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ORIGINAL PAPER

Fatty Acid, Tocopherol and Sterol Compositions of Canadian Prairie Fruit Seed Lipids

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Abstract The seeds of four prairie fruits—chokecherry (*Prunus virginiana*), thorny buffaloberry (*Shepherdia argentea*), Woods' rose (*Rosa woodsii*) and hawthorn (*Crataegus* × *mordenensis*)—from Southern Alberta were investigated. The lipid contents of the seeds were found to be 10.4, 11.5, 3.7 and 3.4%, respectively. The tested seed lipids contained mainly linoleic acid in the range from 27.9 to 65.6% and oleic acid from 19.7 to 61.9%. The thorny buffaloberry and Woods' rose seed lipids contained 29.2 and 30.8% of linolenic acid, respectively. The contents of palmitic and stearic acids ranged from 3.2 to 5.4% and 1.6 to 2.2%, respectively. The contents of total tocopherols in the chokecherry, thorny buffaloberry, Woods' rose and hawthorn seed lipids accounted for 595, 897, 2,358 and 2,837 mg/kg, respectively. The main sterols in the lipids were β-sitosterol, Δ^5-avenasterol, cycloartenol, campesterol, stigmasterol and gramisterol. The results of the present study show that the lipids from the seeds of the investigated prairie fruits could be a good source of valuable essential fatty acids, tocopherols and sterols, thus suggesting their application as functional foods and nutraceuticals.

Keywords Wild fruits · Linoleic and linolenic acids · Tocopherols · Phytosterols

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Introduction

In recent years, much attention has been focused on exploring wild plants as alternative crops for Canadian prairies [1]. Foods produced from wild plants, including fruits, offer health benefits and protection against cancer, stroke and coronary heart diseases [2–5]. A number of fruit species native to North American grasslands are of high economic value owing to their medicinal and nutritional properties [6, 7]. Chokecherry, thorny buffaloberry, hawthorn and Woods' rose fruits are generating increasing scientific interest because of their antioxidant and anticarcinogenic potentials and their abilities to avert or ameliorate degenerative ailments [1–5, 8].

The chokecherry (*Prunus virginiana* L.), belonging to the Rosaceae family, is a shrub or small tree found throughout Canada and most of the United States [1, 9]. Native Americans and early settlers used chokecherries as fruit and in juice, wine, jellies, syrups and beverages [1, 6, 7].

Thorny buffaloberry (*Shepherdia argentea* Nutt.), is part of the Elaeagnaceae family, is native to the Great Plains of North America and is common in Western Canada [10, 11]. Buffaloberry has the potential to be mass-produced. The

buffaloberry plants are very productive, extremely winter-hardy and drought-tolerant, and produce scarlet fruits rich in vitamin C [11].

Hawthorn (*Crataegus* × *mordenensis* Boom) also belongs to the Rosaceae family. Howthorn has been used extensively in traditional Chinese and European herbal medicines [5]. Various medicinal properties have been ascribed to different parts of the hawthorn plant. Extracts prepared from leaves, flowers and fruits date back to ancient times [12]. Hawthorn fruits, leaves and flowers contain flavonoids, oligomeric proanthocyanidins, triterpene acids, organic acids, sterols and cardioactive amines [5]. It has been proposed that the antioxidant and bioactive constituents of hawthorn are responsible for its health and therapeutic properties. Several epidemiological studies have demonstrated that the consumption of hawthorn's bright red berries and extracts of plant parts effectively reduces blood pressure and total plasma cholesterol [13].

Woods' rose (*Rosa woodsii* Lindl.), another member of the Rosaceae family, has been used as a famine food by North American aboriginal tribes [8]. The fruits have been used in tea, jelly, jams, and mixed with dried salmon eggs to extend their shelf-life [8]. Medicinal properties of *R. woodsii* are mainly attributed to the presence of tannins, polyphenols, and oleanolic and pomolic acids (the latter are derivatives of triterpene acids). The leaf extracts also contain compounds that inhibit HIV reverse transcriptase [14, 15].

