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Review

A review of phytochemistry and bioactivity of quince (*Cydonia oblonga* Mill.)

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Phytochemicals isolated from quince (*Cydonia oblonga* Mill.) were reviewed along with their bioactivities tested on animal models and *in vitro* tests. The review covers the findings from traditional medicines of different nations to the recent investigations and consisted of 52 references.

Key words: Phytochemicals, *Cydonia maliformis, Cydonia vulgaris, Pyrus cydonia.*

INTRODUCTION

Quince (*Cydonia oblonga* Miller, *Cydonia maliformis* Miller, *Cydonia vulgaris* Pers., *Pyrus cydonia* L., Farsi name of "Beh", Greek name of "Strythion", and Azari name of "Heyva") is a tree from Rosaceae family. Quince is cultivated in gardens under warm temperature and grows up to 8 m high and 4 m wide. The young branchlets are covered with pale greyish wool, leaves are ellitical, flowers are pink or white, fruits are bright yellowish and usually pear shaped (Gholgholab, 1961). A brief review of medical literature revealed that preparations from different parts of quince have been used as traditional remedies for cough, bronchitis, nausea, fever, diarrhea, cystitis, constipation, hemorrhoids, diabetes, hypertension (Table 1).

Its efficacy has been tested in several experimental or clinical studies. Although herbal medicines possess a number of toxic effects; however, no significant side effect or contraindication related to consumption of products of quince has been reported so far. Quince fruit is also widely used as a food in the form of jam or jelly. In addition to quince, other plants from Rosaceae family also possess beneficial biological activities. As an example, Sancheti et al. (2010) reported the antihyperglycemic, antihyperlipidemic and antioxidant effects of *Chanomeles sinensi*. It should also be noted that, there are other similar names in the literature which belongs to plants other than *C. oblonga*, that is, Chinese quince (*Pseudocydonia sinensis* Schneid), Japanese quince (*Chaenomeles japonica*), and flowering quince (*Chaenomeles speciosa* (Sweet) Nakai). One of the most common methods to explore new medicinal agents, the so-called lead compounds, is screening the biological properties and bioactive compounds of natural products. Among them, herbals represent a safe and easily available category; thus their biological activites had been subjected to various *in vivo* and *in vitro* studies during the last decades. Nowadays, the possiblity for identification of natural bioactive compounds has been improved employing modern techniques for isolation and separation of different constituents. However, prior to initiating the detailed pharmacological analyses of a natural product, its biological effects should be at least tested in an experimental model. During the recent years, a modest number of studies have investigated the efficacy of traditional herbal medicines using modern methodology and favorable outcomes have been achieved raising the possibility for the revival of herbal remedies (Gorji, 2003). In this review, available papers dealing with the phytochemicals and biological activities of quince were reviewed.

PHYTOCHEMISTRY

Oliveira et al. (2007) identified several phenolic compounds of quince leaf including 3-O-, 4-O-, 5-O-caffeoylquinic acids, 3,5-O-dicaffeoylquinic acid, quercetin-3-O-galactoside, quercetin-3-O-rutinoside, kaempferol-3-O-glucoside and kaempferol-3-O- rutinoside.

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Table 1. Medicinal usages of different parts of quince.

Effects/ Ailments treated	Part used	Preparation	Adminstration route	Reference
Antialcoholic,carminative, expectorant, anti cancer	Fruits/Seeds		Oral	Duke et al., 2002
Antibacterial	Seeds, pulp and peel	Extract	*In vitro*	Bonjar, 2004
Antibacterial	Seeds, pulp and peel	Extract	*In vitro*	Fattouch et al., 2007
Antidiabetic	Fruits	Raw/cooked	Oral	Tahraoui et al., 2007
Antidiabetic	Leaves	Hydro-ethanolic extract	Oral	Aslan et al., 2010
Antidiabetic	Leaves		Oral	Palmese et al., 2001
Antidioxidant	Leaves	Hydro-ethanolic extract	Oral	Aslan et al. 2010
Antihemolytic and free radical scavenging	Leaves	Extract	In vitro	Costa et al., 2009
Antihyperglycemic	Leaves	Decoction	Oral	Teresaet al., 2001
Antihyperlipidemic	Leaves	Extract	Oral	Khademi, 2009
Cardiovascular, haemorrhoids, bronchial asmthma and cough	Leaves		Oral	Yildirim et al., 2001
Conjunctivitis	Seeds	Decoction	Eye drop	Siddiqui et al., 2002
Cough, Bronchitis, Constipation	Seeds	Decoction	Oral	Ghanadi et al., 2003
Cough, Bronchitis	Leaves	Decoction	Oral	Tuzlaci and Tolon, 2000
Cystitis	Fruits	Cooked	Oral	Sezik et al., 2001
Diarrhea	Leaves		Oral	Saric-Kundalic et al., 2011
Diarrhea and stomach ulcers	Leaves and seeds		Oral	Saric-Kundalic et al., 2011
Diarrhoea,dysentery, sorethroat,cardiovascular and kidney diseases				Skidmore-Roth, 2001
Diuretic	Leaves	Decoction	Oral	Kültür, 2007
Drug-iduced myocardial necrosis	NM[1]	NM[1]	Oral	Goyal et al., 2010
Emollient for the skin	Fruits	Decoction	Topical	Pieroni et al., 2004
Headache			Oral	Gorji, 2003
Healing on skin lesions	Seeds	Mucilage added to a cream base	Topical	Hemmati et al., 2010
Hemorrohids	Leaves		Infusion	Tuzlaci and Aymaz, 2001
Hypertension	Leaves	Decoction	Oral	Camejo-Rodrigues et al., 2003
Inflammatory bowl disease	Fruits		Oral	Rahimi et al., 2010
Kidney protection	Leaves	Decoction	Oral	Jouyban et al., 2010
Laxative	Fruits	Direct ingestion	Oral	Agelet et al., 2003
Migrain,nausia,common cold and infuenza	Seeds	Boiling the fruits in water	Oral	Hilgert et al., 2001
Phthisis, hepatitis, antiemetic, blenorrhalgia, skin cracking. haemorrhoid, diarrhoea, cancer, whooping cough, digestive and enteritis	NM	NM	Oral	Saganwan (2010)
Stomach ulcer	Leaves		Oral	Saric-Kundalic et al., 2011

1NM, Not mentioned.

Total phenolic content of quince leaves varied from 4.9 to 16.5 g/kg dry matter. In another report from the same group, organic acids composition of quince leaf was investigated; quinic acid (72.2%) and citric acid (13.6%) were the major acidic components (Oliveira et al., 2008). However, they found higher total concentrations of phenolics in quince leaves than in pulps, peels and seeds (Oliveira et al., 2008). Costa et al. (2009) studied the methanolic extract from quince leaf and reported 5-O-caffeoylquinic acid as the major phenolic compound.

The isolated phytochemicals from different parts of quince were reported in Table 2. Phenolic profiles of methanolic extracts of seed, peel and pulp were reported by Magalhaes et al. (2009) in which the total phenol contents were 0.4, 6.3 and 2.5 g/kg, respectively. Alesiani et al. (2010) isolated 59 phytochemicals from quince peels (including five newly characterized phytochemicals). Careful review of Table 2 reveals that a number of compounds could be considered as chemical markers of different parts of quince.

Tsuneya et al. (1983) reported ~120 volatile compounds including hydrocarbons, esters, alcohols, aldehydes, ketones and lactones from quince fruits. Tateo and Bononi (2010) analyzed volatile compounds of whole fruits using a headspace solid phase extraction and identified more than 40 compounds (Table 3). The fruit samples were collected in October and November, and there was an increased pattern for sesquiterpenes from October to November. There was no change in the relative percentage of theaspirane isomers with ripeness (Tateo and Bononi, 2010). Silva et al. (2002) analyzed the phenolic compounds of different parts of quince fruit (peel and pulp) collected from seven geographical places of Portugal. Figure 1 shows the total phenloic compound (TPC) values of fruits collected from different areas of Portugal. There were significant variations in the TPCs of peel and pulp. The minimum TPCs were observed for the fruits collected from Braganca (243.5 mg/kg for peel and 11.7 mg/kg for pulp) and the maximum values were obtained for fruits collected from Pinhel area with the TPCs of 1738.6 mg/kg for peel and 268.3 mg/kg for pulp. The mean ± standard deviation of TPCs for peel and pulp were 975.2 ± 536.1 mg/kg and 130.1 ± 77.6 mg/kg, respectively. As TPCs of peel and pulp are different from each other, the presence of peels characteristics compounds in the commercial products of pulp could be used to detect the adulteration of whole fruits instead of pulp in the preparation of the products (Silva et al., 2002). Water and lipid contents of quince seeds were investigated by Nogala-Kalucka et al. (2010) in which the water content of the seeds as 15.61%, and lipid content of 25.27% were reported. Fat soluble bioactive compounds of the seeds including tocopherols, phytosterols and phenolic acids were reported. Tocopherols consisted of α-tocopherol (16.03 mg/100 g dry seed), β-tocopherol (0.15), γ-tocopherol (0.32) and total tocopherol of 16.49 mg/100 g dry seed were found.

