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Review paper

Plant genus *Elaeagnus*: underutilized lycopene and linoleic acid reserve with permaculture potential

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Abstract – Introduction. *Elaeagnus* is a genus in family Elaeagnaceae found wild or grown as ornamental plants for its dense shrub-like structure, fragrant blossoms and silvery foliage. However, in recent times a convincing number of findings supporting the nutritional potential of its fruit has been published. **Materials and methods.** A literature search was conducted using the keywords '*elaeagnus*' 'silverberry', 'oleaster', 'antioxidant' and 'permaculture' to compile a meaningful review for fueling research interest on this genus. The nutritional and pharmacological relevance of genus *Elaeagnus* was explored and human health-related nutrients identified. **Results and discussion**. The tiny oblong fruit of genus *Elaeagnus* with red flesh and pericarp speckled with gold and silvery spots have been found to be edible. In fact, it has shown promise to be developed as a functional food owing to its richness in antioxidants phenolics acids (benzoic acid, cinnamic acid) and flavonoids (myricetin, epigallocatechin gallate). An abundance of antoxidant lycopene in its fruit has been revealed. The perceived health benefits of the fruit are blood alcohol removal, pain alleviation, wound healing, cancer prevention, antimicrobial and expectorant etc. **Conclusion.** Despite immense food and medicinal potential, the fruit of this genus are languishing in obscurity, and yet to reach mainstream market.

Keywords: *Elaeagnus* spp. / antioxidant / lycopene / food fortification / wound healing / anticancer

Résumé – Les plantes du genre *Elaeagnus* : une source sous-utilisée de lycopène et d'acide linoléic accessible en permaculture. Introduction. Les *Elaeagnus* appartiennent au genre de la famille des Elaeagnaceae dans lequel on trouve des plantes sauvages ou cultivées comme ornementales pour leur structure d'arbuste dense, leurs fleurs parfumées et leur feuillage argenté. Cependant, plusieurs publications récentes présentent un nombre convaincant de résultats soulignant le potentiel nutritionnel de leurs fruits. **Matériels et méthodes.** Les bases de données ont été interrogées à partir des mots clés '*Elaeagnus*', 'silverberry', 'oleaster', 'anti-oxydant' et 'permaculture' afin d'établir un examen sérieux capable d'alimenter l'intérêt de recherches sur ce genre. La valeur nutritionnelle et pharmacologique du genre *Elaeagnus* a également été explorée et les éléments nutritionels en lien avec la santé humaine ont été identifiés. **Résultats et discussion.** Les petits fruits oblongs du genre *Elaeagnus*, de chair rouge et au péricarpe moucheté d'or et d'argent se sont trouvent être comestibles. En fait, les fruits d'*Elaeagnus* ont le potentiel pour développer des aliments fonctionnels grâce à leur richesse en composés aminés phénoliques (acide benzoïque, acide cinnamique) et en flavonoïdes (myricétine, gallate d'épigallocatéchine). Les fruits se sont révélés particulièrement riches en lycopène, composé anti-oxydant. Les bénéfices de ces fruits pour la santé comprennent l'épuration alcoolique du sang, un effet anti-douleur, la cicatrisation des plaies, la prévention de certains cancers, des propriétés antimicrobiennes et expectorantes, etc. **Conclusion.** Malgré l'immense potentiel médicinal et nutritionnel de ses fruits, le genre Eleagnus restera obscurément oublié tant qu'il n'aura pas atteint un marché touchant le grand public.

Mots clés : *Elaeagnus* spp. / anti-oxydant / lycopène / fortification alimentaire / cicatrisation / anti-cancérogène

1 Introduction

The genus *Elaeagnus* is comprised of about 70−80 species [1]. However, only a few have been studied, the most investigated being *E. angustifolia* followed by *E. pungens*, *E. umbellata*, *E. multiflora*, *E. oldhamii*, *E. kologa*, *E. latifolia*, *E. conferta* and *E. glabra*. The compact shrubs have leaves, flowers and berries with gold and silver-colored speckles. They are used as hedge plants in urban area, for their ornamental value (fragrant flowers and shiny foliage), drought tolerance, adjustment to a variety of edaphic and moisture conditions, pollution prevention and bird attraction ability. The spherical or ovoid berries have a big drupe and thin mesocarp (*figure 1*). When raw they are astringent, but

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Figure 1. (A) *Elaeagnus* × *ebbingei* plant (B) ripe fruits on the plant.

