence a 1–4 flowered axillary fascicle, bracteate. Flowers bisexual, regular, usually 5 merous, shortly stalked; sepals free, narrowly obovate, 5–7 mm long; petals free, obovate, 5–7 mm long, yellow, caducous; stamens numerous; ovary superior, usually 5-celled, style short from a cylindrical capsule up to 7–10 cm long, ribbed, with a short beak, usually dehiscing by 5 valves, many-seeded. Seeds angular, 1–3 mm long, dark grey. Seedling with epigeal germination; hypocotyl 1–2 cm long; cotyledons foliaceous, broadly elliptical to circular, 3–8 mm long [4]. Leaves are normally light green colored and are bit bitter in taste. When collected young, jute leaves are tasty and tender; older leaves tend to be more woody and fibrous, making them less ideal for consumption. In addition to adding a distinctive flavor to food, jute leaves also have nutritional value, and they act as thickeners in soups, stews, and sauces.

*Corresponding author: Zakaria Ahmed
Technology Wing, Bangladesh Jute Research Institute, Manik Mia Avenue, Dhaka, Bangladesh.

Apart from their slightly bitter taste jute leaves is a good source of nutrients, vitamins and minerals (Table 1 & 2) [1, 2, 5, 6]. Apart from food use, it is grown as a commercial crop for jute production in India, Bangladesh and China [7].

Table 1 Properties of jute leave (*C. capsularis)*

Constituents	**Per 100 g of the leaves**
Calories	43-58
Moisture (water)	80.4-84.1 g
Protein	4.5-5.6 g
Fat	0.3 g
Total carbohydrate	7.6-12.4 g
Fibre	1.7-2.0 g
Ash	2.4 g
Ca	266-366 mg
P	97-122 mg
Fe	7.2-7.7 mg
Na	12 mg
K	444 mg
β-carotene equivalent	6.41-7.85 mg
Thiamine (Vitamin B_1)	0.13-0.15 mg
Riboflavin (Vitamin B_2)	0.26-0.53 mg
Niacin	1.1-1.2 mg
Ascorbic acid (Vitamin C)	53-80 mg

Table 2 Phytochemical composition of *C. olitorius*

Phytochemicals		**References**
Strophanthidin glycosides		
1 2 3	Erysimoside(strophanthidin 3-O-β-D-glucopyranosyl (1→4)-O-β-D–digitoxopyranoside), Olitoriside (strophanthidin 3-O-β-D-glucopyranosyl (1→4)-O-β-D–boivinopyranoside), Corchoroside A (strophanthidin 3-O- β-D-boivinopyranoside) and helveticoside (strophanthidin 3-O- β-D—digitoxopyranoside), Corchorusoside (A, B, C, D, and E)	[8, 9, 10]
Digitoxigenin glycosides		
1 2 3 4	Glucoevatromonoside (digitoxigenin-3-O-β-D-glucopyranosyl-(1→4)–O-β–D-digitoxopyranoside), Coroloside(digitoxigenin-3-O-β-D-glucopyranosyl(1→4)-O-β-D-boivinopyranoside), Deglucocoroloside(digitoxigenin-3-O-β-D-boivinopyranoside), Evatromonoside(digitoxigenin-3-O-β-D-digitoxopyranoside), Digitoxigenin 3-O-β-D-glucopyranosyl-(1→ 6)-O-β-D-glucopyranosyl-(1→4)-O-β-D-digitoxopyranoside	[8, 9]
Cardiac glycosides		
1	Cannogenol-3-O-β-D-glucopyranosyl–(1→4)-O-β-D-boivinopyranoside,	

2	Periplogenin-3-O-β-D-glucopyranosyl-(1→4)-O-β-D-digitoxopyranoside	[11]
Phenolics		
1 2	5-caffeoylquinic acid (Chlorogenic acid) (2) 3,5-dicaffeoylquinic acid (isochlorogenic acid)	[12, 13, 14]
Flavonoids		
1 2 3 4	Astragalin (kaempferol 3-O-β-D glucopyranoside) Tolifolin (kaempferol 3-O-β-D-galactopyranoside) Jugalanin (kaempferol 3-O-α-L-arabinopyranoside) Isoquercetin (quercetin 3-O-β-D-glucopyranoside)	[13, 15, 16]
Coumarins		
1 2 3 4	Cichoriine Scopolin Saponins Tannins	[12, 17]
Triterpenes		
1	Ursolic acid, Corosolic acid, Oxocorocin	[18, 19, 20]
2	β–Sitosterol	[21]
3	(6S,9R)-roseoside	[6, 10]
4	3,4-di-O-caffeoylquinic acid	[22, 23]
5	3,5-dicaffeoylquinic acid	[10, 14]
6	4-O-caffeoylquinic acid	[22, 23]
7	Alkaloids	[6, 26]
8	Apigenin-7-O-glucoside	[22, 23]
9	Apigenin	[22, 23]
10	Astragalin	[10]
11	Betulabuside A	[10]
12	Caffeic acid	[22, 23]
13	Campesterol	[6, 24]
14	Carvacrol methyl ether	[24]
15	Cedran-5-one	[6, 24]
16	Chlorogenic acid	[10, 14]
17	Cichoriine	[10]
18	Cirsilineol	[22, 23]
19	Cirsiliol	[22, 23]
20	Cis-β-dihydroterpineol	[24]
21	Corchoiononside A , B, C	[6, 10]
22	Corosolic acid	[20]
23	Eicosane	[6, 24]
24	Ethyl salicylate	[24]

25	Ferulic acid	[22, 23]
26	Gingerol	[22, 23]
27	Heptadecane	[6, 24]
28	Heptadecanoic acid	[24]
29	Hexadecane	[24]
30	Isobutyl salicylate	[24]
31	Isochlorogenic acid	[10, 13, 25]
32	Isoquercetin	[10]
33	Jugalanin (kaempferol 3-O-α-L-arabinopyranoside)	[25]
34	Kaempferol	[22, 23]
35	Linoleic acid	[24]
36	l-menthone	[24]
37	Luteolin	[22, 23]
38	Methyl tiglate	[24]
39	Myricetin	[22, 23]
40	Naringenin	[22, 23]
41	Naringin	[22, 23]
42	Nonadecane	[24]
43	Octadecane	[24]
44	Oleanolic acid	[6, 25]
45	Oxocorocin	[20]
46	Palmitic acid	[24]
47	P-coumaric acid	[22, 23]
48	Piperonal	[24]
49	Protocatchuic acid	[22, 23]
50	Quercetin	[22, 23]
51	Quercetin-3-(6-malonylgalactoside)	[14, 25]
52	Quercetin-3-galactoside	[14, 25]
53	Quinic acid	[22, 23]
54	Rosmarinic acid	[22, 23]
55	Rutin	[22, 23]
56	Saponins	[17, 26, 27]
57	Scopolin	[10]
58	Stearic acid	[24]
59	Stigmasterol	[24]
60	Tannins	[17, 23, 27]
61	Tetradecane	[24]
62	Tolifolin (kaempferol 3-O-β-D-galactopyranoside)	[25]

63	Trans-cis-Farnesol	[24]
64	Trans-Phytol	[6, 24]
65	Trans-β-dihydroterpineol	[24]
66	Vanillic acid	[22, 23]
67	β-amyrin	[24]
68	β-sitosterol	[21, 24]
69	1,2-benzenedicarboxylic acid	[28]
70	1,2-benzenedicarboxylic acid, dibutyl ester	[28]
71	Aldehyde	[28]
72	Benzaldehyde	[28]
73	Camphene	[28]
74	Cyclohexane	[28]
75	Fraxinellone	[28]
76	Geranylisobutyrate	[28]
77	Geranyl propionate	[28]
78	Germacrene D	[6, 28]
79	Heneicosane	[28]
80	Hexadecanoic acid	[28]
81	Hexanoic acid, methyl ester	[28]
82	Hexanone	[6, 28]
83	Hexenyl benzoic acid	[28]
84	Hydrocarbons	[28]
85	Isoamyl butyrate	[28]
86	Limonene	[28]
87	Methyl tiglate	[28]
88	Nerolidol	[28]
89	Nonadecane	[6, 28]
90	Octadecanoic acid	[28]
91	Phenyl ethyl tiglate	[28]
92	Sabinene	[28]
93	Terpenes	[28]
94	α-phellandrene	[28]
95	α-pinene	[6, 28]
96	α-terpinene	[28]
97	β-cedrene	[28]
98	β-myrcene	[28]
99	Monogalactosyldiacylglycerol	[6, 29]
100	Phytol	[29]

Table 3a Vitamin C and beta carotene content of jute leaves (mg/100 g dry weight basis)

Component	Treatment			
	Fresh	**Shade dried**	**Solar dried**	**Cooked**
Vitamin C	135.60±8.75	16.82±0.45	11.55±0.24	24.45±0.95
Beta carotene	7.82±0.16	4.65±0.32	4.42±0.28	3.81±0.42

Table 3b Qualitative presentation of phytochemicals in different condition of the jute leaves

Treatment	Phytochemical compounds							
	Flav	**Alka**	**Sap**	**Tan**	**Phe**	**Ant**	**Ster**	**Ter**
Fresh	+	+	+	+	+	+	+	-
Shade	+	+	+	+	+	±	±	-
Solar	+	+	+	+	+	-	-	-
Cooked	+	+	+	+	+	-	-	-
+ Present, – Absent, ± Doubtful								
Alka-alkaloid, Flav-flavonoid, Sap-saponin, Tan- tannin, Phe- phenol, Anth- anthraquinone, Ster-steroids, Terp-terpenoids.								

Deferent experiments have revealed that plant parts, such as leaves, stems, roots, barks, and seeds, of *C. capsularis* and *C. olitorius* contain polysaccharides, flavonoids, phenolics, cardiac glycosides, sterols, fatty acids, triterpenoids, and ionones [30]. Ahmed [6] reported that *C. olitorius*leaves are rich sources of Vitamin A (β-carotene), C, E, B_1, B_2, folic acid and minerals such as iron and calcium in addition to common macromolecules [2, 31, 32, 33] (Table 3a, b & c). Folic acid (folate, B vitamin) substantially higher (0.03 mg/L) than that of other folacin rich vegetables and iron 72 µg/g. Jute leaves yielded a lot of mucilaginous polysaccharide (acidic polysaccharide) and anthocyanin. Leaf extracts yielded alkaloids, terpenoids, tannins, flavonoids, glycosides [34]. It contains two functional compounds, phytol and monogalactosyldiacylglycerol that protect from free radicals [35]. Capsin and capsugenin isolated from the leaves of *C. capsularis* where capsin are responsible for the major bitter taste [36]. β-Sitosterol, scopoletin and fusidic acid also isolated from the leaves [37]. Caffeine and catechine isolated from *C. capsularis* leaves extract [38]. Oleanolic acid was isolated from the leaves of *C. olitorius* of Egyptian origin. Four triterpenoid glycosides (chorchorusins A, B, C and D) isolated from aerial parts of *C. acutangulus*. Leaves of *C. olitorius* contain ionone glucosides which are corchoionosides A, B and C, an ionone glucoside (roseoside) and a monoterpeneglucosidebetulabuside A. Leaves of *C. olitorius* gave four higher fatty acids with a trienone system, corchorifatty acids A, B, C, D, an uncanoic acid, corchorifatty acid E and a trihydroxy fatty acid, corrchorifatty acid F [39]. Air dried powdered leaves of *C. capsularis* in chloroform in the ratio of 1:20 ($^{w}/_{v}$) demonstrated the presence of flavonoids, saponins, tannins, steroids and triterpenes [31, 40]. The leaves of *C. capsularis* gave a new dammaranetriterpine glycoside, capsin [36, 41]. Moreover, triterpineglucosidecapsugenin 30-O-glucopyranoside 36 was isolated from the mature leaves of the species [42].