The α-tocopherol possesses the highest vitamin E activity among others. The phytosterols were campestrol (0.32 mg/g fat), stigmasterol (0.20 mg/g), sitosterol (2.60 mg/g), avanasterol (0.44 mg/g) and total phytosterols of 3.56 mg/g fat. Phytosterols, specially β-sitosterol reduces LDL cholestrol levels and the contribution of β-sitosterol in quince seed is 73% (Nogala-Kalucka et al., 2010). Quince fruit possesses the highest amount of hydroxycinnamic acid derivatives (30.9 mg/100 g) in comparison with chinese quince (6.9 mg/100 g) and apple (12.2 mg/100 g) (Hamauzu et al., 2006). Total phenolic content of methanolic extract of leaf was the highest (27.96 g/kg dried) followed by peel (7.41 g/kg), pulp (1.17 g/kg) and seed (0.52 g/kg) as reported by Carvalho et al. (2010). In addition to these phytochemicals, some volatile compounds isolated from quince are listed in Table 3.

BIOACTIVITY

Antiradical activity

The free radical scavenging activities of the methanolic extracts of quince pulp, peel and seed on 2,2'-diphenyl-1-picrylhydrazyl (DPPH) radicals were investigated to show the antioxidantactivities (Magalhaes et al., 2009). The group used radical scavenging activities of ascorbic acid and 5-O-caffeoylquinic acid as reference compounds. The EC_{50} values for seed, peel and pulp were 12.2, 0.8 and 0.6 mg/ml of methanolic extract. The EC_{50} value of seed extract (Magalhaes et al., 2009) was higher than that of a previous work (2 µg/ml) (Silva et al., 2002). This observation could be due to natural variability, maturity stage of the fruits and edapho-climatic conditions. The EC_{50} values of free radical scavenging activities of ascorbic acid and5-O-caffeoylquinic acid were 8.1 and 15.1 µg/ml. Considering the total caffeoylquinic acid contents of the extracts, that is, 0.8, 2.6 and 1.5 µg/ml, respectively for seed, peel and pulp. The antiradical activity of the extracts were much higher than standard antioxidants, possibly due to additive and synergistic effects of pheytochemicals. The total caffeoylquinic acid contents of the extracts were correlated (r = 0.989) with the antioxidant activities. The correlation coefficient of total phenolic compounds with the antioxidant activity was 0.913 which supports a previous hypothesis (Silva et al., 2004) dealing with the more responsibilities of caffeic acid derivatives for antioxidant activity of quince fruit (Magalhaes et al., 2009).

Antioxidant activity of quince leaf methanolic extract was evaluated using three different assays and the results were compared with those of green tea extract (Costa et al., 2009). The results of Folin-Ciocalteu test on the reducing capacity of methanolic extracts of 12 quince leaf samples collected from different places in northern

Table 2. Phytochemicals isolated from quince.

Compound	Preparation	Unit	Pulp	Peel	Seed	Leaf	Reference
3β-(18-Hydroxylinoleoyl)-28-hydroxyurs-12-ene	Petroleum ether extract			NM			Alesiani et al., 2010
3β-Linoleoylurs-12-en-28-oic acid	Petroleum ether extract			NM			Alesiani et al., 2010
3β-Oleoyl-24-hydroxy-24-ethylcholesta-5,28(29)-diene	Petroleum ether extract			NM			Alesiani et al., 2010
3,5-O-Dicaffeoylquinic acid	Methanolic extract	g/kg	-	-	-	2.22	Carvalho et al., 2010
3,5-O-Dicaffeoylquinic acid	Methanolic extract	g/kg	0.07	0.13	-		Magalhaes et al., 2009
3,5-O-Dicaffeoylquinic acid	Methanolic extract	g/kg				1.38	Costa et al.,. 2009
3-O-Caffeoylquinic acid	Methanolic extract	g/kg	0.50	1.14	0.01	5.54	Carvalho et al., 2010
3-O-Caffeoylquinic acid	Methanolic extract	g/kg	1.00	1.28	0.01		Magalhaes et al., 2009
3-O-Caffeoylquinic acid	Methanolic extract	g/kg				7.85	Costa et al.,. 2009
4-O-Caffeoylquinic acid	Methanolic extract	g/kg	-	0.18	-	0.64	Carvalho et al., 2010
5-O-Caffeoylquinic acid	Methanolic extract	g/kg	0.67	1.65	0.06	10.67	Carvalho et al., 2010
5-O-Caffeoylquinic acid	Methanolic extract	g/kg	1.42	1.84	0.05		Magalhaes et al., 2009
5-O-Caffeoylquinic acid	Methanolic extract	g/kg				15.71	Costa et al.,. 2009
6,9-Dihydroxymegastigmasta-5,7-dien-3-one 9-O-β-D-gentiobioside	Ethanolic extract			NM			Alesiani et al., 2010
6-C-Glucosyl-8-C-pentosyl chrysoeriol	Methanolic extract	g/kg	-	-	0.05	-	Carvalho et al., 2010
6-C-Glucosyl-8-C-pentosyl chrysoeriol	Methanolic extract	g/kg	-	-	0.06		Magalhaes et al., 2009
6-C-Pentosyl-8-C-glucosyl chrysoeriol	Methanolic extract	g/kg	-	-	0.10	-	Carvalho et al., 2010
6-C-Pentosyl-8-C-glucosyl chrysoeriol	Methanolic extract	g/kg	-	-	0.03		Magalhaes et al., 2009
Isoschaftoside	Methanolic extract	g/kg		-	0.02		Magalhaes et al., 2009
Kaempferol glycosides acylated with p-coumaric acid	Methanolic extract	g/kg	-	0.24	-	-	Carvalho et al., 2010
Kaempferol glycosides acylated with p-coumaric acid	Methanolic extract	g/kg		0.05	-		Magalhaes et al., 2009
Kaempferol-3-O-glucoside	Methanolic extract	g/kg	-	0.34	-		Magalhaes et al., 2009
Kaempferol-3-O-glycoside	Methanolic extract	g/kg	-	0.25	-		Magalhaes et al., 2009
Kaempferol-3-O-glycoside	Methanolic extract	g/kg				3.13	Costa et al.,. 2009
Kaempferol-3-O-rutinoside	Methanolic extract	g/kg	-		-	2.47	Carvalho et al., 2010
Kaempferol-3-O-rutinoside	Methanolic extract	g/kg	-	0.21	-		Magalhaes et al., 2009
Kaempferol-3-O-rutinoside	Methanolic extract	g/kg				4.66	Costa et al.,. 2009
Kempferol-3-O-glucoside	Methanolic extract	g/kg	-	0.55	-	-	Carvalho et al., 2010
Kempferol-3-O-glycoside	Methanolic extract	g/kg	-	0.14	-	1.52	Carvalho et al., 2010
Lucenin-2	Methanolic extract	g/kg	-	-	0.03	-	Carvalho et al., 2010
Lucenin-2	Methanolic extract	g/kg	-	-	0.03		Magalhaes et al., 2009
Qercetin-3-O-rutinoside (rutin)	Methanolic extract	g/kg	-	3.29	-	4.90	Carvalho et al., 2010
Quercetin glycoside acylated with p-coumaric acid	Methanolic extract	g/kg	-	0.11	-		Magalhaes et al., 2009
Quercetin glycosides acylated with p-coumaric acid	Methanolic extract	g/kg	-	0.22	-	-	Carvalho et al., 2010
Quercetin glycosides acylated with p-coumaric acid	Methanolic extract	g/kg	-	0.04	-		Magalhaes et al., 2009

Table 2. Contd.

