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Review Article

Nutritional Composition, Phytochemistry and Medicinal Use of Quince (*Cydonia oblonga* Miller) with Emphasis on its Processed and Fortified Food Products

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ABSTRACT

Quince (*Cydonia oblonga* Miller) is a health promoting simple pome fruit which belongs to family *Rosaceae*. It's a native of Iran and Turkey. In India its production is limited to Jammu and Kashmir and Himachal Pradesh. Quince is a low fat fruit and is considered to be a rich source of bioactive compounds, especially antioxidants and nutritional compounds. Several studies have revealed that quince fruit is a good and low-cost natural source of phenolic acids and flavonoids, and it contains high amount of cell wall polysaccharide which makes it a potential source of dietary fibres and pectin. Besides it is an abundant source of minerals such as potassium, phosphorus and calcium. The phytochemical composition of quince has also been extensively investigated. It contains a considerable amount of caffeoylquinic acids, several kaempferol and quercetin glycosides. Quince has conventionally been used as medicinal fruit. The ethno-botanical study exposed that quince has been used to treat sore throat, cough, pneumonia, intestinal discomfort and lung diseases. Some other effects such as antiseptic, hepatoprotective and anti-inflammatory have also been reported. Quince is an astringent and a tough fruit which makes it inedible when unprocessed. As a result, quince is ameliorated by processing it into a variety of products such as candy, jam, jelly, marmalade etc. Quince has also been fortified into many products such as beers and yogurts due to its aromatic and functional properties. Besides this quince seed mucilage, a hydrocolloid can also be used as a bulking agent and a thickener in food products. Thus it can be said that the multifarious effects of quince fruit in terms of nutrients, phytochemicals and anti-oxidants make it possible choice both in the pharmaceutical and food industries.

Keywords: Anti-oxidant; Fortification; Health benefits; Nutrient composition; Quince; Phytochemicals; Value addition

INTRODUCTION

It's a well ascertained fact that health could be improved by increased consumption rates of fruits and vegetables (F and V) [1]. F and V's are the important sources of nutrients including minerals and vitamins. Besides they are also rich source of antioxidants, polyphenols etc. Furthermore, they are generally relatively low in calories, high in dietary fibre, and are beneficial to satiety [2]. Apart from the nutritional aspect fruits and vegetables are also associated with a reduced risk of multiple chronic diseases [1], such as cardiovascular disease and certain types of cancers. The importance of fruits and vegetables in reducing risks of heart disease, aging, and cancer is well-known [3]. They have been known to produce biologically active substances, which are found to be useful as antioxidants [4]. Quince (*Cydonia oblonga* Miller) is a simple pome fruit which belongs to family *Rosaceae*. The quince fruit is considered to be the rich source of functional and nutritional compounds. Several studies have showed that quince fruit is a good and low-cost natural source of phenolic acids and flavonoids, and it contains high amount of cell-wall polysaccharide which makes it

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as a potential source of dietary fibres and pectin. Among dietary antioxidants, phenolic compounds, secondary metabolites from plants are rich with natural antioxidants [5]. The present communication highlights the nutritional composition and phytochemistry of quince (*Cydonia oblonga*) with focus on its medicinal potential. In addition, the review presents a detailed investigation of its processed and fortified products.

ORIGIN AND GEOGRAPHICAL DISTRIBUTION

Quince originates from Asia Minor. It is a native plant of western Asia, and its core of origin is considered to be the Trans-Caucasus region including Armenia, Azerbaijan, Iran, south-western Russia, and Turkmenistan. During ancient times, quince spread from its wild centre of origin to the countries bordering the Himalaya Mountains to the east, and throughout Europe to the west [6]. Now it is distributed worldwide, Turkey is the largest producer with about 25% of world production. China, Iran, Argentina, and Morocco, each produce less than 10%. The United States is a very minor producer of quince fruit, mainly in California's San Joaquin Valley [7]. In India it is produced in Himachal Pradesh, Punjab and Kashmir where it is known as bamchount [5]. Quince is known by diverse names in Hindi it is called as Bihi, in Urdu as Bahee dana, in Arabic as Safarjal and in English as Quince [8,9].

Quince is like a pear or apple shaped golden yellow fruit with leathery skin and is not consumed fresh because of its astringency, strong acidity and hard flesh (presence of stone cells). On ripening the hairs on the peel disappear and this stage is highly demanded for processing it into candy, jam, jelly, marmalade and cakes [10]. Quince is a low fat fruit and a major source of organic acid, sugar, fibres and minerals such as potassium, phosphorus and calcium [11]. *Cydonia oblonga* is grown and cultivated in grounds or gardens under warm temperature and grows up to 8 m in height and 4 m width. The young branches are covered with pale greyish wool, leaves are elliptical, flowers are pink or white, fruits are bright yellowish and usually pear shaped [9]. Fruits have characteristic odour, astringent flavour and plano-convex seeds which arranged in two vertical rows. Quince leaves are (6-11) cm long and elliptical in shape with white hairs on the exterior side [12].

QUINCE PROFILE

Quince is an underutilised fruit with significant nutritional qualities. It is a rich source of carbohydrates, fibre, proteins, vitamins, different organic acids and minerals [13]. Quince is a low fat fruit and is reported to be nutritionally superior to apples [14]. The vitamin C content of quinces (10 mg/100 g) was found to be twice as that of apples (5 mg/100 g) [15] however some authors reported the vitamin C content to be almost same for both quince (13 mg/100 g) and apple (12 mg/100 g) [16]. Quince is also found to be superior to apples in terms of mineral content. The mineral content of quince (Na 9.2 mg, K 189 mg, Ca 66 mg, Mg 10 mg, Fe 1.1 mg, P 25 mg) is reported to be twice as that of apples (Na 2 mg, K 112 mg, Ca 5.5 mg, Mg 6 mg, Fe 0.3 mg, P 8 mg) [14]. Thus this underutilised fruit has a potential of a super fruit (Tables 1-4).