Table 3c Vitamin and Proximate composition (%) of different parameters of *C. olitorius* leaf

Proximate composition (%)					
Moisture	Ash	Crude Fibre	Protein	Lipid	Carbohydrate
79.98 ± 0.22	0.64 ± 0.02	0.33 ± 0.01	6.21 ± 0.04	5.07 ± 0.02	6.25 ± 0.03
Vitamin composition (mg/100 g dry weight)					
Ascorbic acid	Niacin	Riboflavin	Thiamin		
316.80 ± 0.22	0.61 ± 0.02	0.06 ± 0.01	0.04 ± 0.01		

C. olitorius leaves contain macro and micronutrients as well as polyphenols [14, 13, 16]. Among carbohydrates, acidic polysaccharides are of particular interest because of their notable biological effects including antidiabetic and antioxidant. It is also a good source of a diverse category of phytochemicals including alkaloids, saponins, tannins, terpenes, flavonoids, and phenolics. Different extracts exhibit potent antidiabetic, antioxidant, antiinflammatory, anticancer, antimicrobial, hepatoprotective, cardioprotective, neuroprotective, analgesic, and wound healing effects [6]. The genus Corchorus is rich in bioactive molecules such as glycosides, polysaccharides, triterpenes, ionones, phenolics, sterols, and fatty acids [43]. These biomolecules, which are part of a large and varied group of chemical compounds, impart a range of prophylactic and therapeutic applications to the genus. Growing clinical evidence also supports the traditional uses of *Corchorus* as folk medicine. Given the immense genetic diversity, geographical adoptability and biological effects on human health, the genus Corchorus can serve as a potential herbal drug-source for enhancing community health standards and livelihood security of the rural population of Asia and Africa [43]. A study was carried out by Hassan et al [44] for the determination of lipid contents (fatty acids, phytosterols and hydrocarbon components) of seeds, roots, leaves and stems of *C. olitorius* as well as the seeds and vegetative part of *C. capsularis* which showed that cholesterol was the major compound. Research has also shown that these copper-rich leaves can help to reduce the levels of bad cholesterol (LDL) and increase beneficial cholesterol. Jute leaves have about 0.222 mg of copper which can dramatically help to reduce chances of cardiovascular diseases as well as promote a healthy weight. For people suffering from sleeping disorders like sleep apnea and insomnia, jute leaves might be of help. Jute leaves are rich in magnesium which is the mineral that helps to treat and improve such conditions. Magnesium aids in the release of hormones that relax and soothe the nerves. By increasing the magnesium intake, you can improve your sleep quality for restful and uninterrupted sleeping patterns. The skin and cells require vitamin A which aids in promoting wounds healing and regrowth of skin. Vitamin A is essential in the growth of all epithelial cells both externally and internally and it also helps to prevent skin cancer. Jute leaves have an abundance of Vitamin A. Eating them regularly can help prevent various skin conditions like poor complexion, acne, lines and wrinkles keeping your skin looking young and healthy. The Vitamin A contained in jute leaves also helps to promote healthy growth of hair as well. The benefits of eating jute leaves extend to the teeth and gums. They contain calcium which helps in keeping the jaw bone strong and robust. A healthy jaw bone keeps your teeth tightly fit and makes it harder for bad bacteria to grow. To keep your teeth and gums from giving you any trouble, you should maintain a calcium-rich diet which should include daily consumption of jute leaves, especially for young children. Restless leg syndrome is a common condition usually caused by iron deficiency. Because jute leaves are rich in iron, eating them regularly can help to improve the condition. Research shows that the jute plants contain up to 2.73 mg of iron which is more than a third of the daily recommended value. Eating jute leaves can also help to curb muscle spasms which are also considered to be caused by a lack of enough iron. Jute leaves are not only a delicacy in many countries. They are also a super food with numerous health and medical benefits that promote the general well-being of the body. If you're looking to try new and healthy foods, you should consider adding jute leaves to your diet. They are available fresh and dried and both varieties have the same benefits [45]. Singh et al [46] conducted a research to evaluate the suitability of *C. olitorius* leaf powder, as a dietary protein source for fish, *Labeorohita* fingerlings and found that *C. olitorius* leaf powder can be incorporated in the feed of rohu fingerlings up to 20% (significantly $P<0.05$ higher). Tareq et al [47] examined the nutritional components of jute leaf of *C. capsularis*, germplasm (Merha red, Merha green, Birol red), *C. olitorius* accession (Acc-3840), BJRI deshi pat shak-1 and BINA pat shak-1 (Table- 4a & b).

Table 4a Mineral composition of jute genotypes [47]

Genotype	**Mineral composition**				
	Ca%	**K%**	**Na%**	**P%**	**Fe (mg·kg^{-1})**
Merha red	2.36a[a]	1.61ab	0.125a	0.62ab	971c
Merha green	1.93ab	1.67ab	0.118a	0.588b	610d
Birol red	2.21a	1.97a	0.099a	0.613ab	1253b
Acc-3840	2.07ab	1.68ab	0.098a	0.655a	1208b
BJRI deshi pat shak-1	1.62b	1.75ab	0.111a	0.654a	993c
BINA pat shak-1	1.91ab	1.39b	0.091a	0.636ab	1344a
LSD	0.5304	0.3728	0.0575	0.0575	59.97
CV%	14.44	12.26	18.56	5.00	3.10

aValues in columns followed by the same letter are not significantly different, $p \leq 0.05$, LSD.

Table 4b Vitamin composition of jute genotypes [47]

Genotype	Vitamin composition				
	Moisture (%)	Protein (%)	Ash (%)	β -carotene (μg·g^{-1})	Vitamin-C (mg/100 g)
Merha red	85.04a [a]	18.45c	7.770a	125.4a	74.53a
Merha green	82.12cd	22.54a	5.673c	127.5a	75.80a
Birol red	82.57bc	22.68a	6.837b	117.9b	59.83d
Acc-3840	83.06bc	20.72b	5.587c	103.7c	67.30b
BJRI deshi pat shak-1	84.08ab	22.66a	8.580a	115.8b	67.73b
BINA pat shak-1	80.63d	22.83a	5.690c	95.59d	63.85c
LSD	1.725	0.656	0.863	4.161	2.573
CV%	1.14	1.67	7.09	2.00	2.08

[a] Values in columns followed by the same letter are not significantly different, $p \leq 0.05$, LSD.

3. Food uses

Jute leaves contains high amounts of mucilaginous polysaccharides which yield viscous soup when cooked and usually used as an accompaniment for main dishes [48]. In Middle Eastern countries, the leaves are cut into small pieces and boiled in water with salt and pepper to make soup. Jute leaves soup is very popular in the Middle East. In Mediterranean regions, young green leaves and shoots are used to add flavor and viscous texture to soups and stews. Seeds are used for flavoring. Tender leaves and shoots are also eaten raw as salad vegetable in Egypt and India [49]. Dried leaves are used in the preparation of herbal tea. The leaves are used to prepare a stew called "ewedu" in Nigeria, while in Philippines the leaves along with bamboo shoots are consumed as a leafy vegetable. In Nigeria, sticky sauce comparable to okra is prepared and eaten as an accompaniment for starchy dumplings made from cassava, yam or millet. Since, Jute leaf is an annual herb dried leaf powder is used to make this sauce during off season. Sauce is also prepared from powdered and dried immature fruits (bush okra). In East Africa, it is cooked with cowpeas, pumpkin, cocoyam leaves, sweet potato, milk, butter, and meat flavored with pepper and lemon [20, 50]. Recently, Jute leaves are also used for the development of Sushi wrap as a promising viable substitute for Nori [51].

4. Medicinal Benefits

Medical science has made a remarkable advancement through the discovery of numerous drugs and medicines-antibiotics, hormones and vaccines-for the treatment of several diseases caused by pathogenic microbes, even though these pharmaceutically formulated medicines are not totally free from side effects. Nevertheless, more studies are still needed to be done to discover cure for many diseases that still remain incurable. This therefore underscores the need to involve herbal medicine in the fight against diseases, because it is cost effective with little or no side effects. To this end, different plants and herbs should be studied to harness their medicinal values. Studies have shown that plants are the major raw materials used in medical researches for the production of drugs and medicines. In fact, the use of plants in the management and treatment of diseases started with life. Human depends on plants for medicine; both for orthodox and herbal medicine. Through phytochemical screening of plants, it has been revealed that various plants have medicinal values and properties for the treatment of different human diseases. Jute leaves contain 0.0496 mg of vitamin B_6 which is over 30% of the recommended daily value. Most eye diseases are a result of poor diet and nutrient deficiencies. Some of the nutrients that are linked with improving eye health and preventing eye diseases and disorders include Vitamin B_6 and folate among other vitamins. Regular consumption of jute leaves can help in slowing the onset of some eye diseases including age-related muscular degeneration. Patil and Jain [27] stated that successive solvent extracts of *C. olitorius* contains medicinally important bioactive compounds. Phytochemical analysis revealed the presence of phenols, flavonoids, tannins, saponins, alkaloids, fixed oil and fats which concluded that the crude extract of *C. olitorius* is a potential source of various activates and this justifies its use in folkloric medicine [27]. Vitamin C which is abundant in jute leaves is essential in helping the immune system ward off colds and viruses. In addition to fighting colds, vitamin C can also keep us from suffering further complications like lung infections and pneumonia. Jute leaves are rich in fibre too. Dietary fibre is one of the major elements that help in regulating the digestive process. By regularly eating jute leaves, you can avoid constipation, bulk up stool and speed up digestion. Having a fibre-rich diet also helps

to increase the uptake efficiency of nutrients and it reduces symptoms like cramping and gas [45]. Ali et al [39] reported that jute can be a potential medicinal product for the treatment of many diseases. Its leafy vegetable is popularly used in folk medicine for the treatment of fever, chronic cystitis, cold and tumours. There are many health benefits of jute leaf, such as-weight loss (due to the presence fatty acids, Omega 3, Vitamins B, magnesium and zinc), prevents aging (due to antioxidant activity and also it prevents the loss of water through the skin), strengthens bone and teeth (due to the presence of calcium and phosphorus), stabilizes blood pressure (due to Omega 3), helps in hormone stabilization in women and improves brain health (due to Omega 3) [52]. One of the most celebrated medical benefits of jute leaves is their ability to battle inflammation in the body. Because they contain a variety of antioxidants, eating jute leaves can help to protect against damage caused by inflammation. It is also believed that jute leaves have anti-inflammatory properties. In a study conducted in 2015, it was found that the jute plant to have properties that can treat inflammation. By eating jute leaves regularly, one can prevent inflammation [45]. Jute leaves have a variety of properties that are critical in helping manage body weight. Their high fiber content is essential in improving digestion and keeping people feeling full for longer. On the other hand, *C. capsularis* leaves illustrated several pharmacological effects such as anticancer [29], anti-inflammatory, antinociceptive, antipyretic [53] and antimicrobial [54]. Nasreen et al [55] reported that jute leaves contain β-carotene but it varies among different varieties jute leaves and most of the varieties in *C. olitorius* showed higher β-carotene than the varieties of *C. capsularis*. This β-carotene is a carotenoid pigment that converts to vitamin A in human body and plays crucial role in visual functions, reproductive performance and immune system. Health-flourishing effects of plant-derived secondary metabolites in human health, including antioxidative, anticarcinogenic, antibiotic, and pharmacological effects, are well documented [56]. *C. olitorius* leaves are used in the treatment of fever, tumors, pectoral pains, dysentery, aches, enteritis, cystitis, piles and dysuria [57]. *C. capsularis* leaves are also used in ayurvedic for ascites, piles, cystitis, dysuria, fever and gonorrhoea [31].

