Original Research Article

Evaluation of Chemical Composition and Antioxidant Potential of Essential Oil from *Citrus reticulata* Fruit Peels

ABSTRACT

:

Aims: To determine the chemical composition and antioxidising potential of *Citrus reticulata* fruit peel essential oil.
Study design: Isolation of essential oil from *Citrus reticulata* fruit peel and determination of its chemical composition through GC MS studies. Nutrient and phytochemical composition of the essential oil was also determined. The essential oil was also analysed for its antioxidant potential.
Place and Duration of Study: Department of Chemistry, Punjab Agricultural University, Ludhiana (Punjab) India. Between October 2017 to March 2018.
Methodology: Isolation of essential oil from Citrus peels powder was carried out by hydrodistillation using a Clevenger-type apparatus. The chemical composition of essential oil was determined by Gas Chromatography-Mass Spectrometry (GC MS) studies. Proximate analysis of peel powder was carried out through methods of Association of Analytical Chemists (A.O.A.C). The essential oil was also analysed for its phytochemical composition. Antioxidant potential of citrus fruit peel oil was evaluated by a free radical scavenging effect on 1, 1 – diphenyl-2-picrylhydrazyl (DPPH).
Results: The yield of essential oil obtained from citrus fruit peels were found to be 0.3 ml/100 g peel powder. GC-MS studies revealed the presence of limonene (50.42%) as its major constituent. Phytochemical analysis revealed the presence of flavonoids, alkaloids, glycosides, terpenoids, saponins and steroids. Proximate nutritional analysis showed the presence of (%) ash (4.2), crude fat (3.4), crude protein (4.8), crude fibre (8.3) and sugar (7.2) content. The oil showed 15.79 and 69.87 % radical scavenging activity at 200 and 2000 ppm respectively which is less than the standard ascorbic acid used.
Conclusion: Citrus peel is a promising source of various bioactive compounds that play an important role in health promotion and disease prevention**.**

Keywords: Antioxidant potential, Citrus peel, Essential oil, Free radical, Phytochemicals

1. INTRODUCTION

Free radicals such as hydroxyl radical ($OH^{\cdot}$), superoxide anion ($O_2^{\cdot-}$), hydrogen peroxide (H_2O_2) and active oxygen species are constantly formed through normal cellular metabolism in the human body and are involved in the pathogenesis of various human ailments for instance cancer, ageing, atherosclerosis and diabetes [1]. Mammalian cells possess internal defence mechanism which consists of antioxidant compounds and various enzymes such as superoxide glutathione peroxidase, dismutase, and catalase which protect cells against higher levels of free radicals. Extra protection can be provided by the exogenous addition of certain compounds like proteins (albumin and transferin), minerals (zinc and selenium), vitamin A, E and β-carotene *etc.* [2]. Current research has confirmed

that food rich in antioxidants impart a major role in the prevention of cancer [3], neurodegenerative diseases [4] and cardiovascular diseases. So the search for new compounds which contains antioxidant properties is very active field of research. In human diet, most of the antioxidant compounds are obtained from different plant sources and belong to different classes of compounds such as coumarins, tannins, phenolics, flavonoids, procyanidins and xanthones which vary in chemical and physical properties [5]. So they can be viewed as promising antioxidising agents.

Citrus belongs to the family Rutaceae and they are well-known crops with potential socio-economic influence all over the world. Their medicinal features, flavour and nutritional value are well known. Citrus family contains a variety of phytochemicals in various plant parts like fruits, peels, leaves, bark *etc*. which exhibit different biological properties such as insecticidal, seed germination and seedling growth promoters [6], antimicrobial [7] and anti-tumour [8] agents. Intake of citrus fruits in the human diet provides different constituents which are important for human nutrition including dietary fibres, folic acid, flavonoids, coumarins, vitamin C, potassium and pectins [9]. Various flavonoids present in citrus fruits and seeds have strong antioxidative and free radical scavenging activities [10, 11]. Citrus essential oils have been used in many products such as beverages, foods, cosmetics, medical formulations and as flavouring agents. Their volatile components consist of various monoterpenes, sesquiterpene hydrocarbons and their derivatives such as acids, esters, aldehydes, ketones and alcohols [12]. The present work reports the proximate composition of *Citrus reticulata* fruit peel samples, phytochemical analysis and antioxidant potential of essential oil extracted by hydrodistillation from *Citrus reticulata* fruit peels. Antioxidant potential of essential oil was determined by using 1, 1-diphenyl-2-picrylhydrazyl radical (DPPH) scavenging method.

