Original Paper

The effects of short-term sea buckthorn juice consumption on lipid profile and body composition in hypercholesterolemic women

Jana Kopčeková*[1], Jana Mrázová[1], Katarína Fatrcová-Šramková[1], Kristína Jančichová[2], Maroš Bihari[1], Peter Chlebo[1], Július Árvay[3]

[1]*Slovak University of Agriculture in Nitra, Faculty of Agrobiology and Food Resources, Nitra, Slovak Republic*
[2]*Slovak University of Agriculture in Nitra, The AgroBioTech Research Centre, Slovak Republic*
[3]*Slovak University of Agriculture in Nitra, Faculty of Biotechnology and Food Sciences, Slovak Republic*

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The purpose of this study was to determine whether short-term consumption of 100% sea buckthorn juice (SBJ) affects serum lipids and body composition in hypercholesterolemic women. The study included 31 non-medicated adult women aged 40 to 56 years (average age 49.86 ±5.98 years). In this intervention study, volunteers received 50 mL of 100% bio commercial SBJ every day for 4-week period. Anthropometric and biochemical parameters were monitored before and after 4 weeks of consumption of SBJ. Body composition was determined using an multifrequency analyzer InBody720. Routine biochemical analyzes were performed by standard methods in an accredited laboratory of the University Hospital by automatic biochemical analyzer BioMajesty JCA-BM6010/C. Supplementation with 100% SBJ increased high-density cholesterol ($P < 0.05$) and decreased low-density cholesterol ($P > 0.05$). There was also a positive decrease in the LDL-C/HDL-C ratio ($P < 0.01$) and C-reactive protein ($P < 0.001$). We observed a significant weight loss ($P < 0.05$), body fat ($P < 0.01$), body mass index ($P < 0.05$) and visceral fat area ($P < 0.01$). The obtained results show that the daily consumption of SBJ for 4 weeks represents a possible prevention of risk factors for cardiovascular diseases (CVD) in hypercholesterolemic women without pharmacotherapy.

Keywords: cardiovascular disease, sea buckthorn juice; lipid profile; cholesterol; body composition

1 Introduction

Well-accepted evidence from recent years suggests that lifestyle and dietary changes are a key strategy to prevent cardiovascular disease (Mozaffarian, 2016; Yu and Malik, 2018; Dyrcz et al., 2019), the primary reason of death in Europe (Townsend et al., 2022) and worldwide (Mahmoudi et al., 2018; Brandhorst et al., 2019; Soppert et al., 2020). Increased consumption of plant sources, which is currently recommended as a nutritional strategy (Rodríguez-García et al., 2019), contributes to the reduction of the risk of diseases caused by free radicals thanks to the interaction of phenolic and other bioactive compounds (Süli et al., 2014). Among various plant foods, berries have the greatest antioxidant potential due to their high polyphenol content (Kähkönen et al., 1999; Sikora et al., 2012; Chandra et al., 2018). Sea buckthorn, an ancient plant, is a deciduous bush or tree – genus *Hippophae*, family Elaeagnaceae (Wang et al., 2022). About 150 species were recognized in Europe and Asia, among which *Hippophae rhamnoides* L. is the most widespread in Europe. *Hippophae* fruits are called third generation fruits (Ji et al., 2020). Sea buckthorn contains many natural antioxidants in all its parts (Krejcarová et al., 2015). Its leaves, stems, fruits and flowers are a source of almost 200 nutrients and bioactive substances (Wang et al., 2021), including phenolic compounds such as flavonoids (Christaki, 2012; Ji et al., 2020), vitamins, proteins, amino acids and minerals (Cheng et al., 2003), alkaloids, chlorophyll derivatives, amines (Krejcarová et al., 2015), organic acids (Chong et al., 2010; Kumar et al., 2011), fatty acids and phytosterols (Chong et al.,

***Corresponding Author:** Jana Kopčeková, Slovak University of Agriculture in Nitra, Faculty of Agrobiology and Food Resources, Institute of Nutrition and Genomics, Tr. Andreja Hlinku 2, 949 76 Nitra, Slovak Republic
jana.kopcekova@uniag.sk ORCID: https://orcid.org/0000-0002-0989-7868