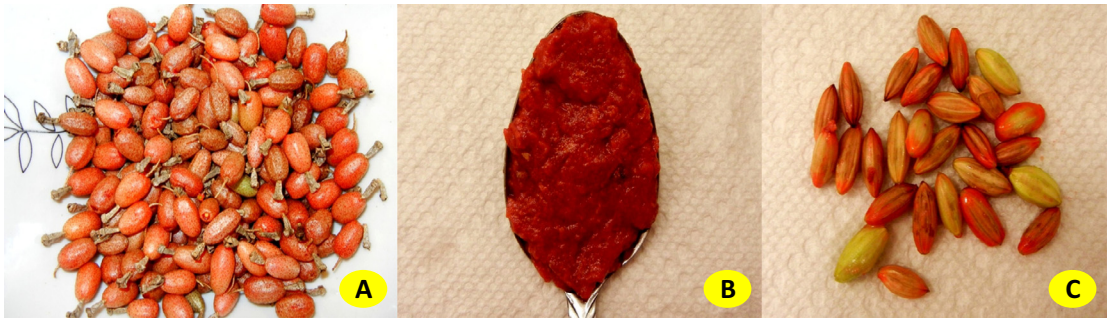

Figure 2. (A) Harvested lycopene-rich ripe fruits (B) Fruit pulp (C) Fat-rich drupes.

when fully ripe they taste sweet with hints of sourness. As the berries ripen, the pericarp color changes and size swells. The soluble sugars, organic acids, lycopene, total protein undergo variation in contents [2].

The red berries are known as oleaster, silverberry, autumn olive, thorn olive, Russian olive, Persian olive and wild olive etc. The berries of many species are consumed as such or processed as juice, herbal tea, wine, soup, sauce, dessert, candy, pudding, ice cream topping, fruit leather, jam and jelly (*figure 2*). Apart from their edibility, the plant parts have been used in folk medicine as anti-inflammatory, muscle relaxant, antipyretic, analgesic, astringent and antiulcer agent [3, 4]. The genus has cosmopolitan distribution, with various species growing in China, Japan, Korea, Taiwan, India, Pakistan, Iran, Turkey and Europe to the USA and Canada. The geographical distribution of the known species has been presented in *table I*. The fruit mostly constitutes a food for wildlife, human consumption being meager. In many parts of the globe, they are vilified as noxious weeds. In last few years, it has been discovered that the fruit is loaded with nutrients and other parts have medicinal properties. This review aims to present the key findings, the impediments and food potential of genus *Elaeagnus* for future innovation.

2 Bioactive profile of the fruit

Phytochemical and nutritional assessments have revealed the interesting profile of this genus. Extraction (water, methanol, ethanol, chloroform, hexane, ethyl acetate and acetone) and structural elucidation by (chromatography, nuclear magnetic resonance and mass spectrometry) have identified many constituents and their respective abundance. The fruits were shown to be rich in various bioactive components *viz.* phenolics, flavonoids, lipids, carotenoids and ascorbic acid [2]. The fruit pulp has antoxidant lycopene in profusion. Many research findings have reported the anticancer efficacy of lycopene to be meadiated through reactive oxygen species (ROS) scavenging, detoxification, antiproliferation and interference wih signal transduction pathways [5]. Also, the seeds have been evaluated to be plentiful in fats and proteins. *E. angustifolia* seed had 8% unsaturated fatty acids dominated by linoleic acid, oleic acid, and stearic acid. The protein content was 11%, of which globulin and albumin were the most prevalent [6]. In the preserved fruit of *E. angustifolia*, 4-hydroxybenzoic acid in the benzoic group and caffeic acid in the cinnamic group were the most abundant phenolic compounds (45.8 and 32 mg 100 g^{-1} dry weight, respectively). Fructose and glucose (32.62–34.60% and 23.37–24.10%, respectively) were found to be the major sugars in these fruit [7].The lycopene content of *E. umbellata* berries was quantified [8]. In fresh fruit, this carotenoid was multiple times higher (15–54 mg 100 g^{-1}) than that of tomato (3 mg 100 g^{-1}), known to be a lycopene storehouse. The comparative results suggest the rationale of promoting elaeagnus berries as a rich source of lycopene. Previously, *E. angustifolia* fruits have been characterized to have polysaccharides, flavonoids, coumarins, phenolcarboxylic acids, tannins, saponins and carotenoids [9]. The potential of *E. conferta* berries as supplementary food was

