The effect of Aronia consumption on lipid profile, blood pressure, and biomarkers of inflammation: a systematic review and meta-analysis of randomized controlled trials

Short: effect of Aronia on lipid profile

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**Conflict of interest**

The authors declare no conflict of interest.

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**Abstract**

Plant derivatives, such as anthocyanin-rich phytochemicals, have been reported to elicit a positive effect on lipid profile. Therefore, the aim of this study was to systematically review and meta-analyze the effects of Aronia consumption on lipid profiles, blood pressure, and biomarkers of inflammation in randomized controlled trials (RCTs). A systematic search was performed in PubMed/MEDLINE, Cochrane and SCOPUS and screening of relevant articles references up to December 2018. We performed this study according to the Preferred Items for Reporting of Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Seven studies were identified and analyzed in this meta-analysis. Our study found a significant increase in high-density lipoprotein (HDL) and diastolic blood pressure following Aronia consumption (Weighted mean differences (WMD): 1.48mg/dl, 95% CI: 1.29, 1.68) and (WMD: 2.55mmHg, 95% CI: 0.63, 4.47), respectively. There was no significant effect on systolic blood pressure and C-reactive protein (CRP), Tumor necrosis factor (TNF), and Interleukin-1 (IL-1). Furthermore, subgroup analysis showed that cholesterol (WMD: -7.18, 95% CI: -13.90, -0.46) and low-density lipoprotein (LDL) (WMD: -5.84, 95% CI: -6.91, -4.77) decreased more significantly in interventions less than 10-weeks in duration. Dose-response analysis demonstrated a significant reduction in triglyceride (TG) levels when dose of Aronia was increased to 300mg/days. In conclusion, the results demonstrated a significant increase in HDL and reduction in total cholesterol and LDL among patients supplementing with Aronia.

**Keywords:** Aronia; chokeberry; blood pressure; Triglyceride; Cholesterol; CRP

**Introduction**

The utilization of natural sources for the prevention of chronic diseases has become significant and substantial in recent years (Jurikova et al., 2017). In the North America region, Aronia genus are traditionally used as medicinal plants in the form of a tea for treatment of cold and influenza. Aronia, is a plant which belongs to the family of Rosaceae, commonly known as chokeberry, and originated from North America and East Canada (Wu, Gu, Prior, & McKay, 2004). Aronia melanocarpa exhibits strong antioxidant activity and therapeutic activities due to the presence, and the high content, of bioactive components, which are putatively suggested to contribute toward the prevention of chronic illness such as metabolic disorders by balancing the lipid proﬁles, fasting plasma glucose, blood pressure levels, control of weight gain and reduction of oxidative stress in humans (Kokotkiewicz, Jaremicz, & Luczkiewicz, 2010; SV Valcheva-Kuzmanova & Belcheva, 2006).

The physiochemical properties of Aronia includes a high volume of phenolic compounds, anthocyanins, ascorbic acid, and radical scavenging activity (Benvenuti, Pellati, Melegari, & Bertelli, 2004; Romani, Vignolini, Ieri, & Heimler, 2016; Xu, Qiu, Ren, Ju, & Jia, 2017). The potential role of Aronia berry polyphenol has been studied on the lipid profile and inflammatory biomarkers of smokers (Liyang Xie et al., 2017), where Xie et al (Liyang Xie et al., 2017) noted significant reductions in total cholesterol and low-density lipoproteins. Phenolic compounds are a group of hydroxylated molecules that are considered to have various biological properties, such as anti-proliferative, anti-viral, anti-diabetic, anticarcinogen, anti-microbial and anti-inflammatory (Hudec et al., 2006; Simeonov et al., 2002). A study by Broncel et al., (Marlena Broncel et al., 2009) revealed that an increased intake of polyphenol, from Aronia berry, for 2 months, reduced biomarkers of cardiovascular diseases (CVD) risk. Further evidence of the efficacy of Aronia (or its species) was highlighted in a study by Duchnowicz et al (Piotr Duchnowicz, Anna Ziobro, Elżbieta Rapacka, Maria Koter-Michalak, & Bożena Bukowska, 2018), whom reported that two months post chokeberry extract supplementation, the lipid peroxidation in children with metabolic syndrome declined by 48% from baseline, total cholesterol level was reduced by 4% and LDL-cholesterol level by 5%, with a concomitant increase in HDL-cholesterol level by 3%, whilst Triacylglycerol levels decreased by 12% (Piotr Duchnowicz et al., 2018).