Quercetin-3-O-galactoside	Methanolic extract	g/kg	-	0.55	-		Magalhaes et al., 2009
Quercetin-3-O-rutinoside (rutin)	Methanolic extract	g/kg	0.02	1.50	-		Magalhaes et al., 2009
Quercetin-3-O-rutinoside (rutin)	Methanolic extract	g/kg				2.21	Costa et al., 2009
Schaftoside	Methanolic extract	g/kg	-	-	0.05	-	Carvalho et al., 2010
Schaftoside	Methanolic extract	g/kg	-	-	0.06		Magalhaes et al., 2009
Stellarin-2	Methanolic extract	g/kg	-	-	0.15	-	Carvalho et al., 2010
Stellarin-2	Methanolic extract	g/kg	-	-	0.08		Magalhaes et al., 2009
Tiglic acid 1-O-β-D-glucopyranoside	Ethanolic extract			NM			Alesiani et al., 2010
Vicenin-2	Methanolic extract	g/kg	-	-	0.07	-	Carvalho et al., 2010
Vicenin-2	Methanolic extract	g/kg	-	-	0.06		Magalhaes et al., 2009

NM: Not mentioned. The work was characterized the presence of this compound.

Table 3. Volatile compounds from quince.

Compound	Part	Unit	Amount*	Reference
α-Bergamotene**	Whole fruit	Relative %	1.31–2.18 (0.88–1.12)	Tateo and Bononi, 2010
(E) or (Z)-Theaspirane	Peel (SDE)	Peak area %	<0.01	Umano et al., 1986
(E) or (Z)-Theaspirane	Peel (SDE)	Peak area %	0.40	Umano et al., 1986
(E)-β-Ocimene	Whole fruit	Relative %	0.05–0.08 (Trace)	Tateo and Bononi, 2010
(E)-2-Hexenal	Peel (heaspace)	Peak area %	0.58	Umano et al., 1986
(E)-2-Hexenal	Peel (SDE)	Peak area %	0.20	Umano et al., 1986
(E)-2-Hexenol	Peel (heaspace)	Peak area %	0.19	Umano et al., 1986
(E)-2-Hexenol	Peel (SDE)	Peak area %	1.93	Umano et al., 1986
(E)-2-Hexeny acetate+ethyl heptanoate	Peel (SDE)	Peak area %	0.81	Umano et al., 1986
(E)-2-Hexenyl acetate	Peel (heaspace)	Peak area %	0.08	Umano et al., 1986
(E)-2-Octenal	Peel (SDE)	Peak area %	<0.01	Umano et al., 1986
α-Farnesene**	Whole fruit	Relative %	82.26–87.34 (70.33–74.48)	Tateo and Bononi, 2010
γ-Terpinene	Whole fruit	Relative %	Trace (0.01–0.03)	Tateo and Bononi, 2010
(Z)-3-Hexen-1-ol	Whole fruit	Relative %	0.03–0.06 (0.01–0.03)	Tateo and Bononi, 2010
(Z)-3-Hexenol	Peel (heaspace)	Peak area %	0.47	Umano et al., 1986
(Z)-3-Hexenol	Peel (SDE)	Peak area %	2.95	Umano et al., 1986
(Z)-3-Hexenyl acetate	Peel (heaspace)	Peak area %	0.58	Umano et al., 1986
(Z)-3-Hexenyl acetate	Peel (SDE)	Peak area %	0.28	Umano et al., 1986
(Z)-3-Hexenyl acetate	Whole fruit	Relative %	1.65–1.84 (0.31–0.41)	Tateo and Bononi, 2010

Table 3. Contd.

(Z)-3-Hexenyl butyrate	Peel (SDE)	Peak area %	<0.01	Umano et al., 1986
1,2,3-Trimethyl-5-(2-propenyl)benzene	Peel (SDE)	Peak area %	<0.01	Umano et al., 1986
1-Butanol	Whole fruit	Qualitative (headspace)	-	Schreyen et al., 1979
1-Butanol	Whole fruit	Relative concentration	0.28	Schreyen et al., 1979
1-Hexanol	Whole fruit	Qualitative (headspace)	-	Schreyen et al., 1979
1-Hexanol	Whole fruit	Relative concentration	0.77	Schreyen et al., 1979
1-Octanol	Whole fruit	Relative concentration	0.32	Schreyen et al., 1979
1-Pentanol	Whole fruit	Relative concentration	0.06	Schreyen et al., 1979
1-Propanol	Whole fruit	Qualitative (headspace)	-	Schreyen et al., 1979
1-Propanol	Whole fruit	Relative concentration	0.49	Schreyen et al., 1979
2,6-Dimethyl-2-heptenal	Whole fruit	Relative concentration	0.1	Schreyen et al., 1979
2,7-Dimethyl-4-hydroxy-5(E),7-octadienoic acid lactone (stereoisomers)	Peel (SDE)	Peak area %	1.82	Umano et al., 1986
2,7-Dimethyl-4-hydroxy-5(E),7-octadienoic cid lactone (stereoisomers)	Peel (SDE)	Peak area %	1.95	Umano et al., 1986
2-Acetylfuran	Whole fruit	Relative concentration	0.12	Schreyen et al., 1979
2-Butanol	Peel (heaspace)	Peak area %	0.31	Umano et al., 1986
2-Butanone	Whole fruit	Qualitative (headspace)	-	Schreyen et al., 1979
2-Butanone	Whole fruit	Relative concentration	0.06	Schreyen et al., 1979
2-Decanone	Whole fruit	Qualitative (headspace)	-	Schreyen et al., 1979
2-Heptanone	Whole fruit	Relative concentration	0.02	Schreyen et al., 1979
2-Heptanone	Whole fruit	Relative %	Trace (0.02–0.04)	Tateo and Bononi, 2010
2-Mehyl propanol	Whole fruit	Qualitative (headspace)	-	Schreyen et al., 1979
2-Methyl 2-buten-1-ol	Whole fruit	Qualitative (headspace)	-	Schreyen et al., 1979
2-Methyl-1-propanol	Peel (heaspace)	Peak area %	8.43	Umano et al., 1986
2-Methyl-1-propanol	Peel (SDE)	Peak area %	1.73	Umano et al., 1986
2-Methyl-2-buten-1-ol	Whole fruit	Relative concentration	7.96	Schreyen et al., 1979
2-Methyl-2-butenal	Whole fruit	Relative concentration	0.2	Schreyen et al., 1979
2-Methyl-2-butenel	Whole fruit	Qualitative (headspace)	-	Schreyen et al., 1979
2-Methyl-2-hepten-6-one	Whole fruit	Qualitative (headspace)	-	Schreyen et al., 1979
2-Methyl-2-hepten-6-one	Whole fruit	Relative concentration	0.95	Schreyen et al., 1979
2-Methylbutanal	Whole fruit	Relative concentration	0.16	Schreyen et al., 1979
2-Methylbutanol	Whole fruit	Qualitative (headspace)	-	Schreyen et al., 1979

Table 3. Contd.