Table I. The studies species of elaeagnus genus, their common names, geographical distribution and verified functions.

No.	Species	Common name	Country found	Verified uses	References
1	*Elaeagnus angustifolia*	Russian olive, oleaster, winter olive	West Asia, Russia, USA, Canada, Turkey	Antioxidant Antinociceptive Anti-inflammatory Antimutagenic Antiulcerogenic Food	[3] [21] [29] [34] [36] [7, 38–40]
2	*Elaeagnus umbellata*	Japanese silverberry, autumn olive	East Asia	Anticancer	[30]
3	*Elaeagnus glabra*	–	Korea	Anticancer	[32]
4	*Elaeagnus multiflora*	Cherry elaeganus, goumi	China, Korea, and Japan	Anticancer	[33]
5	*Eleagnus latifolia*	–	India, Thailand, Vietnam	Antioxidant	[15]
6	*Eleagnus kologa*	–	India	Antimicrobial	[28] [29]
7	*E. oldhamii* Maxim	–	Taiwan	Anti-inflammatory Anticancer	[16] [12]
8	*Elaeagnus pungens*	Thorny olive	China, Japan, USA	Respiratory	[1]
9	*Eleagnus conferta*		India	Blood alcohol removal	[2]
10	*Elaeagnus commutata*	American silverberry, wolf-willow	USA, Canada	–	–
11	*Elaeagnus* × *ebbingei*	Ebbing's silverberry	–	Ornamental plant	–

explored by evaluating their antioxidant activity and chemical composition [10]. The berries were discovered to be a substantial source of carotene, ascorbic acid, protein and magnesium. Flavonol glycosides named elaeagnosides were isolated from the flowers of *E. angustifolia* [4]. Two polysaccharides were prepared from *E. angustifolia.* Both the polysaccharides had common constituents rhamnose, mannose, glucose, and galactose. One of the polysaccharide containing xylose along with the above four monomers exerted a strong free radicals scavenging activity suggesting its potential as an antioxidant [11]. From the leaves of *E. oldhamii* Maxim, several monoterpenes and sesquiterpenes were isolated *viz.* oleanolic acid, ursolic acid, betulin, lupeol, kaempferol and syringic acid [12]. The functional ingredients and the biological effects have been presented in *figure 3*.

3 Antioxidant effect

Antioxidants are known to protect cells from oxidative damage. The total phenolic and flavonoid contents and antioxidant capacity of methanolic extract of fruit of *E. kologa* Schldl. were assessed. Positive correlations were observed between polyphenolic contents and the antioxidant capacities [13]. The berries of *E. umbellata* were investigated for proximate composition, mineral content and physicochemical characteristics. The berry contained 27.8 mg 100 g^{-1} vitamin C and appreciable amount of phenolic, flavonoid, carotenoid, tannin, alkaloid and saponin contents [14]. Seven acylated flavonol glycosides named elaeagnosides A-G, in addition to seven known flavonoids, isolated from the flowers of *E. angustifolia*, demonstrated potential to scavenge DPPH [4]. Ethanolic and methanolic extracts of the *E. angustifolia* leaves and flowers demonstrated that phenolic and flavonoid were higher in Fariman variant compared to Mashhad variant. Also, it was discovered that the leaves contained a higher amount of flavonoids than the flowers [3]. The antioxidant effect of *E. latifolia* was investigated and 70% methanolic extract was reported as an effective antioxidant preparation against DNA damage [15].