The crux of the purported health benefits of Aronia berry supplementation relates to the abundant concentrations of polyphenols, anthocyanins, hydroxycinnamic acids, and proanthocyanidins present within it. Aronia berry has been reported to play a role in the control of hyperglycemia and, invariably, positively influencing blood pressure (Banjari et al., 2017; S Valcheva-Kuzmanova, Kuzmanov, Tancheva, & Belcheva, 2007; Yamane et al., 2016). Therefore, the aim of this meta-analysis was to summarize the results from existing evidence on the effect of Aronia consumption on lipid profile, blood pressure, and biomarkers of inflammation.

**Methods**

The PRISMA statement guideline (Preferred Reporting Items of Systematic Reviews and Meta-Analysis) was followed in order to reporting this meta-analysis(Moher et al., 2015).

Search strategy

A literature search was carried out by two independent reviewers (JR) and (HKV) in medical databases including PubMed/MEDLINE, Scopus, and Cochrane databases with no time limitation up to December 2018. The search strategy can be found as a supplement material (Supplementary Table 1). In order to identify additional studies, all reference lists of eligible articles, reviews and meta-analyses were scrutinized. unpublished articles, conference papers, and thesis were not included in this study. to identifying new articles that may be published after our search, the PubMed’s email alert service was created.

Eligibility criteria

The PICOS (patients, intervention, comparator, outcome, study design) criteria was used to establish study eligibility. All clinical trials were included in this meta-analysis if they fulfilled the following criteria: 1) the study design was RCT, 2) the intervention was Aronia consumption, 3) conducted among adults (age ≥ 18 years), 4) assessed lipid Profile, blood pressure, and Inflammation biomarkers as outcome, 5) were published in English. Studies were excluded if they had the following exclusion criteria: 1) non-RCTs studies, 2) done on animals, 3) done on children, 4) studies without placebo group, 5) investigated the effect of other interventions along with Aronia in cases but not in placebo group, 6) did not report lipid Profile or blood pressure or Inflammation biomarkers at baseline and end of the intervention, 7) uncontrolled RCTs.

Definitions

Outcome was defined as the change in lipid profile (cholesterol, LDL, HDL and triglycerides), blood pressure (systolic and diastolic), and Inflammation biomarkers (C-Reactive Protein (CRP), Interleukin-6 (IL-6), and Tumor Necrosis Factor-alpha (TNF-α)).

Data extraction

Data scanning and extraction were performed by two independent researchers (JR and HKV) and discrepancies were discussed and eventually resolved and confirmed by a senior author (YZ). The following information were extracted: first author’s name, year of publication, type of study population, number of cases and controls, participants’ gender, geographic location, study design, intervention duration, type and dose of intervention and placebo, and Mean and SD of outcome in baseline study and post-intervention.

Quality assessment

two investigators (JR and SMM) independently evaluated the quality of eligible studies. Cochrane criteria was used to systematic assessment of bias in the included studies(Higgins & Green, 2011). Following criteria evaluated: sequence generation sufficiency, allocation concealment, blinding, elucidating of dropouts, selective outcome reporting, and other possible sources of bias.

Data synthesis and statistical analysis

All statistical analyses were performed using Stata software (version 14). Overall effect size of the intervention was estimated by Mean change and standard deviation (SD) of outcome and were defined as weighted mean difference (WMD) and 95% CI. the following formula: SD2 baseline + SD2 final – (2 R\* SD baseline + SD final) (Borenstein, Cooper, Hedges, & Valentine, 2009) was used to calculation the SD of the mean difference for studies that not reported. the random-effects model (DerSimonian and Laird method) was used to calculate the pooled weighted mean difference. Heterogeneity across studies was assessed by using I2 index and Q test (Higgins, Thompson, Deeks, & Altman, 2003). the subgroup analysis was used to identify the probable source of heterogeneity among trials. type of Aronia (Supplement or juice), age of participant (≤40 year or >40 year), and duration of intervention (≤10 week or >10 week) were considered as predefined sources of heterogeneity. sensitivity analysis was performed to investigate the effect of each study on overall analysis. Publication bias was assessed by funnel plot, Egger’s weighted regression tests and Begg’s rank correlation. The nonlinear potential effects of Aronia dosage (mg/day) were examined using fractional polynomial modeling. P <0.05 was considered as statistically significant.