2-Methylbutanol	Whole fruit	Relative %	0.03–0.1 (0.14–0.23)	Tateo and Bononi, 2010
2-Methylbutanol+3-methylbutanol	Whole fruit	Qualitative (headspace)	-	Schreyen et al., 1979
2-Methylbutyl 3-methylbutyrate	Whole fruit	Qualitative (headspace)	-	Schreyen et al., 1979
2-Methylbutyl acetate	Whole fruit	Relative %	0.57–0.64 (0.97–1.20)	Tateo and Bononi, 2010
2-Methylpropanol	Whole fruit	Relative concentration	7.78	Schreyen et al., 1979
2-Methylpropyl hexanoate	Whole fruit	Relative concentration	Trace	Schreyen et al., 1979
2-Nonanoene	Whole fruit	Relative concentration	0.16	Schreyen et al., 1979
2-Octanone	Whole fruit	Relative concentration	Trace	Schreyen et al., 1979
2-Pentadecanone	Whole fruit	Qualitative (headspace)	-	Schreyen et al., 1979
2-Phenylethanol	Whole fruit	Qualitative (headspace)	-	Schreyen et al., 1979
3-Hydoxy-7,8-dihydro-β-ionol	Fruit	Qualitative	-	Winterhalter and Schreier, 1988
3-Hydroxy-β-ionol	Fruit	Qualitative	-	Winterhalter and Schreier, 1988
3-Hydroxy-β-ionone	Fruit	Qualitative	-	Winterhalter and Schreier, 1988
3-Methtlbutyl 3-methylbutyrate	Whole fruit	Qualitative (headspace)	-	Schreyen et al., 1979
3-Methylbutanal	Whole fruit	Relative concentration	0.02	Schreyen et al., 1979
3-Methylbutanol	Whole fruit	Relative concentration	27.8	Schreyen et al., 1979
3-Methylbutyl acetate	Whole fruit	Qualitative (headspace)	-	Schreyen et al., 1979
3-Methylbutyl acetate	Whole fruit	Relative concentration	0.05	Schreyen et al., 1979
3-Methylbutyl benzoate	Whole fruit	Relative concentration	0.25	Schreyen et al., 1979
3-Methylbutyl formiate	Whole fruit	Relative concentration	0.51	Schreyen et al., 1979
3-Oxo-α-ionol	Fruit	Qualitative	-	Winterhalter and Schreier, 1988
4-Hydroxy-β-ionol	Fruit	Qualitative	-	Winterhalter and Schreier, 1988
4-Hydroxy-β-ionone	Fruit	Qualitative	-	Winterhalter and Schreier, 1988
4-Oxo-β-ionol	Fruit	Qualitative	-	Winterhalter and Schreier, 1988
5,6-Dihydroxy-β-ionone	Fruit	Qualitative	-	Winterhalter and Schreier, 1988
5-Hexenyl acetate	Whole fruit	Relative %	Trace (0.23–0.34)	Tateo and Bononi, 2010
5-Methylfurfural	Whole fruit	Relative concentration	Trace	Schreyen et al., 1979
5-Nonanone	Whole fruit	Relative concentration	0.16	Schreyen et al., 1979
7,8-Dihydrovomifoliol	Fruit	Qualitative	-	Winterhalter and Schreier, 1988
Acetaldehyde	Peel (heaspace)	Peak area %	<0.01	Umano et al., 1986
Acetic acid	Peel (heaspace)	Peak area %	<0.01	Umano et al., 1986
Aceton	Peel (SDE)	Peak area %	0.84	Umano et al., 1986
Acetone	Peel (SDE)	Peak area %	<0.01	Umano et al., 1986
Acetone	Whole fruit	Qualitative (headspace)	-	Schreyen et al., 1979
Acetone	Whole fruit	Relative concentration	0.08	Schreyen et al., 1979

Table 3. Contd.

Amyl acetate	Whole fruit	Relative %	Trace (0.07-0.12)	Tateo and Bononi, 2010
Amyl alcohol	Peel (heaspace)	Peak area %	<0.01	Umano et al., 1986
Amyl alcohol	Peel (SDE)	Peak area %	<0.01	Umano et al., 1986
Anisyl propionate	Peel (SDE)	Peak area %	0.28	Umano et al., 1986
Benzaldehyde	Peel (SDE)	Peak area %	0.65	Umano et al., 1986
Benzaldehyde	Whole fruit	Qualitative (headspace)	-	Schreyen et al., 1979
Benzaldehyde	Whole fruit	Relative concentration	3.28	Schreyen et al., 1979
Benzene	Whole fruit	Relative concentration	0.05	Schreyen et al., 1979
Benzothiazole	Whole fruit	Relative concentration	Trace	Schreyen et al., 1979
Benzyl acetate	Whole fruit	Qualitative (headspace)	-	Schreyen et al., 1979
Benzyl acetate	Whole fruit	Relative %	0.06-0.08 (0.02-0.04)	Tateo and Bononi, 2010
Benzyl alcohol	Whole fruit	Qualitative (headspace)	-	Schreyen et al., 1979
Benzyl alcohole	Whole fruit	Relative concentration	0.4	Schreyen et al., 1979
Butanol	Peel (heaspace)	Peak area %	0.21	Umano et al., 1986
Butanol	Peel (SDE)	Peak area %	0.39	Umano et al., 1986
Butyl acetate	Peel (heaspace)	Peak area %	0.40	Umano et al., 1986
Butyl acetate	Whole fruit	Relative concentration	Trace	Schreyen et al., 1979
Butyl acetate	Whole fruit	Relative %	0.32-0.48 (0.54-0.65)	Tateo and Bononi, 2010
Butyl butyrate	Peel (heaspace)	Peak area %	<0.01	Umano et al., 1986
Butyl isobutyrate	Peel (heaspace)	Peak area %	0.06	Umano et al., 1986
Butyl octanoate	Peel (SDE)	Peak area %	<0.01	Umano et al., 1986
Capric acid	Peel (SDE)	Peak area %	<0.01	Umano et al., 1986
cis-3-Hexen-1-ol	Whole fruit	Qualitative (headspace)	-	Schreyen et al., 1979
cis-3-Hexen-1-ol	Whole fruit	Relative concentration	0.68	Schreyen et al., 1979
cis-3-Hexenyl acetate	Whole fruit	Qualitative (headspace)	-	Schreyen et al., 1979
cis-3-Hexenyl acetate	Whole fruit	Relative concentration	0.180	Schreyen et al., 1979
Citral	Whole fruit	Relative concentration	0.22	Schreyen et al., 1979
Dehydrovomifoliol	Fruit	Qualitative	-	Winterhalter and Schreier, 1988
Diacetyl	Peel (SDE)	Peak area %	<0.01	Umano et al., 1986
Dichoromethane(solvent)	Whole fruit	Qualitative (headspace)	-	Schreyen et al., 1979
Dodecane	Whole fruit	Qualitative (headspace)	-	Schreyen et al., 1979
Ethanal	Whole fruit	Relative concentration	0.17	Schreyen et al., 1979
Ethanol	Peel (heaspace)	Peak area %	12.02	Umano et al., 1986
Ethanol	Whole fruit	Relative concentration	1.23	Schreyen et al., 1979
Ethyl (E)-4-decenoate	Peel (SDE)	Peak area %	5.62	Umano et al., 1986
Ethyl (E)-6-nonenoate	Peel (SDE)	Peak area %	<0.01	Umano et al., 1986

Table 3. Contd.

Ethyl (E)-6-octenoate	Peel (SDE)	Peak area %	0.65	Umano et al., 1986
Ethyl (E)-7-dodecenoate	Peel (SDE)	Peak area %	3.26	Umano et al., 1986
Ethyl (E)-9-tetradecenoate	Peel (SDE)	Peak area %	<0.01	Umano et al., 1986
Ethyl (Z)-4-decenoate	Peel (SDE)	Peak area %	4.96	Umano et al., 1986
Ethyl (Z)-6-nonenoate	Peel (SDE)	Peak area %	0.48	Umano et al., 1986
Ethyl (Z)-6-octenoate	Peel (SDE)	Peak area %	1.45	Umano et al., 1986
Ethyl (Z)-9-tetradecenoate	Peel (SDE)	Peak area %	1.79	Umano et al., 1986
Ethyl 2-butenoate	Peel (heaspace)	Peak area %	1.11	Umano et al., 1986
Ethyl 2-butenoate	Whole fruit	Qualitative (headspace)	-	Schreyen et al., 1979
Ethyl 2-hexenoate	Whole fruit	Qualitative (headspace)	-	Schreyen et al., 1979
Ethyl 2-methyl-2-butenoate	Whole fruit	Qualitative (headspace)	-	Schreyen et al., 1979
Ethyl 2-methyl-2-butenoate	Whole fruit	Relative concentration	10.17	Schreyen et al., 1979
Ethyl 2-methyl-2-propenoate	Peel (SDE)	Peak area %	0.33	Umano et al., 1986
Ethyl 2-methylbutyrate	Peel (heaspace)	Peak area %	1.71	Umano et al., 1986
Ethyl 2-methylbutyrate	Peel (SDE)	Peak area %	<0.01	Umano et al., 1986
Ethyl 2-methylbutyrate	Whole fruit	Qualitative (headspace)	-	Schreyen et al., 1979
Ethyl 2-methylbutyrate	Whole fruit	Relative concentration	1.09	Schreyen et al., 1979
Ethyl 2-methylbutyrate	Whole fruit	Relative %	0.01-0.04 (0.08-0.14)	Tateo and Bononi, 2010
Ethyl 2-methylpropionate	Whole fruit	Qualitative (headspace)	-	Schreyen et al., 1979
Ethyl 2-methylpropionate	Whole fruit	Relative concentration	0.025	Schreyen et al., 1979
Ethyl 2-octenoate	Whole fruit	Relative %	Trace (0.20-0.42)	Tateo and Bononi, 2010
Ethyl 3-butenoate	Peel (heaspace)	Peak area %	<0.01	Umano et al., 1986
Ethyl 3-hexenoate	Peel (heaspace)	Peak area %	<0.01	Umano et al., 1986
Ethyl 3-hexenoate	Whole fruit	Relative concentration	0.12	Schreyen et al., 1979
Ethyl 3-hydroxybutyrate	Peel (SDE)	Peak area %	1.19	Umano et al., 1986
Ethyl 3-methylbutyrate	Whole fruit	Qualitative (headspace)	-	Schreyen et al., 1979
Ethyl 3-methylbutyrate	Whole fruit	Relative concentration	1.13	Schreyen et al., 1979
Ethyl 4-octenoate**	Whole fruit	Relative %	0.38–0.46 (0.36–0.46)	Tateo and Bononi, 2010
Ethyl acetate	Peel (heaspace)	Peak area %	22.83	Umano et al., 1986
Ethyl acetate	Peel (SDE)	Peak area %	4.7	Umano et al., 1986
Ethyl acetate	Whole fruit	Qualitative (headspace)	-	Schreyen et al., 1979
Ethyl acetate	Whole fruit	Relative concentration	0.59	Schreyen et al., 1979
Ethyl acetate	Whole fruit	Relative %	Trace (0.60–0.80)	Tateo and Bononi, 2010
Ethyl bezoate	Whole fruit	Relative concentration	Trace	Schreyen et al., 1979
Ethyl butyrate	Peel (heaspace)	Peak area %	5.38	Umano et al., 1986
Ethyl butyrate	Peel (SDE)	Peak area %	0.22	Umano et al., 1986

Table 3. Contd.