5. Exhibit potential for disease control

Ahmed et al [58] stated that *Corchorus* spp. can be a potential medicinal product for the treatment of many diseases. In traditional medicinal practices, it is used to treat constipation, demulcent, dysentery, worm, carminative anthalmitic, intestinal antiseptic, ascites, pain, piles, tumors, dysuria, febrifuge, stomachic, cystitis etc. Till now more than 80 compounds, including glycosides, triterpenes, ionones, phenolics, phytosterols, organic acids, lignins, alkaloids have been isolated and identified from jute plant. The main phytochemical compounds are cardiac glycosides, corchorin, corchotoxin, helveticoside, corchoroside A and B, olitoriside, erysimoside, straphatidol, glycoside, capsularinsteroids and many other secondary metabolites. Modern studies have revealed several biological activities such as acidic polysaccharide, cardiotonic, anti-obisity, gastroprotective, antidiabetcs, antioxidant, anti-inflammatory and cytotoxic activities [58]. The human foreskin has potential to be used as a source of stem cells. Becer et al [59] investigated the apoptotic and proliferative effects of *C. olitorius* on human foreskin cells (hnFSSCs) spheroids and found that *C. olitorius* increased proliferation of hnFSSCs which might increase proliferation of stem cells too. It has been reported that jute halts progression of and helps manage deferent chronic diseases like tumors, obesity, diabetes, and cardiovascular diseases [1]. One of the major challenges facing mankind from time immemorial is disease endemic. Today, several thousands of diseases have been diagnosed, with many of them still being incurable. There are many things that can cause diseases, but microorganisms are the main cause of human, animal and plant diseases. For example, it was discovered in 19th century that microbes can cause numerous infectious diseases, like flu, measles, chickenpox, tuberculosis, whooping cough, cholera, etc. Researchers also discovered in 20th century that microbes contribute also to many non-infectious chronic diseases and conditions, such as some forms of cancer, coronary artery diseases, diabetes, multiple sclerosis, and chronic lung diseases. Microorganisms are of diverse kinds-pathogenic and non-pathogenic microorganisms. As non-pathogenic microbes cause no harm in their hosts, pathogenic microbes cause lots of harms (diseases and death) in their hosts. Study shows that both infectious and non-infectious human diseases are caused by pathogenic microorganisms. As the world population grossly increases, human diseases also increase. Therefore, stresses the need to research more into alternative medicine (herbal medicine), so as to augment orthodox medicine (conventional medicine). Although all parts of the plant have traditionally been used, the leaves are the most common medicinal part of the plant. Jute leaves may not be known to many, but they are a part of the jute plant that's mostly cultivated in Asia, the Middle East, and parts of Africa. Jute leaves are used as a food source in these regions; in fact, they are said to add a distinct flavour to food and also act as thickeners in soups, stews and sauces. Jute leaves are also known as saluyot, ewedu or lalo, depending on the region they are being cultivated or cooked in. The leaves have slightly toothed edges. When harvested young, jute leaves are generally flavourful and tender; on the other hand, older leaves tend to be fibrous and woody. Scientifically known as *C. olitorius*, parts of jute plants are used in many ways. While jute stems are used to make rope, paper and a variety of other products, jute leaves are not just for culinary uses but also are known for their medicinal properties. The leaves are said to have anti-inflammatory properties, which may prevent conditions like arthritis, acne, asthma, cold, etc. Jute leaves are said to be a good source of beta-carotene, which is why it is used in medicines in most parts in Africa and Middle East [16]. Oxidative damage contributes to the development of disease [60, 61]. Cooked jute appears to offer higher concentrations of these vitamins and minerals.

However, that's because a cooked cup of jute leaves contains about three times the number of leaves. Gomaa et al [62] studied on the efficacy of *C. olitorius* leaf extract in the prevention of metabolic syndrome induced in rats by high-fat diet (HFD) and found that it is effective in preventing obesity, hyperlipidaemia, steatosis and insulin resistance. According to Gomaa et al [62], these actions may be mediated by inhibiting of lipase activity, TNF-α, IL-1β and leptin resistance along with increasing of adiponectin. Corchortoxin (strophanthidin) was a cardiac aglycone isolated from *C. capsularis* seeds, showed a cardio-tonic activity. These activities were similar to digitalis genus. However, jute seeds extract showed better activities than corchortoxin. Corchoroside A and B, which also isolated from other plants also showed digitalis like action [63, 64, 65, 66, 67]. Numerous epidemiologic literature has verified an important correlation between the consumption of phenolic compound-rich food and a decreased risk for developing cardiovascular and other diseases [68, 69]. Two antitumor against tumor promoter-induced Epstein-Barr virus activation were isolated from the leaves of *C. capsularis*. The antitumor-promoting activity was examined by an immuno blotting analysis. Their active components were identified as phytol (3,7,11,15-tetramethyl-2-hexadecen-1-ol) and mono-galactosyldiacylglycerol (1,2-di-O-α-linolenoyl-3-O-β-D-galactopyranosyl-sn-glycerol). The content of the latter was found to vary among cultivars. The detectable amount of each active component increased by treatment of the leaves with hot water [29]. Brine shrimp lethality bioassay was carried out to determine the cytotoxicity of the crude methanolic extract of *C. capsularis* leaves and its fructions. Butanol extract was the most potent extract (71.14 % inhibition at a concentration of 1.25 mg/ml), followed by ethyl acetale (28.57 % inhibition at a concentration of 1.25 mg/ml) and methanol extract (14.28 % inhibition at a concentration of 1.25 mg/ml) [3]. Soykut et al [70] studied on the determination of *in vitro* anticancer and apoptotic induction effects of dichloromethane (DCM) and aqueous *C. olitorius* leaf extracts in primary (Colo-320) and metastatic (Colo-741) colon adenocarcinoma cell lines and suggested that *C. olitorius* extracts can induce apoptosis in both of these cancer cell lines while being more effective in metastatic colon adenocarcinoma cell lines. Therefore, the extracts might have potential anticancer effects and possibility to be used as precursor to phytomedicinal colon cancer treatment as oppose to chemotherapy [70].

Toshio et al [71] isolated two antitumor promoters against tumor promoter-induced Epstein-Barr virus activation from the leaves of *C. capsularis* where they found that the detectable amount of each of these active components were increased by treatment of the leaves with hot water. Breast cancer has one of the highest mortality rates among all cancers. Soykut et al [72] evaluated the effectiveness of *C. olitorius* leaves extracted with ethanol plant on viability of estrogen receptor positive breast cancer cell line, MCF-7. *C. olitorius* plant contains strong phytochemicals such as quercetin and caffeoylquinic acid which exert antioxidant properties and are usually effective at reduction in cancer cell proliferation. *Corchorus* spp. leaf has long been used as a remedy in many cultures. Jute leaf products, which include the leaf juice, fried leaf, and some time whole green leaf, are used, among other reasons, as laxatives, in creams for skin care, and as a treatment for a wide range of diseases, respectively. The heterogeneous nature of jute leaf products may contribute to the diverse biological and therapeutic activities that have been observed. Variations in the composition of jute leaf can result in products with different chemical and physical properties, making the comparison of products difficult. The green, leafy vegetable is rich in beta-carotene for good eyesight, iron for healthy red blood cells, calcium for strong bones and teeth, and vitamin C for smooth, clear skin, strong immune cells, and fast wound-healing. Vitamins A, C and E present in jute leaf/Saluyot "spongeup" free radicals, scooping them up before they can commit cellular sabotage. Jute leaf as vegetable contains an abundance of antioxidants that have been associated with protection from chronic diseases such as heart disease, cancer, diabetes, and hypertension as well as other medical conditions. Fresh jute leaf has higher demand. Ayurvedics use the leaves for ascites, pain, piles (laxative), and tumors. Elsewhere the leaves are used for cystitis, dysuria, and fever. The cold infusion is said to restore the appetite and strength [31]. Leishmaniasis, the vector-borne neglected tropical disease, is the second leading infectious disease after malaria. Approximately 350 million people are affected by leishmaniasis per year in 98 countries worldwide [73]. Among the various clinical forms, visceral leishmaniasis is the deadliest [74]. Current antileishmanial drugs exhibit toxicity- and resistance-related issues. Therefore, advanced chemotherapeutic alternatives are in demand, and currently, plant sources are considered preferable choices. Pramanik et al [74] reported that the chloroform extract of *C. capsularis* leaves exhibits a significant effect where leaf-derived β-sitosterol competitivelyinhibited Leishmaniadonov anitrypanothione reductase. *C. capsularis* leaf-derived β-sitosterol (β-sitosterol CCL) as a novel antileishmanial agent that competitively inhibits Leishmaniadonov anitrypanothione reductase.

Overall, the antiparasitic efficiency and the ability of this phytosterol to block one of the most crucial parasitic enzymes emphasize its proficiency as a strong candidate for treatment of visceral leishmaniasis [74]. İşeri et al [75] investigated cytotoxic and genotoxic effects of leaf extracts and seed extracts of the *C. olitorius* on the multiple myeloma-derived ARH-77 cells where the extracts were also evaluated for their total phenol content and free radical scavenging activity and reported the high cytotoxic potential of *C. olitorius* seed extracts and the genotoxic potential of leaf extracts and seed extracts. Dewanjee et al [76] evaluated the protective effect of aqueous extract of *C. olitorius* leaves against $CdCl_2$ intoxication and their results exhibited a significantly increased intracellular Cd accumulation, oxidative stress and DNA fragmentation in the organs. Moreover, the haematological parameters were significantly altered in the $CdCl_2$ treated

and could significantly restore the biochemical, antioxidant and haematological parameters near to the normal status. Their histological studies of the organs supported the protective role of jute leaves, in addition the presence of substantial quantity of phenolic compounds and flavonoids in extract may be responsible for overall protective effect. Jute leaves also contain lycopene, an antioxidant that protects our cells against oxidative damage, which increases your disease risk. Their lycopene content can vary by the preparation method. For example, cooked jute leaves and older jute leaves have higher levels [77]. Jute leaves may have an anti-inflammatory effect on the liver. A study examined rats who ate jute leaves daily for 30 days. At the end of the study, the rats had improved liver antioxidant statuses [78]. Groundwater arsenic contamination in Bangladesh and its adjoining part of West Bengal (India) is reported to be the biggest arsenic calamity in the world in terms of the affected population. Tossa jute (*C. olitorius)* is a popular crop of this arsenic prone population. Das et al [79] evaluated the protective effect of aqueous extract of *C. olitorius* leaves against sodium arsenite (NaAsO(2)) induced cardiotoxicity in experimental rats and concluded that the treatment with aqueous extract of *C. olitorius* prior to arsenic intoxication has significant protecting effect against arsenic-induced myocardial injury. On the other hand, Das et al [80] studied to evaluate the protective effect of aqueous extract of *C. olitorius* leaves against sodium arsenite-induced toxicity in experimental rats and concluded that the treatment with aqueous extract of *C. olitorius* prior to arsenic intoxication has significant role in protecting animals from arsenic-induced hepatic and renal toxicity. Again, Das et al [81] suggested that treatment with aqueous extract of *C. olitorius* prior to arsenic intoxication has a significant role in protecting animals from arsenic-induced toxicity too. Rice accumulatesthe arsenic in different parts during irrigation with arsenic contaminated water and this arsenic are accumulated in different parts of rice which increased dose-dependently. Hence, for irrigation purpose arsenic contaminated water cannot be used. Furthermore, arsenic contaminated rice induced several toxicities in animal model, most of which could be minimized with the food supplementation of *Corchorusolitorius* leaves. Therefore, *C. olitorius* can be used as a potential food supplement to the affected people of arsenic prone zone to ensure the food security [82]. Yan et al [83] investigated the effect of five fractions (crude phenolic extracts using 80 per cent aqueous acetone of whole plant, leaf, stem, washed leaf (WL) and dried water washing material (WW) on the regulation of inflammatory responses in lipopolysaccharide (LPS)-stimulated J774A.1 macrophage cells and found that Linoleic acid autoxidation inhibitions on all fractions were higher than that on α-tocopherol. Moreover, all fractions diminished LPS-induced protein expression of inducible nitric oxide synthase (iNOS) and cyclooxygenase 2 (COX-2). Nitric oxide (NO) and prostaglandin E2 (PGE(2)), downstream products, were also suppressed in dose-dependent manners, except for WL and WW. It was also found that oxidative modification and loss of leaf phenolics after kneading and washing greatly affected DPPH radical scavenging and inflammatory responses [83]. The mosquitocidal activities of *C. capsularis* against a common malarial vector, Anopheles stephensi and a dengue vector Aedes aegypti was studied where Elangovan et al [84] referred to the possible utilization of *C. capsularis* to control mosquito menace to a greater extent. However, On the other hand, in studying of the role of jute leaf (*C. capsularis*) phytochemicals on feeding, growth and reproduction of DiacrisiacasignetumKollar (Lepidoptera: Arctiidae), it appeared that the larval and post larval developmental duration was shorter on mature jute leaf fed insects whereas adult longevity was higher in it ($P < 0.05$) relative to young and senescent leaf fed insects. Fecundity of D. casignetum was also highest on mature leaves followed by young and senescent leaves. The growth and development of D. casignetum were related to the nutrient content relative to the secondary metabolites of these three types of jute leaves. Higher levels of nutritional factors (total carbohydrates, proteins, lipids, nitrogen and amino acids including water content) and lower levels of anti-nutritional factors (secondary metabolites) in mature jute leaves have influenced lower developmental time along with higher growth rate, fecundity and accumulated survivability of D. casignetum than the young and senescent leaves [84, 85].