**Results**

In our initial search from PubMed, Scopus, and Cochrane Library 286 articles were identified (Supplementary Figure 1). After removing duplicates, 195 articles reminded. Based on initial title and abstract screening 160 articles were excluded and 35 articles were retrieved for more detailed evaluation. Nine articles were excluded based on the following reason: 1) No RCT design (n=13), 2) In Vitro trial (n=9), and 3) No placebo (n=7). Finally, 6 articles (7 studies) with 286 participants(M. Broncel et al., 2010; P. Duchnowicz, A. Ziobro, E. Rapacka, M. Koter-Michalak, & B. Bukowska, 2018; Loo et al., 2016; Naruszewicz, Laniewska, Millo, & Dluzniewski, 2007; Petrovic et al., 2016; L. Xie et al., 2017) were included in the meta-analysis.

Study characteristics

Characteristics of the included studies are presented in Table 1. Sample size of the included studies ranged from 15 to 77 individuals with mean age of 36 years. Mean duration of the interventions were 16 weeks (4 to 24 weeks). Included articles were published between 2007 and 2018. They were conducted in the USA(L. Xie et al., 2017), Poland(M. Broncel et al., 2010; P. Duchnowicz et al., 2018; Naruszewicz et al., 2007), Serbia (Petrovic et al., 2016), and Finland(Loo et al., 2016). Mean dose of the Aronia supplement was 228 ml or mg/day (100 – 500 ml or mg/day).

From seven included studies, seven investigated CL(M. Broncel et al., 2010; P. Duchnowicz et al., 2018; Loo et al., 2016; Naruszewicz et al., 2007; Petrovic et al., 2016; L. Xie et al., 2017), four on LDL(M. Broncel et al., 2010; P. Duchnowicz et al., 2018; Naruszewicz et al., 2007; L. Xie et al., 2017), five on HDL(M. Broncel et al., 2010; P. Duchnowicz et al., 2018; Loo et al., 2016; Naruszewicz et al., 2007; L. Xie et al., 2017), seven on TG(M. Broncel et al., 2010; P. Duchnowicz et al., 2018; Loo et al., 2016; Naruszewicz et al., 2007; Petrovic et al., 2016; L. Xie et al., 2017), two on SBP(Loo et al., 2016; L. Xie et al., 2017), two on DBP(Loo et al., 2016; L. Xie et al., 2017), three on IL-6(Loo et al., 2016; Naruszewicz et al., 2007; L. Xie et al., 2017), two on TNF(Loo et al., 2016; L. Xie et al., 2017), and four on CRP(M. Broncel et al., 2010; Loo et al., 2016; Naruszewicz et al., 2007; L. Xie et al., 2017).

Meta-analysis results

Analyses of the effect of Aronia consumption on cholesterol, triglyceride, HDL, LDL, systolic blood pressure, Diastolic blood pressure, CRP, TNF, and IL-1 are shown in figure 1. Following Aronia consumption there was: an increase in HDL (WMD: 1.48, 95% CI: 1.29, 1.68, insignificant between-study heterogeneity: I2 = 00.0% & [P =0.410]) and DBP (WMD: 2.55, 95% CI: 0.63, 4.47, insignificant between-study heterogeneity: I2 = 39.9% & [P =0.197]).

there was no overall effect of Aronia consumption on cholesterol (WMD: -4.51, 95% CI: -13.50, 4.48, significant between-study heterogeneity: I2 = 76.4% [P < 0.001]), TG (WMD: -4.81, 95% CI: -15.26, 5.64, significant between-study heterogeneity: I2 = 91.9% & [P < 0.001]), and TNF (WMD:-0.30 , 95% CI: -1.20, 0.60, insignificant between-study heterogeneity: I2 = 00.0% [P =0.994]), systolic blood pressure (WMD:0.35 , 95% CI:-2.22, 2.92, insignificant between-study heterogeneity: I2 =28.8 % [P < 0.236]), CRP (WMD:0.11 , 95% CI: -0.50, 0.72, significant between-study heterogeneity: I2 = 57.3% [P =0.071]), IL-6 (WMD:0.00 , 95% CI: -2.01, 2.01, significant between-study heterogeneity: I2 = 59.2% [P =0.086]).

Subgroup analysis

Results of the subgroup analyses are summarized in Table 2. We stratified studies based on how the Aronia was administered (Supplement and Juice), age (≤40 and >40y) and duration of Aronia consumption (≤10 and >10 weeks). Subgroup analysis based on Aronia type and age of participants were not source of heterogeneity for CL, TG, LDL, and HDL.