Ethyl butyrate	Whole fruit	Qualitative (headspace)	-	Schreyen et al., 1979
Ethyl butyrate	Whole fruit	Relative concentration	0.24	Schreyen et al., 1979
Ethyl butyrate	Whole fruit	Relative %	0.05–0.07 (0.07–0.11)	Tateo and Bononi, 2010
Ethyl cinnamate	Whole fruit	Relative concentration	0.03	Schreyen et al., 1979
Ethyl crotonate	Whole fruit	Relative concentration	0.62	Schreyen et al., 1979
Ethyl crotonate	Whole fruit	Relative %	Trace (0.01–0.03)	Tateo and Bononi, 2010
Ethyl decanoate	Peel (SDE)	Peak area %	3.08	Umano et al., 1986
Ethyl decanoate	Whole fruit	Relative concentration	Trace	Schreyen et al., 1979
Ethyl decanoate	Whole fruit	Relative %	Trace (0.23–0.29)	Tateo and Bononi, 2010
Ethyl dodecanoate	Whole fruit	Qualitative (headspace)	-	Schreyen et al., 1979
Ethyl dodecanoate+unknown	Peel (SDE)	Peak area %	13.65	Umano et al., 1986
Ethyl heptanoate	Whole fruit	Qualitative (headspace)	-	Schreyen et al., 1979
Ethyl heptanoate	Whole fruit	Relative concentration	0.23	Schreyen et al., 1979
Ethyl heptanoate	Whole fruit	Relative %	0.40–0.54 (0.40-0.67)	Tateo and Bononi, 2010
Ethyl hexadecanoate	Peel (SDE)	Peak area %	<0.01	Umano et al., 1986
Ethyl hexanoate	Peel (heaspace)	Peak area %	1.91	Umano et al., 1986
Ethyl hexanoate	Peel (SDE)	Peak area %	1.43	Umano et al., 1986
Ethyl hexanoate	Whole fruit	Qualitative (headspace)	-	Schreyen et al., 1979
Ethyl hexanoate	Whole fruit	Relative concentration	1.70	Schreyen et al., 1979
Ethyl hexanoate	Whole fruit	Relative %	3.14–3.30 (4.11-4.64)	Tateo and Bononi, 2010
Ethyl isobutyrate	Peel (heaspace)	Peak area %	9.6	Umano et al., 1986
Ethyl nonanoate	Peel (SDE)	Peak area %	<0.01	Umano et al., 1986
Ethyl nonanoate	Whole fruit	Relative concentration	0.10	Schreyen et al., 1979
Ethyl octanoate	Peel (heaspace)	Peak area %	<0.01	Umano et al., 1986
Ethyl octanoate	Peel (SDE)	Peak area %	6.37	Umano et al., 1986
Ethyl octanoate	Whole fruit	Qualitative (headspace)	-	Schreyen et al., 1979
Ethyl octanoate	Whole fruit	Relative concentration	0.83	Schreyen et al., 1979
Ethyl octanoate	Whole fruit	Relative %	6.58–8.35 (15.32–18.62)	Tateo and Bononi, 2010
Ethyl pentanoate	Peel (heaspace)	Peak area %	0.15	Umano et al., 1986
Ethyl propionate	Peel (heaspace)	Peak area %	29.23	Umano et al., 1986
Ethyl propionate	Peel (SDE)	Peak area %	0.18	Umano et al., 1986
Ethyl propionate	Whole fruit	Qualitative (headspace)	-	Schreyen et al., 1979
Ethyl propionate	Whole fruit	Relative concentration	0.16	Schreyen et al., 1979
Ethyl tetradecanoate	Peel (SDE)	Peak area %	<0.01	Umano et al., 1986
Ethyl tiglate	Whole fruit	Relative %	0.11–0.18 (0.25–0.36)	Tateo and Bononi, 2010
Eugenol	Peel (SDE)	Peak area %	0.79	Umano et al., 1986

Table 3. Contd.

Eugenyl methyl ether	Peel (SDE)	Peak area %	1.65	Umano et al., 1986
Furfural	Peel (SDE)	Peak area %	1.22	Umano et al., 1986
Furfural	Whole fruit	Relative concentration	10.14	Schreyen et al., 1979
Heptanal	Peel (SDE)	Peak area %	<0.01	Umano et al., 1986
Heptyl acetate	Whole fruit	Relative concentration	0.1	Schreyen et al., 1979
Heptyl acetate	Whole fruit	Relative %	Trace (0.03–0.07)	Tateo and Bononi, 2010
Hexanal	Peel (SDE)	Peak area %	0.44	Umano et al., 1986
Hexanal	Whole fruit	Relative concentration	0.30	Schreyen et al., 1979
Hexanol	Peel (heaspace)	Peak area %	0.80	Umano et al., 1986
Hexanol	Peel (SDE)	Peak area %	5.58	Umano et al., 1986
Hexanol	Whole fruit	Relative %	0.22–0.28 (0.19–0.22)	Tateo and Bononi, 2010
Hexyl 2-methylbutyrate	Peel (SDE)	Peak area %	<0.01	Umano et al., 1986
Hexyl 2-methylbutyrate	Whole fruit	Relative %	0.01–0.03 (0.06–0.10)	Tateo and Bononi, 2010
Hexyl acatate	Whole fruit	Relative concentration	0.13	Schreyen et al., 1979
Hexyl acetate	Peel (heaspace)	Peak area %	0.68	Umano et al., 1986
Hexyl acetate	Peel (SDE)	Peak area %	1.01	Umano et al., 1986
Hexyl acetate	Whole fruit	Qualitative (headspace)	-	Schreyen et al., 1979
Hexyl acetate	Whole fruit	Relative %	1.97–2.14 (2.53–3.14)	Tateo and Bononi, 2010
Hexyl butyrate	Peel (SDE)	Peak area %	0.69	Umano et al., 1986
Hexyl isobutyrate	Peel (SDE)	Peak area %	0.79	Umano et al., 1986
Hydroquinone monoacetate	Whole fruit	Relative concentration	Trace	Schreyen et al., 1979
Isoamyl acetate	Peel (heaspace)	Peak area %	0.38	Umano et al., 1986
Isoamyl acetate	Whole fruit	Relative %	0.14–0.20 (0.48–0.63)	Tateo and Bononi, 2010
Isobutyl acetate	Peel (heaspace)	Peak area %	0.95	Umano et al., 1986
Isobutyl acetate	Whole fruit	Relative %	0.09–0.13 (0.14–0.18)	Tateo and Bononi, 2010
Isobutyl butyrate	Peel (heaspace)	Peak area %	<0.01	Umano et al., 1986
Isobutyl hexanoate	Peel (SDE)	Peak area %	<0.01	Umano et al., 1986
Isobutyl hexanoate	Whole fruit	Relative %	0.01–0.03 (0.06–0.12)	Tateo and Bononi, 2010
Isobutyl isobutyrate	Peel (heaspace)	Peak area %	0.76	Umano et al., 1986
Isobutyl octanoate	Peel (SDE)	Peak area %	3.02	Umano et al., 1986
Isobutyl octanoate	Whole fruit	Relative %	Trace (0.03–0.05)	Tateo and Bononi, 2010
Isobutyl propionate	Peel (heaspace)	Peak area %	0.50	Umano et al., 1986
Isobutyl tiglate	Whole fruit	Relative %	Trace (0.03–0.06)	Tateo and Bononi, 2010
Isobutyric acid	Peel (SDE)	Peak area %	<0.01	Umano et al., 1986
Isomyl alcohol	Peel (SDE)	Peak area %	0.78	Umano et al., 1986
Limonene	Peel (heaspace)	Peak area %	0.23	Umano et al., 1986

Table 3. Contd.