2. MATERIAL AND METHODS

2.1 Samples and Chemicals

Citrus fruits were purchased from local market of Ludhiana.Voucher specimen of fruit samples were deposited in the department of Fruit Science, PAU, Ludhiana. Different solvents and other chemicals used in the present study were of analytical grade and purchased from S.D. Fine Chem Pvt. Ltd, Mumbai. This study was conducted in department of Chemistry, PAU Ludhiana in October to March 2018. GC MS analysis was carried out from Advanced Instrumentation Research Facility, Jawarharlal Nehru University, New Delhi.

2.2 Isolation of Essential Oil

The fruit peels of *Citrus reticulata* were separated manually, dried under shade, powdered using a blender and the isolation of oil from the powdered material (100g) was carried out by hydrodistillation for 4 hours using a Clevenger-type apparatus. The essential oil obtained was dried over anhydrous sodium sulfate, filtered and stored in an air-tight container covered with aluminium foil at +4ºC for further use.

2.3 Gas Chromatography/Mass Spectrometry (GC/MS) Analysis of Essential Oil

GC-MS analysis of peel oil was carried out with the help of SHIMADZU GC MS QP 2010 using CARBOWAX capillary column using Helium as a carrier gas.The identification of compounds were based on a comparison of their mass spectra with those of Wiley, NBS libraries and FFNSC..

2.4 Quality Analysis of peel powder and Phytochemical Screening of Citrus peel essential oil

Proximate analysis (ash, moisture, crude protein, sugar, crude fibre and crude fat content) of peel powder was carried in accordance with AOAC (2005) method [13]. Total sugar content was determined as described by Dubois *et al.* [14]. Essential oil of Citrus fruit peels was subjected to preliminary phytochemical screening to check the presence of various phytochemicals [15]. Stock solution of the oil with a concentration of 1mg/ml was prepared and used for the screening.

2.5 Testing of Antioxidant Potential

Antioxidant potential of Citrus fruit peel oil was evaluated by free radical scavenging effect on 1, 1 – diphenyl-2-picrylhydrazyl (DPPH) [16]. A series of concentrations of essential oil ranging from 200µg/ml to 2000 µg/ml were prepared in methanol. A standard DPPH solution containing 400 µ mole was prepared in methanol. 1 ml of each concentration of essential oil was then mixed with 3ml of a standard solution of DPPH. Incubation of mixtures was carried out in the dark for 30 minute at room temperature. The absorbance (abs) of mixtures was measured by using Perkin-Elmer 45 UV-Visible spectrometer at 517 nm. DPPH mixture without methanol was used as blank and ascorbic acid was used as a standard. Triplicate of samples were assayed. Inhibition percentage (I %) of DPPH radical by oil was calculated by using the following formula:

$$I = \frac{\text{Absorbance of sample} - \text{Absorbance of blank}}{\text{Absorbance of blank}}$$

2.6 Statistical Analysis

The results of proximate analysis and antioxidant activity were expressed as means ± standard error. T test using SPSS version 20 was used to evaluate data of antioxidant potential of peel essential oil with P = 0.01 accepted as significant.

3. RESULTS AND DISCUSSION

3.1. Extraction Yield

The yield of essential oil obtained from Citrus fruit peels was found to be 0.3 ml/100 g peel powder. It has been reported that yield of Citrus peel essential oil varied with individual plant species ranging from 0.2-2.0% [17]. Essential oil content from fresh, ambient and oven-dried peels of *C. sinensis, C. reticulata and C. paradissi* ranged from 0.24-1.07, 0.30-0.50 and 0.20-0.40g/100g respectively [18].