2010; Patel et al., 2012). Polyphenols are fundamentally involved in the antioxidant activity and their content varies considerably between different varieties of sea buckthorn (Ficzek et al., 2019). The content of total polyphenols in berries ranges from 0.70 to 3.62 g gallic acid equivalents (GAE).kg^{-1} (Sytařová et al., 2020). In a study of Rop et al. (2014), the total phenolic content of six sea buckthorn cultivars ranged from 8.62 to 14.17 g GAE/kg fresh mass. In addition to the known antioxidant effect, polyphenols have antiviral, antimicrobial, antimutagenic, anticarcinogenic, and antiallergic effects. The most active among the carotenoids, which give sea buckthorn its typical yellow to orange color, is β-carotene. It also contains lycopene, zeaxanthin, β-cryptoxanthin (Yang and Kallio, 2002). Very important is its high content of vitamin C (Vilas-Franquesa et al., 2020), which ranges from 52.86 to 896 mg.100 g^{-1} (Teleszko et al., 2015; Kuhkheil et al., 2017), and is significantly more than in rose hips, black currants or raspberries (Malinowska and Olas, 2016). Sytařová et al. (2020) in 9 sea buckthorn cultivars originating from Slovak Republic, determined the amount of vitamin C in the berries from 0.98 to 3.65 g.kg^{-1}. Interestingly, sea buckthorn fruits do not comprise ascorbate oxidase (Rafalska et al., 2017), and thus also products made from sea buckthorn, such as juice, contain a large amount of vitamin C (Beveridge et al., 1999). Food supplements are currently the only way for many to achieve a sufficient intake of antioxidants (Drossard et al., 2014; Starek et al., 2015). Drinking fruit juices is very popular in many countries (Bhardwaj et al., 2014; Singh et al., 2015) and is suitable for supplementing the necessary nutrients, such as vitamins, minerals, but also biologically active substances such as carotenoids and polyphenols (Chandrasekara and Shahidi, 2018; Aadil et al., 2019). Recent studies show that juice consumption is a suitable prevention of several diseases – cancer, neurodegenerative and CVD (Bhardwaj et al., 2014; Peluso et al., 2014; Rodriguez-Roque et al., 2014). One of the main factors in the prevention and treatment of CVD is healthy nutrition with sufficient intake of foods with effective bioactive components. In our work, we focused on evaluating the effect of sea buckthorn juice intake on serum lipids and body composition in hypercholesterolemic women.

2 Material and methods

This (pre-post) intervention study included a 31 non-medicated slightly hypercholesterolemic women aged from 40 to 56 years with serum total cholesterol concentration 5.20–8.00 mmol.L^{-1}. Before starting the study, all volunteers were informed about all risks and profits and confirmed their participation in the study in writing. Body composition and biochemical indicators were monitored before and after 4 weeks of nutrition intervention. The values obtained at baseline the study were used as control. The study was approved by the Ethics Committee at the Specialized Hospital St. Zoerardus Zobor, n. o. Nitra, Slovak Republic (protocol number 3/101921/2021).

2.1 Dietary Intervention

Volunteers consumed 50 mL of 100% commercial SBJ daily for 4 weeks as part of their normal diet. The juice was provided by ZAMIO Ltd., Trhovište, Slovak Republic. The juice was made by cold pressing from organic sea buckthorn fruits (*Hippophaë rhamnoides* L.), without additives, stabilized only by pasteurization. Study beverages were provided in 700 mL glass bottles and participants were instructed to refrigerate the bottle after opening. Composition of sea buckthorn juice used in this study is presented in Table 1. The volunteers had to maintain their lifestyle during the study, including dietary habits and physical activity.

