Sea buckthorn berries: A potential source of valuable nutrients for nutraceuticals and cosmoceuticals

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Lalit Bal
Jawaharlal Nehru Krishi Vishwavidyalaya

Venkatesh Meda
University of Saskatchewan

Satya NARAYAN Naik
Indian Institute of Technology Delhi

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Sea buckthorn berries: A potential source of valuable nutrients for nutraceuticals and cosmoceuticals

Lalit M. Bal [a,b,*], Venkatesh Meda [b], S.N. Naik [a], Santosh Satya [a]

[a] Centre for Rural Development and Technology, Indian Institute of Technology, Hauz Khas, New Delhi 110016, India
[b] Dept. of Chemical and Biological Engineering, University of Saskatchewan, Saskatoon, Saskatchewan, Canada S7N 5A9

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ABSTRACT

Sea buckthorn (*Hippophaė rhamnoides* L.), an ancient crop with modern virtues has recently gained worldwide attention, mainly for its nutritional and medicinal value as the berries contain different kinds of nutrients and bioactive compounds including vitamins, fatty acids, free amino acids and elemental components. This review briefly summarises the current literature and discusses its potential as a crop and its post harvest processing. The available compositional data regarding sea buckthorn berries is tabulated to produce a comprehensive source of recent information on chemical and medicinally important constituents of different origin and varieties. The presence of valuable chemicals and nutritionally important constituents in sea buckthorn berries, and from the scientific knowledge of their importance, it is clear that sea buckthorn berry is one of the most important sources of these constituents, and should be used as alternative nutritional sources in the commercial market. Similarly in depth investigation on the effect of processing on the total nutrient content of sea buckthorn berries species growing in different agro-ecological regions needs to be carried out. Thus, several important knowledge gaps identified in this paper would give impetus to new academic and R&D activities, in turn generating innovative job profile in food and cosmoceutical industries.

1. Introduction

Sea buckthorn (genus *Hippophaė*) is a berry-bearing, hardy bush of the family *Elaeagnaceae,* naturally distributed in Asia and Europe and also introduced in North and South America. It includes 6 species and 12 subspecies, of which *Hippophaė rhamnoides,* commonly known as sea buckthorn, sandthorn or seaberry is a unique plant, currently being domesticated in several parts of the world (Li, 2003; Li & Schroeder, 1996; Rousi, 1971). It is a hardy plant, drought and cold resistant, useful for land reclamation and farmstead protection through its vigorous vegetative reproduction and strong, complex root system with nitrogen-fixing nodules (Rongsen, 1992).

Sea buckthorn is an optimal pioneer fascinating plant, the berries has been used for medicinal and nutritional purposes in Russia, Europe, and Asia for many centuries. This future food source, has been gaining attention because of its nutritional benefits as it has been reported to contain more than 190 compounds in the seeds, pulp, fruit and juice. These compounds include fat soluble vitamins (A, K, and E), fatty acids, lipids, organic acids, amino acids, carbohydrates, vitamins C, B_1, B_2, folic acid, tocopherols and flavanoids, phenols, terpenes and tannins. Many of the substances that found in sea buckthorn are known to have beneficial effects on health (Li & Wang, 1998). It has been well established in the literature that berries and seeds contain high amounts of natural antioxidants including ascorbic acid, tocopherols, carotenoids, flavonoids, as well as health beneficial fatty acids (Gao, Ohlander, Jeppsson, Bjork, & Trajkovski, 2000; Kallio, Yang, & Peippo, 2002; Rosch, Bergmann, Knorr, & Kroh, 2003). In spite of several importance of whole sea buckthorn plant, the most important part are berries, from which the juice is extracted and that is the reason why the sea buckthorn berries gain popularity in whole world (Beveridge, Li, Oomah, & Smith, 1999). All this indicates vast potential of sea buckthorn berries as a food resource. In the present paper literature on the chemical and medicinal constituents of sea buckthorn berries/juice and various processing methods and their effect on nutritive value of processed berries of different origin and varieties have been discussed so as to get a clear concept over the compositional importance for the future nutritional research. Future R&D areas in relation to above aspects for enhancing quality control have been identified.

2. Food potential of sea buckthorn berries

According to Schroeder and Yao (1995), sea buckthorn berries are among the most nutritious and vitamin-rich fruits found in the plant kingdom. The berries are rich in carbohydrates, protein and fat soluble vitamins, antioxidants (i.e. vitamins C and E, β-carotene, and lycopene), essential fatty acids, amino acids, phytosterols, and flavonoids, in addition to chemical elements (i.e. iron, calcium, etc.)

* Corresponding author at: Centre for Rural Development and Technology, Indian Institute of Technology, Hauz Khas, New Delhi 110016, India. Fax: +91 11 26591121.
E-mail address: lalit.bal@gmail.com (L.M. Bal).

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(Beveridge et al., 1999; Mironov, 1989; Zhang, Yan, Duo, Ren, & Guo, 1989). Apart from being nourishing, the juice has a freezing point of −22 °C allowing it to remain liquid even in sub-zero temperatures (Siberian Pine Nut Oil, 2011).

2.1. Nutritional properties and bioactive compounds in sea buckthorn berries

The female plants produce ripe sea buckthorn berries yellow, orange, or red in colour, are spherical in shape, and range in size between 3 and 8 mm in diameter (Li, 2003). The waxy skinned berries contain a single sheathed seed and a juice filled cellular structure (Beveridge, Harrison, & Drover, 2002). Sea buckthorn berries generally consist of pulp (68%), seed (23%), and peel (7.75%) (Oomah, 2003; Yang & Kallio, 2001; Zadernowski, Nowak-Polakowska, Lossow, & Nesterowicz, 1997). Sea buckthorn berries are nutritious, though very acidic and astringent, unpleasant to eat raw, unless 'bletted' (frosted to reduce the astringency) and/or mixed as a juice with sweeter substances such as apple or grape juice. The chemical and nutritional composition of sea buckthorn berries vary considerably between different subspecies, with the origin, climate, time of harvesting and method of processing (Yang, Karlsson, Oksman, & Kallio, 2001). George and Cenkowski (2005) specified that the physical characteristics of sea buckthorn berry were influenced by the harvest time whereas bioactive compounds did not vary significantly with respect to harvest time. Recently, Zheng, Kallio, Linderborg, and Yang (in press) concluded that the chemical composition of *H. rhamnoides* ssp. *sinensis* varies greatly with growth locations (variation in latitudes and altitudes). It is also reported that sea buckthorn fruit berries and seed oil contain various kinds of bioactive substances (Mingyu, Xiaoxuan, & Jinhua, 2001). The nutritional value, biochemical constituents and the mineral compositions for different varieties have been compiled and presented in Table 1.

Table 1 provides a comparative list of the nutritional composition of sea buckthorn berries.