3.2 Chemical Composition of Essential Oil

GC MS studies of essential oil revealed the presence of 80 compounds in essential oil extracted from peels of *Citrus reticulate* as shown in Figure 1. The various compounds detected along with their retention time and percentages are shown in Table 1. The various compounds detected were limonene (50.42%), n- hexadecanoic acid (5.65%), alpha sinensal (3.14%), carveol (3.09%), myrecene (3.03%), delta-cadinene (2.53%), alpha-farnesene (1.67%), beta-sinensal (1.65%), alpha-copaene (1.49%), beta-copaene (1.30%), alpha-humulene (1.23%) alpha-terpineol (1.19%), [1,1'-bicyclopentyl]-2-one (1.16%) and decanal (1.28%). Many reports on Citrus peel essential oil chemical composition confirmed the presence of limonene as major compound [19, 20]. Limonene is listed as a flavouring agent in the code of Fedral Regulation and is considered as safe [21]. It is used to cure gastric disorders and has an antiproliferative effect on cancer cells [22]. Antimicrobial, expectorant antiviral, sedative, and antilithic activities of limonene have also been reported [23]. The results of the chemical composition of Citrus peel essential oil partly agree with the previously reported data in literature from the same species because the chemical composition of essential oils varies depending upon the age of the plant, harvesting time, geographical and ecological conditions [24, 25].

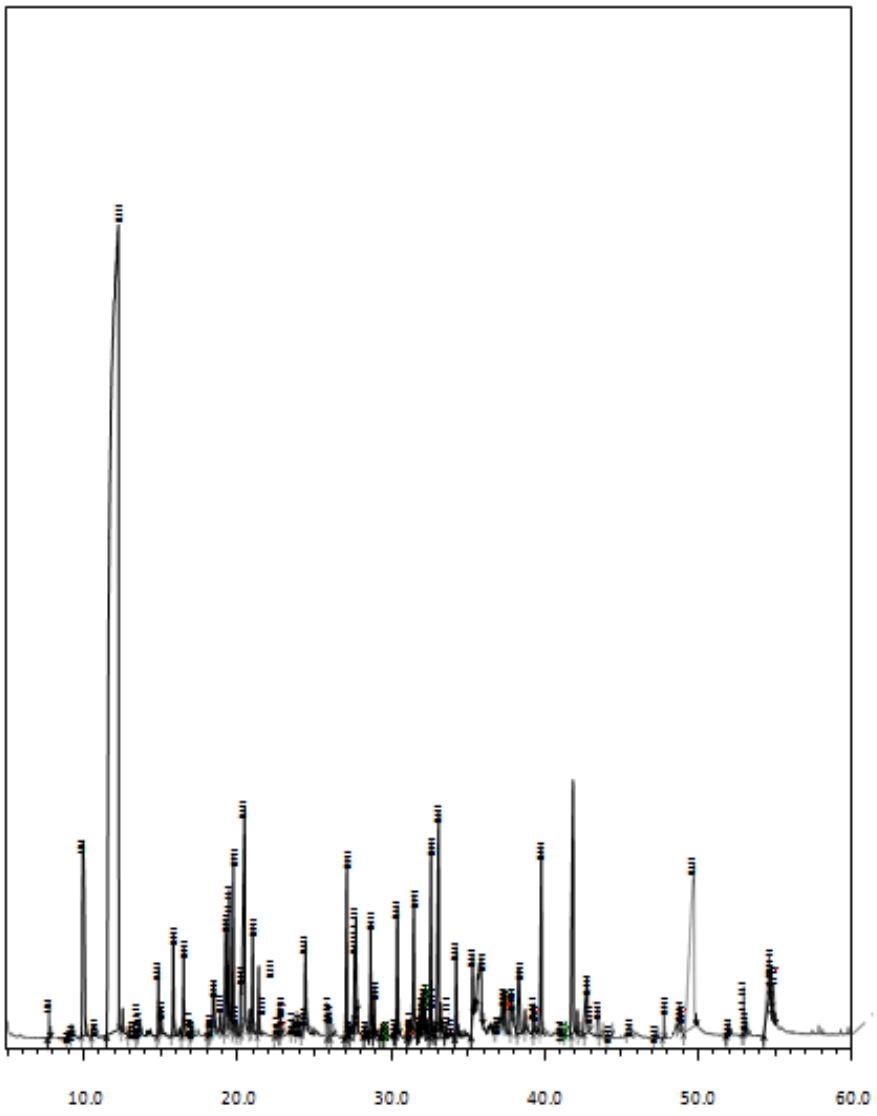
TABLE 1. Chemical composition of citrus peel essential oil