The use of functional foods and their bioactive constituents have been considered as a new approach in the prevention and management of type-2 diabetes and its complications. Saliu et al [86] evaluated the antidiabetic potentials of jute leaf (*C. olitorius*) on low dose streptozotocin/high fat diet induced diabetic rats and found that jute leaf could be a good source of functional food for dietary intervention in the management of type-2 diabetes and its associated complications. Oboh et al [87] reported the inhibitory action of polyphenol-rich extracts (free and bound) of *C. olitorius* on α-amylase, α-glucosidase and angiotensin I converting enzyme (ACE), as well as to identify the phenolic compound responsible for these activities. From their study it was found that the enzyme inhibitory activity of *C. olitorius* extracts may be attributed to the presence of caffeic acid, chlorogenic acid and isorhamnetin, which justify the use of jute leaf in folklore for the management of diabetes and hypertension. Saliu et al [78] studied on impaired liver function, which is associated with decreased hepatic delta-aminolevulinic acid dehydratase (δ-ALAD) activity, in diabetes mellitus and described the effect of dietary jute leaf (*C. olitorius*) on hepatic δ-ALAD activity in high-fat fed combined with low-dose streptozotocin administered diabetic rats. Saliu et al [78] suggested that restoration of hepatic δ-ALAD activity, modulation of hepatic function biomarkers, and increase in antioxidant status could be possible underlying events mediating the hepatoprotective effect of jute leaf in diabetic conditions. Shariare et al [88]reported that Phytol, a pharmacologically active compound present in *C. olitorius* leaf exhibit a range of activity including anti-inflammatory, antioxidant, anticancer, hepatoprotective etc. *In-vivo* anti-inflammatory study showed significant activity for *C. olitorius* leaf extract against carrageenan induced paw edema, which is significantly increased while delivered through

liposomes. *In-vitro* cancer cell line study data suggests that liposomal delivery of phytol was more active at lower concentration compared to pure phytol, for specific cell lines [88]. *C. olitorius* is reportedly used in ethno-medicine to arrest threatened miscarriage and other conditions associated with excessive uterine contractions. The plant is also used as a purgative, demulscent and an anti-inflammatory agent [89]. According to Orieke et al [89] *C. olitorius* leaf extract (COLE) may be a good tocolytic, anti-diarrheal and anti-inflammatory agent and offers hope of new drug discovery for such uses. Owoyele et al [90] provided information about the antipyretic and anti-inflammatory effects of *C. olitorius* root and showed that *C. olitorius* root is another good source of phytomedicine that can be used effectively to treat inflammation and pyrexia that accompany some diseases.Several studies have reported on *C. olitorius* regarding various pharmacological properties, such as antioxidant, anti-inflammatory, analgesic, and anticancer properties. Tosoc et al [91] studied to evaluate the anticancer properties, such as the antiproliferative, anti-angiogenic, and antitumor activities, of the *C. olitorius aqueous* extract and its bioactive compounds, chlorogenic acid (CGA) and isoquercetin (IQ), against human melanoma (A-375), gastric cancer (AGS), and pancreatic cancer (SUIT-2), using in vitro and in vivo biological assays where they concluded that *C. olitorius aqueous* extract has promising anticancer effects on various types of human cancer cells. Moreover, they inferred that *C. olitorius aqueous* extract and its compounds are potential nutraceutical products that could be used for cancer treatment. Recently, *C. olitorius* has been approved for its antitumor activity (Li et al 2012). According to Li et al [92], ethanol extract of *C. olitorius* might be effective against hepatocellular carcinoma through induction of apoptosis via mitochondria-dependent pathway. *C. olitorius* is an African leafy vegetable of high nutritional interest. Guzzetti et al [93] assessed its agricultural suitability to sustainable cultivation conditions and its potential benefits for human nutrition, its phytochemical content in response to conservation agriculture practices [i.e., no-tillage (NT) and cover crop maintenance] and low water regime were evaluated and compared with response under conventional agriculture management. Their research showed that *C. olitorius* can be a promising crop for improving both agricultural sustainability and health benefits due to the great amount of antioxidant compounds in leaves, whose occurrence is not altered by stressful farming conditions. Azuma et al [14] identified six phenolic antioxidative compounds [5-caffeoylquinic acid (chlorogenic acid), 3,5-dicaffeoylquinic acid, quercetin 3-galactoside, quercetin 3-glucoside, quercetin 3-(6-malonylglucoside), and quercetin 3-(6-malonylgalactoside) (tentative)], ascorbic acid and alpha-tocopherol from the leaves of *C. olitorius* by NMR and FAB-MS. Their results showed that 5-caffeoylquinic acid was a predominant phenolic antioxidant in *C. olitorius* leaves [14].

6. Antioxidants activity

Antioxidants also turn free radicals into waste by-products, which are eliminated from the body. Consumption of antioxidant-enriched fruits and vegetables is known to lower the risk of several diseases caused by free radicals [94]. Such health benefits are mainly due to the presence of phytochemicals such as polyphenols, carotenoids, and vitamin E and C [95]. Oboh et al [96] studied a comparative study of the antioxidant properties of hydrophilic extract and lipophilic extract constituents of the leafy vegetable and concluded that the additive/synergistic antioxidant activities of the hydrophilic and lipophilic constituents may contribute to the medicinal properties of *C. olitorius* leaf. The protection fruits and vegetables provide against diseases are attributed to the various antioxidants they contain [97]. Antioxidants are compounds that inhibit or delay the oxidation of other molecules by inhibiting the initiation or propagation of oxidizing chain reactions [98]. They neutralize free radical reactive species that are generated endogenously through aerobic metabolism [99]. Antioxidants are substances that prevent and stabilize the damage caused by free radicals by supplying electrons from antioxidants to these damage cells. Antioxidants may be defined as complex determined compounds that function as defensive shields against several diseases [100]. Phenolic compounds are an important group of plant-based biologically active compounds that strengthen the organism and prevent disease [101,102]. Plant polyphenols are secondary metabolites characterized by one or more hydroxyl groups binding to one or more aromatic rings [103]. Phenolic compounds have a particularly strong antioxidant effect [104, 105, 106]. Omenna and Ojo [107] evaluated the comparative phytochemical composition of kenaf and jute leaves where they infer that kenaf and jute leaves are rich in phytochemicals and antioxidants. Alexopoulou et al [108] reported that kenaf leaf was applied to Guinea worms and the stem bark has been used for anaemia in Africa. In addition, Jaihyunk et al [109] reported the presence of phyto compounds in the hexane extracts of the different parts of the kenaf plant by GC-MS analysis. Copper cause oxidative damage in plant cells and plant extracts are the sources of free radical scavengers. İşeri et al [110] tested the hypothesis that whether *C. olitorius* (jute) and *Urtica pilulifera* (Roman nettle) seed extract treatments of germinated seeds affect copper induced oxidative and genotoxic damage or antioxidant response in tomato where they found that jute seed extract contained salicylic acid and quercetin which can be correlated with the evoked effects. In wound healing, antioxidants counter the excess proteases and reactive oxygen species (ROS) often formed by neutrophil accumulation in the wounded area and protect protease inhibitors from oxidative damage. Fibroblasts and other cells may be killed by excess ROS and skin lipids will be made less flexible. Antioxidants substances reduce the possibility of these adverse events occurring hence appear to be important in the successful treatment of wounds [111, 112]. Compounds with high radical-scavenging capacity have been shown to facilitate wound-healing. Vya et al [113] reported that the methanol extract of *C. olitorius* leaves exhibited a high degree of wound

healing activity and the antioxidant activity. Moreover, according to Vya et al [113], *C. olitorius* displayed significant free-radical-scavenging activity in a concentration dependant manner in in-vitro assays. Also, the powder ointment and the water extract of *C. olitorius* have been shown to have a wound-healing property. The traditional uses of this plant to treat wound has therefore been confirmed. The free radical scavenging properties of *C. capsularis* found in Malaysia was studied [40]. The air-dried leaves of the plant (20 g) were soaked in distilled water (1:20; w/v) for 72 h at room temperature. The collected supernatants were tested for the free radical scavenging activity against the DPPH and superoxide anion radical scavenging assays. The extract showed remarkable antioxidant activity in both assays with the percentage of inhibition nearly 90% [40]. The crude methanolic extract of *C. capsularis* (leaves) and its fructions (5-25 µg/µl), were tested for the free radical scavenging activity against the DPPH and superoxide anion radical scavenging assays. Extracts were found to show remarkable antioxidant activity in both assays with the percentage of inhibition. Hexan extract caused 65.44-97.43 % inhibition and appeared the most potent antioxidant extract, followed by butanol, methanol and ethyl acetate extracts [3]. Sadat et al [114] carried out a study to evaluate the in vitro preliminary phytochemical analysis and antioxidant activity of methanolic leaf extracts of *C. olitorius* and revealed that the jute leaf possesses different phytonutrients and exhibited 1,1-diphenyl 2-picrylhydrazyl radical scavenging activity and therefore, may be used for therapeutic purposes. Various phytochemical, mineral, and antioxidant potency properties of 30 genotypes belonging to *C. capsularis* and *C. olitorius* were evaluated by Biswas et al [1]**.** Ali et al [32] investigated on the antioxidant activities and HPLC profiling of polyphenolic compounds in ethanol extract of *C. olitorius* and *C. capsularis* leaves where they evaluated the total antioxidant capacity by phosphomolybdenum method and identification and quantification of polyphenolic compounds by HPLC-DAD system. According to their results, eight polyphenolic compounds were found in the *C. capsularis* leaves but *C. olitorius* leaves contain six polyphenolic compounds. Therefore it could be suggested that *C. olitorius* and *C. capsularis* leaves contain a significant amount of several polyphenolic compounds that could be used as a natural antioxidant for functional foods [40]. Leaves of *C. olitorius* have a large quantity of antioxidants compounds connected with various biological properties, which include diuretic, analgesic, antipyretic, antimicrobial activities, antitumor [53], phenolic antioxidative compounds [14], hypoglycemic and gastroprotective [115]. Jute leaves are rich in Vitamins E, A and C which are potent antioxidants that protect the cells from free radicals and can help to improve vision and fertility. It is also found to be rich in antioxidant compounds such as caffeoylquinic acid, quercetin glycosides, vitamin E and omega-3 fatty acids [14, 13, 16, 116].

7. Anti-inflammatory, analgesic, cytotoxic and antipyretic effects

The antinociceptive and anti-inflammatory properties of *C. capsularis* leaves chloroform extract were investigated in experimental animal models. The antinociceptive activity was measured using the writhing, hot plate and formalin tests, while the anti-inflammatory activity was measured using the carrageenan-induced paw edema test. The extract was used in the doses of 20, 100 and 200 mg/kg. It was administered subcutaneously, 30min prior to subjection to the respective assays. The extract was found to exhibit significant ($p<0.05$) antinociceptive and anti-inflammatory activities Zakaria et al [40]. Dietary phenolics are known for their potent antioxidant and anti-inflammatory activities, making them promising candidates for protection against neuroinflammation and neurodegeneration. Wagdy et al [117] investigated the hydroalcohol extract of Egyptian species of *C. olitorius* leaves for its neuroprotective effects in a lipopolysaccharide-induced neuroinflammatory mouse model where they showed the promising effects of *C. olitorius* leaves in limiting neurodegeneration and cognitive impairment caused by neuroinflammation and glial cell activation. Their findings can be use in the modulation of neuroinflammatory pathways improving the neuroinflammation-related neurodegeneration and cognitive decline. This makes *C. olitorius* leaves a promising candidate as a nutraceutical supplement to be used against neuroinflammation-related disorders [117]. The antinociceptive, anti-inflammatory and antipyretic properties of an aqueous extract of *C. capsularis* leaves were studied in experimental animals. The antinociceptive activity was measured using the abdominal constriction, hot plate and formalin tests, while, the anti-inflammatory and antipyretic activities were measured using the carrageenan-induced paw edema and brewer's yeast-induced pyrexia tests, respectively. The extract was used as 11.57, 57.85, and 115.7 mg/kg, it was administered subcutaneously, 30 min prior to subjection to the mentioned assays. The extract was found to exhibit significant antinociceptive, anti-inflammatory and anti-pyretic activities in a dosage-independent manner [53]. Özlem et al [118] investigated and evaluated the cytotoxic and genotoxic effects, total phenol content and free radical scavenging activity of leaf extracts and seed extracts of the *C. olitorius* on the multiple myeloma-derived ARH-77 cells and it was revealed that the extracts induced genotoxic damage on ARH-77 cells. They demonstrated the high cytotoxic potential of *C. olitorius* seed extracts and the genotoxic potential of leaf extracts and seed extracts. It can be concluded from their study that *In vitro* cytotoxic effect and genotoxicty of leaf extracts may be attributed to pro-oxidant effect of phenol compounds, whereas cytotoxic potential of seed extracts may be related to direct effect of bioactive constituents [118].