2.1.1. Moisture, ash and total soluble solids (TSS)

The moisture content (g/100 g fresh wt) of berries is highest i.e. 80–87% (species not mentioned) as reported by Lõugas et al. (2006). The lowest in the range of 20–32% as reported by Sabir, Maqsood, Ahmed, et al. (2005) for the Pakistani varieties. The variation of moisture is due to the variation in origin and climate. But moisture content of pulp from berries is 84.9–97.6% for the Indian sea buckthorn (Dhyani et al., 2007). This moisture content is 5.43–21.9% for cv. Indian-Summer (Li et al., 1998) and 22.4% for Indian varieties (Chauhan et al., 2001) of seed from sea buckthorn berries. The ash content of the berries is reported in the range of 1.76–1.8% (Chauhan et al., 2001; Katiyar et al., 1990).TSS (°Brix) of sea buckthorn berries is 10.19–22.74 (highest) for Chinese varieties as reported by Zhang, Yan, et al. (1989) and 9.3–17.3 (lowest) for cv. Indian-Summer as reported by Li et al. (1998). But the TSS of pulp from berries is 26.2–27.9 (Arimboor et al., 2006) and 8.86–9.72 (Dhyani et al., 2007) for Indian varieties. The TSS of juice from berries is 10.7–13.2 (Arimboor et al., 2006).

2.1.2. Vitamins

Sea buckthorn berries are well known for their extraordinarily high levels of vitamin C. The vitamin C concentration in berries varies from 360 mg/100 g of berries for the European subspecies *rhamnoides* (Plekhanova, 1988; Rousi & Aulin, 1977; Wahlberg & Jeppsson, 1990, 1992; Yao et al., 1992) to 2500 mg/100 g of berries for the Chinese subspecies *sinensis* (Yang, Wang, & Su, 1988; Yao & Tigerstedt, 1994; Zhao et al., 1991). The pulp of the Indian sea buckthorn berries contains 223.2 mg/100 g of vitamin C. Approximately 75% of the vitamin C in the pulp of berries was retained in the juice during processing, resulting in 168.3–184.0 mg/100 g of vitamin C in the final clear juice (Arimboor et al., 2006). Dharmananda (2004) reported that the Portland sea buckthorn fruit has a high vitamin C content in a range of 114 to 1550 mg/100 g (Dharmananda, 2004) with an average content (695 mg/100 g) about 12 times greater than oranges, placing sea buckthorn fruit among the most enriched plant sources of vitamin C. The concentration of vitamin C in sea buckthorn fruit has been found to be higher than strawberry, kiwi, orange, tomato, carrot and hawthorn (Bernath & Foldesi, 1992). The Turkestanica sea buckthorn fruit has vitamin C content in the range of 200 to 1500 mg/100 g which is 5 to 100 times higher than any other fruit or vegetable (Ahmad & Kamal, 2002). The variation of vitamin C concentration in sea buckthorn berries is because of the specific geographic nature of the area, where short reproductive season prevails (Yao & Tigerstedt, 1995).

The vitamin E content in sea buckthorn berries is 160 mg/100 g (Eliseev, 1989; Ma & Cui, 1989; Wahlberg & Jeppsson, 1990, 1992; Zhang, Yan, et al., 1989). The juice contains 162–255 mg/100 g for Chinese varieties (Zhang, Yan, et al., 1989) and pulp 481 mg/100 g for Pakistani varieties (Zeb, 2004a). Whereas, the Chinese varieties seed contains 40.1–103.0 mg/100 g vitamin E (Ma et al., 1989). The vitamin E content in sea buckthorn is higher than that found in wheat embryo, safflower, maize and soybean (Bernath & Foldesi, 1992). They are also rich in several other vitamins, including B_1, B_2, K and bioflavonoids (Bekker & Glushenkova, 2001).

According to the former Soviet Union researcher, flavonoids in fresh fruit, the highest content is 854 mg/100 g, whereas according to a Chinese researcher, the average in fresh fruit is 354 mg/100 g. Studies also showed that in sea buckthorn from a high sea level area, the flavonoids content was higher (Yuzhen & Fuheng, 1997). But it is reported that the flavonoids content is as high as 1000 mg/100 g (Tian, 1985; Wang, 1987; Xu, 1956).

Sea buckthorn fruits are rich in pigments and lipoproteins located in membranes and the fleshy mesocarp. Carotenolipoprotein complexes are located particularly in fruit membranes where polar lipids may function as bridge compounds between the polar (protein) and non-polar (carotenoids) moieties (Pintea, Marpeau, Faye, Socaciu, & Gleizes, 2001).

Carotenoid content is the main parameter by which sea buckthorn oil is traded commercially (Beveridge et al., 1999). Carotenoids vary widely depending on the source of the oil, ranging from 314 to 2139 mg/100 g for Chinese grown sea buckthorn (Zhang, Xu, et al., 1989). Pulp and fruit oils are a good source of carotenoids as can be seen by their rich colours, at about 900–1000 mg/100 g for Pamirs sea buckthorn (Mironov, 1989).

2.1.3. Sugars

Sugar components mainly glucose, fructose and xylose are important ingredients of sea buckthorn berries. Total soluble sugars reported for Chinese origins ranged from 5.6 to 22.7% in raw juice (Kallio, Yang, Tahvonen, & Hakala, 1999; Ma et al., 1989; Tong et al., 1989; Zhang, Yan, et al., 1989). Chinese origins show higher concentrations of total sugars than Russian ones (Kallio et al., 1999; Shyrko & Radzyuk, 1989), which, in turn, are higher in sugars than Finnish origins (Kallio et al., 1999). Glucose is a major sugar component in all origins. Both glucose and fructose account for around 90% of the total sugar content for Chinese and Russian origins (Kallio et al., 1999; Ma et al., 1989), but only for about 60% for Finnish ones. The presence of sugar alcohols mannitol, sorbitol, and xylitol at low levels has been observed (Makinen & Soderling, 1980). Yang (2009), reported sugar contents in berries of three subspecies (*Hippophaë rhamnoides* ssp. *sinensis, rhamnoides* and *mongolica*) collected from China, Finland and Russia over four consecutive years. The sum of fructose and glucose varied widely from 0.6 g/100 ml in juice of Finnish berries of ssp. *Rhamnoides* to 24.2 g/100 ml in juice of wild Chinese berries of ssp. *sinensis*. Also the annual variations were recognised in the sugar content among berries collected in different years and this could be explained by the slight variation in the collecting dates and the weather conditions over the years.

Table 1
Comparative list of the nutritional composition of sea buckthorn berries.