4 Anti-inflammation

The usage of plant bioactives for easing pain has been in practice since ages but the relevance are surfacing with the empirical findings. Pain and allergic conditions (asthma, bronchitis and atopic dermatitis) are manifestations of inflammation. The genus *Elaeagnus* has proved to be effective in exerting anti-inflammation. One lignanoid compound, isoamericanol B isolated from the leaves of *E. oldhamii* Maxim. was shown to possess an anti-inflammatory effect based on its ability to produce nitric oxide in lipopolysaccharide-stimulated RAW 264.7 cells [16]. Osteoarthritis (joint inflammation) afflicts scores of people, women in particular. In many cases, the conventional therapy (glucocorticoids and non-steroidal anti-inflammatory drugs) proves to be deficient in managing inflammatory disorders and exerts adverse effects. In that scenario, complementary therapy is sought after. Efficay of *E. angustifolia* L. in reducing pain as well as stiffness of the debilitating diseases were investigated in female patients. An 8 week intervention with 15 g day^{-1} of *E. angustifolia* L. medulla and fruit powders were assessed. Immunological and statistical tests revealed that the supplementation favourably modulated cytokine levels. It decreased the proinflammatory cytokines tumor necrosis factor alpha (TNF-α) and matrix metalloproteinase-1 (MMP-1) and concurrently enhanced the anti-inflammatory cytokine interleukin-10 (IL-10) [17, 18]. To exploit the calcium richness of *Elaeagnus*, nanodrugs with

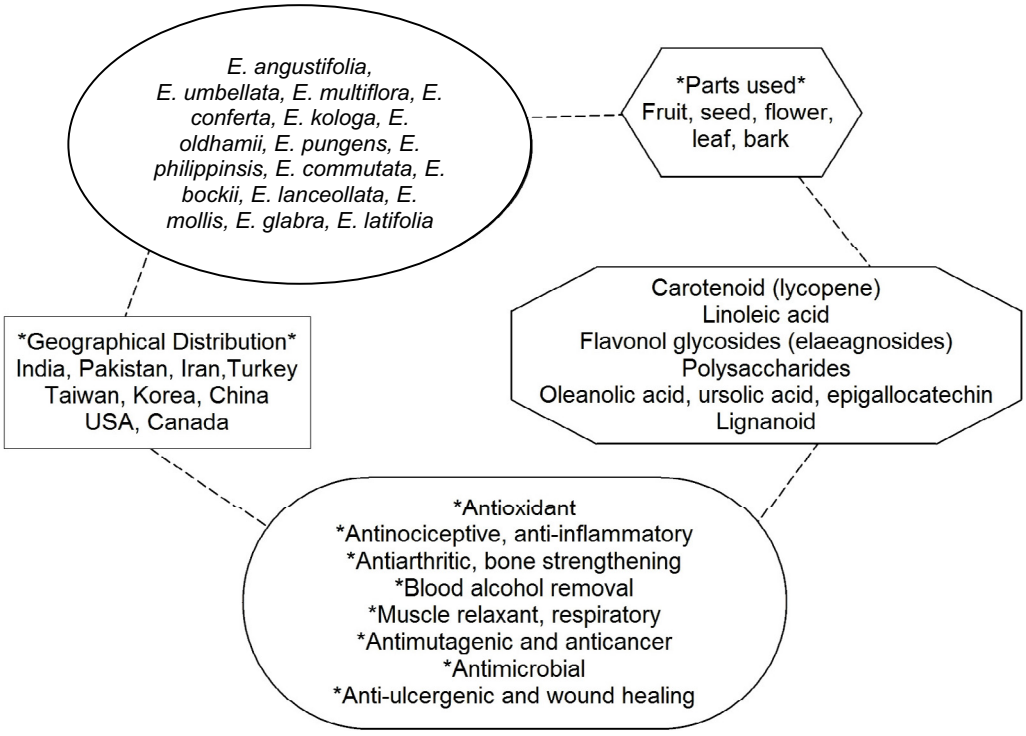

Figure 3. The geographical distribution, functional constituents and biological roles of various *Elaeagnus* species.

polymeric shells were fabricated as a preventive strategy against osteoporosis [19]. The polyamide nanocapsules containing *E. angustifolia* extract and calcium carbonate were prepared and administered to rats for 3 weeks, along with calcium tablets. *E. angustifolia* prescribed group had a higher levels of calcium in their blood [20].