2.2 Anthropometric measurements and biochemical analysis

Body height was measured using a Tanita WB-300 in a vertical position and no shoes. Body composition (BW, BFM, VFA, SMM, FFM, BMI, WHR, WC, ICW, ECW

Table 1 Concentration of phytochemicals in SBJ

Parameter	Units	Quantity	Parameter	Units	Quantity
TPC	mg GAE.g^{-1}	1.56 ±0.03	Resveratrol	mg.L^{-1}	2.48 ±0.08
Rutin	mg.L^{-1}	18.26 ±0.21	Neochlorogenic acid	mg.L^{-1}	1.03 ±0.06
Benzoic acid	mg.L^{-1}	142.47 ±1.12	Cryptochlorogenic acid	mg.L^{-1}	5.53 ±0.15
Caffeic acid	mg.L^{-1}	7.13 ±0.34	Vitamin C	mg.100 g^{-1}	385.41 ±0.38
Coumaric acid	mg.L^{-1}	6.23 ±0.03	Total carotenoids	mg.100 g^{-1}	64.79 ±5.27
Ferulic acid	mg.L^{-1}	18.14 ±0.21	Antioxidant activity (inhibition of DPPH)	%	42.50 ±0.43
Myricetin	mg.L^{-1}	12.28 ±0.38			

TPC – total phenolic content; GAE – gallic acid equivalents and TBW) was determined using an multifrequency analyzer InBody720 (Biospace Co. Ltd., Seoul, Korea). Blood pressure was determined with a digital electronic sphygmomanometer Omron M7 Intelli IT, HEM-7361T-EBK (Omron Healthcare, Tokyo, Japan).

Blood samples were obtained at baseline and after 4 weeks of SBJ consumption from a peripheral vein in the elbow pit by qualified personnel in the morning on an empty stomach between 7 a.m. and 9 a.m., using a closed vacuum system. After centrifugation (3,000 × g for 10 min at 4 °C), blood serum was subjected to routine biochemical analyzes by standard methods in an accredited laboratory of the University Hospital with a BioMajesty JCA-BM6010/C automatic biochemical analyzer (JEOL Ltd., Tokyo, Japan). We monitored serum lipids (T-C, LDL-C, HDL-C, TG); inflammation marker (CRP); markers of kidney (urea, creatinine and uric acid) and markers of liver (ALT, AST and GGT).

Table 2 Basic parameters of volunteers

Parameter	Mean ±SD	Min.–Max.
Age (year)	49.86 ±5.98	40–56
BW (kg)	72.34 ±13.53	49.20–100.8
BMI ($kg.m^{-2}$)	24.82 (22.32; 30.53)	19.56–38.41
WC (cm)	92.63 ±13.33	72.40–120.60
T-C ($mmol.L^{-1}$)	5.93 (5.48; 6.63)	5.21–8.33
HDL-C ($mmol.L^{-1}$)	1.69 ±0.23	1.15–2.01
LDL-C ($mmol.L^{-1}$)	3.96 ±0.91	2.70–5.84
TG ($mmol.L^{-1}$)	0.96 (0.85; 1.11)	0.50–3.15
GLU ($mmol.L^{-1}$)	4.8 ±0.33	4.20–5.40
SBP (mm Hg)	127.76 ±17.40	85–159
DBP (mm Hg)	86.00 ±10.43	73–110

BW – body weight; BMI – body mass index; WC – waist circumference; T-C – total cholesterol; HDL-C – high density cholesterol; LDL-C – low density cholesterol; TG – triglycerides; GLU – glucose; SBP – systolic blood pressure; DBP – diastolic blood pressure; Q1 – first quartile; Q3 – third quartile. Values are expressed as mean ±SD or median (Q1; Q3), minimum (min.) and maximum (max.)

2.3 *Statistical analysis*

Using the Shapiro-Wilk test, we determined whether the variables were normally distributed. The parametric variables were compared by the paired *t*-test, values are expressed as mean ±standard deviation (SD). The Wilcoxon test was used for nonparametric variables and data are expressed as median (Q1; Q3 quartiles). A *p*-value less than 0.05 ($P < 0.05$) is statistically significant. Software Statistica Cz version 14 (TIBCO Software, Inc., Palo Alto, CA, USA) was used for evaluation.