Nutrients	Species/Varieties	Contents			Reference
		Berries/Juice	Seed and oil	Pulp from berries	
Moisture (%, w/w)	Indian SB	–	–	84.9–97.6	Dhyani et al. (2007)
	Pakistani SB	20.0–32.0	–	–	Sabir, Maqsood, Ahmed, et al. (2005)
	Canadian SB	86.74–83.43	–	–	George and Cenkowski (2005)
	Chinese SB	74.0	–	–	Ma and Cui (1987)
	SNM	80.0–87.0	–	–	Lõugas et al. (2006)
	SNM	79.7–85.8	–	–	Lõugas (2008)
	cv. Indian-Summer	73.6–85.3	5.43–21.9	–	Li, Oomah, and Walker (1998)
	Chinese SB	72.2–75.5	–	–	Ma et al. (1989)
	Chinese SB	61.5–79.4	–	–	Zhang, Yan, et al. (1989)
	Indian SB	52.4	–	–	Katiyar et al. (1990)
	Indian SB	58.7	22.4	–	Chauhan et al. (2001)
	Turkestanica SB	–	5.5	–	Zeb and Malook (2009)
Ash (%)	Indian SB	1.76	–	–	Katiyar et al. (1990)
	Indian SB	1.8	–	–	Chauhan et al. (2001)
	Turkestanica SB	–	2.05	–	Zeb and Malook (2009).
TSS (°Brix)	Indian SB	–	–	8.86–9.72	Dhyani et al. (2007)
	Indian SB	10.7–13.2	–	26.2–27.9	Arimboor et al. (2006)
	cv. Indian-Summer	9.3–17.3	–	–	Li et al. (1998)
	Chinese SB	10.83–15.55	–	–	Tong et al. (1989)
	Chinese SB	10.19–22.74		–	Zhang, Yan, et al. (1989)
	Indian SB	10–12	–	–	Chauhan et al. (2001)
Vitamin C (mg/100 g)	European subsp. *rhamnoides*	360–2500	–	–	Yao et al. (1992), Zeb (2004a)
	Pakistani SB	250–333	–	–	Sabir, Maqsood, Ahmed, et al. (2005)
	Pakistani SB	150–250	–	–	Sabir et al. (2003)
	European Subsp. *rhamnoides*	28–310	–	–	Yao et al. (1992), Rousi and Aulin (1977)
	Fluviatilis ssp.	460–1330	–	–	Darmer (1952)
	Chinese *sinensis* ssp.	200–2500	–	–	Zheng and Song (1992), Yao et al. (1992)
	Chinese Subsp. *Sinensis*	460–1330	–	–	Yao et al. (1992)
	Finnish SB	29–176	–	–	Tiitinen et al. (2005)
	Chinese SB	502–1061	–	–	Ma et al. (1989)
	Subsp. *Sinensis*	200–780	–	–	Zheng and Song (1992)
	Subsp. *Sinensis*	600–2500	–	–	Yao et al. (1992)
	Chinese SB	1348	–	–	Liu and Liu (1989)
	Chinese SB	513–1676	–	–	Zhang, Yan, et al. (1989)
	Subsp. *rhamnoides*	165.7–293.3	–	–	Rousi and Aulin (1977)
	Subsp. *rhamnoides*	150–310	–	–	Darmer (1952)
	Subsp. *rhamnoides*	27.8–201	–	–	Yao et al. (1992)
	Subsp. *fluviatilis*	460–1330	–	–	Darmer (1952)
	Subsp. *mongolica*	40–300	–	–	Plekhanova (1988)
	Indian SB	168.3–	–	223.2	Arimboor et al. (2006)
	Indian SB	509	–	–	Katiyar et al. (1990)
	Indian SB	422–416	–	–	Chauhan et al. (2001)
	Chinese SB	502–106	–	–	Ma et al. (1989)
	SNM	360–2500	–	–	Li and Schroeder (1996)
	Chinese SB	1348	–	–	Liu and Liu (1989)
	Chinese SB	513–1676	–	–	Zhang, Yan, et al. (1989)
	Chinese SB	780.0	–	–	Mingyu et al. (2001)
	Portland SB	114–1550	–	–	Dharmananda (2004)
	SNM	200–1 500	–	–	Rongsen (1992)
	Turkestanica SB	200–1500	–	–	Ahmad and Kamal (2002)
	Chinese SB	300–1600	–	–	Xu (1956), Tian (1985), Wang (1987)
	Turkestanica SB	–	35.4	–	Zeb and Malook (2009)
Vitamin E (mg/100 g)	Pakistani SB	216	64–93	481	Zeb (2004a)
	SNM	160	–	–	Zhang, Yan, et al. (1989), Ma and Cui (1989), Eliseev (1989), Wahlberg and Jeppsson (1990, 1992)
	Chinese SB	–	40.1–103.0	–	Ma et al. (1989)
	Chinese SB	162–255	61.0–113.0	–	Zhang, Yan, et al. (1989)
Vitamin K (mg/100 g)	Indian SB	110–230	–	–	Dhyani et al. (2007)
	Chinese SB	–	109.8–230.0	–	Mingyu et al. (2001)
	SNM	100–200		–	Xu (1956), Tian (1985), Wang (1987)
Flavonoids (mg/100 g)	European Subsp.	354–854	–	–	Yuzhen and Fuheng (1997)
	SNM	1000	–	–	Xu (1956), Tian (1985), Wang (1987)
	Soviet Union SB	854	–	–	Yuzhen and Fuheng (1997)
	Chinese SB	354	–	–	Yuzhen and Fuheng (1997)
Phytosterols (mg/100 g)	SNM	–	1640	–	Li et al. (2007)
	Pakistani SB	–	3300–5500	–	Sabir, Maqsood, Ahmed, et al. (2005)
	Pakistani SB	–	–	1300–2000	Sabir et al. (2003)
Total carotenoid or Vit A (mg/100 g)	SNM	3–15	–	–	Yao and Tigerstedt (1995), Zeb (2004a)
	Caucasus	–	50–85	330–370	Mironov (1989)
	Pamirs	–	trace	900–1000	Mironov (1989)
	Indian SB	6.8–6.9	–	–	Chauhan et al. (2001)
	SNM	30–40	–	–	Bernath and Foldesi (1992), Wolf and Wegert (1993)
	Canadian SB	836.75	20–85	–	George and Cenkowski (2005)
	cv. Indian-Summer	9.4–34.5	–	–	Li et al. (1998)

Table 1 (*continued*)