The antinociceptive effect of *E. angustifolia* fruit was evaluated on rats. A dose of 1,000 mg kg^{-1} of total and aqueous endocarp extract increased tail flick latency. In the formalin test, the same dose extract alleviated the animal response to painful stimuli. Flavonoids, terpenoids and cardiac glycosides were credited for these effects [21]. The antinociceptive effect of *E. angustifolia* fruit seed extracts in mice was further confirmed using hot-plate and writhing tests. Following intraperitoneal injection, the extracts led to significant pain alleviation in a dose-dependent fashion [22]. The musle relaxant effect of *E. angustifolia* fruit seeds was determined in mice by traction test. The intraperitoneal administration of water and ethanolic extracts brought muscle relaxation in a dose-dependent manner akin to diazepam (a drug to treat seizures and muscle spasms). The beneficial effect was attributed to the flavonoids in the extract [23].

Respiratory tract inflammatory disorders such as asthma and chronic bronchitis have responded well to elaeagnus concoctions. The effects of *E. pungens* leaf extract on guinea pig tracheal and bronchial smooth muscle cells were investigated. The butanol fraction induced airway smooth muscle relaxation. The relaxant effect of the extract was not related to potassium channels, nitric oxide, cyclic guanosine monophosphate (cGMP) or β-adrenoceptors, but mediated through the inhibition of diavalent calcium channels [1].

5 Blood alcohol removal

The rate of ethanol clearance from blood varies in individuals. If not metabolized properly, it can lead to liver damage and functional changes in gastrointestinal epithelial cells as well as other deleterious effects. Hepatic alcohol dehydrogenase (ADH) and aldehyde dehydrogenase (ALDH) are key enzymes responsible for the metabolism of ethanol into acetate for subsequent oxidation and elimination from the liver [24]. The effect of *E. conferta* Roxb dry fruit powder on the activities of ADH and ALDH was evaluated. A 30-min pretreatment wih the extract at 400 and 800 mg kg^{-1} led to a faster clearance of blood alcohol after the alcohol ingestion. The concentration of blood alcohol at 4 h after alcohol intake decreased by 21.2% in mice pretreated with 800 mg kg^{-1} of the extract. These results suggest that pretreatment with the fruit powder might expedite blood alcohol removal by promoting the activities of ADH and ALDH [2].

6 Antimicrobial

It is well documented that plants of this genus are capable of arresting pathogenic microbes. The concoctions from various parts of *E. umbellata* exhibited inhibitory effect againt both Gram positive and negative pathogens. The ether extract of flower and acetone extract of fruits could restrain *P. aeruginosa* [25]. Various organic fractions of *E. angustifolia* bark ethanol extract were assessed for their anitimicrobual properties. The extract exhibited efficacy against *E. coli*, *S. aureus, B. subtilis,* and *S. enterica* [26]. *E. angustifolia* crude extract

and its hexane, ethyl acetate and aqueous fractions eliminated *E. coli* and *S. aureus*. The proliferation of *P. aeruginosa* could be controlled only by the hexane and ethyl acetate fractions. Also, the *E. angustifolia* fractions exerted antifungal effect on various Aspergillus species [27]. *E. kologa* leaf extract was screened for antibacterial components. The methanolic extract demonstrated significant antibacterial action towards *Bacillus subtilis* [28]. Another disc diffusion assay-based evaluation of *E. angustifolia* methanolic extract showed strong inhibition against *Yersinia enterocolitica*, a foodborne pathogen [29]. Though above studies reflect the antimicrobial efficacy of various Elaeganus species, the identification of the bioactive compounds are yet to be achieved.