Limonene	Whole fruit	Relative concentration	0.02	Schreyen et al., 1979
Limonene	Whole fruit	Relative %	0.04–0.07 (0.35–0.64)	Tateo and Bononi, 2010
Linalol	Whole fruit	Relative concentration	0.2	Schreyen et al., 1979
Methanol	Whole fruit	Relative concentration	<0.01	Schreyen et al., 1979
Methyl hexanoate	Whole fruit	Relative concentration	0.02	Schreyen et al., 1979
Methyl hexanoate	Whole fruit	Relative %	0.18–0.24 (0.11–0.16)	Tateo and Bononi, 2010
Methyl octanoate	Whole fruit	Relative concentration	Trace	Schreyen et al., 1979
Methyl octanoate	Whole fruit	Relative %	0.09–0.14 (0.28–0.34)	Tateo and Bononi, 2010
Nonanal	Whole fruit	Relative %	0.03–0.05 (0.02–0.04)	Tateo and Bononi, 2010
Octanol	Whole fruit	Relative %	0.05–0.07 (0.04–0.06)	Tateo and Bononi, 2010
Oxygenated monoterpene	Whole fruit	Relative concentration	1.52	Schreyen et al., 1979
Oxygenated monoterpene	Whole fruit	Relative concentration	1.58	Schreyen et al., 1979
Prenyl acetate	Whole fruit	Relative %	0.06–0.09 (0.22–0.30)	Tateo and Bononi, 2010
Propyl 2-methyl-2-butenoate	Whole fruit	Relative concentration	0.26	Schreyen et al., 1979
Propyl acetate	Whole fruit	Qualitative (headspace)	-	Schreyen et al., 1979
Propyl hexanoate	Whole fruit	Relative %	Trace (0.04–0.07)	Tateo and Bononi, 2010
Propyl octanoate	Peel (SDE)	Peak area %	<0.01	Umano et al., 1986
Propyl octanoate	Whole fruit	Relative %	Trace (0.03–0.06)	Tateo and Bononi, 2010
tarns-β-Farnesene	Whole fruit	Relative concentration	0.04	Schreyen et al., 1979
Theaspirane (isomer)**	Whole fruit	Relative %	0.10–0.21 (0.05–0.07)	Tateo and Bononi, 2010
Theaspirane (isomer)**	Whole fruit	Relative %	0.06–0.08 (0.02–0.04)	Tateo and Bononi, 2010
Toluene	Whole fruit	Relative concentration	0.05	Schreyen et al., 1979
trans-α-Farnesene	Peel (SDE)	Peak area %	5.92	Umano et al., 1986
Unknown	Peel (heaspace)	Peak area %	0.48	Umano et al., 1986
Unknown	Peel (SDE)	Peak area %	13.81	Umano et al., 1986
Unknown	Whole fruit	Qualitative (headspace)	-	Schreyen et al., 1979
Unknown	Whole fruit	Relative concentration	19.75	Schreyen et al., 1979
Vomifoliol	Fruit	Qualitative	-	Winterhalter and Schreier, 1988
α-Terpineol	Whole fruit	Relative concentration	0.04	Schreyen et al., 1979
β-Decalone	Whole fruit	Relative concentration	Trace	Schreyen et al., 1979
β-Ionone	Peel (SDE)	Peak area %	0.73	Umano et al., 1986
γ-Caprolactone	Whole fruit	Qualitative (headspace)	-	Schreyen et al., 1979
γ-Caprolactone	Whole fruit	Relative concentration	Trace	Schreyen et al., 1979
γ-Decalactone	Peel (SDE)	Peak area %	<0.01	Umano et al., 1986
γ-Dodecalactone	Peel (SDE)	Peak area %	<0.01	Umano et al., 1986
Δ^3-Carene	Whole fruit	Relative concentration	0.05	Schreyen et al., 1979

* Values of Tateo and Bononi (2010) were collected in October 2007 and the in the paranthese were collected in November 2007. ** The correct isomer was not characterized. SDE: steam disstilation extraction.

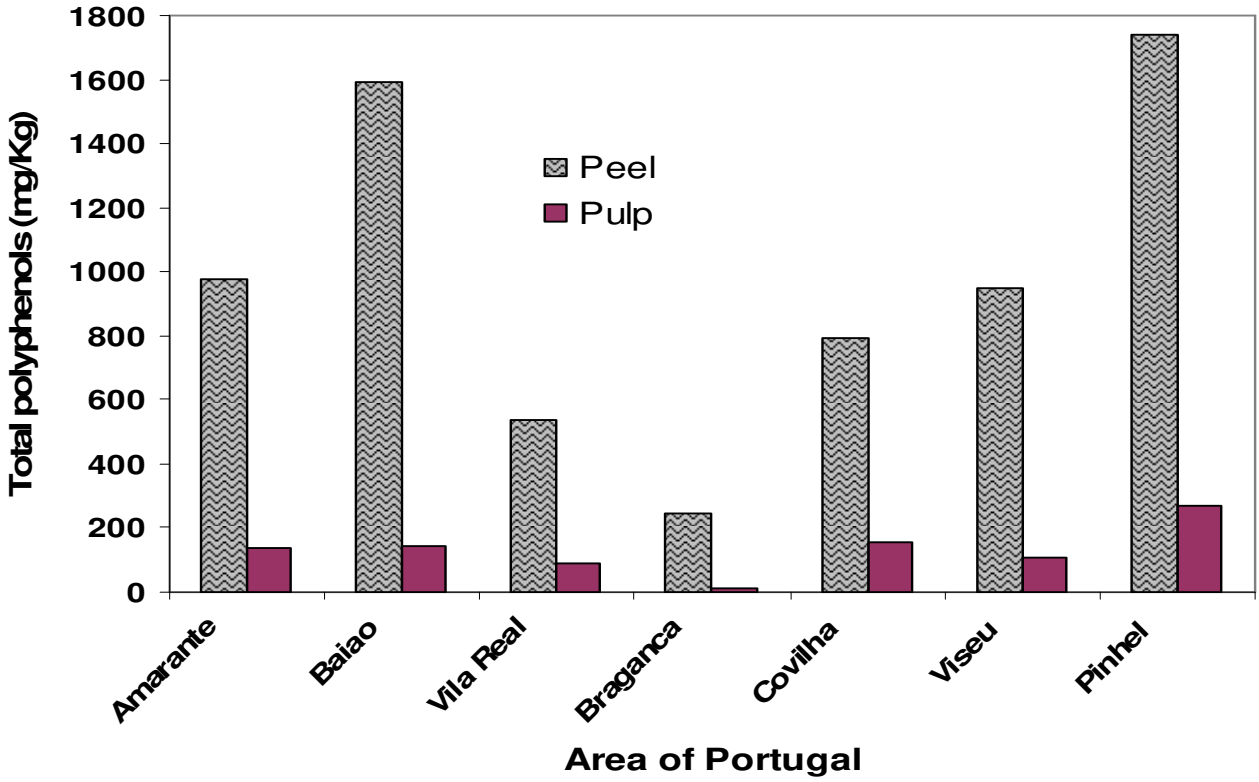

Figure 1. Total phenloic compounds of quince fruits collected from different areas of Portugal (Silva et al., 2002).

and central parts of Portugal in June and October of 2008 varied between 164.5 and 294.5 g of 5-O-caffeoylquinic acid/kg dry leaf with the mean value of 227 g of 5-O-caffeoylquinic acid/kg dry leaf which was more than that of green tea (112.5 g of 5-O-caffeoylquince acid/kg dry leaf) (Costa et al., 2009). In the second set of experiments, DPPH free radical scavenging activity of quince leaf and green tea methanolic extracts were investigated and the EC_{50} of 21.6 µg/ml and 12.7 µg/ml were found. The difference was statistically significant ($p<0.005$) revealing that green tea possesses more capacity. Considering high phenolic content of quince leaf in comparison with peel, pulp and seed, more antioxidant activity of leaf (EC_{50} of 21.6 µg/ml) is expected in which the EC_{50} values were 600, 1700 and 2000 µg/ml, respectively for peel, pulp and seed (Costa et al., 2009).