Nutrients		Species/Varieties	Contents			Reference
			Berries/Juice	Seed and oil	Pulp from berries	
Total carotenoid or Vit A (mg/100 g)		Chinese SB	4.6–12.0	–	–	Ma et al. (1989)
		Chinese SB	2.0–16.1	314–2139	–	Zhang, Xu, and Yu (1989)
		SNM	16–28	–	–	Li and Schroeder (1996)
		SNM	11	–	–	Xu (1956), Tian (1985), Wang (1987)
Minerals (PPM)	Fe	Indian SB	–	0.36–0.647	0.703–1.127	Dhyani et al. (2007)
		Pakistani SB	4–15	–	0.04–0.255	Sabir, Maqsood, Ahmed, et al. (2005), Sabir, Maqsood, Hayat, et al. (2005)
		Pakistani SB	–	–	0.064	Kallio, Yang, and Peippo (2002)
		Chinese SB	–	–	0.022	Jian-Zhong and Xiao-Feng (2006)
		Indian SB	1.6	–	–	Katiyar et al. (1990)
		Chinese SB	4.13–10.9	–	–	Zhang, Yan, et al. (1989)
		Turkestanica SB	–	290.25	–	Zeb and Malook (2009)
	Mg	Indian SB	–	1.806–3.04	0.62–1.92	Dhyani et al. (2007)
		Pakistani SB	–	–	0.139–0.249	Sabir, Maqsood, Ahmed, et al. (2005), Sabir, Maqsood, Hayat, et al. (2005)
		Pakistani SB	150–240	–	–	Sabir, Maqsood, Hayat, et al. (2005)
		Pakistani SB	–	0.47–0.73	0.41–0.56	Kallio, Yang, and Peippo (2002)
		Chinese SB	–	0.56–0.79	0.34–0.53	Jian-Zhong and Xiao-Feng (2006)
		Chinese SB	39.8–103	–	–	Zhang, Yan, et al. (1989)
		Chinese SB	53.3–165	–	–	Tong et al. (1989)
		Turkestanica SB		758.0		Zeb and Malook (2009)
	Cu	Indian SB	–	0.023–0.097	0.09–1.33	Dhyani et al. (2007)
		Pakistani SB	–	0.038–0.12	0.0115–0.04	Kallio, Yang, and Peippo (2002)
		Chinese	–	0.06–0.095	0.0113–0.014	Jian-Zhong and Xiao-Feng (2006)
	Zn	Indian SB	–	0.497–2.83	0.817–2.47	Dhyani et al. (2007)
		Pakistani SB	–	0.088–0.27	0.08–0.12	Kallio, Yang and Peippo (2002)
		Chinese SB	–	0.14–0.27	0.089–0.13	Jian-Zhong and Xiao-Feng (2006)
		Turkestanica SB	–	96.5	–	Zeb and Malook (2009)
	As	Indian SB	–	0.063–0.145	0.06–0.213	Dhyani et al. (2007)
		Chinese SB	<0.5	–	–	Liu and Liu (1989)
	Na	Indian SB	–	0.05–0.49	0.47–0.63	Dhyani et al. (2007)
		Indian SB	6.9	–	–	Katiyar et al. (1990)
		Chinese SB	17.7–125	–	–	Zhang, Yan, et al. (1989)
		Chinese SB	18.0–89.8	–	–	Tong et al. (1989)
		Turkestanica SB	–	47.65	–	Zeb and Malook (2009)
		Pakistani SB	20–80	–	–	Sabir, Maqsood, Hayat, et al. (2005)
		Pakistani SB	–	0.65–0.8		Sabir, Maqsood, Ahmed, et al. (2005), Sabir, Maqsood, Hayat, et al. (2005)
	K	Indian SB	–	9.33–13.42	10.12–14.84	Dhyani et al. (2007)
		Pakistani SB	–	2.8–7.2		Sabir, Maqsood, Ahmed, et al. (2005), Sabir, Maqsood, Hayat, et al. (2005)
		Pakistani SB	–	0.34	1.5	Kallio, Yang and Peippo (2002)
		Pakistani SB	140–360	–	–	Sabir, Maqsood, Hayat, et al. (2005)
		Indian SB	62.2	–	–	Katiyar et al. (1990)
		Chinese SB	100–806	–	–	Tong et al. (1989)
		Turkestanica SB	–	88.0	–	Zeb and Malook (2009)
	P	Indian SB	–	0.61–0.69	–	Dhyani et al. (2007)
		Pakistani SB	110–133	–	–	Sabir, Maqsood, Hayat, et al. (2005)
		Indian SB	7.4	–	–	Katiyar et al. (1990)
		Chinese SB	–	0.34	–	Jian-Zhong and Xiao-Feng (2006)
		Pakistani SB	–	0.11–0.133		Sabir, Maqsood, Ahmed, et al. (2005), Sabir, Maqsood, Hayat, et al. (2005)
		Chinese SB	82.1–206	–	–	Zhang, Yan, et al. (1989)
		Turkestanica SB	–	0.43	–	Zeb and Malook (2009)
	Ca	Pakistani SB	70–98	–	–	Sabir, Maqsood, Hayat, et al. (2005)
		Indian SB	67.1	–	–	Katiyar et al. (1990)
		Chinese SB	93.9–173	–	–	Zhang, Yan, et al. (1989)
		Chinese SB	64–256	–	–	Tong et al. (1989)
		Turkestanica SB	–	912.0	–	Zeb and Malook (2009)
Oil content (%)		Pakistani SB	1–4.5	7.69–13.7	19.2–29.1	Sabir et al. (2003), Sabir, Maqsood, Ahmed, et al. (2005)
		Turkestanica SB	–	5.3–15.7	17.8–34	Yang (2001)
		Pakistani SB	–	7.7–13.7	17.8–29.1	Sabir, Maqsood, Ahmed, et al. (2005)
		Finnish SB	–	–	0.7–3.6	Tiitinen et al. (2005)
			–	9.9–19.5	1.5–3.5	Rongsen (1992)
		Canadian SB	–	0.26–0.74	0.11–1.34	George and Cenkowski (2005)
		Chinese SB	0.26–1.43 (Juice)		–	Zhang, Yan, et al. (1989)
		Chinese SB	–	7.4–9.9	1.8–2.9	Ma et al. (1989)
		cv. Indian-Summer	–	9.69–20.2	–	Li et al. (1998)
		SNM	–	8–12	–	Li and Schroeder (1996)
		Chinese SB	–	6.47–10.5	–	Zhang, Xu, et al. (1989)

*sea buckthorn (SB), species not mentioned (SNM).

2.1.4. Organic acid

The berries of sea buckthorn contain organic acids mainly malic and quinic acids together constituting around 90% of all the fruit acids in different origins. Large variations in concentrations of acids have been also reported among different origins. Russian berries showed relatively lower concentrations of total acidity (2.1–3.2 g/100 ml), Finnish genotypes were intermediate with a range of 4.2–6.5 g/ 100 ml, while Chinese genotypes showed the highest concentrations of organic acid with a range of 3.5–9.1 g/100 ml (Kallio et al., 1999; Ma et al., 1989; Zhang, Yan, et al., 1989). However, to what extent the variations in the above mentioned traits have a genetic base is unknown (Kallio et al., 1999).

2.1.5. Amino acids

A total of 18 out of 22 known amino acids have been found in sea buckthorn fruit (Mironov, 1989; Zhang, Yan, et al., 1989), half of which are essential since they play a critical role in various processes within our bodies such as energy production, building cells and muscles, fat loss, and mood and brain functions. Sea buckthorn juice is rich in various free amino acids. Chen (1988) detected 18 kinds of free amino acids in the juice of Chinese sea buckthorn (Table 2). The total amino acids content of Chinese sea buckthorn given by Zhang, Yan, et al. (1989) contains more apartic acid (426.6 mg/100 g) than revealed by Chen (1988) as given in Table 2. Of these, eight free amino acids (threonine, valine, methionine, leucine, lysine, trytophan, isoleucine, and phenylalanine) are essential for the human body.