Some previous reports have revealed that oils of fruit seeds might serve as a potential source of n-3 and n-6 fatty acids and some other biologically active phytochemicals such as tocopherols and sterols [16]. Furthermore, recent studies have revealed that dietary n-3 fatty acids can play a very important role in decreasing the prevalence of cardiovascular heart disease and cancer [16–18]. Although some fruit species from Canadian prairies have been investigated for their nutritional, medicinal and antioxidant attributes, very little research has been conducted on the lipid profiles of their seeds. The main objective of the present research was to evaluate the fatty acid, tocopherol and sterol compositions of the seed lipids from fruits of chokecherry, thorny buffaloberry, hawthorn and Woods' rose native to Southern Alberta.

Materials and Methods

Materials

Fully ripened fruits from wildly grown chokecherry (*P. virginiana*), thorny buffaloberry (*S. argentea*), Woods' rose (*R. woodsii*) and cultivated hawthorn (*Crataegus mordenensis*) plants were collected in the Oldman River Valley during August and October 2007. Three different samples for each of the four fruits were randomly collected from several plants grown in three different locations. The seeds were removed, washed in tap water and air-dried at room temperature. All reagents of analytical or HPLC purity and sterol standards were purchased from Sigma–Aldrich (St. Louis, MO, USA). Standards of tocopherols were obtained from Calbiochem-Novabiochem (San Diego, CA, USA). Standards of fatty acid methyl esters were purchased from Nu-Chek-Prep, Inc. (Quantitative Standard Mixture #463; Elysian, MN, USA).

Lipid Extraction

The air-dried seeds were ground into fine powder using a coffee grinder prior to lipid extraction. Ground seeds (40 g) were homogenized with 400 mL of chloroform:methanol (2:1, v/v) following the Folch procedure [19]. Extraction was repeated thrice on each set of seeds. The solvent/lipid mixture was filtered through paper filter into a separatory funnel. Distilled water (100 mL) was added to combined extracts, and after mixing, the mixture was allowed to separate into two layers. The lower lipid–chloroform layer was collected in a round-bottom flask, and the solvent was removed under reduced pressure on a rotary evaporator (BÜCHI Labortechnik AG, Flawil, Switzerland) at 35 °C. The oil samples were transferred to brown glass vials with iso-octane, flushed with nitrogen, and stored at –18 °C until they were analyzed.

Fatty Acid Composition

The seed lipids were methylated into fatty acid methyl esters using AOCS Official Method Ce 1–62 [20]. The FAMEs were analyzed on a Trace GC Ultra gas chromatograph (Thermo Electron Corporation, Rodano, Italy) using a Trace TR-FAME fused silica capillary column (100 m × 0.25 mm × 0.25 μm; Thermo Scientific, Waltham, MA, USA). The FAME samples (1 μL) were injected with an AS 3000 autosampler (Thermo Electron Corporation). Hydrogen was used as carrier gas at a flow rate of 1 mL min^{-1}. The column temperature was held at 70 °C for 5 min, then programmed to 160 °C at 25 °C min^{-1}, with the latter temperature held for 30 min. The temperature was then increased to 210 °C at 3 °C min^{-1}, with the upper temperature held for 30 min. The detector temperature was set at 250 °C. Fatty acids were identified by comparing retention times with standards. The fatty acid composition is reported as the weight percentage of oil.

Sterol Analysis

Plant sterols were analyzed using the procedure described by Rudzińska et al. [21]. To 0.5 g oil, 500 μg of 5-α-

cholestane dissolved in chloroform were added as an internal standard. Saponification was performed with 1 M methanolic KOH at room temperature for 18 h. Unsaponifiables were extracted with diethyl ether after water was added to the saponification mixture. Sterols were silylated with Sylon BTZ (Supelco, Oakville, Canada) and analyzed on a Hewlett-Packard model 6890 GC (Agilent, Wilmington, DE, USA) equipped with a DB5 capillary column (30 m × 0.32 mm × 0.25 μm; J&W Scientific, Folsom, CA, USA). Separation was done isothermally at 290 °C, and at a helium flow rate of 1.6 mL min^{-1}. The injector and detector temperatures were set at 310 °C, and samples were injected in a split mode (1:25). Identification of phytosterols was done on a GC/MS (Trace 2000/Finnigan-Polaris Q, Thermo Electron, San Jose, CA, USA) using the same chromatographic conditions as described above.