Peak	RetentionTime	Percentace	Name of compound
1	7.708	0.27	alpha- Pinene
2	9.219	0.08	Sabinene
3	9.952	3.03	Myrcene
4	10.614	0.20	Z,Z,Z-1,4,6,9-Nonadecatetraene
5	12.238	50.42	Limonene
6	12.520	0.12	Z- Beta- Ocimene
7	12.960	0.05	gamma-Terpinene
8	13.627	0.11	n-Octanol
9	14.860	0.45	Linalool
10	15.036	0.17	n-Nonanal
11	15.831	0.77	trans-para-Mentha-2,8-dien-1-ol
12	16.501	0.73	P-Mentha-E-2,8(9)-dien-1-ol
13	16.967	0.03	3-(methoxy)-3-methyl-6-prop-1-en-2 –
14	17.078	0.04	cis β-Terpineol
15	18.121	0.08	alpha 2,4-Cyclohexadiene-1-methanol
16	18.258	0.08	n- Octanol
17	18.465	0.45	(-)-terpinen-4-ol
18	18.884	0.13	trans-Isocarveol
19	19.226	1.19	alpha-Terpineol
20	19.465	1.16	[1,1'-Bicyclopentyl]-2-one
21	19.725	1.28	Decanal
22	19.931	0.09	Octyl-acetate
23	20.471	3.09	trans-Carveol
24	20.819	0.15	Carvomenthol
25	20.991	0.81	5-Isoprorpenyl-2-methyl-2-
26	21.384	0.50	2-methyl-5-(1-methylethene) 2-
27	22.483	0.07	3-methyl-6-(1- methylethene) 2-
28	22.751	0.22	Perillaldehyde
29	22.817	0.18	Undecanol
30	23.588	0.15	Limonen-10-ol
31	23.946	0.04	Perilla alcohol
32	24.271	0.12	n-Undecanal
33	24.430	0.92	4-vinyl- Guaiacol
34	25.866	0.24	alpha-Cubebene
35	26.096	0.19	3,7-dimethyl 6-Octen-1-ol
36	27.116	1.49	alpha-Copaene
37	27.325	0.06	Neryl acetate
38	27.624	0.54	beta-Copaene
39	28.281	0.06	alpha-, trans-Bergamotene
40	28.666	0.84	Dodecanal
41	28.898	0.34	(E)-Caryophyllene
42	29.336	0.06	beta-Copaene
43	29.593	0.07	alpha.-Guaiene
44	30.217	0.07	6,10-Dimethylundeca-5,9-dien-2-one
45	30.401	1.23	alpha-Humulene
46	31.100	0.07	Cadina-1,4-diene