2.1.6. Volatile compounds

Berries of sea buckthorn have a unique aroma not comparable to any other common fruit. The compounds were mainly esters of short chain, branched or n-fatty acids and alcohols. The profile of the volatiles is clearly dependent on the time of harvesting of the berries (Yang, 2001). Chinese berries contained higher proportions of ethyl 3-methylbutanoate, butyl pentanoate, 2-methylpropyl 3-methylbutanoate and pentyl 3-methylbutanoate than the Finnish berries, which, again, were rich in ethyl 2-methylbutanoate, ethyl 3-methylbutanoate and ethyl hexanoate (Kallio et al., 1999; Ma & Cui, 1987). Hirvi and Honkanen (1984) identified a total of 60 compounds from sea buckthorn volatile oil. Esters, particularly ethyl and 3-methylbutyl esters, were the most numerous compounds found. Other compound groups identified were terpenes, alcohols and phenols, aldehydes and ketones, as well as organic acids. Cakir (2004) identified thirty volatiles, mainly aliphatic esters, alcohols and hydrocarbons, from steam distilled oil of sea buckthorn. Proper investigations by quantitative sensory profiling and correlation analysis are required in order to evaluate the effects of various volatiles on the overall aroma of sea buckthorn berries.

Table 2
Contents of various amino acids in sea buckthorn berry juice.

Amino acids (mg/100 g)	*H. rhamnoides. L* (Zhang, Yan, et al., 1989)	Chinese SB *H. rhamnoides* subsp. *Sinensis* (Chen, 1988)
Aspartic acid	426.6	3.72
Serine	28.1	5.31
Glutamine	19.4	2.65
Glycine	16.7	–
Alanine	21.2	2.50
Cysteine	3.3	0.82
Valine	21.8	2.85
Ammonia	41.8	–
Tyrosine	13.4	1.79
Isoleucine	17.4	0.97
Methionine	2.3	1.12
Proline	45.2	12.28
Phenylalanine	20.0	3.21
Histadine	13.7	1.06
Lysine	27.2	3.49
Threonine	36.8	6.24
Tryptophan	–	0.51
Leucine	–	1.94
Phenylalanine	–	0.47
Arginine	11.3	0.47
Glycin	–	0.64

2.1.7. Mineral elements

There are many mineral elements present in berries/juice and seed of sea buckthorn and at least 24 chemical elements present in sea buckthorn juice, e.g. nitrogen, phosphorus, iron, manganese, boron, calcium, aluminum, silicon and others (Tong et al., 1989; Wolf & Wegert, 1993; Zhang, Yan, et al., 1989). Potassium plays an important role in the ionic balance and helps in maintaining the tissue excitability of the human body (Indrayan, Sharma, Durgapal, Kumar, & Kumar, 2005). Potassium is the most abundant of all the elements investigated in berries or juice (Chen, 1988; Kallio et al., 1999; Tong et al., 1989; Zhang, Yan, et al., 1989). Concentration of potassium is more abundant among all the elements investigated in the fruits and seeds of *H. rhamnoides*. It varied between 10.12 and 14.84 ppm in the pulp and between 9.33 and 13.42 ppm in the seed (Dhyani et al., 2007) of the Indian species. More than tenfold variation of elemental concentrations was observed for Mo and Fe in juice as well as for Fe in dry mass within the Chinese sea buckthorn. Kallio et al. (1999) compared eight elements between the Chinese and Finnish sea buckthorn and found that Finnish berries had less iron, calcium and lead but more cadmium than the Chinese berries. It was found that the fruit maturity affects the level of N, Ca, K, Na, Mg, Cu, Fe, Zn, and Mn (Bounous & Zanini, 1988). In liqueurs prepared from sea buckthorn, traces of Al, As, Ca, Cd, Cr, Cu, Fe, K, Mg, Mn, Na, Li, Pb, Rb, and Zn were detected by Harju and Ronkainen (1984). The Finnish berries contain less amount of Fe, Ca, and Pb, but more Cd than the Chinese berries. Difference may be originating from the natural contents of elements in the soil as well as contamination in both soil and air. Other macro and micronutrients, viz. sodium, magnesium, iron, copper, zinc, etc. are found to be present in less to moderate quantity in fruit pulp and seeds.

2.1.8. Sea buckthorn oil

The most valuable components of the sea buckthorn berries are their oils. Generally, the oil from the pulp/peel fraction is combined due to the difficulty involved with separation. Both seeds and berry pulp have high total lipid content, including tocopherols, tocotrienols, carotenoids, as well as omega-3 and omega-6 fatty acid families (Yang & Kallio, 2002a). Yang and Kallio (2001) measured the oil content of the seeds (7.3% w/w dry basis (db)), pulp/peel (1.7% w/w db), and whole berry (includes seed) in wild *sinensis* berries (2.1% w/w db). The composition of the sea buckthorn seed and pulp oils varies according to the subspecies, origins, cultivation activities, harvesting time of the berries, and the extraction method (Yang & Kallio, 2002b). The oil from the sea buckthorn berry contains on average 35% of the rare and valuable palmitoleic acid (16:1n-7) which is a component of skin fat and is known to support cell tissue and wound healing. The seed oil is characterized by its high oleic acid content (17%) and its one to one ratio of omega-3 (alpha linolenic) and omega-6 (linoleic) at approximately 34% and 31% respectively. The relationship of equivalence between the two omegas is critical because they self check each other in a delicate balance to regulate thousands of metabolic functions through prostaglandin pathways. Nearly every biological function is interconnected with balance between omega-6 and omega-3.

The seed oil and pulp oil differ considerably in the composition of fatty acids. Saturated fatty acids are found in the oil extracted from the pulp; primarily palmitic acid and palmitoleic acid (Kallio, Yang, Peippo, Tahvonen, & Pan, 2002) with palmitoleic acid comprising 30% of the total (Parimelazhagan, Chaurasia, & Ahmed, 2005).

The seed oil contains over 95% of the recoverable tocopherols which are present at a high concentration (140 mg/100 ml), 1% phytosterols and small amounts of tocotrienols (Parimelazhagan et al., 2005). Radical-scavenging proanthocyanidins can be found in the seed (Fan, Ding, & Gu, 2007). The oil contains significant amounts of β-carotene and vitamin E, making the oil of sea buckthorn an effective medicine for many diseases (Ahmad & Kamal, 2002). Oil from the juice and pulp is rich in palmitic (16:0) and palmitoleic acids (16:1), while the oil from the seeds contains unsaturated fatty acids of C18 type oils, linoleic (18:2) and linolenic acid (18:3). The oil from the seeds and juice also contain vitamin E and carotene (Bernath & Foldesi, 1992; Ma & Cui, 1989). The European sea buckthorn pulp oil had palmitoleic (16:1n-7), palmitic (16:0) and oleic acids as the major fatty acids. The pulp oil is rich in α-tocopherol (120 mg/100 g oil) (Yang, Ahotupa, Maatta, & Kallio, in press).