Tocopherol Analysis

Tocopherols were determined using a modified version of an HPLC method described previously [22]. Fifty milligrams of oil were made up to volume with heptane in a 5-mL volumetric flask wrapped in aluminum foil. Chromatography was performed using a Finnigan Surveyor Plus HPLC System (Thermo Electron Corporation, Waltham, MA, USA) and Finnigan Surveyor model FL Plus fluorescence detector. A 10 μL sample was injected onto a Monochrom 5 μ Diol column (250 × 4.60 mm; Varian Inc., Palo Alto, CA, USA). A mobile phase of hexane (93%) and tert-butyl-methylether (7%) at a flow rate of 0.6 mL/min was used. Excitation at 292 nm and emission at 394 nm were set for the detection of tocopherols. Tocopherol standards were used to identify and quantify the tocopherol contents.

Statistical Analysis

Three different samples of each of the four fruits were collected and analyzed individually in triplicate. Data are presented as mean values ± SD of triplicate determinations. Analysis of variance (ANOVA) was performed using Minitab 2000 Version 13.2 statistical software (Minitab Inc., State College, PA, USA). A probability value of $P \leq 0.05$ was considered to denote a statistically significant difference.

Results and Discussion

Lipid Contents

The data for the total seed lipid contents in four prairie fruits—chokecherry (*P. virginiana*), thorny buffaloberry (*S. argentea*), hawthorn (*C. mordenensis*) and Woods' rose (*R. woodsii*)—are summarized in Table 1. The seed lipid yields (3.4–11.5%) varied significantly ($P \leq 0.05$) within the fruits analyzed. The lipid contents of thorny buffaloberry (11.5%) and chokecherry seeds (10.4%) are comparable with the oil contents reported for Canadian raspberry seeds (10.7%) [23]. No literature reports are available in order to compare the lipid contents of the wild fruit seeds investigated in the present study. However, some earlier studies revealed that Canadian berries and chokecherries are not only a rich source of essential micronutrients and antioxidants, but they also contain considerable amounts of lipids [16, 24]. According to Ozcan et al. [25], hawthorn fruits contained 0.9% of oil, less than the amounts found in the seeds studied here. Hosseinian et al. [24] reported fat contents ranging from 0.3 to 4.4% in fruits of Manitoba strawberry, Saskatoon berry, raspberry, wild blueberry, chokecherry and seabuckthorn, although the lipid contents of the seeds of these fruits were not analyzed.

Fatty Acid Composition

The contents of saturated fatty acid (SFA) in the seed lipids of chokecherry, thorny buffaloberry, Woods' rose and hawthorn were below 10% (Table 1). These levels of SFA were comparable to those reported for marionberry, boysenberry, red raspberry and blueberry seed oils (2.3–8.7%) [16]. Palmitic and stearic acids were the main components among the SFAs. Medium-chain SFAs, including caprylic, capric, lauric and myristic acids, were found at low levels (Table 1).

The contents of monounsaturated fatty acid (MUFA), which mainly consisted of oleic acid in the tested seed lipids, ranging from 21.7% in Woods' rose to 63.5% in chokecherry. Small amounts of vaccenic acid were also found in all seed lipids (Table 1). The present analysis indicated that chokecherry seed lipids are a rich source of MUFA, with levels comparable to regular canola and olive oils.