Table 1: Nutritional profile of Quince (g/100 g).

	Biro and Lindner [14]	Sharma et al. [16]	Sood and Bhardwaj [17]	Gani et al. [18]	Rasheed et al. [13]
Moisture	86.9	84.6	82	80.36	84.27
Ash	0.6	-	2.5	1.29	0.62
Crude protein	0.6	-	0.45	1.58	0.49
Crude Fibre	1.9	1.6	5.7	5.44	1.65
Crude Fat	-	-	0.07	2.29	0.24

Table 2: Vitamin content in 100 g of Quince.

Vitamin	Biro and Lindner [14]	Souci et al. [15]	Sharma et al. [16]	Sood and Bhardwaj [17]	Rasheed et al. [13]
Retinol	0	5.5 μg	-	-	-
Thiamine	25 μg	30 μg	-	-	-
Carotene	-	0.03 mg	-	-	-
Riboflavin	25 μg	30 μg	-	-	-

Niacin	0.2 mg	0.2 mg	-	-	-
Ascorbic acid	10 mg	13 mg	16.8 mg	15.6 mg	15.46 mg

Table 3: Mineral profile of Quince (mg/100 g).

Minerals	Biro and Lindner [14]	Sharma et al. [16]	Sood and Bhardwaj [17]	Gani et al. [18]
Potassium	189	248	179	-
Phosphorous	25	26	12	525
Sodium	9.2	8	4	-
Calcium	66	18	7	248
Magnesium	10	-	7	-
Iron	1.1	-	1	29
Copper	0.006	-	0.13	-
Zinc	0.013	-	0.04	0.4
Manganese	0.002	-	-	-

Table 4: Nutritional constituents of different parts of Quince.

	Fruit (Pulp and Peel)
Amino Acids	Twenty-one free amino acids are found in several samples of quince fruit (pulp and peel) [19]. The three major free amino acids detected in pulps are aspartic acid, asparagine, and hydroxyproline. While, the three most abundant amino acids in quince peels are glycine, aspartic acid, and asparagine [20]. However, the hydroxyproline content is found to be significantly higher in pulp [10,21,22].
Fatty Acids	Fatty acids present in the fruit includes linoleic acid and oleic acid [23]
Sugars	The monosaccharides present in the fruit include rhamnose, mannose, D-glucose, L-arabinose, and galactose [24].
	Seeds
Amino Acids	The amino acids profile of seeds include L-glycine, L-valine, Lalanine, L- proline, L-leucine, L-isoleucine, L-glutamic acid, Lserine, L-threonine, L-methionine, L- cysteine, L-phenyl alanine, hydroxyproline, L-asparagine, L-aspartic acid, L-glutamine, ornithine, L-tyrosine, L-histidine, and L-tryptophan which constitute about 1.3-1.7 mg/kg of sample. Moreover, L-aspartic acid, L-glutamic acid, and L-asparagine contribute about (60-75)% of total amino acids. [25]
Fatty Acids	Seeds contain fatty acids like palmitic acid, linoleic acid, stearic acid, oleic acid, and eicosanoic acid [26]
Sugars	Sugars like L-arabinose, xylose, mannose, galactose, and D-glucose are found to present in quince seeds [27].

PHYTOCHEMISTRY OF DIFFERENT PARTS OF QUINCE

Fruit (Pulp and Peel)

Polyphenols: Quince fruits are reported to have thirty-four poly phenols which include caffeoylquinic acid derivatives and coumaroylquinic acid derivatives [28]. Quince fruits are characterized by the presence of mono and dicaffeoylquinic acids (3-O-caffeoylquinic, 4-O-caffeoylquinic, 5-Ocaffeoylquinic, and 3,5-O-dicaffeoylquinic acids), Quercetin-3-O-galactoside, quercetin-3-O-rutinoside, kampferol-3-O-glucoside and kampferol-3-O-rutinoside which have been found in pulp. Peels were characterized by the presence of several additional constituents like quercetin and kampferol derivatives acylated with p-coumaric acid. Chlorogenic acid (5-O-caffeoylquinic acid) was found to be the most abundant phenolic compound in the pulp (37%), whereas rutin (quercetin 3-O-rutinoside) is the main one in the peel (36%) [21]. The major phenolic acid 5-O-caffeoylquinic acid is reported to be 57% in peel and 29% pulp [29]. The Total Phenol Content (TPC) in peel and pulp is found to be 6.3 and 2.5 g/kg respectively and the ratio of TPC of Quince peel to pulp (TPC peel: TPC pulp) is reported to be about 4.7 [23]. The fruit also contains Poly Phenol Oxidase (PPO) enzyme and other phenolic components like flavan-3-ols, including procyanidin B2, procyanidin trimmers, and tetramers, epicatechin, kaempferol, quinic acid, and quercitin derivatives [30].

Organic acids: The organic acids in pulp and peel include oxalic, citric, ascorbic, malic, quinic, shikimic, and fumaric acids [21,31,32].

Volatile compounds: Volatile components in quince fruit include actetates, like (Z)-3-hexenyl acetate, ethyl acetate, 5-hexenyl acetate, Volatile esters (ethyl decanoate, ethyl-2-octenoate, sesquiterpenes (α-bergamotene, and α-farnesene), etc., cis and trans marmelo oxide [33-35]. C_{13} non-isoprenoids are also reported to be found in quince [36].

Seeds

Polyphenols: Quince seed has a distinct phenolic profile, composed by several C-glycosil flavones, lucenin-2, vicenin-2, stellarin-2, isoschaftoside, schaftoside, 6-C-pentosyl-8-C-glucosyl chrysoeriol and 6-C-glucosyl-8C-pentosyl chrysoeriol, kaempferol-3-Orutinoside [22]. Seeds are however reported to be rich in 6,8-di-C-glucosyl chrysoeriol (Stellarin-2) (18%). The seed extract was found to have lower phenolic content of 0.4 g/kg. [31]. The flavones are the major part of phytochemical constituents (63%-66%) the prominent flavones being isoschaftoside (18%), cafeoylquinic acids (35%-37%), and 5-O-caffeoylquinic acid (19%-24%).