8. Antimicrobial effect

Senu et al [119] evaluated the antimicrobial effect of the ethanol extracts of *C. olitorius* leaf at 150, 100, 50, 25 mg/mL on eight organisms and found that at 100 mg/mL and below, all the bacteria were resistant to the extract except *Shigelladysenteria* which was susceptible at the concentration of 100 mg/mL, but at the concentration of 150 mg/ml all the bacteria were susceptible except *Bacillus subtilis*. Rume [3] used disc diffusion method to determine the antibacterial and antifungal activity of the crude methanolic extract of *C. capsularis* leaves and its functions against Gram positive bacteria (*Bacillus subtilis, Staphylococcus aureus*, β-hemolytic *Streptococcus*, *Bacillus cereus* and *Streptococcus pyrpgen*), Gram negative bacteria (*Shigella boydii, Salmonella typhi E. coli, Klebsiella* sp. and *Vibrio mimicus*), yeast and fungi (*Candida albicans, Saccharomyces cerevisiae* and *Bacillus megaterium*). *C. capsularis* extracts possessed antifungal and anti-yeast activity, and N-hexane fraction of methanolic extract of leaves of *C. capsularis* showed the highest activities against Gram positive, Gram negative bacteria and fungi with a zone of inhibition 0.9-1.5 mm, followed by hexane extract [3, 120]. Yakoub et al [121] analyzed the antioxidant and antibacterial activities of *C. olitorius* extracts. Antimicrobial test showed also that increasing concentrations of phenolic extracts increased the clear diameter zone around the tested bacteria and that ethanolic extract exhibited the best antibacterial activity against *Staphylocaccusaureus*, *Micrococcus luteus*, *Bacillus cereus*, *Escherichia coli*, *Klebsiella pneumoniae*, *Salmonella enterica*, *Salmonella typhi*, and *Enterobacter* sp. [121] which suggest that ethanolic extract might be used as a natural antioxidant and antimicrobial for functional foods. Hayder and Enas [122] investigated the chemical constituents, pharmacological activity and antiviral activity of the *C. olitorius* against measles virus, where they stated the significant antiviral activity of the aqueous layer of *C. olitorius* leaves against measles virus which was due to the presence of phenols and flavonoids in the aqueous layer of *C. olitorius* leaves.

9. Insecticidal effect and pesticidal use

The mosquitocidal activities of *C. capsularis* against a common malarial vector, *Anopheles stephensi* and a dengue vector *Aedes aegypti* were studied. The larvicidal activity exerted by ethyl acetate was more prominent than acetone and methanol extracts in all concentrations tested against *Ae. aegypti* larvae. Evaluation of the lethal concentration values (LC_{50} and LC_{90}) of acetone, ethyl acetate and methanol extract of the plant against *An. stephensi* and *Ae. aegypti* revealed that LC_{50} of 197.34 ppm and LC_{90} of 358.59 ppm was recorded for acetone extract against the *An. stephensi*; furthermore, the larvae of *Ae. aegypti* showed the LC_{50} and LC_{90} values of 222.45 and 383.06 ppm respectively, with the treatment with the acetone extract of *C. capsularis*. Minimum LC_{50} values were observed among the experimental larval groups treated with methanol extract of *C. capsularis* were 176.19 ppm and 182.06 ppm against *An. stephensi* and *Ae. Aegypti,* respectively. With regard to the ovicidal activity of acetone, ethyl acetate and methanol extract, it was apparent that 300-450 ppm concentrations resulted with no hatchability on *An. stephensi* and 375-450 pp concentrations in *Ae. aegypti*. The authors referred to the possible utilization of *C. capsularis* to control mosquito menace to a greater extent [84]. The efficacy of emulsified petroleum ether extract of Corchorus capsularis seed was studied against three stored product pests (*Callosobruchus chinensis*, *Sitophilusoryzae* and *Tribolium castaneum Herbst*) in adult phase. The residual film technique method was conducted to determine the LC_{50} value of the mentioned plant extract against three stored product pests. LD_{50} (µg /cm) of *C. capsularis* against *C. chinensis* was 74.26 (50.26 - 109.74) after 24 h and 6.67 (0.49 - 90.07) after 48 h. LD_{50} against S. oryzae was 84.61 (61.98-115.50) after 24 h and 32.87 (16.03-67.39) after 48 h. While, LD_{50} against *T. castaneum* was 547.08 (477.38-626.97) after 24 h and 452.51 (380.30 - 538.42) after 48 h [123]**.** However, On the other hand, in studying of the role of *C. capsularis* leaf phytochemicals on feeding, growth and reproduction of *DiacrisiacasignetumKollar* (Lepidoptera: Arctiidae), it appeared that the larval and post larval developmental duration was shorter on mature jute leaf fed insects whereas adult longevity was higher in it ($P < 0.05$) relative to young and senescent leaf fed insects. Fecundity of *D. casignetum*was also highest on mature leaves followed by young and senescent leaves. The growth and development of *D. casignetum* were related to the nutrient content relative to the secondary metabolites of these three types of jute leaves. Higher levels of nutritional factors (total carbohydrates, proteins, lipids, nitrogen and amino acids including water content) and lower levels of anti-nutritional factors (secondary metabolites) in mature jute leaves have influenced lower developmental time along with higher growth rate, fecundity and accumulated survivability of *D. casignetum* than the young and senescent leaves [84].

Jute leaves contain Hydrogen cyanide (HCN) and several cardiac glycosides. Negm et al [65] report the LD_{50} of issue extracts to mice. The lethal dose of Corchoroside A to cats is 0.053-0.0768 mg/kg and Corchoroside B 0.059-0.1413, but some authors say that Corchoroside A is twice as active as Corchoroside B [124]. Anthracnose spots caused by *Colletotrichumgloeosporioides* may infect 50-90% of a jute population, but spraying with copper oxychloride at 0.5% strength checked the spread, holding it to 5-10%. This species was badly infested by 3 species of weevils (*Myllocerus* spp.) while *C. capsularis* was unaffected. The semilooper (*Anomissabulifera*) may stunt the growth, reducing fiber yields by ca 13-32 %. The yellow mite, *(Polyphagotarsonemuslatus*) may also reduce yields [124].

10. Source of nanoparticles

The green synthesis of nanoparticles has attracted many researchers because of the high demand to produce clean, nontoxic chemicals, environmentally benign solvents, and renewable materials. Moreover, this methodology improves the biocompatibility of the obtained NPs [79, 125, 126, 127]. For instance, many successful attempts have been reported in the literature, which achieve the synthesis of nanoparticles using biological systems, such as yeast, fungi, and bacteria [79, 125, 126, 127, 128]. Recently, the use of plant extracts has proven to be one of the most successful techniques for growing nanoparticles. Most of these studies employed broths, obtained from boiling fresh plant leaves [66,129, 130, 131, 132, 133, 134]. So far, it has been established that the antioxidant components of the studied plant extracts are responsible for the reduction of metal salts, leading to the growth and stabilization of the NPs [129, 130, 66, 127,131, 132, 133, 134]. The plant extracts are generally mixtures containing a variety of compounds, including active component(s) [126, 127,135]. In spite of the fact that each active constituent in herbal extracts claims efficacy, the combined components may reciprocally affect their respective pharmacokinetic behavior, thus hampering the extract's safety and efficiency [135, 136, 137, 138]. The eco-friendly process for the synthesis of nanoparticles like- silver nanoparticles (AgNP) and gold nanoparticles (AuNP) are now focuses on mechanism of the antibacterial activity of AgNPs and the anticancer activity of AuNPs. Biomolecules in the plant extract are involved in reduction of metal ions to nanoparticle in a one-step and eco-friendly synthesis process. Natural plant extracts contain wide range of metabolites including carbohydrates, alkaloids, terpenoids, phenolic compounds, and enzymes. A variety of plant species and plant parts have been successfully extracted and utilized for AgNP and AuNP syntheses. Green-synthesized nanoparticles eliminate the need for a stabilizing and capping agent and show shape and size-dependent biological activities. Nanoparticles are important in the field of pharmaceuticals for their strong antibacterial and anticancer activity [27, 139,140,141]. Gold nanoparticles (AuNPs) are extremely promising objects for solving a wide range of biomedical problems. The gold nanoparticles production by biological method ("green synthesis") is eco-friendly and allows minimization of the amount of harmful chemical and toxic byproducts [142]. A facile bottom-up "green" synthetic route of gold nanoparticles (Au NPs) is described, using a leaf extract of *C. olitorius* as a reducing and stabilizing agent [127]. Ismail et al [127] reported a one-step green synthesis of gold nanostructures using naturally occurring biodegradable plant-based surfactants from *C. olitorius* leaves, without any special reducing or capping agents.

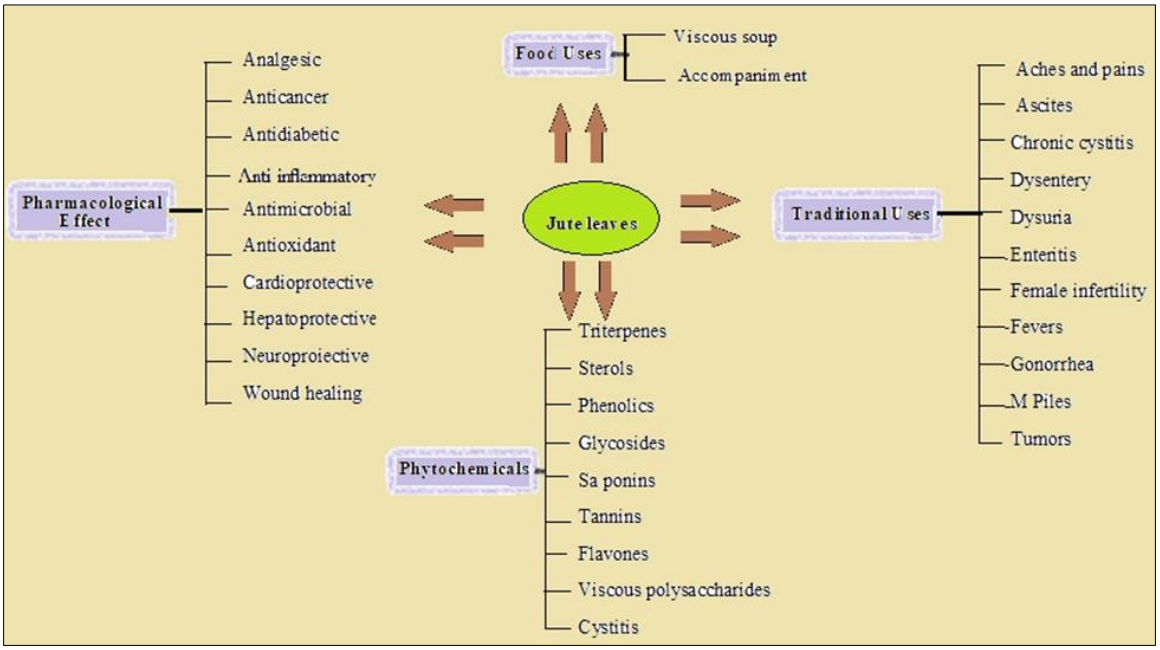

Figure 1 Different uses of jute leaf

11. Conclusion

Demand for medicinal plants is increasing in both developed and developing countries due to the growing recognition of natural products being equally effective, safe, non-narcotic, and affordable and has no side effects. Biologically active pure compound is better than crude extract. However, to get the overall view regarding the phytochemical composition and biological activities of any plant, it is important to pick the most potential part by investigating several parts (leaf, stem bark, root bark, fruits, flowers etc.) of that plant. Secondary metabolite molecules in plants food are attributed with