The seed lipids of the investigated fruits contained high levels of polyunsaturated fatty acids (PUFAs), ranging from 28.2% (chokecherry) to 68.1% (Woods' rose). Among PUFAs, linoleic acid was the most prevalent in hawthorn seed lipids (Table 1). In the thorny buffaloberry and Woods' rose seed lipids, linoleic and linolenic acids were present at approximately the same level (Table 1). Our results are in agreement with the findings of Malainey et al. [26], who found that the chokecherry, hawthorn and rosehip fruits were a good source of oleic (52.9%), linoleic (56.9%), and linolenic (39.3%) acids. The chokecherry seed lipids contained similar amounts of stearic, oleic, linoleic and linolenic acids to those found in hazelnut [26]. The level of C18:2 observed in the hawthorn seed lipids

Table 1 Lipid contents (g/100 g of fruit seeds) and fatty acid compositions (%) of seed lipids from prairie fruits

Fatty acids	Chokecherry	Thorny buffaloberry	Woods' rose	Hawthorn
C8:0	$0.39 \pm 0.10_{i}^{a}$	$0.34 \pm 0.05_{j}^{c}$	$0.29 \pm 0.06_{n}^{d}$	$0.40 \pm 0.05_{k}^{b}$
C10:0	$0.09 \pm 0.02_{m}^{a}$	$0.08 \pm 0.02_{m}^{b}$	$0.05 \pm 0.01_{r}^{c}$	$0.08 \pm 0.02_{n}^{a}$
C12:0	$0.04 \pm 0.01_{m}^{c}$	$0.05 \pm 0.02_{m}^{c}$	$0.10 \pm 0.03_{q}^{a}$	$0.04 \pm 0.02_{o}^{b}$
C14:0	$0.05 \pm 0.02_{m}^{c}$	$0.11 \pm 0.03_{l}^{a}$	$0.07 \pm 0.03_{q}^{b}$	$0.05 \pm 0.01_{o}^{c}$
C15:0	$0.04 \pm 0.01_{m}^{d}$	$0.10 \pm 0.03_{I}^{a}$	$0.05 \pm 0.02_{r}^{b}$	$0.04 \pm 0.02_{o}^{c}$
C16:0	$3.20 \pm 0.10_{e}^{d}$	$4.85 \pm 0.30_{e}^{b}$	$3.70 \pm 0.15_{g}^{c}$	$5.37 \pm 0.25_{e}^{a}$
C16:1	$0.28 \pm 0.05_{j}^{b}$	$0.19 \pm 0.05_{k}^{c}$	$0.57 \pm 0.10_{l}^{a}$	$0.05 \pm 0.02_{o}^{d}$
C17:0	$0.07 \pm 0.02_{m}^{c}$	$0.05 \pm 0.02_{m}^{c}$	$0.13 \pm 0.05_{p}^{a}$	$0.09 \pm 0.03_{n}^{b}$
C17:1	$0.10 \pm 0.03_{l}^{a}$	$0.04 \pm 0.02_{m}^{d}$	$0.07 \pm 0.03_{q}^{b}$	$0.04 \pm 0.01_{i}^{c}$
C18:0	$1.57 \pm 0.10_{g}^{c}$	$2.20 \pm 0.10_{f}^{a}$	$1.59 \pm 0.25_{i}^{c}$	$1.92 \pm 0.10_{g}^{b}$
C18:1 n-9	$61.90 \pm 0.71_{b}^{a}$	$28.75 \pm 1.00_{c}^{b}$	$19.70 \pm 0.50_{e}^{c}$	$21.35 \pm 0.52_{c}^{c}$
C18:1 n-7[a]	$1.12 \pm 0.03_{h}^{b}$	$2.50 \pm 0.15_{c}^{a}$	$0.85 \pm 0.15_{k}^{b}$	$0.34 \pm 0.10_{l}^{c}$
C18:2	$27.90 \pm 0.60_{c}^{c}$	$29.30 \pm 0.71_{c}^{c}$	$37.10 \pm 1.00_{b}^{b}$	$65.55 \pm 0.95_{b}^{a}$
C18:3 n-6	ND	$0.12 \pm 0.05_{l}^{a}$	$0.11 \pm 0.03_{q}^{b}$	ND
C18:3 n-3	$0.27 \pm 0.05_{k}^{c}$	$29.21 \pm 0.85_{c}^{a}$	$30.75 \pm 0.50_{c}^{a}$	$0.76 \pm 0.10_{i}^{b}$
C20:0	$0.13 \pm 0.05_{l}^{c}$	$0.20 \pm 0.05_{k}^{c}$	$0.80 \pm 0.12_{k}^{b}$	$1.31 \pm 0.10_{h}^{a}$
C20:1	$0.14 \pm 0.03_{l}^{c}$	$0.39 \pm 0.02_{i}^{b}$	$0.40 \pm 0.06_{m}^{b}$	$0.46 \pm 0.04_{j}^{a}$
C21:0	ND	$0.06 \pm 0.02_{m}^{b}$	$0.21 \pm 0.03_{o}^{a}$	ND
C20:2	ND	$0.08 \pm 0.02_{m}^{b}$	$0.10 \pm 0.02_{q}^{a}$	ND
C22:0	$0.04 \pm 0.02_{m}^{c}$	$0.05 \pm 0.01_{m}^{c}$	$0.70 \pm 0.06_{k}^{a}$	$0.34 \pm 0.04_{I}^{b}$
C23:0	$0.23 \pm 0.10_{k}^{a}$	$0.04 \pm 0.02_{m}^{c}$	$0.05 \pm 0.02_{r}^{c}$	$0.04 \pm 0.02_{o}^{b}$
C22:2	$0.04 \pm 0.01_{m}^{c}$	$0.05 \pm 0.02_{m}^{c}$	$0.08 \pm 0.02_{q}^{b}$	$0.07 \pm 0.02_{o}^{a}$
C24:0	$0.05 \pm 0.02_{m}^{c}$	$0.06 \pm 0.03_{m}^{c}$	$0.46 \pm 0.05_{m}^{a}$	$0.18 \pm 0.03_{m}^{b}$
Others	$2.35 \pm 0.22_{f}^{a}$	$1.18 \pm 0.15_{h}^{c}$	$2.07 \pm 0.15_{h}^{b}$	$1.52 \pm 0.20_{i}^{c}$
SFA	$5.90 \pm 0.19_{d}^{c}$	$8.13 \pm 0.41_{d}^{b}$	$8.20 \pm 0.34_{f}^{b}$	$9.86 \pm 0.50_{d}^{a}$
MUFA	$63.54 \pm 0.89_{b}^{a}$	$31.87 \pm 0.90_{b}^{b}$	$21.73 \pm 0.61_{d}^{c}$	$22.24 \pm 0.40_{c}^{c}$
PUFA	$28.21 \pm 0.70_{c}^{a}$	$58.76 \pm 0.97_{a}^{a}$	$68.10 \pm 1.10_{a}^{b}$	$66.38 \pm 0.87_{b}^{b}$
n-6/n-3	$103 \pm 2.75_{a}^{a}$	$1.00 \pm 0.25_{g}^{c}$	$1.21 \pm 0.20_{j}^{c}$	$86.3 \pm 3.10_{a}^{b}$
Lipids content (g/100 g of fruit seeds)	10.4 ± 1.0^{b}	11.5 ± 0.7^{a}	3.7 ± 0.4^{c}	3.4 ± 0.5^{c}