3 Results and discussion

In our study, we focused on evaluating the impact of short-term consumption of 100% sea buckthorn juice on serum lipids and body composition in hypercholesterolemic women. The study included 31 non-medicated adult women aged 40 to 56 years (average age 49.86 ±5.98 years). Average value of total cholesterol was 6.17 ±0.99 $mmol.L^{-1}$. Up to 67.86% of participants had a borderline high (5.20–6.19 $mmol.L^{-1}$) and 32.14% high level of total cholesterol (≥6.2 $mmol.L^{-1}$). We also noted the presence of other risk factors for cardiovascular diseases (CVD) in the monitored group. The main baseline parameters of the study subjects are summarized in Table 2.

In this intervention study, volunteers consumed 50 mL of 100% bio commercial SBJ every day for 4-week period. In general, despite its bitter and sour nature, the juice was well accepted. SBJ consumption was well tolerated by participants and did not show changes ($P > 0.05$) in liver and kidney function in serum following 4 weeks of SBJ intake (Table 3). In addition, laboratory studies show that oil from sea buckthorn provides liver protection from the adverse influence of poisonous chemicals (Cheng, 1990), and sea buckthorn extracts help normalize liver enzymes (Gao et al., 2003).

Numerous epidemiological studies have shown that a high level of T-C, LDL-C, TG and lower levels of HDL-C are associated with increased risk of CVD (Jellinger et al.,

Table 3 Effect of short-term supplementation of SBJ on kidney and liver markers

Parameter	Baseline	Week 4	*p*-value
ALT ($\mu kat.L^{-1}$)	0.24 (0.21; 0.32)	0.26 (0.23; 0.33)	>0.05
AST ($\mu kat.L^{-1}$)	0.31 (0.27; 0.35)	0.33 (0.29; 0.37)	>0.05
GGT ($\mu kat.L^{-1}$)	0.28 (0.25; 0.35)	0.30 (0.28; 0.37)	>0.05
Urea ($mmol.L^{-1}$)	4.68 ±1.29	4.88 ±1.17	>0.05
Creatinine ($\mu mol.L^{-1}$)	66.40 ±9.07	66.91 ±8.80	>0.05
Uric acid ($\mu mol.L^{-1}$)	270.35 ±60.05	283.64 ±63.54	>0.05

ALT – alanine aminotransferase; AST – aspartate aminotransferase; GGT – gamma glutamyl transferase; SD – standard deviation; Q1 – first quartile; Q3 – third quartile. Values are expressed as mean ±SD or median (Q1; Q3).