The seeds of quince also contain some fat soluble bioactive compounds which include tocopherols, phytosterols and phenolic acids. Tocopherols consisted of α-tocopherol, β tocopherol, γ-tocopherol among which α-tocopherol possesses the highest vitamin E activity. The phytosterols present include campestrol, stigmasterol, sitosterol, avanasterol. Amongst which β-sitosterol is a specific phytosterol which reduces LDL cholestrol levels. [37]

Organic acids: Six identified organic acids that constitute the organic acid profile of quince seeds are: citric, ascorbic, malic, quinic, shikimic and fumaric acids [38]. The total organic acids are reported to be 0.8 g/kg of the sample. Ursolic acid, tormentic acid, and β-daucosterol and 34 carbon chromone are also found to be present in quince seeds [39].

Quince seed mucilage

Quince seed mucilage is reported to be a mixture of cellulose and water soluble polysaccharide. Acidic hydrolysis reveals the presence of L-arabinose, D-xylose, and aldobiouronic acids [40]. The water soluble portion of mucilage was found to be made of partially O-acetylated (4-O-methyl-D-glucurono) D-xylan with high proportion of glycuronic acid [27]. Upon hydrolysis, the mucilage produced arabinose, xylose, mannose, galactose, and glucose. Uronic acid (35%) was also confirmed to be present in seed mucilage.

The sugars found in the quince mucilage are D-xylose, 4-O-methyl glucose, and D-glucose. Other sugars present include 2,3,4-tri-O-methyl-D-xylose, 2,3-di-O-methyl-D-xylose, 3-O-methyl-D-xylose, and 2,3,4-triO-methyl-D-xylose whereas branching in (1→4)-β-D-xylan backbone at 2-position was observed with 4-O-methyl-α-Dglucopyranosyluronic acid and α-D-glucopyranosyluronic acid [27]. Quince seed mucilage has a wound healing activity too [41].

TRADITIONAL MEDICINAL USES OF QUINCE

Fruit

Quince fruit is said to be a cardiac, brain, liver and stomach tonic. In traditional medicine fruits are reported to have anti-inflammatory, antiemetic and ulcer healing effects. They are reported to be astringent, gastric tonic, and suitable to cure haemorrhoid bleeding [42]. Diseases of respiratory system, hypertension and metabolic diseases like hypercholesterolemia, hyperlipidaemia, diabetes mellitus, inflammation of the kidneys, urinary tract and bladder, constipation and bloating are other traditional reported effects [43]. The fruit is also reported to be effective against nervousness, insomnia, abdominal pain, diarrhoea, dysentery, leucorrhoea, haemoptysis, uterine haemorrhages, wounds and many skin diseases, it has been also used as a sedative, antipyretic, antiseptic, cicatrizing and hepatoprotective agent [44,45].

Seeds

Seeds have been found to be astringent, emollient. They have been reported to be used for the treatment of Gastro Intestinal (GI) disorders like diarrhoea, dysentery, intestinal colic and constipation. They are also found to be effective against respiratory tract disorders like cough, sore throat, bronchitis [46]. The mucilage of the seed has been found to be used for healing dermal wounds [47].

MODERN MEDICINAL USES/ PHARMACOLOGICAL USES OF QUINCE

Fruit

Anti-allergy and anti-inflammatory effects: In a research, it was observed that Gencydo® (combination of lemon (Citrus limon) juice and Quince fruit extract) caused reduction of histamine, IL-8, and TNF-α release from mast cells induced by Immunoglobulin-E (IgE) and phorbolmyristate acetate (PMA/A23187) in allergic disorders. Furthermore, Gencydo® is also reported to block eotaxin release from human bronchial epithelial cells [48].

Quince fruit hot water extract was evaluated for alleviation of type I allergy (atopic dermatitis) in NC/Nga mice, divided into control and treated groups. Control group was fed with AIN-93M diet and treated groups received (2.5 and 5)% hot water Quince fruit extract for 8 weeks. It was found that control group developed skin dermatitis. Moreover, treated group mice have low IgE level especially with 5% hot water Quince fruit extract (994 ± 205 ng/mL) as compared to control (1635 ± 289 ng/mL). The study revealed the anti-allergic potential of Quince fruit [49].

In another study, hot water extract of Quince fruit was found eective against IgE stimulated late phase allergic reactions of mast cells. The elevation of interleukin-13 and tumor necrosis factor-α expression level was found to reduce by Quince Hot water extract. Besides it was also found to supress Leukotriene C_4 and prostaglandin D_2 production in Bone Marrow-Derived Mast Cells (BMMCs) after 1 and 6 h of stimulation [50].

The anti-allergy effect of lemon (*Citrus medica* L.) and Quince fruit was investigated. The synergistic effect of both the extracts resulted in the significant degranulation of basophils, production of tumor necrosis factor (TNF-α) and interleukins IL-8 and from human mast cells. However no anti-allergic effect was observed individually by the extracts. The major phenolics in citrus and quince extracts as revealed by LC-MS analysis were eriocitrin and neochlorogenic acid respectively [51].

Quince fruit peel phenolics has been investigated for their anti-inflammatory and anti-allergic role after aggravating inflammationin human THP-1 cell line by Lipopolysaccharide (LPS). Quince fruit peel extract was found to significantly inhibit the release of inflammatory mediators such as cytokines (TNF-α) and interleukins (IL-8) by inducing release of Interleukin-10 and Interleukin-6 from mast cells. The study also revealed that poly-phenolic extract from Quince peel also inhibited the activation of pro-inflammatory eectors cells by LPS [52].