ND not detected

Values are mean ± SD of three samples of each fruit, analyzed individually in triplicate

Means in the same row followed by different superscript letters indicate significant differences ($P < 0.05$) among types of fruit. Means in the same column followed by different subscript letters indicate significant differences ($P < 0.05$) within fruit fatty acids

[a] Vaccenic acid

was similar to arrowgrass seeds [26]. The results of the present study showed that the content of linolenic acid in thorny buffaloberry and Woods' rose seed lipids was slightly lower than that found in the cold-pressed black raspberry seed oil [27]. However, the amounts of linolenic acid were greater than those reported for cold-pressed cranberry, raspberry and hemp seed oils [23, 28].

The tested seed lipids had n-6 to n-3 fatty acid ratios of 1 for buffaloberry and Woods' rose and 86 and 103 for hawthorn and chokecherry, respectively (Table 1). The ratios for thorny buffaloberry and Woods' rose seed lipids were lower than those reported for seed oils of red raspberry, marionberry, boysenberry, blueberry, hemp, cranberry, raspberry and black raspberry [16, 23, 27, 28]. Studies have revealed that the current dietary ratio of n-6 to n-3 fatty acids is about 10–20, and the recommended ratio is estimated to be from 3 to 5 [16–18]. Thus, thorny buffaloberry and Woods' rose lipids could help to reduce n-6 to n-3 ratios when applied to food.