2.1.9. Phytosterols

Phytosterols are plant sterols, with structures similar to cholesterol, which on consumption are capable of lowering the plasma cholesterol in humans. Elevated blood cholesterol is one of the well established risk factors for coronary heart disease, and lowering this indicator can impact on the incidence of heart disease (Thurnham, 1999). Phytosterols are the major constituents of the unsaponifiable fraction of sea buckthorn oils. The major phytosterol in sea buckthorn oil is sitosterol (β-sitosterol), with 5-avenasterol second in quantitative importance. Other phytosterols are present in relatively minor quantities. The total quantity of phytosterol is quite high in sea buckthorn and may exceed soybean oil by 4–20 times. The sterol content in different varieties ranged from 1.3 to 2%.

2.1.10. Antioxidants

These are compounds that inhibit or delay the oxidation of other molecules by inhibiting the initiation or propagation of oxidizing chain reactions. Restrictions on the use of synthetic antioxidants are being imposed because of their carcinogenicity (Branen, 1975; Ito, Fukushima, Hasegawa, Shibata, & Ogiso, 1983). Thus, the interest in natural antioxidants has increased considerably (Loliger, 1991). Natural antioxidants can be phenolic compounds (tocopherols, flavonoids, and phenolic acids), nitrogen compounds (alkaloids, chlorophyll derivatives, amino acids, and amines), or carotenoids as well as ascorbic acid (Gordon, 1990; Hall & Cuppet, 1997; Larson, 1988). The antioxidant activity of sea buckthorn berries has been reported by various researchers. Velioglu et al. (1998) reported the antioxidant value (AOX): 0.036, antioxidant activity: 93.6%, oxidation rate ratio (ORR): 0.064, antioxidant activity coefficient (AAC): 827.6 and total phenolics (mg/100 g): 1112 of sea buckthorn berries (*H. rhamnoides* L. cv. Indian-Summer) among the 28 selected plant products. They found that the sea buckthorn fruit had the highest antioxidant activity: 93.6% among the medicinal plants.

Gorbatsova, Lõugas, Vokk, and Kaljurand (2007) investigate the antioxidant content in sea buckthorn berries. The antioxidant compounds that were analyzed are *trans*-resveratrol, catechin, myricetin, quercetin, p-coumaric acid, caffeic acid, L-ascorbic acid, and gallic acid (linear range of 50–150 mmol/L) in six different varieties of sea buckthorn berries extracts (sea buckthorn varieties: "Trofimovskaja (TR)," "Podarok Sadu (PS)," and "Avgustinka (AV),") received from two local Estonian companies. Trans-resveratrol, catechin, AA, myricetin, and quercetin were found in the extracts of sea buckthorn. Moreover, AA, myricetin, and quercetin contents were quantified. The biggest average AA content was found in TR (740 mg/100 g of dried berries). Furthermore, the same varieties gave the biggest quercetin content 116 mg/100 g of dried berries.

2.2. Products available/Consumer products

Despite its highly acidic nature and exotic flavor, sea buckthorn berries have a good potential for producing various processed products like ready-to-serve beverage, squash, syrup, jam and jellies. Judicious blending of sea buckthorn juice/pulp with other fruits such as papaya, apple and orange in different ratios could be a promising way for processing of sea buckthorn and for minimizing astringency. Products on the market from sea buckthorn range from oil, juice, and food additives to candies, jellies, cosmetics, and shampoos (Schroeder & Yao, 1995).

Sea-buckthorn fruit can be used to make pies, jams, lotions and liquors. The juice or pulp has other potential applications in foods or beverages (Dharmananda, 2004). For example, in Finland, it is used as a nutritional ingredient in baby food. Fruit drinks were among the earliest sea buckthorn products developed in China. Sea buckthorn based juice is even popular in Germany, Scandinavian and Nordic countries. It provides a nutritious beverage, rich in Vitamin C and carotenes. For its troops confronting extremely low temperatures, India's Defence Research Development Organization established a factory in Leh to manufacture a multi-vitamin herbal beverage based on sea buckthorn juice (Cenkowski, Yakimishen, Przybylski, & Muir, 2006). The seed and pulp oils have nutritional properties that vary under different processing methods (Cenkowski et al., 2006; Dharmananda, 2004). Sea buckthorn oils are used as a source for ingredients in several commercially available cosmetic products and nutritional supplements (Dharmananda, 2004). Jam from the berries, are fermented products from the pulp (Li, 1999). Juice, pulp oil, seed oil, cream and pigments are the main commercial products from sea buckthorn berries (Kumar, 2003).

The literature describing the formation of these products is both scattered and limited. Due to high nutritional value and its growing demand, it could be suggested that sea buckthorn berries might be explored for uses in different food commodities such as jams, juices, beverages, etc. for value-addition.

3. Potential health benefits of sea buckthorn berries

Sea buckthorn berries are traditionally known for their medicinal properties as well as their high nutritional value. Although, used for centuries in its native Europe and Asia, sea buckthorn berries have recently gained worldwide attention, mainly for its nutritional and medicinal value. It is used in about two hundred industrial products including life saving drugs and herbs to treat cancer, heart ailments, ulcers, hepatic disorders, burns and brain disorders. Some of the health benefits cited for sea buckthorn berries products include: anti-inflammation, antimicrobial action, pain relief, the promotion of tissue regeneration, boosting of the immune system, and protection against cancer and cardiovascular disease (Li, Beveridge & Oomah, 2003).

For its hemostatic and anti-inflammatory effects, berry fruits are added to medications for pulmonary, gastrointestinal, cardiac, blood and metabolic disorders in Indian, Chinese and Tibetan medicines. Sea buckthorn berry components have a potential anticarcinogenic activity (Teng, Lu, Wang, Tao, & Wei, 2006; Zeb, 2006). Fresh juice, syrup and berry or seed oils are used for colds, fever, exhaustion, as an analgesic or treatment for stomach ulcers, cancer, and metabolic disorders. The oil from fruits and seeds is used for liver diseases, inflammation, disorders of the gastrointestinal system, including peptic ulcers and gastritis, eczema, canker sores and other ulcerative disorders of mucosal tissues, wounds, inflammation, burns, frostbite, psoriasis, rosacea, lupus erythematosus, and chronic dermatoses. In ophthalmology, berry extracts have been used for keratosis, trachoma, eyelid injuries and conjunctivitis. The sea buckthorn is also known to kill tiny parasitic mites called Demodex. Nutrient and phytochemical constituents of sea buckthorn berries have a potential value as antioxidants that may affect inflammatory disorders, cancer (Dharmananda, 2004; Zeb, 2006) or other diseases (Zeb, 2006); although no specific health benefits have yet been proved by clinical research in humans. Until recently, most of the research into the medicinal, nutraceutical and cosmoceutical properties of sea buckthorn has originated in China and Russia where studies have been ongoing since the 1950s.