Alesiani et al. (2010) tested the DPPH radical-scavenging capacity, superoxide radical-scavenging activity, total antioxidant capacity of 59 isolated phytochemicals from quince peels. The most active antioxidants were quercetin and quercetin 3-O-rutinoside (Alesiani et al., 2010). Total phenolic compounds of quince seed was reported as 104.35 mg/g dry seed and the antioxidant activity of 64.25% for scavenging of DPPH free radicals (Nogala-Kalucka et al., 2010). Total phenolic content of quince fruit was measured by Folin-Ciocalteu method and was 302 mg/100 g which was five times more than that of apple fruit (61 mg/100 g) (Hamauzu et al., 2005). The reported total phenolic content was higher than a previous report (Silva et al., 2002) in which the mean value of 26.8 mg/100 g was reported, probably because of different extraction procedures employed in these works. Figure 2 illustrates the hydroxycinnamic acid derivatives and flavan-3-ol contents of quince fruit. Hamauzu et al. (2005) reported the IC_{50} of 12.1 for the antioxidant activity for SDS/LH-AAPH system and EC_{50} of 7.5 for DPPH radical scavenging activity of quince fruit. Quince fruit extract at the concentration of 0.5 mg/ml inactivates the influenza viruses, most probably because of the existance of procyanidins (Hamauzu et al., 2005).

Antiproliferative activity

Carvalho et al. (2010) investigated the bioactivity of the methalonic extracts of leaf, pulp, peel and seed of quince by determining phenolic profiles and suppresion effects of the extracts on the prolifration of selected human cancer cells using 3-(4,5 dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide (MTT) bioassay. The antiproliferative activities of the extracts were tested on human renal (A-498 and 796-P) and colon (Caco-2) cancer cell lines. Quince leaf extract possesses

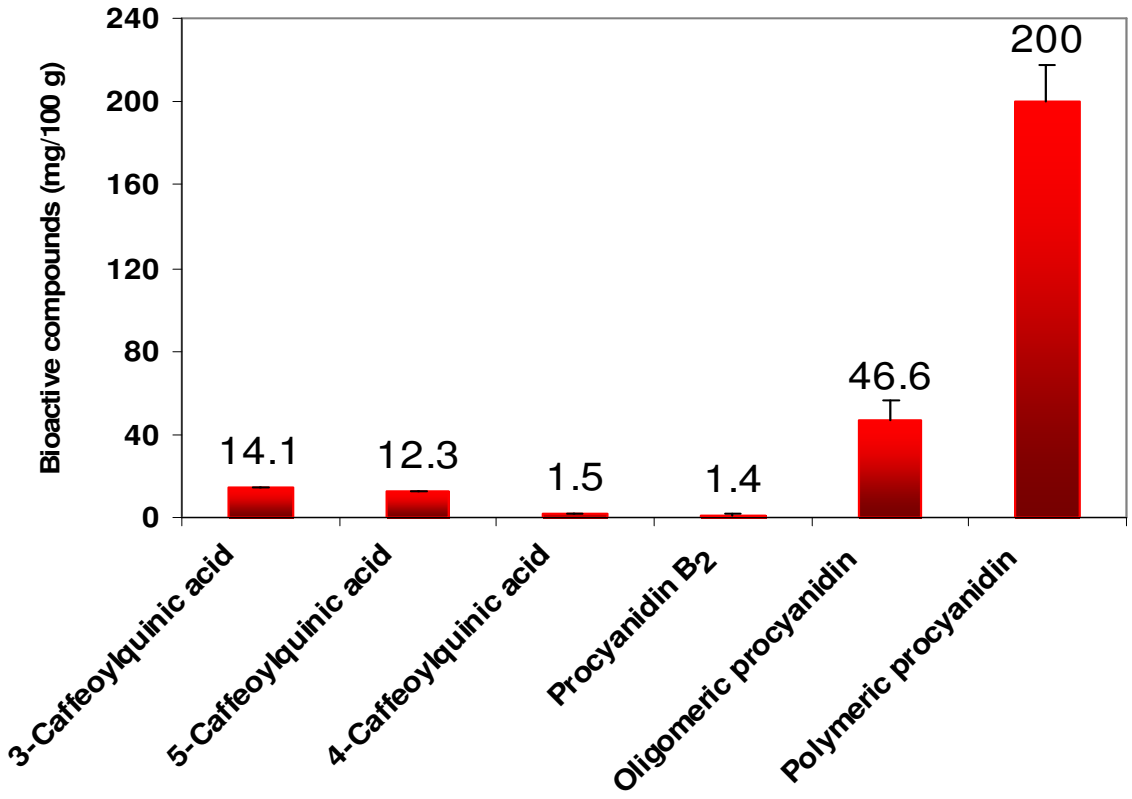

Figure 2. Hydroxycinnamic acid derivatives and flavan-3-ol contents of quince fruit (Hamauzu et al., 2005).

concentration dependent growth inhibitory effect on Caco-2 cells and no effect was observed on renal cancer cell lines. Seed extract inhibits the proliferation of renal cancer cell lines at the highest tested dose (500 mg/kg), whereas no significant inhibition is observed at lower concentrations. This is a valuable finding since renal cell carcinoma is highly resistant against current chemotherapeutic agents (Boivin et al., 2009).

Alesiani et al. (2010) investigated the antiproliferative activities of the isolated phytochemicals from quince peels against murine melanoma B16-F1 cells in which the most active phytochemical to inhibit the growth of melanoma cells was ursolic acid with the IC_{50} of 10.2 µM.

Antihemolytic activity

The activity of the methanolic extract of seed, peel and pulp was investigated on the 2,2'-azobis(2-aminopropane) dihydrochlorid (AAPH) induced hemolysis. The hemolysis of human erythrocytes was induced by thermal decomposition of AAPH producing free peroxyl radicals and was used as an *in vitro* model of free radical-induced damage on biological membranous. There is a lag time of 2 h, due to endogenous antioxidants of erythrocytes. The IC_{50} values of pulp and peel extracts were 652 and 695 mg/ml, respectively, which were observed after 3 h of incubation. There was no protective effect of seed extracts. These findings are in agreement with the antioxidant activities of the extracts (Magalhaes et al., 2009). Antihemolytic activity of quince leaf was compared with that of green tea. Both methanolic extracts significantly protected the erythrocytes from hemolysis induced by AAPH as dose dependant manner after a lag time of 2 h. The IC_{50} values were 30.7 and 24.3 µg/ml, respectively for quince leaf and green tea extracts in which no statistically significant difference was observed ($p>0.25$) (Costa et al., 2009).

Antiallergic activity

Shinomiya et al. (2009) investigated the antiallergic effects of hot-water extract of quince fruit using *in vivo* and *in vitro* tests. The release of β–hexosaminidase was reduced significantly after addition of 50, 100 and 200 µg/ml of hot-water extract to cell culture without any changes in the proliferation and viability of the cells suggesting the inhibited degranulation process (Shinomiya et al., 2009).

In another work by Kawahara and Iizuka (2011), hot water extract of quince fruit was concentrated and freeze

Table 4. Summary of biochemical parameters of Khademi (2009).

Group	Cholestrol (mg/dl)	Triglyceride (mg/dl)	LDL (mg/dl)	HDL (mg/dl)	AST (mg/dl)	ALT (mg/dl)	Cr (mg/dl)	ALP (mg/dl)
Control (N = 6)	76.66±23.20	179.33±8.14	22.80±6.41	68.67±8.50	50.33±11.01	68.00±17.52	1.46±0.20	56.33±3.20
Case (N = 18)	2468±1002.09	1925.71±208.19	2232.85±914.62	50.57±2.70	86.33±18.82	104.57±19.70	2.02±0.31	230.00±63.73
NT (N = 5)	1406.00±343.40	1037.33±328.92	1073.33±56.80	40.00±3.50	83.00±0.19	87.00±2.84	2.03±0.20	145.66±45.01
AT (N = 5)	813.66±437.61	386.67±185.14	682.33±368.20	54.00±8.08	45.00±8.54	57.66±15.65	1.44±0.43	134.00±26.21
QE (N = 5)	511.66±174.41	138.33±68.30	534.00±52.32	60.00±6.11	45.00±12.10	68.66±4.72	1.54±0.22	121.05±39.50

dried. The effect of the extract was investigated on IGE-dependent late phase immune reactions of mast cells on a well extablished mast cell like model, that is, basophilic leukemia cell line (RBL-2H3). This group showed the effects of the extract on the expression of interleukin-13 and tumor necrosis factor α on RBL-2H3 cells in which the expressions were reduced in a dose-dependent manner. Concerning the recent findings of Passante et al. (2009), stating that the RBL-2H3 cells are not fully representatives of the mast cells and basophils, Kawahara and Iizuka (2011) also reported the following results of the effects of quince extract treatment:

(1) Suppression of histamine release from mouse bone marrow-derived mast cells (BMMCs) without any change in their proliferation and viability,
(2) Significant inhibition of IGE and antigen induced interleukin-13 and tumor necrosis factor α in BMMCs
(3) Alleviating leukoterine C_4 release,
(4) Lowering porstaglandin D_2 levels,
(5) Suppression of the expression of cyclooxygenase 2 (COX-2) without any change in COX-1 expression (Kwahara and Iizuka, 2011).

