Journal of Functional Foods 23 (2016) 464–473

Available online at www.sciencedirect.com

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A review of the potential health benefits of pine nut oil and its characteristic fatty acid pinolenic acid

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ARTICLE INFO

Article history:
Received 22 January 2016
Received in revised form 28 February 2016
Accepted 2 March 2016
Available online 31 March 2016

Keywords:
Pinolenic acid
Pinus koraiensis
Pinus sibirica
Pine nut oil
Health

ABSTRACT

Pine nuts contain pinolenic acid (PNLA), which represents 14–19% of fatty acids present. Here we review research on pine nut oil (PNO) and PNLA from studies performed *in vitro*, in animal models and in humans. PNLA has anti-inflammatory action and may improve lymphocyte function. PNO and PNLA have favourable effects on appetite control, perhaps by increasing the blood concentrations of key satiety hormones. Less weight gain and fat deposition were observed in mice fed with high fat diets containing PNO. *In vitro* research demonstrated that PNLA is a potent dual agonist for co-activation of free fatty acid receptors 1 and 4, which could enhance glucose-dependent insulin secretion and insulin sensitivity. PNO increased the activity of antioxidant protective enzymes in serum and decreased the concentration of malondialdehyde, an indicator of lipid peroxidation. Thus, PNLA and its parent PNO could be of potential benefit to human health, although this requires further investigation.

Contents

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http://dx.doi.org/10.1016/j.jff.2016.03.003
1756-4646/

1. Introduction

Pine nuts have a range of culinary uses in many parts of the world. Pine nuts come from the *Pinus* genus, and 29 species have been listed as having edible nuts by the Food and Agriculture Organization of the United Nations (FAO, 2015). Pine nuts derived from *Pinus koraiensis* (Korean pine), *Pinus sibirica* (Siberian pine), *Pinus pinea* (stone pine) and *Pinus gerardiana* (chilgoza pine) are most commonly consumed by humans (Destaillats, Cruz-Hernandez, Giuffrida, & Dionisi, 2010). The nuts are usually 9–12 mm long (Zadernowski, Naczk, & Czaplicki, 2009) and have a high oil content (see section 2). The oil is rich in fatty acids including Δ5-unsaturated polymethylene-interrupted fatty acids (Δ5-UPIFAs), which are characteristic of the seeds of gymnosperms and differ from the structure of other polyunsaturated fatty acids (PUFAs). Pinolenic acid (PNLA; all *cis*-5, -9, -12-18:3) is the major Δ5-UPIFA in pine nuts and their oil (Wolff & Bayard, 1995). Other Δ5-UPIFAs in pine nut oils (PNOs) are sciadonic acid (all *cis*-5, -11, -14-20:3) and taxoleic acid (all *cis*-5, -9-18:2) (Destaillats et al., 2010). The potential influence of PNOs and their characteristic fatty acid constituent, PNLA, on physiological and health related outcomes has been assessed in a number of research studies, mainly performed *in vitro* and in experimental animals. The aim of this review is, for the first time, to collate, summarize and discuss the research findings with PNO and PNLA. Only research with Korean or Siberian PNO is considered.

1.1. Data sources

The PubMed database was accessed in September 2015 to identify relevant studies for this review. The terms used for the search were "Korean pine nut oil", "Siberian pine nut oil", "*P. koraiensis*", "*P. sibirica*" and "pinolenic acid", all separately. Studies about other *Pinus* genus or those not relevant to health were excluded.

2. Sources and composition of pine nut oils

The high demand for pine nuts has led to an increase in their worldwide production (FAO, 2015). China, Korea, Russia (Siberia) and Pakistan are the main countries exporting pine nuts (FAO, 2015). Pine nuts have many culinary uses in their own right and the oil may also be extracted and used.

Oil yield depends upon the mode of extraction (e.g. cold pressing, solvent extraction), but is typically reported to be 45 to 65 g/100 g of nut (Chen, Zhang, Wang, & Zu, 2011b; Ryan, Galvin, O'Connor, Maguire, & O'Brien, 2006; Zadernowski et al., 2009). Oil from *P. sibirica* is reported to be composed of 99.4 wt% nonpolar lipids and 0.60 wt% polar lipids (Zadernowski et al., 2009). Triacylglycerols (TAGs) are an important constituent of the nonpolar lipids; Acheampong, Leveque, Tchapla, and Heron (2011) identified 58 different TAG species in the oil of *P. koraiensis* using non-aqueous reversed phase chromatography-electrospray ionization-mass spectrometry with silver nitrate. Because of their high TAG content, pine nuts and PNO have a high content of fatty acids (esterified into TAGs). The fatty acids in pine nuts are typically 50% PUFAs, 40% monounsaturated fatty acids (MUFAs) and 10% saturated fatty acids (SFAs) (Ryan et al., 2006). The fatty acid composition of *P. sibirica* and *P. koraiensis* oils determined by several researchers is presented in Table 1. Linoleic acid (all-*cis*-9-, 12–18:2) is the major PUFA and the most common fatty acid in PNO. Oleic acid (*cis*-9-18:1) is the dominant MUFA and is the second most abundant fatty acid. PNLA is the most prevalent UPIFA, typically comprising 14 to 19 wt% of total fatty acids (Table 1). Palmitic acid (16:0) and stearic acid (18:0) represent the major SFAs in PNO (Ryan et al., 2006; Zadernowski et al., 2009). Fig. 1 shows a gas chromatogram profile of the fatty acids present in the oil of *P. sibirica* demonstrating the presence and relative abundance of palmitic acid, oleic acid, linoleic acid, and PNLA. The content of PNLA in oil from *P. koraiensis* has been markedly enriched up to 45% of fatty acids by Lee, Lee, Lee, Kim, and Rhee

Table 1 – Reported fatty acid compositions of oil from *P. sibirica* and *P. koraiensis*. Data are individual fatty acid percentage of total fatty acids.

Authors	Oil	Extraction method	Fatty acid analytical method	PNLA	LA	OA	SA	PMA
Deineka & Deineka, 2003	*P. sibirica*	Acetone	Reverse-phase HPLC	17.0	49.0	23.8	2.5	6.3
Zadernowski et al., 2009	*P. sibirica*	Cold-pressing	GC	19.2	46.0	24.7	2.8	4.8
		Hexane		18.5	46.4	24.8	2.8	4.1
Destaillats et al., 2010	*P. sibirica*	Hexane	GC	18.3	43.5	25.5	2.5	4.4
	P. koraiensis			14.6	45.2	27.5	2.2	4.9
Asset et al., 1999	*P. koraiensis*	Chloroform-methanol	GC	14.9	48.4	25.5	1.8	4.2
Wolff & Bayard, 1995	*P. koraiensis*	Chloroform-methanol	GC	14.9	48.4	24.1	1.8	4.2

Abbreviations: PNLA, pinolenic acid; LA: linoleic acid; OA, oleic acid; SA, stearic acid; PMA, palmitic acid; HPLC, high-performance liquid chromatography; GC: gas chromatography.