47	31.240	0.07	gamma-Muurolene
48	31.473	1.30	beta.-Copaene
49	32.049	0.22	Bicyclogermacrene
50	32.212	0.24	alpha-Muurolene
51	32.600	1.67	(E,E)-, alpha-Farnesene
52	32.758	0.03	gamma-Cadinene
53	33.098	2.53	delta-Cadinene
54	33.233	0.20	Sesquisabinene
55	33.544	0.07	trans-Cadina-1,4-diene
56	34.246	0.79	alpha-Elemol
57	35.303	0.54	(-)-Spathulenol
58	35.846	1.28	n-Dodecanoic acid
59	36.803	0.08	Ethyl iso-allocholate
60	37.237	0.22	Epicubenol
61	37.421	0.31	gamma-Eudesmol
62	37.873	0.08	alpha.-Cadinol
63	38.311	0.99	Cadin-4-en-10-ol
64	38.722	0.15	3,7-dimethyl 6-octenal
65	39.281	0.22	Humulene
66	39.780	1.65	beta-Sinensal
67	40.973	0.05	2,6,10-trimethyl 2,6,9,11-
68	41.842	3.14	alpha-Sinensal
69	42.120	0.19	2-pentyl-2-Nonenal
70	42.747	0.94	tetradecanoic acid
71	43.507	0.28	Nootkatone
72	44.096	0.05	Cryptomeridiol
73	47.189	0.05	Farnesyl acetone
74	47.751	0.26	methyl- Hexadecanoate
75	48.745	0.12	2-dodecen-1-yl(-) succinic anhydride
76	49.688	5.65	n-Hexadecanoic acid
77	52.933	0.32	Methyl ester 9,12-
78	54.591	0.94	Linoleic acid
79	54.729	0.19	Methyl Linoleate
80	54.884	0.31	Dodecenyl Succinic Anhydride
Total		95.98	

111

112



GC/MS spectrum of Citrus fruit peel essential oil

Figure 1: GC/MS spectrum of citrus fruit peel essential oil

3.3 Quality and phytochemical analysis

Citrus peel powder was revealed for moisture, ash, crude fat, crude protein, crude fibre and sugar content determination for quality analysis (Table 2). The moisture content of the sample was found maximum (49.0±0.47%). This was followed by crude fibre content (8.3±0.42%). The sugar content was found to be 7.2±0.07% which was followed by crude protein content (4.8±0.13%). Ash content in the sample was 4.2±0.17%.and fat content was found to be least (3.4±0.14%). These results were in

agreement with work reported on essential oils of Citrus species [26]. Hence, Citrus fruit peels can be used as a noble source of crude fibres having various health benefits such as their ability to reduce hypertension and hyperlipidemia, serum LDL-Cholestrol level and prevents colon cancer [27]. Phytochemical analysis of.essential oil from *Citrus reticulata* fruit peels showed the presence of terpenoids, flavonoids, alkaloids, glycosides, saponins and steroids [28]. Tannins and phenols were absent in essential oil as shown in Table 3. These phytochemicals play an important role in human health and are actively used in nutraceuticals [29, 30].

TABLE 2. Proximate composition of citrus peel sample

Composition	Percentage dry weight basis
Moisture content	49.0±0.47
Ash content	4.2±0.17
Fat content	3.4±0.14
Crude protein content	4.8±0.13
Crude fibre content	8.3±0.42
Sugar content	7.2±0.07

The results were significant at P = 0.01.

TABLE 3. Phytochemical constituents of citrus peel essential oil

Phytochemicals	Terpenoids	Alkaloids	Glycosides	Flavonoids	Tannins	Saponins	Steroids	Phenols
	+	+	+	+	-	+	+	-

Key: (+) present
(-) absent

3.4 Antioxidant Activity

Antioxidant activity of essential oil of Citrus fruit peels has been tested by DPPH radical scavenging activity taking ascorbic acid as standard. The essential oil showed lower antioxidant potential as compared to ascorbic acid as shown in Figure 2. From the results, it was revealed that the radical scavenging activity of oil was concentration dependent and increased with increase in concentration.

These values are in agreement with as reported in the literature [31]. The antioxidant properties of Citrus fruit peel essential oil are mainly due to the presence of monoterpene, sesquiterpene hydrocarbons and their derivatives such as limonene (57.57%) whose antioxidant properties have been reported in the literature [32, 33, 34]. Limonene showed antioxidative properties even at a lower concentration of the order of 10-50 µg/ml [35]. Limonene which was a major component in *Wedelia prostrate* along with alpha-pinene showed 88.15% DPPH radical scavenging activity [36]. The antioxidant potential of citrus peel essential oil vary depending upon the chemical composition and is mainly attributed to its major constituent, but the antagonistic or synergistic effect of various components in the mixture has to be taken into account [37].