Subgroup analysis of duration of intervention showed that CL (WMD: -7.18, 95% CI: -13.90, -0.46) and LDL (WMD: -5.84, 95% CI: -6.91, -4.77) decreased more significantly, in intervention with less than 10-week duration compare intervention with longer duration.

Sensitivity analysis and Non-linear dose-responses

Non-linear dose-responses between Aronia consumption and unstandardized mean difference in TG showed in Figure 2. Dose-response analysis demonstrated a significant reduction in TG levels by increasing dose of Aronia to 300mg/days.

Sensitivity analysis did not show significant differences beyond the limits of 95% CI between calculated SESs for Aronia intervention studies (Supplemental figure 2).

Non-linear dose-responses between Aronia consumption and unstandardized mean difference in Cholesterol, HDL, LDL, CRP were not significant, and they are presented in supplemental figure 3.

Risk of bias

Cochrane risk of bias assessment was conducted, and presented in Fig 3, where studies were scored as Low, Hugh or Unclear risk of bias for random sequence generation, allocation concealment, blinding of participants, personnel and outcome assessors, incomplete outcome data, selective outcome reporting and other sources of bias.

The Egger’s and Begg’s tests did not show any publication bias for Cl (p=0.05, p=0.09), TG (p=0.19, p=0.29), CRP (p=0.50, p=0.49), LDL (p=0.48, p=0.98), HDL (p=0.28, p=0.32), SBP (p=-, p=0.31), DBP (p=-, p=0.31), TNF (p=-, p=0.37), and IL-6 (p=0.57, p=0.60), Respectively (Fig 4).

**Discussion**

This review aimed to estimate the effect of Aronia consumtion on Cholesterol, Triglyceride, HDL, LDL, Systolic blood pressure, Diastolic blood pressure, CRP, TNF, and IL-1, through the conducting of a meta-analysis of RCTs. To the best of our knowledge this is the first systematic review and meta-analysis of randomized controlled trials investigating the effects of Aronia on the aforementioned variables. The results demonstrated that significant increases in HDL and DBP were observed among patients receiving Aronia compared with the control group. The results showed a significant reduction in total cholesterol and LDL when duration of intervention is less than 10 weeks. Furthermore, Dose-response analysis demonstrated a significant reduction in TG levels by increasing dose of Aronia to 300mg/day. However, the present results did not show any significant effect of Aronia consumption on IL-6, TNF, CRP, and SBP levels. Furthermore, combined results did not show any difference between consumptions Aronia juice and Aronia supplementation on cholesterol and TG levels.

The results demonstrated that there was a statistically significant increase in HDL and DBP among those receiving Aronia when compared with the control group, and a reduction in total cholesterol and LDL, when the duration of intervention was less than 10 weeks. Increases in HDL levels and concomitant reduction in TG levels could be construed as a positive health finding given that decreases in HDL, and increased TG levels, respectively, have been associated with higher risk of cardiovascular events (Kannel, Dawber, Thomas Jr, & McNamara, 1965; Mendis, 2010). Furthermore, a dose-response analysis demonstrated a statistically significant reduction in TG levels by increasing dose of Aronia to 300mg/day. However, no statistically significant for differences in levels of IL-6, TNF, CRP, and SBP levels were found in this study. It is conceivable that our review being unable to find such a reduction may be because of the heterogenous modality Aronia administration. Circumspectly, it is therefore recommended that administration type be carefully considered by researchers and clinicians.

To the best of our knowledge this is the first systematic review of randomized controlled trials attempting to investigate the effects of Aronia, so we are unable to contextualize our findings with other published results. There are a few discrepancies in the articles related to the review in terms of the population being studied, duration of administration of Aronia, and mode of administration. Although there is promising antecedence for the provenance of Aronia in improving blood lipid profiles in a few animal studies (Jurgoński, Juśkiewicz, & Zduńczyk, 2008; S Valcheva-Kuzmanova et al., 2007; Yamane et al., 2016), when performing this meta-analysis, on the whole, we were unable to support such assertions, with meaningful improvements only noted in a few markers. Given the lack of consensus provided for certain variables, it is strongly recommended that studies with suitably powered sample sizes, and high quality RCTs, would enable equivocality to be ameliorated.