7 Cancer therapy

Since the chemotherapeutics are proving insufficient to comabt cancer, interest has been shifted towards finding natural antidotes. Acetone extracts of fruits from 6 genotypes of *E. umbellata* were evaluated for their anticancer effect and the underlying mechanism. Pretreatment of mouse epidermal cells with the *E. umbellata* fruit extracts inhibited the activation of activator protein-1 (transcription factor playing key role in tumorigenesis) and nuclear factor-kappaB (NF-kB) induced by either tetradecanoylphorbol acetate (a tumour promoter) or ultraviolet-B (UVB) radiation. Extracts of all variants inhibited proliferation of human leukemia HL-60 cancer cells and human lung epithelial cancer A549 cells. Also, it triggered apoptosis of HL-60 cells. Among the 6 studied genotypes, 'Brilliant Rose' and 'Jewel' exerted remarkable effects [30]. Methanolic extract of *E. glabra* at a dose of 200 mg mL^{-1} reduced the aggressiveness of human fibrosarcoma HT1080 cells in a dose-dependent manner. The peptidases MMP-2 and MMP-9 have been recognized to control cancer invasion and metastasis. Their elevated level in serum and plasma is a hallmark of cancer [31]. The lowered level of MMP-2 and MMP-9 led to the conclusion that the extract possessed tumor suppressive ability [32]. The potential of *E. multiflora* fruits in cancer prevention was investigated. Its seed extract reduced the viability of human colon cancer HT-29 cells at the dose above 1,600 mg mL^{-1}, effectively reduced cyclooxygenase-2 (enzyme promoting inflammation) and phosphorylated Akt (known to suppress apoptosis) expression. Both seed and flesh extracts inhibited cell growth and induced apoptosis of the cancer cells. Results suggested that the *E. multiflora* berry extracts with anti-inflammation and anti-proliferation properties can be used to inhibit cancer growth [33]. The methanol extract of *E. angustifolia* was screened for its antimutagenic activity against sodium azide (a mutagen capable of inactivating respiratory enzyme cytochrome *c* oxidase) by Ames test. The results showed moderate inhibition of mutagenicity [29]. The leaves of *E. oldhamii* are used for treating lung disorders in Taiwan. Taking cue from this information, the leaf extract was investigated against non-small cell lung cancer A549 cells by the MTT assay. The components oleanolic acid, coumaroyl oleanolic acid, caffeoyl oleanolic acid, caffeoyl ursolic acid and trans-tiliroside were identiftied to be the effective cytotoxic agents [12].

8 Wound healing

Plants though poorly exploited for wound healing are promising candidates for low cost and side effect-free treament options.The anti-ulcerogenic activity of several plant extracts including that of *E. angustifolia* L. fruit on 96% ethanol-induced ulcers in rats was determined in a study conducted in Turkey [34]. The fruit methanolic extract showed potency when compared to the reference compound misoprostol (a synthetic prostaglandin E1 administered for prevention of gastric ulcers, treatment of missed miscarriage, labor and abortion induction). The efficacy of 19% *E. angustifolia* topical gel in the treatment of symptomatic oral lichen planus (inflammatory condition that affects mucous membranes lining oral cavity) was determined through a double-blind study [35]. Application of the gel on the lesion, thrice a day for 2 weeks showed signs of healing. Significant decrease in pain was observed in gel group and the prescribed percentage of the gel was effective in treating the inflammatory auto-immune oral mucosa. The histological changes and wound healing effect of aqueous extract of *E. angustifolia* on rats with artificial bruises were investigated [36]. The results indicated a significant increase in wound contraction, epithelialisation time and hydroxyproline (an essential component of collagen) content in the treated group after a 10 and 15 days prescription period. The results demonstrated that the aqueous extract of *E. angustifolia* expedites wound healing, and the therapeutic effect might be due to the increased re-epithelialization and collagen deposition in wound.