2012; Graham et al., 2012; Lyons et al., 2014). Increases in TG and T-C levels could affect the constriction and obstruction of vessels in the heart, which are significantly correlated with the risk of CVD (Karimi et al., 2000). In addition, an increase in the LDL-C level could induce atherosclerosis due to the accumulation of LDL-C in the intima-media of the artery, which could then promote thrombocytopoiesis (Esmaeili and Ahmadi, 2004), but high concentrations of functional HDL-C can remove cholesterol from cells and atheroma (Chapman, 2005). A 5% reduction in LDL-C is significant because it could reduce the risk of coronary heart disease (CHD) by 5–15%, and every 1% reduction in LDL-C is associated with a 1–3% reduction in CHD risk (Grundy et al., 2004; Cohen et al., 2006; Brown and Goldstein, 2006). Most studies investigated the effects of sea buckthorn oil or its extracts on the physiological determinants of cardiovascular risk (Bal et al., 2011; Suryakumar and Gupta, 2011; Xu et al., 2011; Sayegh et al., 2014), the consumption of sea buckthorn juice has not yet been systematically monitored. In our study, the lipid profile in blood serum did not change (P >0.05) with the exception of HDL-C, which was significantly increased by supplementing with 100% SBJ daily for 4 consecutive weeks (P <0.001) in individuals with hypercholesterolemia. Similarly, Eccleston et al. (2002) detected a significant increase in HDL-C with no effect on LDL-C and TG in healthy volunteers after juice consumption. The results of Yang (1995) showed that 4-week treatment with dried *Hippophae* emulsion reduced blood T-C, atherosclerosis index and increased HDL-C. The results of a study with 229 volunteers consuming 28 g of sea buckthorn berries for 3 months indicated increased blood concentrations of quercetin and isohamnetin, but consumption of sea buckthorn berries did not affect T-C, LDL-C, HDL-C and TG (Larmo et al., 2009). HDL-C has been identified as one of the most important molecules in the prevention of CVD due to its multiple anti-inflammatories, anti-atherogenic, and antioxidant properties. Studies have shown that a healthy diet, characterized by high consumption of fruits, vegetables, legumes, fish, nuts, and olive oil, could increase the number of HDL-C particles (Luna-Castillo et al., 2021). Each 1% increase in HDL-C results in a 2–3% reduction in the risk of coronary heart disease (Sabaka et al., 2012). T-C, HDL-C and LDL-C are important parameters in determining CVD risk (German and Shapiro, 2020), however was proposed that LDL-C/ HDL-C ratio is a more reliable indicator of cardiovascular risk than the isolated parameters, particularly LDL-C (Kastelein et al., 2008; Zou et al., 2021). Daily consumption of SBJ for 4-weeks period significantly positive modified the LDL-C/HDL-C ratio in all volunteers (P <0.01). Improvement of LDL-C/HDL-C ratio also observed Habanova et al. (2022), who investigated the effect of consuming 300 mL of apple/berry juice for 6 weeks. The CRP is a nonspecific positive acute-phase protein that immediately rises after initiating an inflammatory state (Dallmeier et al., 2012) and is an even more sensitive indicator of imminent cardiovascular risk than other inflammatory indicators or lipid parameters (Koenig et al., 1999; Carmen Zaha et al., 2020; Prabhu et al., 2016; Del Pinto et al., 2018; Ruparelia et al., 2020). In our study, the level of CRP significantly decreased after consumption of sea buckthorn juice (P <0.001), which may be positive for reduction of cardiovascular risk factors (Ridker et al., 2002). The effect of short-term supplementation of SBJ on lipid profile, CRP and glucose are shown in Table 4.

Obesity, risk factor for CVD (Hasani-Ranjbar et al., 2013; Barroso et al., 2017) is induced by chronic low-grade inflammation, which can act synergistically with oxidative stress. Thus, the fruits and vegetables with a high content of antioxidant phytochemicals has an important activity against obesity (Kim et al., 2011; Aguirre et al., 2016; Turner-McGrievy et al., 2017; Paraíso et al., 2019; Wang et al., 2019). Huang et al. (2015) found that a vegetarian diet can be of considerable importance in weight reduction. Similarly, Marranzano et al. (2018) found that a higher intake of flavonoids caused a reduction in body weight. Dupak et al. (2022) found that after 3 months of

Table 4 Effect of short-term supplementation of SBJ on lipid profile, CRP and glucose

Parameter	Baseline	Week 4	p-value
T-C (mmol.L^{-1})	5.93 (5.48; 6.63)	6.06 (5.68; 6.67)	>0.05
HDL-C (mmol.L^{-1})	1.69 ±0.22	1.82 ±0.26	<0.001
LDL-C (mmol.L^{-1})	3.96 ±0.91	3.93 ±0.90	>0.05
TG (mmol.L^{-1})	0.96 (0.85; 1.11)	1.00 (0.76; 1.39)	>0.05
LDL-C/HDL-C ratio	2.37 ±0.58	2.23 ±0.57	0.0084
CRP (mg.L^{-1})	4.4 (4.05; 5.95)	4.00 (3.75; 4.7)	<0.001
GLU (mmol.L^{-1})	4.80 ±0.33	4.70 ±0.36	>0.05

T-C – total cholesterol; HDL-C – high density cholesterol; LDL-C – low density cholesterol; TG – triglycerides. CRP – C-reactive protein; GLU – glucose; SD – standard deviation; Q1 – first quartile; Q3 – third quartile. Values are expressed as mean ±SD or median (Q1; Q3)

Table 5 Effect of short-term supplementation of SBJ on body composition and blood pressure