The *in vivo* and *in vitro* testing of hot-water extract of quince fruit was done for the anti-allergic properties. The cell culture studies stated a considerable decrease in the release of β-hexosaminidase on addition of (50, 100 and 200) μg/ mL of hot-water extract to cell culture. The control group showed atopic dermatitis i.e., marks appeared on the face, ear, nose, neck and dorsal skin of mice however the quince treated mice showed significantly lower severity [53].

Anti-diabetic activity: The aqueous fruit extract of *Cydonia oblong* Miller was found potential to overcome complications associated with diabetes. Oral Daily dose of extract for 28 days of (80, 160 and 240) mg/kg body weight was administered to male Sprague-Dawley rats in which diabetes was induced by streptozotocin (60 mg/kg). The anti-diabetic effect in the diabetic rats was evaluated by measuring their Fasting Blood Glucose (FBG). The results revealed that the FBG was significantly reduced in a dose dependent manner. Besides Gas Chromatography-Mass Spectrometry (GC-MS) assay was done for the identification of the active fraction for anti-hyperglycaemic effect. The results identified 5-hydroxymethylfurfural or 5-HMF (a well-known natural compound) as a component of active fraction (methanolic fraction) that may be partly responsible for the ant diabetic and anti-hyperglycemic effects of quince [54].

The aqueous fruit extract of *Cydonia oblong* Miller fruit was used to evaluate its effect in streptozotocin-induced diabetic rat's lipid profile as well as some biochemical parameters. The results depicted that Quince fruit extract successfully reduced total cholesterol level, serum triglycerides, ALT, AST ALP, LDL and increased the HDL and in the diabetic rat. The extract also resulted in the prevention of diabetes-induced increase in serum urea and creatinine levels as the markers of renal dysfunction. Thus it could be concluded that the aqueous fruit extract of Cydonia oblong Miller fruit is said to have hypolipidemic, hepatoprotective, and renoprotective effects in streptozotocin-induced diabetic rats [55].

Anti-oxidant activity: The extracts of quince were analysed for the radical scavenging potential which was compared with that of synthetic antioxidants. The strong properties reported correspond to those obtained from peel material with a (70-80)% inhibitory effect on DPPH radicals [21].

The antioxidant functions of quince phenolic extracts evaluated by linoleic acid peroxidation system and the DPPH radical scavenging system were found to be superior to that of chlorogenic acid and ascorbic acid [3].

Methanolic extracts of pulps, peels and seed parts were prepared and evaluated to quench the stable free radical 2,2'-diphenyl-1picrylhydrazyl (DPPH) and to inhibit the 2,2'-azobis (2-amidinopropane) dihydrochloride (AAPH)-induced oxidative hemolysis of human erythrocytes. The DPPH free radical scavenging activities of pulp and peel were reported to be similar (EC50 of 0.6 mg/ml and 0.8 mg/ml, respectively), while seed extract presented much lower antioxidant potential (EC50 of 12.2 mg/ml). Oxidative action of AAPH, revealed that pulp and peel extracts exhibited significant protection of the erythrocyte membrane from hemolysis, in a time- and concentration-dependent manner [56].

The phenolic fraction and organic acid fraction of methanolic extracts were analysed by HPLC/UV. The strong anti-oxidant activity was found to be in the phenolic fraction as compared to the whole methanolic extract and the weakest was found in the organic acid extract. The methanolic peel extract showed that highest antioxidant capacity and the phenolic seed extract exhibited the strongest antioxidant activity [29].

Seed

Anti-spasmodic activity: The anti-spasmodic activity of quince seed extract was investigated using rabbits and guinea-pigs. The results suggested that the crude extract of *Cydonia oblonga* seeds produced atropine sensitive spasmodic effects in isolated ileum and jejunum of guinea-pig and rabbit. The results were compared to a standard Ca^{++} antagonist Verapamil. The study suggested that the spasmodic property of seed extract is due to the presence of substance in it resulting in the activation of muscarinic receptors, while Ca^{++} antagonist mechanism probably resulted in antispasmodic actions seen in gut and tracheal tissues [57].

Anti-cancer activity: The seed extracts of quince is found to have no effect on colon cancer cell growth, whereas it is observed to have a strong anti-proliferative efficiency against renal cancer cells at higher concentrations of (500 μg/mL) [58].

Anti-diabetic activity: The anti-diabetic ability of Cydonia Seed Extract (CSE) was investigated in using a L6 skeletal muscle model of insulin resistance. The results depicted that CSE has a positive effect on insulin-stimulated glucose consumption, lactic acid production and glycogen synthesis in differentiated L6 myotubes. CSE at 12.5 μg/ml was found to increase the glucose consumption and glycogen synthesis in L6 myotubes. The *in vitro* results suggested that CSE promoted glucose metabolism and hypoglycemic effect thus making CSE potential for prevention and treatment of diabetes [59].

Wound healing activity: The effectiveness of wound healing by Quince seeds Mucilage Cream (QMC) on skin wounds of white Iranian rabbits by applying 5%, 10%, and 20% of QMC in eucerin base was studied. The results suggested that QMC (20%) applied for time period of 13 days resulted in complete wound healing [60].

Quince seed extract finds application in healing skin infections. The wound healing rate in mice infected with *Staphylococcus aureus* by application of quince seed extract and silver nano particles was compared and measured. The results depicted that the group treated with Quince seed extract (Ethanolic and acetonic) had a great impact on wound healing as compared to mupirocin and silver nano particles, thus suggesting quince seed extract as an effective candidate in healing skin infections caused by *S. aureus* [61].

The effect of quince seed extract for healing second degree burn wounds was studied. The results suggested that 1% ointment of Quince seed extract produced 99.5% of wound healing as compared to sulfadiazine standard (92.97%) [62].