9 Food applications

Till now eleagnus fruits are consumed by wildlife only. However, owing to the emerging health benefits these fruits are soaring in popularity as a human food. High fruit-yielding varieties are being used for edible landscaping. Foragers consume these fruit as jam, fruit leather, salsa, wine and pies. Dried berries of *E. angustifolia* are consumed in Turkey during the winter months [7]. The ripe fruits are opulent in the antioxidant lycopene. To understand the abundance of lycopene in these fruits a gene regulation study was conducted and coordinated expression of carotenogenic genes during fruit ripening was unveiled [37]. The *E. angustifolia* fruit mesocarp flour alone or in partial substitution (5, 10, 15, 20, and 25%, w/w) with wheat flour for cookie making was evaluated [38]. The fortification at 25% level, increased total dietary fiber content (raised from 2.76 to 8.42 g 100 g^{-1}) and decreased the caloric contents (reduced from 452.77 to 424.6 kcal 100 g^{-1}) of the product. The incorporation increased size and imparted a darker colour to the cookies. The addition of mesocarp four at 5% level in the cookie formulation was approved by panellists in terms of sensory quality. The herbal tea "Zhourat" is popular in Lebanon and Syria as a digestive, sedative and expectorant. It contains a mix of herbs and flowers, including *E. angustifolia* [39]. *E. angustifolia* flour and crust were incorporated in ice cream and their impact was assessed. Results showed that the addition enhanced sensory value as well antioxidant content of the product [40].

10 Future directions

The family *Elaeagnaceae* consists of three genera *Hippophae*, *Shepherdia* and *Elaeagnus.* The species *Hippophae rhamnoides* (sea buckthorn) has established itself for food and medicinal attributes [41, 42]. Its berries and leaves possess a high content of carotenoids. Hippophae cerebroside, oleanolic acid, ursolic acid, 19-alpha hydroxyursolic acid, plamitic acid, 1-o-heaxadecanolenin are some other characteristic phytochemicals in its fruits [43]. The fruit extract offers significant protection against arsenic-induced oxidative injury [44]. The supplementation effects of vitamin E and *H. rhamnoides* extract for three weeks on nicotine-induced oxidative stress in rat liver were investigated. From the level of superoxide dismutase and glutathione reductase, it was inferred that the extract alone as well as in combination with vitamin E was able to protect liver from the adverse effect of nicotine abuse [45]. This species ameliorated functional dyspepsia (non-ulcer stomach discomfort) in children by elevating the levels of appetite modulators, leptin (hunger suppressing hormone) and neuropeptide Y (hunger stimulating hormone), thus increasing gastric emptying and digestive ability [46]. Also, its berries and leaves yielded antioxidant acylated flavonol glycosides (isorhamnetin, quercetin and kaempferol) [47]. *Shepherdia argentea* (buffaloberry) berries used to be an integral part of Native American diet. Carotenoids, vitamin C, leucoanthocyanins, catechols, flavonols have been recognized as chief phytochemicals in its fruits [48]. Two tannins, shephagenins A and B isolated along with hippophaenin A and strictinin from its leaf extract exerted remarkable inhibitory activity against human immunodeficiency virus (HIV)-1 reverse transcriptase [49]. The fruit rich in carotenoid and phenolic antioxidants showed potential to ease diabetic microvascular complications, hyperglycemia, and metabolic syndrome symptoms (modulation of lipid metabolism and energy expenditure [48, 50]. The comparative profiles of phytochemical constituents and biological roles of the three genera have breen presented in *table II*.

The above findings support the assumption that *Elaeagnus* genus could be exploited for nutrition and pharmaceuticals. Also, the recent empirical results corroborate this notion. However, the so-far discovered health potentials are only a fraction of its phytochemical wealth. It is vilified as invasive, escaped, introduced plant in several regions. The United States Department of Agriculture (USDA) labels *E. angustifolia* as noxious weed in Colorado, Connecticut and New Mexico; *E. pungens* is invasive for Florida and Tennessee. *E. umbellata* is invasive for Connecticut, Massachusetts, New Hampshire, West Virginia (USDA plants). Several studies have sought to determine the significant factors promoting its rampant proliferation on certain sites [52]. Other impediments in popularity are the big drupe, thin pulp and sourness.