Regarding clinical importance, it is evident that the usage of Aronia is helpful in increasing HDL levels, with concurrent reductions of TC, LDL and TG when consumed in dosages over 300mg. Given that Aronia is a naturally occurring food, it is likely to elicit less side effects or complications when compared to commercially available, man-made medications. For example, Valcheva-Kuzmanova et al. reported an anti-hyperlipemic effect, and no internal adverse effects following consumption of Aronia juice (Valcheva-Kuzmanova); whilst weight gain is the primary side-effect of many pharmacotherapies such as sulfonylureas, α-glucosidase inhibitors, and thiazolidinediones, and this side-effect is particularly undesirable (Gershell; Banjari). Furthermore, in patients where pharmacotherapy is necessitated, Aronia could be employed safely as an adjunct therapy; Vendrame et al asserted that berries, such as Aronia, as part of a dietary strategy could greatly reduce the need for pharmacotherapy, associated with potentially deleterious side effects and constituting a considerable financial burden. Moreover, such Aronia supplementation also presents little risk of interaction with any existing treatments, whereas some other herbal supplements have demonstrable side-effects. For example, cranberry (Yang; Hamann) and ginseng (Anetzsky; Gurley) can interfere with warfarin, inhibiting the CYP2C9 enzyme and increasing the risk of bleeding, whilst Ginkgo (Vale; Matthews; McEwan) and Garlic (Tattelman; McEwan) have been shown to interact negatively with aspirin, reducing platelet activity and increasing the risk of bleeding. Thus, although there are no known reports of Aronia eliciting negative or injurious side-effects, careful observation by clinicians is still advised when administering Aronia. This review facilitates clinician, and other key stakeholders, understanding of the importance of a natural food supplement, which may be conducive to the positive treatment of individuals suffering with non-communicable diseases, particularly given the markedly reduced side-effects associated with a complementary, phytotherapy. It is imperative that future studies place importance upon well-constructed methodology and study design, the source and type of Aronia, the mode of administration and the utilization of standardized outcome variables. Such actions would reduce the equivocal nature of some findings, leading to a consensus of the efficacy of Aronia supplementation.

In this meta-analysis, combined results did not show any difference between consumptions Aronia juice and Aronia supplementation. The extracted form of Aronia was used for supplementation, whichcontained all bioactive components of Aronia, such as polyphenols, anthocyanins, hydroxycinnamic acids, and proanthocyanidin s(M. Broncel et al., 2010; P. Duchnowicz et al., 2018; Naruszewicz et al., 2007; L. Xie et al., 2017). In interventions with juice of Aronia, bioactive components are consistent with the extracted form of Aronia(Loo et al., 2016; Petrovic et al., 2016), so it is likely that both forms of administration had equivalent effects; notwithstanding, the influence of administration type should be more acutely investigated in further RCTs.

**Conclusion**

The results of current meta-analysis study highlight that Aronia supplementation may lead to a significant increase in HDL, and reduction in total cholesterol and LDL, respectively, and thus, is of contemporary, clinical interest. This information may be operationalized by health care providers and clinicians seeking a complimentary therapy for their patients. However, the literature remains somewhat equivocal as to whether certain biomarkers are meaningfully impacted, thereby highlighting the need for putative mechanisms to be investigated further, and further experimental studies, preferably RCT’s, be conducted.

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**Table 1. Characteristics of included studies**

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Author | Location | year | Participants (n) | Gender(1women, 2men, and 3 both | Age (year) | dose (mg or ml/ day) | Type | Duration of study(week) | Population study | Out come |
| Duchnowicz, P. | Poland | 2018 | 77 | 3 | 16 | 300 | Supplement | 8 | Metabolic Syndrome | CL, LDL, HDL, TG |
| Xie, L. | USA | 2017 | 49 | 3 | 35 | 500 | Supplement | 12 | healthy adult | CL, LDL, HDL, TG, SBP, DBP, IL-6, TNF, CRP |
| Petrovic, S. | Serbia | 2016 | 15 | 2 | 18 | 100 | juice | 4 | handball players | CL, TG |
| Petrovic, S. | Serbia | 2016 | 17 | 1 | 17 | 100 | juice | 4 | handball players | CL, TG |
| Loo, B. M. | Finland | 2016 | 37 | 3 | 55 | 300 | juice | 16 | blood pressure | CL, HDL, TG, SBP, DBP, IL-6, TNF, CRP |
| Broncel, M. | Poland | 2010 | 47 | 3 | 45 | 300 | Supplement | 8 | Metabolic Syndrome | CL, LDL, HDL, TG, CRP |
| Naruszewicz, M. | Poland | 2007 | 44 | 3 | 66 | 255 | Supplement | 24 | patients after myocardial infraction | CL, LDL, HDL, TG, IL-6, CRP |