The effect of quince seed mucilage on healing the skin lesions induced by T-2 toxin was studied. The rabbits were divided in 5 groups. Group 1 and group 2 received the positive control (poison) and negative control (eucerin). Group 3, 4 and 5 received the mucilage treatment of 5%, 10%, and 15% respectively. A toxin solution of T-2 toxin was applied twice on skin with 24 h interval. The results revealed that groups 1, 2, and 3 showed erythema and inflammation however in group 4 and 5 complete healing of the damaged skin was observed depicting a counter balance of the dermal toxicity of the toxin [53].

PROCESSED/ VALUE ADDED PRODUCTS FROM QUINCE *CYDONIA OBLONGA*

Quince due to its astringency cannot be consumed as such. It's a tough fruit which makes it inedible before processing. In order to negate its inedibility in raw form it has been reported to be processed into number of products such as jams, jellies, marmalades and candies.

The formation of dried fruit sheets of quince using quince pulp and cactus pear pulp has been reported. The formulation was dried using forced air tunnel dehydrator at a temp of 57°C-60°C for 6 h-8 h. The formulation developed with 50% quince and 50% cactus pulp showed higher pH value of 4.2, lower acidity (1.32%) and lower vitamin C content than the other formulations. However the sensory characteristics showed no significant differences during the storage [63].

The processing and processed products of Japanese quince (*Chaenomeles japonica*) have been studied. The products developed from the quince included fruit juice, purée and aroma extracts. The fruit juice with and without prior treatment with pectolytic enzymes was developed by crushing and centrifugation or by pressing. Some consumer products such as chaenomeles ice cream, lemonade, jam, curd and yoghurt were also developed from the quince fruit. The pectin extracted from the quince was used in improving bread quality. A min amount of 0.5% addition of pectin resulted in 7% increase in bread volume. The pectin was found to have a positive effect on crumb hardness and elasticity [64].

The study of the composition of peeled and unpeeled quince jams and the subsequent influence of the processing on the phenolics, amino acids and organic acid profile of the developed product has been reported. The thermal processing resulted in a change in the free amino acid profile due to hydrolysis. However, the phenolics and the organic acids did not show significant changes [65].

The principal compound analysis of fifty-one varieties of commercialised quince jam was done in order to study their phenolic, organic acid and free amino acid profile. The PCA (Principal Compound Analysis) of phenolic compounds revealed a strong difference between quinces jams prepared from peeled fruits and unpeeled fruits. The results suggested 37.4% difference between the contents of 3-O- and 5-O-caffeoylquinic acids and all flavonoids and 17.0% difference in the contents of 4-O- and 5-O-caffeoylquinic acids against 3-O-caffeoylquinic and 3,5-dicaffeoylquinic acids. The results conferred that most of the commercialised quince jams were prepared from unpeeled fruits [21].

The rheological properties of quince nectar by the application of ohmic heating were studied. Different holding times (0, 10, 15, 20, and 30) minutes and temperature ranges (65-75)°C were applied by use of the concentric viscometer. Different models including Newtonian, Bingham, Herschel Bulkley, Power law and Casson Models were fitted to the Shear stress-shear rate data. The results suggested that Herschel-Bulkley model was the best model to fit the experimental rheogram with regression coefficients (R^2) as high as 0.9997 and Standard Errors (SE) as low as 0.054. The nectar was found to be non-Newtonian and pseudoplastic in the heating range of (20-75)°C. The activation energy value for ohmic heating was found to be 9.88 ± 3.24 kJ/mol suggesting that ohmic heating had no electric effect and it could be used as an alternative heating method for fruit nectar [66].

The development of jams and jellies from underutilised quince fruit has been carried out and it has been reported that quince jelly contained more pectin and vitamin C as compared to the jam. Both developed products were found to be a rich source of phytochemicals such as malic acid and ascorbic acid [16].

The development of fibre products from quince pomace having useful functional and physiological properties has been reported. The obtained products showed comparable hydration properties to those reported for citrus and apple pulps. The isolated fractions obtained after applying drying conditions to the products with or without previously extracting it with ethanol or water were evaluated for chemical composition, physical and functional properties. The dried fractions showed high spontaneous water absorption rate in the kinetics assay. Oil absorption seemed to essentially depend on the microstructural characteristics of the fibre powders, whereas parameters involving water absorption were really determined by the material's hydrophilicity. Specific volume, which was also in part a direct function of structural differences, was associated to the ability for oil uptake [67].

The rheological behaviour of quince puree was studied using a viscometer. The results suggested quince puree as a non-Newtonian, pseudo plastic fluid. The puree was found to be thixotropic in nature with apparent viscosity changing slightly with time. The change in apparent viscosity over time depicted that the quince puree doesn't have gel properties [68].

The study of optimisation technique based on response surface methodology was done. The quince slices were subjected to osmotic dehydration using sucrose solutions at different concentration (40 and 60 °Brix), processing time (1, 1.5, and 2) h, and ultrasonication time (0, 15, and 30) min. Water loss, solid gain, and weight reduction factors were analysed. The results inferred that 27.25 min for ultrasound time, 120 min for osmosis time, and 50.52% for sucrose concentration resulted in water loss of 34.68 (g/100 g fresh sample), solid gain of 18.66 (g/100 g fresh sample), and weight reduction of 16.21 (g/100 g fresh sample). Also 297.86 min time, and 80°C for temperature were the optimal conditions to obtain shrinkage of 52.84%, moisture content of 0.1971, and rehydration ratio of 1.451 [69].

The development a quince snack enriched with prebiotic inulin and alternative sweetener stevia has been reported. The developed quince snack besides having functional properties also had an improved taste due to the addition of stevia. The results revealed that the quince had a porosity of 0.35 cm^3/cm^3 implying that the tissue was highly suitable for vacuum infusion. Also it was found that the Ultrasound (US) and Vacuum Infusion (VI) treatment gave the highest weight gain and maintained the higher springiness. The colour changes and browning index were lower as compared to the non-treated dried quince [70].