The preparations from the fruit and seeds of sea buckthorn have demonstrated great promise in the treatment of the mucous membranes including ulcers and gastro-intestinal disorders as well as vaginal problems. Additional studies have shown that sea buckthorn oils and juice have a positive effect on the cardiovascular system and cholesterol lowering activity. Sea buckthorn berries oil is used in cosmetic preparations and for various skin conditions. Due to high contents of antioxidants, sea buckthorn oil is being extensively used as an anti-inflammatory, anti bacterial, analgesic and for the promotion of tissue regeneration. Also the rich content of essential fatty acids, antioxidants and vitamins, offer sea buckthorn oils support to women's health — not only to improve perimenopausal symptoms but also to maintain the health and well-being of women throughout life-time. Sea buckthorn pulp and seed oil left over from juice preparation can be used for medicinal and cosmetic purposes (Zeb, 2004b).

In view of the purported medicinal benefits of sea buckthorn berries, its utilization could be a great advantage for the health of the people. Being a good source of bioactive phytochemicals, sea buckthorn berries have been processed by hundreds of industries in China and Russia for nutraceutical and cosmoceutical products.

4. Post harvest processing of sea buckthorn berries

Processing begins with the harvesting of berries in the fall. The berries remain on the branches all winter if left undisturbed (Li & Schroeder, 1996). Berries are harvested by hand, although investigations of mechanical harvesters are underway and hormonal treatment to decrease the force required to detach berries looks promising (Li & Schroeder, 1996). The effect of hormones such as ethylene on the processing character of the berries has not been determined, but berry ripening correlates with higher internal ethylene concentrations in the seed (Demenko, Levinsky, & Mikityik, 1986). This would suggest that the berries might display a climacteric respiration pattern. If this proves true, then this fact would have a significant consequence for subsequent storage and processing of the fruit. This factor probably deserves attention in the near future (Beveridge et al., 1999).

Sea buckthorn berries when overripe carry a strong musky odor with rancid taste, detectable even in the field. Washing may reduce or change the odor (Beveridge et al., 1999; Li, 2002). To avoid this problem, berries must be harvested at the correct stage, quickly transported to the processing plant, and be cooled immediately to temperatures around 4–6 °C to retard growth of microorganisms. The total number of publications available describing the processing of sea buckthorn berries is rather limited (Chen, Liu, & Yu, 1995; Liu & Liu, 1989; Liu et al., 1989; Zhou & Chen, 1989); however, from the available data it is clear that the process is similar to that depicted in Fig. 1. Following is a diagram of a processing method that can be used to separate useful components of the berries, yielding the key products of juice, dried fruit nutrients, and oil from the seeds and pulp; residues can be utilized as a valuable animal feed. New technologies, involving supercritical carbon dioxide extraction, are now being used to efficiently produce the oil products.

4.1. Effect of processing/drying on the nutritional properties

Drying with moisture reduction provides extended shelf life to fresh fruits and vegetables. Drying methods have different effects on the microstructure and quality of dehydrated products. Drying by conventional dryers at higher temperature usually results in overall quality loss due to surface drying and is also energy intensive. Freeze-dried food materials remain a benchmark quality because of the structure preservation during the removal of water (Aguilera, Chiralt, & Fito, 2003), contrary to the significant structural changes caused by air-drying. Gutierrez, Ratti, and Belkacemi (2008) worked on the effects of air-drying and freeze-drying on the extraction yields and quality of oils from Quebec sea buckthorn (cv. *Indian-summer*) seeds and pulp. Oil extractions were carried out using hexane. Air-dried (ADS) and freeze-dried (FDS) seeds, gave a similar extraction yields (~12% w/w), whereas those of air-dried (ADP) and freeze-dried (FDP) pulps were significantly different (35.9 ± 0.8 vs. 17.1 ± 0.6% w/w).

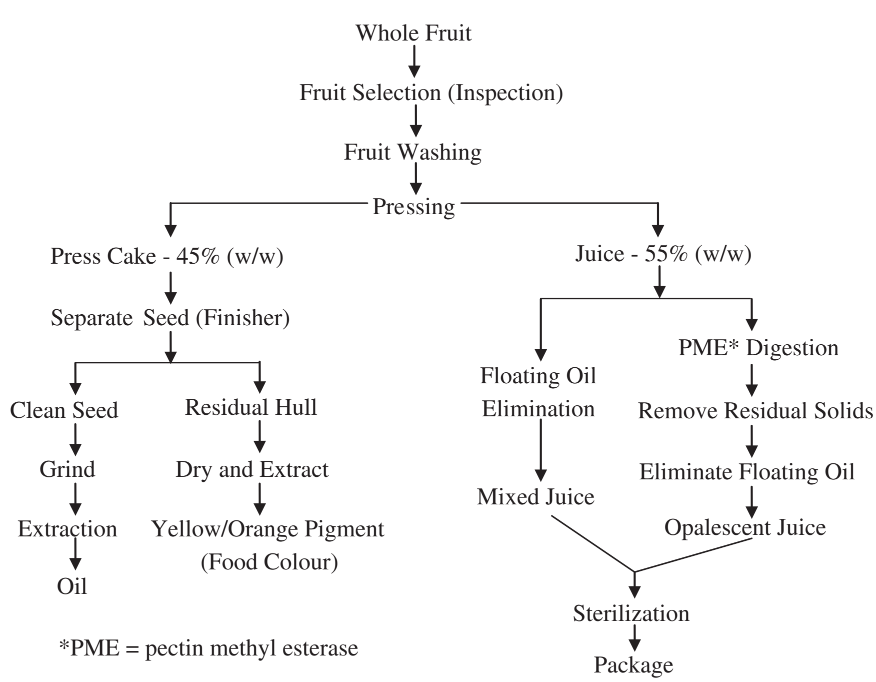

Fig. 1. Processing of sea buckthorn berries (Source: Beveridge et al., 1999).

Fatty acid analysis revealed that α-linolenic (37.2–39.6%), linoleic (32.4–34.2%) and oleic (13.1%) acids were the main fatty acids in seed oils, while pulp oils were rich in palmitoleic (39.9%), palmitic (35.4%) and linoleic (10.6%) acids. Lipid fractionation of crude oils, obtained by solid phase extraction (SPE), yielded mainly neutral lipids (93.9–95.8%). Sea buckthorn seed oils exhibited four thermal structural transitions between −50 °C and 0 °C, whereas multiple transitions were observed in melting profiles of pulp extracts. The peroxide values of seed and pulp oils were ca. 1.8 meq/kg and between 3.0 and 5.4 meq/kg, respectively. The melting behavior of seed and pulp oils showed multiple endothermic transitions, as observed normally in vegetable oils. Drying method did not have a marked effect on oil quality. However, it is worth mentioning that oils from freeze-dried pulps had a much lower peroxide value bearing out their enhanced quality.