various biological activities. Various findings demonstrate that leaves of *C. capsularis* and *C. olitorius* with the high level of phytochemical constituents include flavonoids, polyphenols, tannins, and saponins that possess strong radical scavenging activity and antioxidant power. Therefore, this jute leaf could be a promising potential as an outstanding source of natural antioxidants in food, pharmaceutical, and cosmetics industries. Researchers studied the phytochemical and antioxidant activity of methanolic extract of leaves of *C. olitorius* and find out the presence of different secondary metabolites and antioxidants. The presence of these bioactive compounds in jute leaf establishes it as a potential source of a natural therapeutic agent that can be used against different infectious and other diseases. These extracts might have potential anticancer effects and possibility to be used as precursor to phytomedicinal colon cancer treatment. *C. olitorious* is easily available and economically cheap and therefore can be used for the medicinal purposes. Finally, investigations on the isolation and identification of antioxidant components in this particular plant will lead us to know the chemical entities with potential for clinical use. The *C. olitorius* extracts may serve as a substitute for chemical antioxidant substances and hence might have the potential to serve as bio-preservatives too. *C. capsularis* can be taken as alternative sources for other constituents applicable to the nutrition, medicine and cosmetics. The phytochemical and antioxidant properties of methanolic extract of leaves of *C. olitorious* indicated the presence of different secondary metabolites and antioxidants. According to Ahmed [6], jute leaf has diverse pharmacological activities due to presence of polysaccharides and phenolic compounds which would be beneficial to popularize the utilization of jute leaf as functional food ingredient in food formulations. The presence of these bioactive compounds in jute leaf establishes it as a potential source of a natural therapeutic agent that can be used against different infectious and other diseases. C*. olitorious* is easily available and economically cheap and therefore can be used for the medicinal purposes.

Compliance with ethical standards

Acknowledgments

We thank Dr. Aleya Nasreen, PSO, Microbiology Department, BJRI and Ms. Taslima Rahman, SO, Microbiology Department, BJRI for comments that greatly improved the manuscript. We thank our colleagues from Bangladesh Jute Research Institute for sharing their pearls of wisdom with us during the course of this review.

Disclosure of conflict of interest

All authors declare that they have no competing interests.

References

[1] Biswas A, Dey S, Li D, Liu Y, Zhang J, Huang S, Pan G and Deng Y. Comparison of phytochemical profile, mineral content, and In vitro antioxidant activities of Corchorus capsularis and Corchorus olitorius leaf extracts from different populations. J Food Quality. Article ID 2931097, 2020; 14 pages.

[2] Islam MM. Rahman M. In: Hand book on agricultural technologies of jute, kenaf and mesta crops. Bangladesh Jute Research Institute, Manik Mia Avenue, Dhaka-1207, Bangladesh, 2008; 92.

[3] Rume JM. Phytochemical, antimicrobial and biological investigations of methanolic extract of leaves of Corchorus capsularis. Thesis for bachelor degree of pharmacy, 2010; East West University.

[4] Kirtikar KR. Basu BD. Medicinal Plants of India. New Delhi: Indian Council of Medical Research. 1975; Vol. 4.

[5] Vorpur.com, Bangladesh's Leading Online Health Food Store Based On Dhaka, http://www.vorpur.com/vegetable-organic-jute-vegetables-spinach-leaves-argaanik-pat-shak/.

[6] Ahmed Z, Banu H, Akhter F. Izumori K. A simple method for D-xylose extraction from jute stick and rice husk. Online J Biol Sci. 2001; 1: 001-1004.

[7] Holm LG. A Geographical Atlas of World Weeds. 1979; New York: Wiley.

[8] Mahato SB. Subodh K. Cardiac Glycosides from Corchorus olitorius. 1989; 2065-8.

[9] Goda Y. Sakai S. Nakamura T. Akiyama HTM. Identification and Analyses of Main Cardiac Glycosides Seeds and Their Acute Oral Toxicity in Corchorus to Mice olitor. 1998; J Food Hyg Soc Japan.

[10] Yoshikawa M. Murakami T. Shimada H. Fukada N. Matsuda H. Sashida Y. et al. Corchorusosides A, B, C, D, and E, new cardiotonic oligoglycosides from the seeds of Corchorus olitorius L. (Moroheiya). Heterocycles. 1998; 5(48): 869-73.

[11] Nakamura T. Goda Y. Sakai S. Kondo K. Akiyama H. Toyoda M. Cardenolide glycosides from seeds of Corchorus olitorius. Phytochemistry. 1998; 49(7): 2097-101.

[12] Masayuki V. Shimada H. Saka M. Yoshizumi S. Yamaharaa J. Matsuda H. Absolute stereostructures of corchoionosides A,B and C, histamine release inhibitors from the leaves of vietnamese Corchorus olitorius l. (tiliaceae). Chem Pharm Bull. 1997; 45(3): 464-9.

[13] Handoussa H. Hanafi R. Eddiasty I. El-Gendy M. El Khatib A. Linscheid M. et al. Anti-inflammatory and cytotoxic activities of dietary phenolics isolated from Corchorus olitorius and Vitis vinifera. J Funct Foods. 2013; 5(3): 1204-16.

[14] Azuma K. Nakayama M. Koshioka M. Ippoushi K. Yama-guchi Y. Kohata K, et al. Phenolic antioxidants from the leaves of Corchorus olitorius L. J. Agri. Food Chem. 1999; 47(10): 3963–6.

[15] Hiroshi K. Seiji T. Yasutoshi YMS. Cconstituents of Corchorus olitorius. Natural Medicine. 1994; 48(3): 213-214.

[16] Zeghichi S. Kallithraka S. Simopoulos AP. Nutritional composition of molokhia (Corchorus olitorius) and stamnagathi (Cichorium spinosum). World Rev Nutr Diet. 2003; 91:1-21.

[17] Mibei EK. Ojijo NKO. Karanja SM. Kinyua JK. Phytochemical and antioxidant analysis of methanolic extracts of four african indegenous leafy vegetables. Ann Food Sci Technol. 2012; 13(1): 37-42.

[18] Qureshi AK. Chemical constituents of Corchorus capsularis and C.olitorius (Jute Plant), Part IV: Isolation of Corosolic Acid, Ursolic Acid and corosin and Correlation of Corosin with Tormentic Acid. 2013; 65(4): 1473-8.

[19] Manzoor-I-Khuda M. Habermehl G. Chemical constituents of Corchorus capsularis and C. olitorius (jute plant), Part IV isolation of corosolic acid, ursolic acid and corosin and correlation of corosin with tormentic acid. Z Naturforsch B. 1979; 34: 1320-5.

[20] Hasan HT. Kadhim EJ. Phytochemical investigation of Corchorus olitorius L. leaves cultivated in Iraq and it's in vitro antiviral activity. Iraqi J Pharm Sci. 2018; 27: 115-22.

[21] Ragasa CY. Vivar JLA. Tan MCS. Shen CC. Chemical constituents of Corchorus olitorius L. Int J Pharmacogn Phytochem Res. 2016; 8(12): 2085-9.

[22] Ademiluyi AO. Oboh G. Aragbaiye FP. Oyeleye SI. Ogunsuyi OB. Antioxidant properties and in vitro α-amylase and α-glucosidase inhibitory properties of phenolics constituents from different varieties of Corchorus spp. J Taibah Univ Med Sci 2015; 10: 278-87.

[23] Ben YAR. Abdehedi O. Jridi M. Elfalleh W. Nasri M. Ferchichi A. Flavonoids, phenols, antioxidant, and antimicrobial activities in various extracts from Tossa jute leave (Corchorus olitorus). Ind Crops Prod. 2018; 118: 206-13.

[24] Mekhael MKG. Hassan A. Hanna A. Simon A. Tóth G. Duddeck H. Phytochemical investigation of Corchorus olitorius and Corchorus capsularis (family Tiliaceae) that grow in Egypt. Egypt Pharm J 2019; 18: 123-34.

[25] Kohda H. Tanaka S. Yamaoka Y. Moringa S. Ohara Y. Constituents of Corchorus olitorius L. Natu Med. 1994; 48: 213-4.

[26] Nduka AG. Oluwatoyin AO. Temitope AO. Odutola O. Hypoglycemic and hypolipidemic effects of Corchorus olitorius leaves as a food supplement on rats with alloxan-induced diabet. Ukrain Biochem J. 2020; 92: 63-9.

[27] Patil DK. Jain AP. Extraction, qualitative and quantitative determination of secondary metabolites of Corchorus olitorius. J Drug Deliv Ther. 2019; 9(1-s): 252-255.

[28] Driss D. Kaoubaa M. Ben MR. Kallel F. Eddine AB. Ellouz CS. Antioxidant, antimutagenic and cytotoxic properties of essential oil from Corchorus olitorius L. flowers and Leaf. Free Radic Antioxid. 2016; 6: 34-43.

[29] Furumoto T. Wang R. Okazaki K. Hasan AF. Ali MI. Kondo A. et al. Antitumor promoters in leaves of jute (Corchorus capsularis and Corchorus olitorius). Food Sci Technol Res. 2002; 8: 239-43.

[30] Khan MSY. Bano S. Javed K. Mueed MA. A comprehensive review on the chemistry and pharmacology of Corchorus species- a source of cardiac glycosides, triterpenoids, ionones, flavonoids, coumarins, steroids and some other compounds. J. Sci. Indus. Res. 2006; 65: 283–298.

[31] Islam MT. Freitas RM. Sultana I. Mahmood A. Hossain JA. Homa Z. Chowdhury MMU. A Comprehensive Review of Corchorus Capsularis: A Source of Nutrition, Essential Phytoconstituents and Biological Activities. J Biomed Pharma Res. 2013; 2 (1): 1-8.

[32] Ali MM. Ahmed KS. Hossain H. Roy B. Rokeya B. Rahman MT. Jahan IA. Rahman MM. Total antioxidant capacity and profiling of polyphenolic compounds in jute leaves by HPLC-DAD. Food Res. 2021; 5 (1): 343 –348.

[33] Adeniyi SA. Ehiagbonare JE. Nwangwu SCO. Nutritional evaluation of some staple leafy vegetables in Southern Nigeria. Int J Agri Food Sci. 2012; 2(2): 37-43.

[34] Barku VYA. Boye A. Quansah N. Antioxidant and wound healing on the extrats of Corchorus olitorius leaf. World Essays J. 2013; 1(3): 67-73.

[35] Elangovan A. Dhanasekaran S. Anandan A. Krishnappa K. Gokulakrishnan J. Elumalai K. Mosquitocidal activities of Corchorus capsularis L (Malvaceae) against a common malaria vector, Anopheles stephensi (Liston) and a dengue vector Aedes aegypti (L) (Diptera: Culicidae). Int J Recent Sci Res. 2012; 3(6): 564-568.

[36] Hasan CM. Islam A. Ahmed M. Ahmed M. Waterman PG. Capsugenin, a dammarane triterpene from Corchorus capsularis. Phytochemistry. 1984; 23(11): 2583- 87.

[37] Ramadevi D. Ganapaty S. Phytochemical examination of Corchorus capsularis roots. Int J Pharmacognosy Phytochem Res. 2013; 5 (3): 173-76.

[38] Tabassum T. Extraction, identification and estimation of caffeine and catechin from Corchorus capsularis leaves extract. Thesis of a bachelor degree in pharmacy, 2009; East West University.

[39] Ali MM. Ray B. Rokeya B. Nasreen MA. Ahmed Z. Potential Healing Powers with Jute Plant- A Review. Int J of Sci: Basic and Applied Res. 2019; 48(5): 10-23.

[40] Zakaria ZA. Sulaiman MR. Gopalan HK. Ghani ZDFA. Nor RNSRM. Jais AMM. Abdullah FC. Antinociceptive and Anti-inflammatory Properties of Corchours capsularis Leaves Chloroform Extract in Experimental Animal Models. The Pharmaceutical Society of Japan. 2007; 127(2): 339-65.