Table 2 Results of subgroup analysis of included randomized controlled trials in meta-analysis

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Variables | type of Aronia | | age | | duration of consumption(week) | |
| **CL** | Supplement | Juice | ≤40 | >40 | ≤10 | >10 |
| No. of comparison | 4 | 3 | 4 | 3 | 4 | 3 |
| WMD  (95% CI) | -6.53  (-18.13, 5.07) | -0.74  (-0.92, 9.43) | -8.57  (-17.91, 0.75) | 1.75  (-18.98, 22.49) | -7.18  (-13.90, -0.46) | 0.63  (-21.28, 22.55) |
| p value | 0.27 | 0.88 | 0.07 | 0.86 | 0.03 | 0.95 |
| I2 (%) | 84 | 0 | 69 | 0.81 | 9 | 89 |
| p-heterogeneity | 0.001 | 0.610 | 0.020 | 0.005 | 0.344 | 0.001 |
| **TG** |  |  |  |  |  |  |
| No. of comparison | 4 | 3 | 4 | 3 | 4 | 3 |
| WMD  (95% CI) | -8.33  (-21.69, 5.03) | 2.56  (-7.07, 12.19) | -0.97  (-13.32, 11.37) | -16.83  (-34.18, 0.52) | -6.09  (-19.36, 7.18) | 2.51  (-1.49, 6.52) |
| p value | 0.22 | 0.60 | 0.87 | 0.05 | 0.36 | 0.21 |
| I2 (%) | 95 | 0 | 95 | 0 | 77 | 0 |
| p-heterogeneity | 0.001 | 0405 | 0.001 | 0.562 | 0.004 | 0.401 |
| **LDL** |  |  |  |  |  |  |
| No. of comparison | 4 | 0 | 2 | 2 | 2 | 2 |
| WMD  (95% CI) | - | - | -11.79  (-23.84, 0.25) | -9.22  (-18.45, 0.01) | -5.84  (-6.91, -4.77) | -7.46  (-31.26, 16.33) |
| p value | - | - | 0.05 | 0.66 | 0.01 | 0.53 |
| I2 (%) | - | - | 97 | 64 | 1 | 85 |
| p-heterogeneity | - | - | 0.001 | 0.94 | 0.314 | 0.009 |
| **HDL** |  |  |  |  |  |  |
| No. of comparison | 4 | 1 | 2 | 3 | 2 | 3 |
| WMD  (95% CI) | - | - | 1.29  (0.68, 1.91) | 1.20  (-0.59, 3.00) | 1.54  (1.34, 1.74) | 0.89  (0.26, 1.52) |
| p value | - | - | 0.001 | 0.19 | 0.001 | 0.006 |
| I2 (%) | - | - | 71 | 0 | 0 | 0 |
| p-heterogeneity | - | - | 0.60 | 0.842 | 0.861 | 0.875 |

WMD, weight mean difference

**Figure 1.** Meta-analysis of effect of Aronia consumption on Cholesterol (a), Triglyceride (b), HDL (c), LDL (d), Systolic blood pressure (e), Diastolic blood pressure (f), CRP (g), TNF (h), and IL-1(i)

a) Cholesterol

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b) Triglyceride

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c)HDL

C:\Users\mah el\Desktop\3.tif

d)LDL

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e) Systolic blood pressure

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f) Diastolic blood pressure

C:\Users\mah el\Desktop\6.tif

g) CRP

C:\Users\mah el\Desktop\7.tif

h) TNF

C:\Users\mah el\Desktop\8.tif

i)IL-1

C:\Users\mah el\Desktop\9.tif

**Figure 2.** Non-linear dose-responses between Aronia consumption and unstandardized mean difference in TG. The 95% CI is depicted in the shaded regions.

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**Figure 3.**  Cochrane risk of bias assessment

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**Figure 4.** Funnel plot to assess publication bias on Cholesterol (a), Triglyceride (b), HDL (c), LDL (d), Systolic blood pressure (e), Diastolic blood pressure (f), CRP (g), TNF (h), and IL-1(i)

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