Tocopherols

The seed lipids of the investigated fruits revealed the presence of significant amounts of tocopherols (Table 2). The hawthorn seed lipids had the highest level of total tocopherols, at 2,837 mg/kg, followed by Woods' rose (2,358 mg/kg), thorny buffaloberry (897 mg/kg) and chokecherry (595 mg/kg) seed lipids. The major tocopherol in the

Table 2 Content of tocopherols in seed lipids of prairie fruits (mg/kg of lipids)

Tocopherol	Chokecherry	Thorny buffaloberry	Woods' rose	Hawthorn
α-Tocopherol	$32.6 \pm 3.0_c^b$	$184 \pm 20.4_c^c$	$399 \pm 34.9_d^c$	$2{,}673 \pm 80.8_b^a$
β-Tocopherol	$6.3 \pm 1.5_d^b$	ND	ND	$164 \pm 13.8_c^a$
γ-Tocopherol	$556 \pm 20.8_b^c$	$713 \pm 32.1_b^a$	$1{,}871 \pm 84.0_b^b$	ND
δ-Tocopherol	ND	ND	$88.0 \pm 10.4_c$	ND
Total tocopherols	595 ± 21.5^b	897 ± 52.6^a	$2{,}358 \pm 50.2^c$	$2{,}837 \pm 77.5^d$

ND not detected

Values are mean ± SD of three samples of each fruit, analyzed individually in triplicate. Means in the same row followed by different superscript letters indicate significant differences ($P < 0.05$) among types of fruit. Means in the same column followed by different subscript letters indicate significant differences ($P < 0.05$) within fruit tocopherols

hawthorn seed lipids was the α isomer, which accounted for 94.2% of the total tocopherols. The thorny buffaloberry, Woods' rose and chokecherry seed lipids, on the other hand, contained the highest concentrations of γ-tocopherol, which contributed 79.5, 79.3 and 93.4%, respectively, of the total tocopherols (Table 3). The hawthorn seed lipids also contained 5.8% of β-tocopherol, whereas thorny buffaloberry and Woods' rose seed lipids were devoid of this isomer. The Woods' rose seed lipids contained δ-tocopherol at 3.7% of the total tocopherols. Tocopherols in vegetable oils are believed to protect polyunsaturated fatty acids from oxidation. The α-tocopherol has stronger vitamin E potency, whereas the δ-tocopherol possessed greater antioxidant activity than either γ-, β- or α-tocopherols [25].

The total tocopherol contents in the tested hawthorn and Woods' rose seed lipids were higher than those of blueberry, red raspberry, marionberry, and boysenberry seed oils [16], but they were lower than that reported for hexane-extracted raspberry (*Rubus idaeus* L.) seed oil: 3,600 mg/kg of oil [23]. The tocopherol concentrations of chokecherry and thorny buffaloberry seed lipids measured in our study were higher than those reported for blueberry (110.7 mg/kg) and marionberry (410 mg/kg) seed oils [16], and lower than those for raspberry (*R. idaeus* L.) seed oils: 1,980–3,600 mg/kg of oil [23]. These values were somewhat comparable with those for cottonseed and sunflower oils [29]. The high levels of tocopherols detected in the analyzed seeds of chokecherry, thorny buffaloberry, Woods' rose and hawthorn would offer excellent protection against oxidative degradation and could protect lipids during storage and processing, thus showing the potential to be used to protect edible oils and foods. Data on the tocopherol contents of chokecherry, thorny buffaloberry, Woods' rose and hawthorn seeds lipids are lacking, and so it is impossible to make comparisons.