[41] Quader MA. Gray AI. Waterman PG. Lavaud C. Massiot G. Hasan CM. Ahmed MD. Capsugenin 25,30-O-β-di-glucopyranoside: a new glycoside from the leaves of Corchorus capsularis. J Nat Prod. 1990; 53: 527-30.

[42] Quader MA. Ahmed M. Hasan CM. Waterman PG. Capsugenin-30-O-β-di-glucopyranoside: a new glycoside from the leaves of Corchorus capsularis. J Nat Prod. 1987; 50:479-81.

[43] Kumari N. Choudhary SB. Sharma HK. Singh BK. Kumar AA. Health-promoting properties of Corchorus leaves: A review. J Herb Med. 2019; 15: 100240.

[44] Hassan Z. Maged KG. Mekhael AG. Hanna AS. Gábor T. Helmut D. Phytochemical investigation of Corchorus olitorius and Corchorus capsularis (Family Tiliaceae) that grow in Egypt. Egyptian Pharm J. 2019; 18(2): 123-134.

[45] Jute Trading Ltd https://www.jutebag.co.uk/benefits-of-jute-leaves/. 2021.

[46] Singh P. Paul BN. Rana GC. Giri SS. Evaluation of jute leaf as feed ingredient for Labeo rohita fingerlings. Indian J Anim Nutr. 2016; 33(2): 203-207.

[47] Tareq MZ. Bashar KK. Amin MR. Sarker MDH. Moniruzzaman M. Sarker MSA. Islam MS. Nutritional composition of some jute genotypes as vegetables, International J. Vegetable Sci. 2019.

[48] Adebo HO. Ahoton LE. Quenum FJ. Adoukonou-Sagbadj H. Bello DO. Chrysostome CA. Ethnobotanical knowledge of jute (Corchorus olitorius L.) in Benin. Eur J Med Plants. 2018; 26: 1-11.

[49] Ali SI. Nasir Y. Flora of Pakistan. Karachi: Dep. of Botany, Univ. of Karachi. 1999; p. 192.

[50] Abdul S. Kaushik C. Jute-A biological elixir with multifaceted applications: An overview. Int J Res Pharm Sci. 2015; 6: 323-32.

[51] Castro MP. Obtinalla CO. Lucente ME. Evaluation of jute (Corchorus olitorius) leaves as a sushi wrap. Adv Nutr Food Sci. 2018; 3:1-5.

[52] Adekanye M. Six health benefits of jute leaf (Ewedu). https://guardian.ng/life/health-benefits-of-jute-leaf-also-known-as-ewedu-for-humans/. 2019.

[53] Zakaria ZA. Kumar GH. Nor RNS. Sulaiman MR. Fatimah CA. Mat JAM. Somchit MN. Ismail MS. Antinociceptive anti-inflammatory and antipyretic properties of an aqueous extract of Corchorus capsularis leaves in experimental animal models. Pharm Bio. 2009; 47(2): 104-110.

[54] Mondal TK. Sohel MD. Kawsar MH. Laso D. Phytochemical and antimicrobial investigations of different fractions of the methanolic extract of Corchorus capsularis leaves. African J Pharma Pharmaco. 2017; 11(17): 209-216.

[55] Nasreen MA. Ahmed Z, Ali MM. Tahmina. Determination of β-carotene in jute leaves by spectrophotometry and thin layer chromatography. World J Biol Pharm Health Sci. 2022; 9(2): 11–20.

[56] Lee YH. Choo C. Watawana MI. Jayawardena N. Waisundara VY. An appraisal of eighteen commonly consumed edible plants as functional food based on their antioxidant and starch hydrolase inhibitory activities. J Sci Food Agri. 2015; 95(14): 2956-2964.

[57] Adegoke AA. Adebayo-Tayo BC. Phytochemical composition and antimicrobial effects of Corchorous olitorius leaf extracts on four bacterial isolates. J Medicinal Plants Res. 2009; 3(3): 155-159.

[58] Ahmed Z. Ray B. Rokeya B. Ali MM. Nasreen MA. Potential Healing Powers with Jute Plant- A Review. Int J Sci: Basic Appl Res. 2019; 48: 10-23.

[59] Becer E. Soykut G. Kabadayi H. Mammadov E. ÇaliŞ İ. Vatansever S. Obtaining Stem Cell Spheroids from Foreskin Tissue and the Effect of Corchorus olitorius L. on Spheroid Proliferation. Turk J Pharm Sci. 2020; 17(3): 265-270.

[60] Tan BL. Norhaizan ME. Liew WP. Sulaiman RH. Antioxidant and Oxidative Stress: A Mutual Interplay in Age-Related Diseases. Fronti pharma. 2018; 9: 1162.

[61] USDA (US Department of Agriculture) https://fdc.nal.usda.gov/fdc-app.html#/food-details/169354/nutrients.

[62] Gomaa AA. El-Sers DA. Al-Zokeim NI. Gomaa MA. Amelioration of experimental metabolic syndrome induced in rats by orlistat and Corchorus olitorius leaf extract; role of adipo/cytokines. J Pharm Pharmacol. 2019; 71(2): 281-291.

[63] Frerejacque M. Durgeat M. Digitalis like poisons of jute seed. Compt Rend. 1954; 238: 507-509.

[64] Banergee P. Corchortoxinm a cardiac agent from jute seeds. Helv Chim Acta, 1949; 32: 2385-2392.

[65] Negm S. EI-Shabrawy O. Arbid M. Radwan AS. Toxicological study of the different organs of Corchorus olitorius L. plant with special reference to their cardiac glycosides content. Zeitsc Ernaehrungsw. 1980; 19(1): 28-32.

[66] Rao EV. Rao DV. Pavanaram SK, von Euw J. Reichstein T. Structure of Corchoroside β- Glycosides and aglycones. Helv Chim Acta. 1971; 54(7): 1960-1968.

[67] Rao MR. Liu TP. Meng ZJ. Comparative studies on the cardiotonic action of corchoroside A, ouabain and strophanthin K on the heart-lung preparation of guinea pig and cat. Yao Xue Xue Bao. 1979; 14(5): 257-266.

[68] [68] Weichselbaum E. Wyness L. Stanner S. Apple polyphenols and cardiovascular disease- a review of the evidence. Nutrition Bulletin. 2010; 35(2): 92-101.

[69] Spencer JPE. The impact of fruit flavonoids on memory and cognition. British J Nutri. 2010; 104(3): S40-S47.

[70] Soykut G. Becer E. Calis I. Yucecan S. Vatansever S. Apoptotic effects of Corchorus olitorius L. leaf extracts in colon adenocarcinoma cell lines. Prog Nutri. 2018; 20(4): 689-698.

[71] Toshio F. Rong W. Katsuichiro O. Feroj AFMH. Idris MA. Akira K. Hiroshi F. Antitumor promoters in leaves of jute (Corchorus capsularis and Corchorus olitorius). Food Sci Technol Res. 2002; 8 (3): 239–243.

[72] Soykut G. Becer E. Calis I. Vatansever S. The Effect of Corchorus olitorius L. Extract on Viability of Breast Cancer Cells: A friend or a foe? Curr. Pers. MAPs. 2019; 2(2): 113-118.

[73] Valdivia HO. et al. Comparative genomics of canine-isolated Leishmania (Leishmania) amazonensis from an endemic focus of visceral leishmaniasis in Governador Valadares, southeastern. Brazil Sci Rep. 2017; 7: 40804.

[74] Pramanik PK. Chakraborti S. Bagchi A. Chakrabort T. Bioassay based Corchorus capsularis L. leaf derived β sitosterol exerts antileishmanial effects against Leishmania donovani by targeting trypanothione reductase. Scientific Reports. 2020.

[75] İşeri ÖD. Yurtcu E. Sahin FI. Haberal M. Corchorus olitorius (jute) extract induced cytotoxicity and genotoxicity on human multiple myeloma cells (ARH-77). Pharm Biol. 2013; 51(6): 766-70.

[76] Dewanjee S. Gangopadhyay M. Sahu R. Karmakar S. Cadmium induced pathophysiology: prophylactic role of edible jute (Corchorus olitorius) leaves with special emphasis on oxidative stress and mitochondrial involvement. Food Chem Toxicol. 2013; 60: 188-98.

[77] Nasreen MA. Ahmed Z. Ali MM. Shimu T. Jute leaves: A potential sources of lycopene. Int J Veg Sci. 2021; 1-9.

[78] Saliu JA. Ademiluyi AO. Boligon AA. Oboh G. Schetinger MRC. Rocha JBT. Dietary supplementation of jute leaf (Corchorus olitorius) modulates hepatic delta-aminolevulinic acid dehydratase (δ-ALAD) activity and oxidative status in high-fat fed/low streptozotocin-induced diabetic rats. J Food Biochem. 2019; 43(8): e12949.

[79] Das AK. Sahu R. Dua TK. Bag S. Gangopadhyay M. Sinha MK. Dewanjee S. Arsenic-induced myocardial injury: protective role of Corchorus olitorius leaves. Food Chem Toxicol. 2010; 48(5): 1210-7.

[80] Das AK. Bag S. Sahu R. Dua TK. Sinha MK. Gangopadhyay M. Zaman K. Dewanjee S. Protective effect of Corchorus olitorius leaves on sodium arsenite-induced toxicity in experimental rats. Food Chem Toxicol. 2010; 48(1): 326-35.

[81] Das AK. Dewanjee S. Sahu R. Dua TK. Gangopadhyay M. Sinha MK. Protective effect of Corchorus olitorius leaves against arsenic-induced oxidative stress in rat brain. Environ Toxicol Pharmacol. 2010; 29(1):64-9.

[82] Hosen SM. Das D. Kobi R. Chowdhury DU. Alam MJ. Rudra B. Bakar MA. Islam S. Rahman Z. Al-Forkan M. Study of arsenic accumulation in rice and evaluation of protective effects of Chorchorus olitorius leaves against arsenic contaminated rice induced toxicities in Wistar albino rats. BMC Pharmacol Toxicol. 2016; 17(1): 46.

[83] Yan YY. Wang YW. Chen SL. Zhuang SR. Wang CK. Anti-inflammatory effects of phenolic crude extracts from five fractions of Corchorus Olitorius L. Food Chem. 2013; 1138(2-3): 1008-14.

[84] Roy N. Role of Chorchorus capsularis phytochemicals on the feeding dynamics of Diacrisia casignetum Kollar (Lepidoptera: Arctiidae). J Entomo Zool Studies. 2014; 2(4): 227-236.

[85] Al-Snafi AE. The contents and pharmacological importance of Corchorus capsularis- A review. IOSR J Pharm. 2016; 6(6): 58-63.

[86] Oboh G. Schetinger MR. Stefanello N. Rocha JBT. Antidiabetic potentials of jute leaf (Corchorus olitorius) on type-2 diabetic rats. J Emerg Tren Engin Appl Sci. 2015; 6(7).

[87] Oboh G. Ademiluyi AO. Ayodele JA. Henle T. Jamiyu AS. Uwe S. Inhibitory effect of polyphenol-rich extracts of jute leaf (Corchorus olitorius) on key enzyme linked to type 2 diabetes (α-amylase and α-glucosidase) and hypertension (angiotensin I converting) in vitro, J Func Foods. 2012; 4(2): 450-458,

[88] Shariare MH. Noor HB. Khan JH. Uddin J. Ahamad SR. Altamimi MA. Alanazi FK. Kazi M. Liposomal drug delivery of Corchorus olitorius leaf extract containing phytol using design of experiment (DoE): In-vitro anticancer and in-vivo anti-inflammatory studies, Colloids and Surfaces B: Biointer. 2021; 199: 111543.

[89] Orieke D. Ohaeri OC. Ijeh II. Ijioma SN. Gastrointestinal and uterine smooth muscles relaxant and anti-inflammatory effects of corchorus olitorius leaf extract in laboratory animal models. J Ethnopharmacol. 2020; 247: 112224.

[90] Owoyele BV. Oyewole AL. Alimi ML. Sanni SA. Oyeleke SA. Anti-inflammatory and antipyretic properties of Corchorus olitorius aqueous root extract in Wistar rats. J Basic Clin Physiol Pharmacol. 2015; 26(4): 363-8.