Phylloquinone (vitamin K_1) is the primary dietary source of vitamin K. Processing effects and stability of phylloquinone were investigated during juice and concentrate production from sea buckthorn (Gutzeit, Baleanu, Winterhalter, & Jerz, 2007). During industrial juice production a loss of about 36% to 54% phylloquinone in the generated juice due to technological processing of the berries. Factors such as pH and several production procedures result in a depletion of phylloquinone in the juice up to 54.2%. Sea buckthorn berries and juice were stored at 6, 25, and 40 °C up to 7 days to determine the effects of storage time and storage temperature on phylloquinone. Storage of freshly harvested berries resulted in a significant increase of phylloquinone ranging from 21% up to 186% (wet weight) can be explained by the increase in the enzymatic activities in the berries at an elevated temperature. The juices showed almost identical significant degradation of phylloquinone of about 18% to 32% at 6, 25, and 40 °C indicating that the intensity of decomposition is independent on temperature (6 to 40 °C) and storage time in the range of consumer storage conditions. Thus, a low pH value and homogenous distribution of phylloquinone in a liquid matrix might be influencing factors for degradation of phylloquinone in sea buckthorn juices. Also, though the temperature affects the most important consumer storage parameter do not influence the vitamin K_1 content of sea buckthorn juice. Moreover, when berries were stored in the range of 6 to 40 °C a significant increase of phylloquinone was detectable.

The primary vitamin in sea buckthorn berries is vitamin C containing values of approximately 400 mg/100 g. Processing effects were investigated during juice and concentrate production from sea buckthorn berries (*H. rhamnoides*) and storage stability of juices was determined for up to 7 days using berries and juices from 2 different growing areas (Gutzeit, Baleanu, Winterhalter, & Jerz, 2008). During industrial juice production the technological processing of the berries caused a loss of about 5% to 11% total ascorbic acid (TAA) in the generated juice. The production of the concentrated juice resulted in 50% depletion of TAA. Sea buckthorn berries and juice were stored at 6, 25, and 40 °C for up to 7 days to investigate the temperature effects on TAA during storage. Analysis of kinetic data suggested that the degradation follows a 1st-order model. The results of the experiments showed that storage of sea buckthorn juices for 7 days at cold temperature (6 °C) already resulted in a degradation of TAA of about 11% to 12%.

A stable isotope dilution assay for the quantification of pantothenic acid in sea buckthorn berries, juice, and concentrate using a four-fold labeled isotopologue of vitamin B_5 as the internal standard was adopted using reversed phase liquid chromatography–mass spectrometry with electrospray ionization (Gutzeit, Klaubert, Rychlik, Winterhalter, & Jerz, 2007). Because of a rapid sample clean up procedure without the necessity of external calibration, this methodology permits the accurate analysis of a high number of samples within a short time. Sea buckthorn juice was stored at 25 and 40 °C for up to 7 days to determine the effects of storage temperature on the stability of pantothenic acid. Analysis of kinetic data suggested that the degradation follows a first-order model. The results of the experiments showed that the storage of sea buckthorn juice for 7 days at ambient temperatures (25 °C) already resulted in a significant degradation of pantothenic acid of about 18%. The processing effects of juice production and subsequent concentration revealed a decrease of about 6–7% in the juice and of 23% in the juice concentrate.

German workers have reported the extraction of yellow carotenoids pigments from sea buckthorn waste using supercritical CO_2 extraction. Pressure had the greatest influence on extraction with yields increasing with extraction pressure, resulting an increase in the yield (67% at 60 MPa and 85 °C) of the carotenoids (Messerschmidt, Raasch, & Knorr, 1993).

Seglina, Karklina, Ruisa, and Krasnova (2006) suggested that the biochemical content of juice and syrup of sea buckthorn depends on the processing technologies and equipment used. The changes of vitamin C, total carotenoids, total acids and soluble solids in the juice and syrup were investigated depending on the processing technology. Three different techniques were used for juicing: Voran cold (frozen berries were thawed to room temperature and pressed in a Voran 60 K press at a pressure of 300 bars); Condo Line (frozen berries were thawed to room temperature and pressed in a Condo Line RD press, which partially disrupts the berry peel); Voran heated (frozen berries were heated to 98 °C for 5 min immediately before pressing with a Voran 60 K press at 300 bars). Vitamin C in sea buckthorn fruits has a good stability in processing. The highest content of total carotenoids was found in the flesh and in the peel of sea buckthorn, and it is essentially different depending on the processing technology—the juice and syrup with the highest content of total carotenoids (in medium 10.7 mg/100 g) can be obtained by heating of berries over a period of 5 min before juice processing.

Due to the very short harvesting season of sea buckthorn berries, an accelerated process of microwave/thin layer drying can reduce the moisture to safe storage levels immediately after harvest. Use of microwave has been reported for better bulk drying of sensitive biomaterials. Advanced research suggested that addition of vacuum to microwaves offers all advantages of dielectric heating but at a reduced processing temperature being the function of operating pressure. In addition, a volumetric heat transfer mechanism coupled with drying in vacuum provides an ideal low-temperature drying technique resulting in better organoleptic quality. The results show that the target moisture content could be achieved in much lesser time of drying when vacuum is supplemented to microwave drying (Lin, Durance, & Scaman, 1998; Xu, Min, & Mujumdar, 2004; Zhang, Tang, Mujumdar, & Wang, 2006).

5. Conclusions and future prospects

Sea buckthorn berries contain a large variety of substances which possess a strong biological activity. Due to the changes in consumer preference towards natural products with functional properties, in recent years, the use of sea buckthorn berries as a natural food ingredient has been increasing. The fruits are rich in carbohydrates, protein, organic acids, amino acids and vitamins, also contain dense contents of carotenoids, vitamin E, dietary minerals, β-sitosterol and polyphenolic acids. Above discussion reveals that sea buckthorn berries have huge bio-industrial potential which remains unexplored so far. The current research on this ancient crop with modern virtues is very fascinating leading to emergence of new avenues of its utilization including food and pharmaceutical potential. The production potential of this species and sustainable harvest of edible and other useful parts can boost the local economy and has serious ramification on the socio-economic and environmental balance. Analysis of published literature revealed a number of advanced methods for post harvest processing of sea buckthorn berries but clarity on the quality criteria was found lacking. Also, processing techniques to take care of the food safety aspect would enhance the export potential of this wonderful product. The untapped and underutilized wild bioresources, *Hippophaė*, where disturbances to ecosystem are minimal (only fruits are harvested and not the total plant biomass), could contribute to a household's food and livelihood in potential wild edibles has begun to attract attention as being one of the income-generating components of the non-farm part of rural economy.

The main drawbacks of sea buckthorn berries are very short harvesting season and high moisture content which thwarts its utilization as value added products. Therefore it is proposed to develop microwave drying technology to produce dehydrated products rich in nutraceutical and cosmoceutical constituents. The developed technology can be utilized to produce sea buckthorn tea, beverages, and natural food ingredients and also utilized the sea buckthorn seed oil for cosmetic products such as creams, shampoos, soaps, etc. The promotion of berry cultivation, and the processing and sale of sea buckthorn products, could generate a source of livelihood for local populations and also serve as a model to be replicated in other areas. There is no doubt that the future holds a great promise for the sea buckthorn. This ancient plant with its powerful and healing synergies has much to contribute to this planet and its inhabitants.

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