Troubleshooting and commercialization moves are very essential. Germpalm conservation, hybridization, integration in edible landscaping and rehabilitation are some steps in this direction. This genus encompasses about 80 species, but only a few have so far been investigated. Many of them are endemic species and are obscure in terms of their economical value. Some endemic species like *E. mollis* (endemic to China) are endangered. Microsatellite simple sequence repeat (SSR) markers were used to assess the genetic diversity within *E. mollis* and human interference was discovered to be the reason for its threatened status [53]. Also, this microsatellite marker furnished information regarding genetic variability, population structure and origin of *E. angustifolia* [54]. Bioprospecting and preserving their germline could give future option for cloning and hybrid generation. Few hybrid varieties with desirable characteristics have been developed. *Elaeagnus* × *ebbingei*, an ornamental hybrid, is a cross between *E. macrophylla* and *E. pungens.* Surprisingly, very few cultivars have been developed for pomology purposes. As the spectre of food scarcity is rising, the permaculture revolution is picking up. It is a small-scale, self-managable horticultural design with minimal interference to the natural ecosystem [55]. This agroecological-driven cultivation strategy strives for sustainability by holistic, multifunctional food production in a fast-changing resource-depleting world [56, 57]. Here, the nexus between permaculture and *Elaeganus* genus has been cited as the ornamental species of the latter grown for urban settings can be exploited for procurement of food. As of now, the *Elaeagnus* berries are largely underutilized. Mostly foragers harvest them and recommend consumption. Most shrubs of this genus are sturdy, drought-tolerant, fire resistant, rapid growing and are capable of fixing nitrogen. These traits make this genus desirable for rehabilitation of barren and arid landscapes where only adaptive plants can thrive. Afforestation of such degraded lands with *Elaeagnus* species can prevent soil erosion, provide windbreaks and fruits. The versatile benefits of these plants imply negligible socio-economic risk associated with their plantation. A study undertook a multicriteria decision-making strategy and agreed upon the candidacy of *E. angustifolia* for the rehabitation project in the river basin of Uzbekistan [58].

It is important to thoroughly conduct cytotoxicity studies before approval of a new food candidate. In this regard, this genus has not resulted in any major undesirable characteristics. *E. angustifolia* pollen allergy leading to rhinoconjunctivitis and asthma was reported in some patients [59]. Though it is a rare occurrence, more investigations on its palatability are warranted.

A very timely review of the importance of ingestion of berries has been reported by Seeram [60]. It discusses the nutritional benefits of mainstream as well as underutilized berries, and recommends the integration of the latter in diets.

11 Conclusion

It is quite clear that this genus is opulent in nutrients, particularly lycopene and has obvious benefits for consumer health. However, it is underexploited owing to hindrances such as its stigma as an invasive plant, slight pulp, big drupe and sparse investigations. The hurdles are trivial and it deserves to be cultivated for commercial production. In fact, horticulturists are already showing interest in this genus. It is touted as the ‘plant of the future’ and the ‘plant with market potential’. It is expected that Eleagnus berries will attract the attention of

Table II. Comparison of the phytochemical profile and therapeutic functions of three genera of family *Elaeagnaceae*.

Other genera of *Elaeagnaceae*	Dominant phytochemicals	Biological functions	References
Hippophae rhamnoides (sea buckthorn)	Carotenoid, isorhamnetin, quercetin, kaempferol, hippophae cerebroside, oleanolic acid, ursolic acid, 19-alpha-hydroxyursolic acid, palmitic acid,1-O-hexadecanolenin	Protect from nicotine abuse Cytoprotective Improve alpha-linolenic acid in plasma Counteract arsenic toxicity Ameliorate dyspepsia	[45] [41] [42] [44] [46]
Shepherdia argentea (buffaloberry)	Carotenoids, vitamin C, leucoanthocyanins, catechols, flavonols, tannins (hippophaenin A, strictinin, shephagenins)	Inhibit HIV-1 reverse transcriptase Alleviate diabetes complications	[49] [48] [50]
Elaeagnus sp. (silverberry)	Vitamin C, carotenoid (lycopene), linoleic acid, tannin, flavonoid, flavonol glycosides (elaeagnosides A-G), isoamericanol B	Antioxidant Anti-inflammation Antiulcerogenic Anticancer Antimicrobial Blood alcohol metabolism	[13] [15] [36] [32] [26] [2]

farmers and food companies in the near future and this review will be a catalyst for it.

Conflict of interest: There is no conflict of interest in the submission of this manuscript.

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