[91] Tosoc JPS. Nuñeza OM. Sudha T. Darwish NHE. Mousa SA. Anticancer Effects of the Corchorus olitorius Aqueous Extract and Its Bioactive Compounds on Human Cancer Cell Lines. Molecules. 2021; 26(19): 6033.

[92] Li X. Yu Y. Xiao Y. Jin M. Hong Q. Chen A. Yang C. Protein digestibility of enzymatic hydrolysis feather meal in vitro and its application in growing pigs. Chinese J Anim. Nutr. 2012; 48 (15): 33-36.

[93] Guzzetti L. Panzeri D. Ulaszewska M. Sacco G. Forcella M. Fusi P. Tommasi N. Fiorini A. Campone L. Labra M. Assessment of Dietary Bioactive Phenolic Compounds and Agricultural Sustainability of an African Leafy Vegetable Corchorus olitorius L. Front Nutr. 2021; 8: 667812.

[94] Hamid K. Saha MR. Urmi KF. Habib MR. Rahman MM. Screening of different parts of the plant Pandanus odorus for its antioxidant activity. Int J Appl Biol Pharm. 2010; 1:1364–8.

[95] Steinmetz KA. Potter JD. Vegetables, fruit, and cancer prevention: a review. J Am Diet Assoc. 1996; 96: 1027–39.

[96] Oboh G. Raddatz H. Henle T. Characterization of the antioxidant properties of hydrophilic and lipophilic extracts of Jute (Corchorus olitorius) leaf. Int J Food Sci Nutr. 60 Suppl. 2009; 2:124-34.

[97] Azeez L. Adeoye MD. Majolagbe TA. Lawal AT. Badiru R. Antioxidant activity and phytochemical contents of some selected Nigerian fruits and vegetables. American J Chem. 2012; 2(4): 209-213.

[98] Henriques F. Guiné R. Barroca MJ. Chemical properties of pumpkin dried by different methods. Crotian J Food Tech Biotech Nutri. 2012; 7(1-2): 98-105.

[99] Bennett LE. Jegasothy H. Konczak I. Frank D. Sudharmarajan S. Clingeleffer PR. Total polyphenolics and anti-oxidant properties of selected dried fruits and relationships to drying conditions. J Func Foods. 2011; 3: 115-124.

[100] Nath R. Roy S. De B. Duttachoudhury M. Anticancer and antioxidant activity of Croton: a review. Inter J Pharma Pharma Sci. 2013; 5: 63-70.

[101] Sun J. Chu YF. Wu X. Liu RH. Antioxidant and antiproliferative activities of common fruits. J Agri Food Chem. 2002; 50(25): 7449-7454.

[102] Gharras HE. Polyphenols: food sources, properties and applications-a review. Int J Food Sci Tech. 2009; 44(12): 2512-2518.

[103] Zhou Y. Jiang Z. Lu H. Xu Z. Tong R. Shi J. Jia G. Recent Advances of Natural Polyphenols Activators for Keap1-Nrf2 Signaling Pathway. Chem Biodiver. 2019; 16(11): e1900400.

[104] Hider RC. Liu ZD. Khodr HH. Metal chelation of polyphenols. Methods in Enzymo. 2001; 335: 190-203.

[105] Scalbert A. Johnson IT. Saltmarsh M. Polyphenols: antioxidants and beyond. American J Clin Nutri. 2005; 81(1): 215S-217S.

[106] Pandey KB. Rizvi SI. Plant polyphenols as dietary antioxidants in human health and disease. Oxidative Med Cellul Longevity. 2009; 2(5): 270-278.

[107] Omenna EC. Ojo AI. Comparative phytochemical screening of kenaf and jute leaves. J Nutr Health Food Eng. 2018; 8(5): 366–369.

[108] Alexopoulou E. Papattheohari Y. Christou M. et al. Kenaf: A multi–purpose crop for sever industrial applications. London, Springer–verlag. 2013; p. 1–15.

[109] Jaihyunk R. Soon–Jae K. Joon–Woo A. et al. Phytochemicals and antioxidant activity in the kenaf plant (Hibiscus cannabinus L.). J Plant Biotech. 2017; 44:191–202.

[110] İşeri ÖD. Körpe DA. Sahin FI. Haberal M. Corchorus olitorius and Urtica pilulifera extracts alleviate copper induced oxidative damage and genotoxicity in tomato. Acta Biol Hung. 2018; 69(3): 300-312.

[111] Houghton PJ. Hylands PJ. Mensah AY. Hensel A. Deters AM. *In vitro* tests and ethnopharmacological investigations: Wound healing as an example. J Ethnopharmacol. 2005; 100: 100-107.

[112] Hamid AA. Aiyelaagbe OO. Usman LA. Ameen OM. Lawa A. Antioxidants: Its medicinal and pharmacological applications. African J Pure Appl Chem. 2010; 4(8): 142-151.

[113] Vya B. Boye A. Quansah N. Antioxidant and wound healing studies on the extracts of Corchorus olitorius leaf. Sci Res Review J. 2013; 1(3): 67-73.

[114] Sadat A. Hore M. Chakraborty K. Roy S. Phytochemical analysis and antioxidant activity of methanolic extract of leaves of Corchorus olitorius. Int J Curr Pharm Res. 2017; 9(5): 59-63.

[115] [115] Lorenzen S. Thuss-Patience P. Al-Batran SE. et al. Impact of Pathologic Complete Response on Disease-Free Survival in Patients with Esophagogastric Adenocarcinoma Receiving Preoperative Docetaxel-Based Chemotherapy. Annals of Oncology, 2013; 24: 2068-2073.

[116] Mahmoud AS. Thao N. Mario A. Corchorus olitorius Linn: A Rich Source of Ω3-Fatty Acids. Pharm Anal Acta. 2016; 7(6).

[117] Wagdy R. Abdelkader RM. El-Khatib AH. Linscheid MW. Hamdi N. Handoussa H. Neuromodulatory Activity of Dietary Phenolics Derived from Corchorus olitorius L. J Food Sci. 2019; 84(5): 1012-1022.

[118] Özlem Dİ. Erkan Y. Feride IS. Mehmet H. Corchorus olitorius (jute) extract induced cytotoxicity and genotoxicity on human multiple myeloma cells (ARH-77). Pharma Biol, 2013; 51: 6, 766-770,

[119] Senu AJ. Olusola EM. Afolashade OO. The In-vitro effect of Corchorus olitorius (Linn.) on the antibacterial activities of five antibiotics. Global Res J Microbiol. 2012; 2(2): 113.

[120] Ahmed Z. Akhter F. Alamgir M. Isolation of some jute retting fungi from natural source and their effect on dry ribbon retting of CVL-1 jute (Chorchorus capsularis), Bangladesh J Sci Res. 1999; 17: 107-109.

[121] Yakoub ARB. Abdehedi O. Jridi M. Elfalleh W. Nasri M. Ferchichi A. Flavonoids, phenols, antioxidant, and antimicrobial activities in various extracts from Tossa jute leave (Corchorus olitorus L.). Indus Crops Products. 2018; 118: 206–213.

[122] Hayder TH. Enas JK. Phytochemical investigation of Corchorus olitorius L. leaves cultivated in Iraq and it's In vitro antiviral activity. Iraqi J Pharm Sci. 2018; 27(2): 115-122.

[123] Talukder D. Khanam LAM. Toxicity of four plant based products against three stored product pests. J Bio Sci. 2009; 17: 149-153.

[124] Duke JA. Wain KK. Medicinal plants of the world. Computer index with more than 85,000 entries. 1981; 3 vols.

[125] [125] Sawle BD. Salimath B. Deshpande R. Bedre MD. Prabhakar BK. Venkataraman A. Biosynthesis and stabilization of Au and Au–Ag alloy nanoparticles by fungus, Fusarium semitectum. Sci Technol Adv Mater. 2008; 9: 035012.

[126] Hussain I. Singh NB. Singh A. Singh H. Singh SC. Green synthesis of nanoparticles and its potential application. Biotech Lett. 2016; 38: 545–560.

[127] Ismail EH. Saqer AMA. Assirey E. Naqvi A. Okasha RM. Successful Green Synthesis of Gold Nanoparticles using a Corchorus olitorius Extract and Their Antiproliferative Effect in Cancer Cells. Int J Mol Sci. 2018; 19(9): 2612.

[128] Kunoh T. Takeda M. Matsumoto S. Suzuki I. Takano M. Kunoh H. Takada J. Green Synthesis of Gold Nanoparticles Coupled with Nucleic Acid Oxidation. ACS Sustain. Chem Eng 2018; 6: 364–373.

[129] Shankar SS. Rai A. Ahmad A. Sastry M. Rapid synthesis of Au, Ag, and bimetallic Au core-Ag shell nanoparticles using Neem (Azadirachta indica) leaf broth. J Colloid Interface Sci. 2004; 275: 496–502.

[130] Philip D. Green synthesis of gold and silver nanoparticles using Hibiscus rosa sinensis. Phys E Low Dimens Syst Nanostruct. 2010; 42: 1417-1424.

[131] Fayaz AM. Girilal M. Venkatesan R. Kalaichelvan PT Biosynthesis of anisotropic gold nanoparticles using Maduca longifolia extract and their potential in infrared absorption. Colloids Surf B Biointer. 2011; 88: 287–291.

[132] Jayaseelan C. Ramkumar R. Rahuman AA. Perumal P. Green synthesis of gold nanoparticles using seed aqueous extract of Abelmoschus esculentus and its antifungal activity. Ind Crops Prod. 2013; 45: 423–429.

[133] Gopinath K. Venkatesh K.S. Ilangovan R. Sankaranarayanan K. Arumugam A Green synthesis of gold nanoparticles from leaf extract of Terminalia arjuna for the enhanced mitotic cell division and pollen germination activity. Ind Crops Prod. 2013; 50: 737–742.

[134] Ganeshkumar M. Sathishkumar M. Ponrasu T. Dinesh MG. Suguna L. Spontaneous ultra fast synthesis of gold nanoparticles using Punica granatum for cancer targeted drug delivery. Colloids Surf B Biointer. 2013; 106: 208–216.

[135] Nahrstedt A. Butterweck V. Lessons learned from herbal medicinal products: The example of St. John's Wort. J Nat Prod. 2010; 73: 1015–1021.

[136] Qiao X. Ye M. Xiang C. Wang Q. Liu CF. Miao WJ. Guo DA. Analytical strategy to reveal the in vivo process of multi-component herbal medicine: A pharmacokinetic study of licorice using liquid chromatography coupled with triple quadrupole mass spectrometry. J Chromato. A. 2012; 1258: 84–93.

[137] Esimone CO. Nwafor SV. Okoli CO. Chah KF. Uzuegbu DB. Chibundu C. Eche MA. Adikwu MU. In vivo evaluation of interaction between aqueous seed extract of Garcinia kola Heckel and ciprofloxacin hydrochloride. Am J Ther. 2002; 9: 275–280.

[138] Gunaratna PC. Kissinger PT. Kissinger CB. Gitzen JF. An automated blood sampler for simultaneous sampling of systemic blood and brain microdialysates for drug absorption, distribution, metabolism, and elimination studies. J Pharma Toxicol Methods. 2004; 49: 57–64.

[139] Anwer MM. Sarkar S. Alam MM. Hossain SMM. Hoque MM. Haque MT. Saifullah K. Influence of Low Temperature Argon and Oxygen Plasma Treatment on the Band-gap of Jute. Int J Engi Appl Sci. 2018; 5(3): 79-82.

[140] Anwer MM. Kayser MA. Sarkar S. Hossain SMM. Akter S. Kamal TB. Jahan FN. Fourier Transform Infrared Spectroscopic Analyses of Argon and Oxygen Plasma Treated Jute. Int J Engi Appl Sci. 2018; 5(7): 5-8.

[141] Anwer MM. Kayser MA. Sarkar S. Hossain SMM. Akter S. Kamal TB. Jahan FN. Scanning Electron Microscopy Analysis of Argon Plasma Treated Jute Fiber. Int J Engi Appl Sci. 2018; 5(7): 9-11.

[142] Mikhailova EO. Gold Nanoparticles: Biosynthesis and Potential of Biomedical Application. J Fun Biomat. 2021; 12(4): 70.