Parameter	Baseline	Week 4	*p*-value
BW (kg)	72.34 ±13.53	72.04 ±13.30	0.0301
BFM (kg)	24.81 ±10.14	24.19 ±9.80	0.0063
BMI ($kg.m^{-2}$)	24.82 (22.32; 30.53)	24.68 (22.43; 30.11)	0.0305
VFA (cm^2)	101.09 ±36.81	99.04 ±36.76	0.0019
SMM (kg)	26.10 ±2.76	26.32 ±2.79	>0.05
FFM (kg)	47.53 ±4.70	47.85 ±4.72	>0.05
ICW (kg)	21.55 ±2.10	21.72 ±2.14	>0.05
ECW (kg)	13.29 ±1.35	13.33 ±1.32	>0.05
TBW (kg)	34.84 ±3.43	35.04 ±3.44	>0.05
WHR	0.93 ±0.07	0.93 ±0.07	>0.05
WC (cm)	92.63 ±13.33	92.24 ±13.42	>0.05
SBP (mmHg)	127.76 ±17.40	127.60 ±14.53	> 0.05
DBP (mmHg)	86.00 ±10.43	85.72 ±8.02	> 0.05

BW – body weight; BFM – body fat mass; BMI – body mass index; VFA – visceral fat area; SMM – skeletal muscle mass; FFM – fat-free mass; ICW – intracellular water; ECW – extracellular water; TBW – total body water; WHR – waist to hip ratio; WC – waist circumference; SBP – systolic blood pressure; DBP – diastolic blood pressure; SD – standard deviation; Q1 – first quartile; Q3 – third quartile. Values are expressed as mean ±SD or median (Q1; Q3)

sea buckthorn supplementation (500 and 1,000 $mg.kg^{-1}$ BW), body weight did not change significantly in Zucker diabetic fatty (ZDF) rats compared to the control group. Analyzing of body composition during the 4 weeks of supplementation with SBJ, we can observe a statistically significant decrease of BW ($P<0.05$), BFM ($P<0.01$), BMI ($P<0.05$) and VFA ($P<0.01$). Weight reduction may cause a reduction on the muscular mass (Nuttall et al., 2015), the current study demonstrated that taking SBJ for 4 weeks caused an increase of SMM and FFM ($P>0.05$). Results of Lehtonen et al. (2011) showed that sea buckthorn berries/berry fractions consumption (equivalent of 100 g fresh berries/daily) for 33–35 days, as well as consumption of 28 g of sea buckthorn berry for 3 months (Larmo et al., 2013) had a considerable impact on the metabolic profiles of overweight and obese women. In our study, consumption of SBJ led to a small decrease in SBP and DBP, which was not statistically significant ($P>0.05$), on the contrary, Eccleston et al. (2002) found that SBJ has a positive effect on blood pressure. The effect of short-term supplementation of SBJ on body composition and blood pressure are shown in Table 5.

4 Conclusions

In recent years, abundant epidemiologic studies have demonstrated specific biological activities of phytonutrients or phytochemicals from fruits and vegetables, which can have a significant impact on the course of some diseases, particularly cardiovascular. The purpose of this clinical trial was to evaluate the impact of 4-weeks consumption of 100% sea buckthorn juice on lipid parameters and body composition in non-medicated slightly hypercholesterolemic women. Sea buckthorn is a dietary source of many bioactive compounds with antioxidant, anti-platelet, anti-cancer, anti-bacterial and antiviral activities. Studies that have evaluated the effects of sea buckthorn juice consumption on human lipid profile and obesity prevention as cardiovascular risk factors are limited. Data from this study suggest that daily consumption of sea buckthorn juice promotes improvements in cardiovascular health in several ways, including beneficial changes in blood lipids and weight management through loss of body fat. The daily drinking of SBJ with a considerable amount of phytonutrients (polyphenols, vitamin C and carotenoids) led to a positive modulation of the HDL-C and ratio LDL-C/HDL-C. Findings also indicate that sea buckthorn juice may reduce body weight, body fat, visceral fat area and C-reactive protein. The obtained results show that short-term supplementation of sea buckthorn juice represents a possible prevention of risk factors for CVD in hypercholesterolemic women without pharmacotherapy. Further studies with a larger number of participants, a longer period, and the use of variable juice intake are recommended to verify the health benefits of sea buckthorn juice in disease prevention and treatment.

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