In a separate investigation conducted in Germany (Grundemann et al., 2010), a commercial lemon-quince fruit preparation was evaluated for its antiallergic effects which were reported on the patients earlier by Baars and De Bruin (2005). Grundemann et al. (2010) reported that the preparation showed:

(1) Inhibition of degranulation and histamine release from basophils and mast cells. This effect was comparable with azelastine.
(2) Inhibition of the production of interleukin 8, tumor necrosis factor α and GM-CSF by mast cells. These are essential for the orchestration of the early and late-phase allergic reactions and the observed effects using 0.8 mg/ml were comparable with dexamehasone.
(3) Potential inhibition of eotoxin from human lung epithelial cells without any effect on RANTES release in
comparison to dexamethasone.
(4) No effect on the expression of eotoxin receptor CRR3 on human eosinophils (Grundemann et al., 2010).

ANIMAL STUDIES

Lipid lowering effects

Khademi (2009) investigated the effects of hydro-methanolic extract of quince leaf on the lipid profile of rabbits fed with cholestrol enriched diet (2% w/w). The animals of case group (N = 18) were fed for two months with cholestrol enriched diet, then blood samples were collected. Six rabbits of control group were fed with normal diet for two months and their blood samples were taken. Fifteen rabbits of case group were divided in three groups; no treatment (NT), atrovastatin (AT) and quince extract (QE) groups, and then fed with normal diet for three months. The animals of AT and QE groups were received atrovastatin (0.5 mg/kg/day) and quince leaf extract (dried extract, 50 mg/kg/day), respectively. The blood samples of NT, AT, and QE groups were collected at the end of the third month, and the biochemical parameters were determined using routin methods. Table 4 lists a summary of Khademi's findings in her MSc project supervised by Prof. Soleymani Rad and Dr. Ghanbari. Significant increases ($P<0.05$) in the mean values of cholestrol I(C), triglyceride (TG), low denisty lipoprotein (LDL), aspartate aminotransferase (AST), alanine transaminase (ALT), creatinine (Cr), and alkaline phosphatase (ALP) in the case group after receiving cholestrol enriched diet in comparison with the control group which received normal diet, whereas significant decrease ($P<0.05$) in high density lipoprotein (HDL) level

Table 5. Summary of TBARS and GSH percentage decreases in rats receiving quince extract in comparison with control group.

Diabetic contents	Dose (mg/Kg)	Kidney	Liver	Heart
TBARS	250	-[a]	-[a]	45.7
TBARS	500	12.7	-[a]	37.9
GSH	250	19.8	-[a]	-[a]
GSH	500	-[a]	-[a]	-[a]

[a]No significant effect.

was observed in case group. Khademi (2009) has used atrovastatin as a golden standard antihyperlipidemic drug and comparison of her findings in QE and NT groups revealed that quince leaf extract decreases C, TG, LDL, AST, ALT, Cr, and ALP plasma levels and increases HDL level. Her observation showed that there is no significant difference between QE and AT groups revealing that the lipid lowering activity of quince extract is the same as that of atrovastatin.

Kidney protecting effects

Histological comparison of kidney tissues of rabbits fed with cholesterol enriched diet, with and without quince leaf decoction, mild glomerular injury and moderate tubular damage were
apparent in all rabbits in the disease group. Meanwhile, milder tubular injury was detected in all animals receiving quince leaf decoction. It is concluded that the probable protective effects of quince leaf decoction on the hypercholesterolemia-induced renal injury might be attributed to both its antioxidants and lipid-lowering characteristics (Jouyban et al., 2010).

Antidiabetic effects

Aslan et al. (2010) investigated the antidiabetic and antioxidant activities of three herbal remedies used in Trukish traditional medicine including the effects of quince leaves hydro-ethanolic extract on normal and streptozocin-induced diabetic rats. There was no significant effect on normal rats after intake of 2 g/kg glucose. However significant reduction in the blood glucose levels of diabetic rats was reported at a time period of 0 to 3 h. The beneficial effect of the extract (250 or 500 mg/kg dried extract) was the same as a standard antidiabetic drug (tolbutamide, 100 mg/kg) and there was no significant difference between glucose levels of the extract and tolbutamide treated rats. The antioxidant activity of the quince extract was evaluated by glotathione (GSH) and thiobarbituric acid reactive substance (TBARS) contents of kidney, liver and heart of diabetic rats. Table 5 summerized the percentage of decreased TBARS and GSH contents of the diabetic rats receiving quince extract in comparison with diabetic control group. Based on Aslan et al. (2010) findings, there was no significant decrease in GSH contents of diabetic and non-diabetic rats and significant decreases were observed in TBARS of heart tissue of diabetic rats when compared with diabetic control group.

It should be noted that there was no significant difference between mean values of TBARS of heart tissue in diabetic rats receiving quince extract and that of non-diabetic control group. Streptozocin induced diabetus did not increase TBARS content of liver tissue, therefore quince extract did not show any beneficial effect on TBARS of liver tissue. The low dose of quince extract (250 mg/kg) exhibited slight and non-significant decrease on kidney TBARS, whereas the higher dose (500 mg/kg) showed significant ($p<0.01$) decrease in TBARS content of kidney. Based on these findings, Aslan et al. (2010) recommended long term use of quince in type II diabetic patients to protect against the complications of diabetus mellitus.

Healing effects

Hemmati et al. (2010) investigated the healing effect of quince seed mucilage on the skin lesions induced by T-2 toxin. The rabbits were divided into five groups; group 1: receiving the poison as positive control, group 2: receiving eucerin as negative control, groups 3 to 5: receiving 5, 10, and 15% mucilage treatment. A soluion of T-2 toxin (83 mg/ml) in methanol was prepared and 12 µl were applied on skin twice with 24 h interval. On the day eight, erythema and inflammation were observed in groups 1, 2 and 3, but the complete healing of the skin damage by 10 and 15% guince seed (groups 4 and 5) was observed and normal skin with grown hairs was the outcome of treatment with quince seed mucilage. Hemmati et al. (2010) proposed the following possible mechanisms of healing effects of quince seed mucilage:

(1) Preventing impaired protein synthesis by T-2 toxin.
(2) Acting as an obstacle between T-2 toxin and skin along with reducing water evaporation.
(3) Acting as antioxidant.

(4) Acting as the growth factor.
(5) Affecting fibroblast activities and increaising collagen production.
(5) Facilitation the formation of granulation tissue and increasing blood circulation
(6) Neutralizing dermal toxicity of the toxin.

Antiallergic effects

Shinomiya et al. (2009) studied the development of atopic dermatitis-like skin lesions in mice, serum levels of IgE and the release of β–hexosaminidase from rat basophilic leukemia cell line. The results showed that atopic dermatitis like signs appeared on the face, ear, nose, neck and dorsal skin of mice in control group after three weeks, whereas the severity scores of the signs in quince treated mice were significantly low. The IgE levels of control and quince treated animals with 5% hot-water quince extract orally were 1635±289 and 994±205 ng/ml in which the difference was statistically significant ($P<0.01$).

CONCLUSION

Detailed phytochemical investigations could result in new lead compounds to be used in development of more active medicinal agents. In addition, the information gathered from phytochemical studies could be used to detect adulteration of quince products. As examples, in some cases, apple and pear have been added to the quince jam, because of their low cost and texture similarities. These adulterations could be monitored by two dihydrochalcons, that is, phloretin 2'-xylosylosylglucoside and phloretin 2'-glucoside, found in apple and arbutin found in pear, another fruit from Rosaceae family (Andrade et al., 1998). A number of compounds could be considered as chemical markers of different parts of quince (Table 2). In this work, recent findings on quince were reviewed and the available information from traditional medicines of different nations were gathered.

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