The effect of addition of some berries and fruits during quince jam processing on the composition and quantification of major polyphenolic compounds, antioxidant activity and colour properties of quince and mixed quince jams was studied. The results illustrated that the polyphenolic content in quince jam was found to be 484.5 mg/100 g. The phenolic compounds and antioxidant activity ($p<0.05$) of highest level were found in samples in order of addition of chokeberry>black currant>flowering quince. The overall results suggested that mixed jams can represent a good source of antioxidant compounds and can have an attractive and appealing colour for the consumer [71].

The quality evaluation of quince value added products like Ready-To-Serve beverage (RTS), jam and fruit bar during storage was conducted. The results revealed an increase in the TSS, acidity and reducing sugars and a decrease in the ascorbic acid and total sugars. The developed products were found to be acceptable up to storage interval of 9 months at ambient conditions except RTS beverage. The products were also found to be microbiologically safe during 9 months of storage except for RTS beverage [72].

Quince was reported to be freeze dried and investigation of the drying kinetics of quince in mashed form was done. The effect of various parameters like initial moisture content, heat load power and the initiation time of heat application were studied on the drying rate and performance of dryer. The experimental data was subjected to mathematical models. The drying kinetics revealed the primary and secondary drying stages with 7.47% and 5.94% of mean relative percent deviation for the kinetics models. The results suggested that the drying time is significantly reduced by applying a high heat load power at the beginning of the process [73].

The antioxidant property and storage stability of quince juice phenolic compounds was studied. The quince juices produced from different cultivars widely grown in Poland were compared on the basis of polyphenolic compounds and antioxidant activity. The results suggested that the quince juice produced from different quince cultivars showed a wide range of variations in the chemical parameters. The phenolic compounds in the analysed juices were found to be higher than in commonly consumed apple juices [31].

The evaluation of the biochemical and antioxidant activity of Japanese quince fruit and its products (syrup and candied fruit slices) was carried out. The results illustrated that a high amount of Vit C was found in the hybrid clone C.47 (55 mg 100 g^{-1}) and in 'Lichtar' (106 mg 100g^{-1}). The latter also showed higher phenolic compounds (422.6 mg 100 g^{-1}) and stronger antiradical activity (12.35 µmol TE/g). The vitamin C content in candied quince slices was (116-124) mg 100 g^{-1} of the product however the higher amount was retained in candied slices of 'Lichtar'. Sugar syrup produced from the hybrid clone C.47 had higher concentration of ascorbic acid (56.4 mg 100 g of syrup) and candied slices produced from the same had higher content of phenolic compounds (917 mg 100 g^{-1}) and stronger antiradical activity-30.89 µmol TE g^{-1} [74].

The development of quince tea and study of the effect of two drying methods on the antioxidant activity of the quince has been reported. The study suggested that Oven-dried quince contained higher amounts of phenolics than the sun-dried and quince peel contained more phenolics than quince flesh. In conclusion the Sun-dried and flesh samples showed lower radical scavenging effect and reducing antioxidant capacity than oven-dried and quince peel, respectively [75].

The study of quality and sensory attributes of quince and apple leather was done. The leather was enriched by maqui (*Aristotelia chilensis* Mol. Stuntz) extract in order to enhance its antioxidant capacity and was analysed for various parameters. The results suggested that leathers had an intermediate a_w (0.56-0.69), a moisture content of 17 kg water/100 kg, and a TSS of 70 °Brix. The addition of antioxidant rich extract changed the leather's color and browning index. The Total Phenols (TP) and Anti-Oxidant Activity (AOA) were found to be higher ($p \leq 0.05$) in quince formulations. An increase in almost 40% and 45% in total phenol and AOA was seen in apple puree. A decrease in the antioxidants up to 59% was found in leathers as compared to fruit puree. Also a slight decrease in the total phenol was reported however the AOA remained unchanged during storage [76].

The development of dried quince slices and the effect of osmotic pre-treatment on the physical properties of quince were studied. The results suggested that osmotic solution of saccharose at a temperature of 60°C showed a positive effect on quality of dried quince. The treatment also showed a positive effect on the physical properties of quince resulting in the prevention of fruit tissue darkening during convective drying [77].

The quince candies were developed and the influence of three different packaging materials *viz.* polyethylene pouch, laminate, and plastic jar on physicochemical and antioxidant properties of developed quince candies was studied. The results suggested that quince candies packed in laminate had a good consumer acceptance with a storage life of more than 4 months. Quince candies packed in laminate retained better physicochemical and antioxidant properties in comparison with polyethylene and plastic jar [78].

Quince liquor was obtained after macerating quinces from three varieties (*Vranja*, *ALM3* and *ZM2*). The quinces were macerated with or without skin and the two ratios of quince:ethanol used were 50:50 and 25:75, and two alcohol content used were 60% and 30%. The results suggested the highest contents of total polyphenols and antioxidant activity was found in the liquors prepared using fruits with skin and 50:50 quince:ethanol ratio with polyphenols being 1000 mg/100 mL and antioxidant activity being 37.1 mmol Trolox/100 mL. The quince peel was the main source of phenolic acids, especially flavonols [79].

The sensory attributes and physicochemical changes during the storage of smoothies prepared by mixing apple, pear, quince and flowering quince juices (AJ, PJ, QJ, FQJ) and with Sour Cherry Puree (SCP) was studied. A total of 17 different products (12 smoothies and 5 semi-products) pre and post storage were studied for phenolic compounds, antioxidant activity (ORAC, ABTS, FRAP) and physical parameters (viscosity and colour) for a period of 6 months at 4°C and 30°C respectively. The polyphenol content in mg of sour cherry/flowering quince smoothie was found to be 517.75 mg and sour cherry/pear smoothie was found to be 333.36 mg/100 g as determined by UPLC-PDA-FL. The smoothies added with FQJ and QJ were characterized by high content of polyphenolic compounds even after 6 months of storage. Apart from being high in the polyphenols content and antioxidant activity, the obtained smoothies were attractive to consumers, especially those with addition of apple and quince juices [80].