Sterols

The Woods' rose seed lipids had the highest amount of total sterols, followed by thorny buffaloberry, hawthorn and

Table 3 Sterol content and composition in seed lipids of prairie fruits (% of total sterols)

Sterols	Chokecherry	Thorny buffaloberry	Woods' rose	Hawthorn
Campesterol	$5.00 \pm 0.27_d^b$	$3.90 \pm 0.30_d^b$	$7.50 \pm 0.45_e^a$	$4.88 \pm 0.30_e^b$
Stigmasterol	$1.28 \pm 0.10_e^b$	$1.00 \pm 0.15_f^b$	$8.00 \pm 0.50_e^a$	$1.65 \pm 0.20_f^b$
β-Sitosterol	$66.00 \pm 1.50_b^b$	$72.50 \pm 3.10_b^a$	$60.14 \pm 0.91_b^c$	$61.00 \pm 2.50_b^c$
Δ^5-Avenasterol	$18.00 \pm 0.85_c^a$	$15.80 \pm 0.62_c^b$	$11.83 \pm 0.70_c^c$	$14.99 \pm 1.05_c^b$
Gramisterol	$2.10 \pm 0.17_e^a$	$1.95 \pm 0.30_e^a$	$1.20 \pm 0.12_f^a$	$1.25 \pm 0.30_f^a$
Cycloartenol	$5.60 \pm 0.30_d^b$	$1.00 \pm 0.10_f^d$	$9.30 \pm 0.50_d^a$	$1.89 \pm 0.25_f^c$
Δ^7-Stigmasterol	ND	ND	$1.90 \pm 0.20_f$	ND
Δ^7-Avenasterol	$2.00 \pm 0.25_e^c$	$2.40 \pm 0.20_e^b$	ND	$11.14 \pm 0.50_d^a$
24-Methylenecycloartanol	ND	$0.65 \pm 0.10_f^a$	ND	$1.10 \pm 0.20_f^a$
Citrostadienol	ND	$0.60 \pm 0.15_f^b$	ND	$2.00 \pm 0.15_f^a$
Total sterol content (mg/kg of lipids)	$3{,}555 \pm 130^d$	$8{,}400 \pm 99^b$	$8{,}617 \pm 124^a$	$7{,}050 \pm 180^c$

ND not detected

Values are mean ± SD of three samples of each fruit, analyzed individually in triplicate. Means in the same row followed by different superscript letters indicate significant differences ($P < 0.05$) among types of fruit. Means in the same column followed by different subscript letters indicate significant differences ($P < 0.05$) within fruit sterols

chokecherry (Table 3). The sterol fractions of the tested seed lipids mainly consisted of β-sitosterol, Δ^5-avenasterol, Δ^7-avenasterol, cycloartenol, campesterol, stigmasterol and gramisterol (Table 3). Small amounts of 24-methylene-cycloartanol, Δ^7-stigmasterol and citrostadienol were also detected. The contribution from the most prevalent sterol, β-sitosterol, was highest in thorny buffaloberry seed lipids, whereas Woods' rose seed lipids contained the lowest level of this sterol (Table 3). The high levels of β-sitosterol detected in the present study of the seed lipids of different berry fruits are similar to that found in cranberry seed oil [30]. β-Sitosterol is known to be the principal plant sterol found in many seeds and oilseeds. Studies have shown that people with a diet containing 60–130 mg/day of plant sterols have a lower incidence of prostate cancer [31]. Phytosterols also appear to play a role in modulating immune function and inflammation by affecting the production of inflammatory cytokines [31, 32].

The levels of β-sitosterol seen in the present analysis of Woods' rose, hawthorn and chokecherry seed lipids are in close agreement with those reported for soybean, maize, groundnut, palm, palm kernel and sunflower oils [31]. The thorny buffaloberry seed lipids exhibited a higher content of β-sitosterol than those reported for most of the common vegetable oils [31]. Data on the sterol content and composition of chokecherry, buffaloberry, Woods' rose and hawthorn seed lipids are lacking, and so comparisons are impossible.

The results of our study demonstrated that the fruit seeds of chokecherry, thorny buffaloberry, Woods' rose and hawthorn, native to Southern Alberta prairies, are potential sources of considerable amounts of lipids rich in n-6 and n-3 fatty acids, tocopherols and sterols. There is the potential for these prairie fruits to be used and positioned in the marketplace as functional foods and nutraceutical ingredients. The seeds could also be utilized to extract valuable oil which could be incorporated into various food commodities offering health benefits.

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