The development of a liqueur with addition of quince peel extract for improving its antioxidant activity and phenolic content was reported. The results suggested that quince peel extract could be used as a natural alternative for the natural colouring of the fruit liqueurs. The fruit liqueurs developed had improved levels of polyphenols that confer to their antioxidant activity. It was also found to be a cost-effective and an eco-friendly method which could help in plant pigments valorisation in beverage industry [81].

The processing of quince into candy, jam and dehydrated slices was reported with a comparative study of their proximate composition and antioxidant properties which showed a significant variation. The study suggested that processed products of quince showed higher total phenolic content and antioxidant properties as compared to fresh pulp. The total phenols were found in the range of (69.12-78.67) mg GAE/100g. The anti-oxidant parameters i.e. reducing power, Peroxide value (H_2O_2), Ferric Reducing Antioxidant Power (FRAP) and 2,2-diphenyl-1-picrylhydrazyl (DPPH) were found in the range of (70.9-89.5)%, (36.02-51.20)%, (1.40-1.68) µM and (79.91-82.61)% respectively [82].

Development of a low calorie quince jam using stevioside as an artificial sweetener and pectin as a stabilizer has been reported. The developed jam had 0.4% pectin, 0.27% stevioside and 50% sugar. The water activity and pH of the jam increased however, there was a significant decrease in the content of monomeric anthocyanin, total phenolic compounds, vitamin C, Brix, viscosity, acidity and a* value. The study inferred that the production of this low calorie jam can be recommended to people who look forward for low-calorie foods [83].

The quince slices were dried using electro hydrodynamic method and hot air dryer. The study investigated the effect of two different drying methods on the quince slices based on the drying kinetics, energy consumption, potent antioxidant activity and phenolic compounds. The results inferred that the phenolic compounds are 1.3 times more in the hot dried slices as compared to the slices dried via electro hydrodynamic process. Similarly, the antioxidant capacity of dried quince slices is 1.15 times as much in hot drying compared to electro hydrodynamic process. Thus suggesting that Electro Hydrodynamic (EHD) process has a negative effect on the total phenolic compounds and anti-oxidant activity of the dried quince [84].

The physical and powder properties of freeze dried quince powder on addition of maltodextrin in different amounts was studied. The results revealed an increase in the drying time with a decrease in the moisture content and water activity values. Furthermore, a change in the colour value was also recorded on addition of sugar and maltodextrin. The values of density, flow and reconstitution properties were also significantly affected by the amount of maltodextrin and powdered sugar added samples [85].

The effect of processing on quality attributes and phenolic profile of quince dried bar snack was studied. The TSS in puree was found to be 14.4°Brix which increased to 75°Brix in bars. An increase in the titratable acidity was also found with TA approaching 1.5 g malic acid kg^{-1} fresh weight. Fresh puree showed the presence of Quercetin, p-coumaric acid and trans-cinnamic acid which was found to increase after the thermal processing. However, the gallic acid concentration showed a decrease after the thermal processing. The results conferred that a minimum cooking time of 5 mins was found sufficient to obtain the highest concentration of most phenolic, however a cooking time of 20 min was found best for the concentration of p-coumaric acid [86].

The development of dried quince slices using four different drying methods (sun drying, microwave drying, solar drying and hot air oven drying) and four different pre-treatments (no blanching, blanching, no blanching+ascorbic acid and blanching +ascorbic acid) was done. All the dried quince slices were packed in Low Density Poly Ethylene (LDPE) pouches and stored for six months and observed for physico-chemical, microbiological and sensory characteristics. The results suggested that the hot air dried quince slices showed highest rehydration ratio, lowest shrinkage and maximum L* and b* values with a minimum a* value. The maximum amounts of reducing sugars, total sugars, protein, minerals, crude fibre, antioxidant activity and total phenol content was also retained in the hot air dried quince slices [87].

The development of a nutraceutical formulation, Chewing Candy (CC) based on sea buckthorn (*Hippophaerhamnoides* L.) and quince (*Cydonia oblonga* L.) juice and juice by-products (BuJ, QuJ, BuBP, and QuBP respectively) with use of two texture forming ingredients agar and gelatine was reported. The results depicted that the juice and juice by products BuJ, QuJ, BuBP, and QuBP respectively showed antimicrobial activity against all the pathogens tested however, the largest inhibition zones were observed for BuJ and QuJ, respectively against the pathogen *Bacillus* and *Proteus mirabilis*. The CC prepared with agar and BuBP (131.7) and with gelatin and QuJ (132.0) showed the best acceptability. Moreover, the antioxidant activity of CC was increased by five times on addition of juice and juice by-products [88].

The effect of thermal and High-Pressure Carbon Dioxide (HPCD) treatment of quince juice on the inactivation, aggregation and conformational changes of Poly Phenol Oxidase (PPO) were studied. The results suggested that High-Pressure Carbon Dioxide (HPCD) exhibited inactivation of PPO at (55-65)°C whereas at the same temperature thermal processing alone could not inhibit PPO activity. The browning rate was found to be higher in thermal treated juice as compared to HPCD treated juice. HPCD was found to induce decrease in intensities of fluorescence and circular dichroism spectra revealing destruction and rearrangement of configurational nature of PPO molecule. The Particle size also suggested that on HPCD treatment a structural change in PPO molecule was found which led to initial dissociation and subsequent aggregation of PPO molecule. Thus it could be concluded that HPCD method was found to be more effective thermal treatment for the in activation of PPO molecule. However HPCD treated juices showed a slight decrease in the pH as compared to the control which is due to the dissolution of CO_2 in the quince juice during the HPCD treatment. Moreover, the Total Soluble Solid (TSS) values didn't show a significant change but an increase in brightness (L* value) of quince juice was observed [89].

The study of the characterisation and marmalade processing potential of quince cultivars ('Fuller', 'Smyrna', 'Portugal', 'Provence', 'Mendonza Inta-37', 'Alaranjado', 'Lajeado', 'CTS 207', 'D'Angers' and 'Bereczy') cultivated in tropical Brazilian regions was carried out. The influence on the physical-chemical characteristics, rheological properties and the consumer acceptance of the developed marmalade was studied. The results suggested that different quince cultivars showed a great variability among themselves with respect to the physical and physicochemical characteristics. All the cultivars studied for marmalade production were similar to each other with high sensory acceptance. However, cultivar Mendonza Inta-37 resulted in less acceptable marmalade [90].

The optimisation of quince juice using thermosonication treatment was done. The thermosonication treatment was done at different temperatures (30, 35, 40, 45 and 50)°C, different amplitudes (40%, 45%, 50%, 55% and 60%) and at different times (2, 4, 6, 8 and 10) min in order to optimize the bioactive components (total phenolic content, ascorbic acid and total antioxidant capacity) and color values (L*, a* and b*). The results suggested that he optimization values for quince juice were 38.7°C, 5.6 minutes and 50.9 amplitude. Total phenolic (591.15 mg GAE/L), and total antioxidant levels (DPPH 0.214 mg TEAC/mL and CUPRAC 0.149 mg TEAC/mL) were higher in quince juice treated with thermosonication than in fresh quince juice. However, the thermosonication process resulted in the decrease in the amount of vitamin C (ascorbic acid 3.78 mg/100 mL). Overall thermosonication is considered as a promising technique to improve bioactive components compared to thermal pasteurization [91].

The inactivation and structural changes in Poly Phenol Oxidase (PPO) molecule through structural analysis in quince juice subjected to ultrasonic treatment was investigated. The results revealed that the PPO activity in the treated juice was decreased to 35% using a high ultrasonic intensity (400 W for 20 min) compared to the untreated juice. The ultrasonic treatment resulted in the inactivation of PPO molecule due to the protein aggregation, distortion of tertiary structure, and loss of α helix conformation of secondary Hence, it could be concluded that the ultrasound processing at high intensity and duration results in the inactivation of the PPO enzyme by means of aggregation induction and modifications in the structure. Also the physicochemical parameters (°Brix, color and pH) of the treated quince juice were retained without any significant effect on their quality [92].

FORTIFIED PRODUCTS OF QUINCE *CYDONIA OBLONGA*

Quince is a rich reservoir of anti-oxidants and nutrients which makes it a suitable candidate for fortification in foods.

The use of quince scalding water which is rich in antioxidants (phenolic acids and flavonoids) has been reported to be used to fortify yogurt. The developed yogurt had higher pH and lower lactic acid content as compared to the control yogurts owing to its high polyphenol content. The quince scalding water also showed a significant effect on the rheological and textural properties of the quince [93].

The effect of quince powder on rheological properties of batter and physico-chemical and sensory properties of sponge cake was studied. The quince slices were dried in an infrared-hot air dryer and the powdered quince was supplemented at five concentrations (control, 5, 10, 15 and 20)%. Due to the increasing level of substitution of quince powder the volume of the cake was found to decrease. On increasing the quince powder levels from 0% to 15%, the values of density, consistency and hardness showed an increase. However, the volume, cohesiveness, resilience, chewiness and crumb L values of the samples showed a decrease. The overall acceptability of the cake with 10% quince powder was found to be better [94].

The texture profile analysis and stress relaxation characteristics of sponge cake substituted with (0, 5, 10, 15 and 20)% dried quince powder was studied. The quince powder was dried in an infrared hot air dryer (375 W, 60°C and 1 m/s flow rate). The results suggested that Peleg-Normand and four-element Maxwell models both fitted to the mechanical stress relaxation data of quince sponge cakes. The values of hardness and consistency of sponge cakes were found to the increase on quince powder substitution. However, elasticity, cohesiveness, resilience and chewiness showed a decrease in the values [95].

The effect of the addition of quince pomace powder (0-15)% and water content (25-35)% on the rheological properties of the batter and the physicochemical characteristics and sensory properties of sponge cake was analysed. The results revealed an increase in the viscosity, batter consistency, dietary fibre, firmness and overall acceptability of cake on substitution with quince pomace. However, a decrease in the moisture content, and density of cake was reported. RSM results revealed that 12.56% of quince pomace powder and 29.62% of water content was found to have most and desired physicochemical quality. The optimised product had total phenol content 8.32 (mg/g), iron 0.361 (mg/Kg dry weight) and calcium 1160 (mg/Kg dry weight). The values were found higher than the control. Also the SEM results revealed uniformity in the cake number of cavities in the cake structure [96].

The analysis of the effect of incorporation of freeze dried Japanese quince fruit FJQF (0-9)% to the cookies in order to improve their antioxidant attributes, sensory and volatile characteristics during storage was done. The results revealed that the Cookies containing FJQF exhibited 2-3.5 fold higher radical scavenging activity and also higher contents of volatile hexanal, heptanal, octanal, 2-heptenal, (E) than control cookies. Moreover, less secondary lipid oxidation products were found in FJQF cookies when compared to control cookies. The volatile profile of the enriched cookies was dominated by Acetic acid ranging from 7.05%-23.37%. The overall results suggested that cookies containing 1.0% and 1.5% FJQF had better overall acceptance as compared to those containing 6.0% and 9.0% [97].

CONCLUSION

Quince (*Cydonia oblonga*) is a reservoir of nutrients and bioactive compounds that have therapeutic value. The fruit prevents various ailments such as diabetes, cancer, ulcers and respiratory disorders. The fruit is ascribed to have numerous pharmacological activities viz., antioxidant, hypoglycaemic, antibacterial etc. Due to its exceptional nutritional quality it is processed into number of value added products like jams, jellies, marmalades, juices etc. The extensive medicinal use, phytochemical composition and nutritional value of quince make it suitable to be called as a super fruit.

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