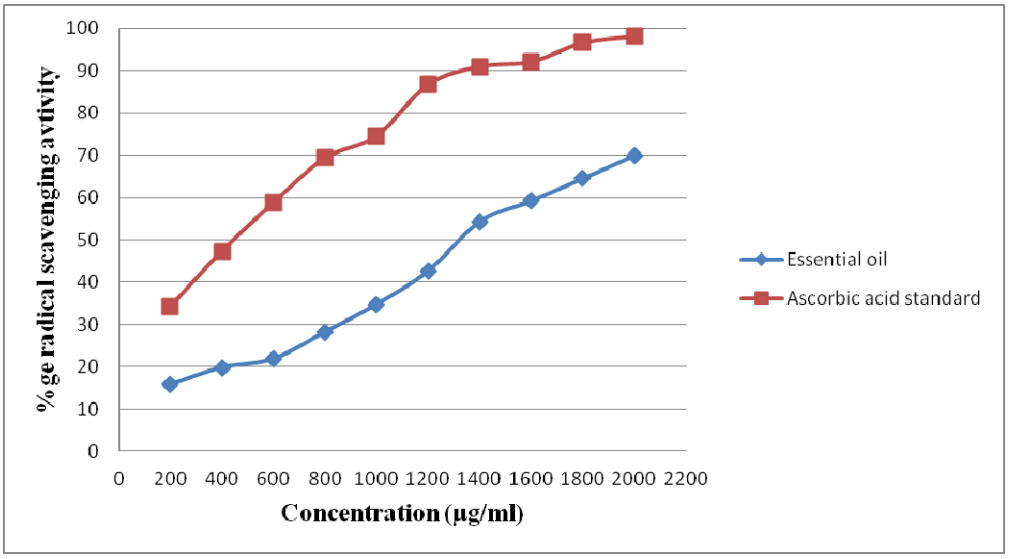


Figure 2: DPPH radical scavenging activity of essential oil and ascorbic acid as standard

4. CONCLUSION

From the above discussion, it is concluded that *Citrus reticulata* peel is a good source of different phytochemicals having medicinal properties and various dietary nutrients such as fibers, sugars and proteins. Hence it can be used as a novel dietary source of these nutrients. Citrus peel essential oil also has free radicals scavenging activity which was mainly due to the presence of various monoterpenes, sesquiterpenes and their derivatives. So intake of Citrus peel may reduce the risk of many oxidation related problems. Hence Citrus peel essential oil can be used as a natural antioxidant as a substitute for synthetic antioxidants which may be toxic or carcinogenic.

REFERENCES

1. Moskovitz J, Yim MB, Chock PB. Free radicals and disease. Arch Biochem Biophys. 2002;397:354-59. doi: 10.1006/abbi.2001.2692

2. Ostrovidov S, Franck P, Joseph D, Martarello L, Kirsch, G, Belleville F, et al . Screening of new antioxidant molecules using flow cytometry. J Med Chem 2002;43(9):1762-69. doi: 10.1021/jm991019j

3. Kris-Etherton P M, Hecker K D, Bonanome A, Coval S M, Binkoski A E, Hilpert K F, et al . Bioactive compounds in foods: their role in the prevention of cardiovascular disease and cancer. Am J Med 2002;113(9):71-88. doi: 10.1016/S0002-9343(01)0095-0 PMID: 12566142

4. Di Matteo V, Esposito E. (2003). Biochemical and therapeutic effects of the antioxidants in the treatment of Alzheimer's disease, Parkinson's disease, and amyotrophic lateral sclerosis. 2003 Curr Drug Targets CNS Neurol Disord 2003;2: 95-107. doi: 10.2174/1568007033482959

5. Sravani T, Paarakh P M. Antioxidant activity of Hedychium spicatum Buch. Ham Rhizomes. Indian J Nat Prod Resour. 2012;3:354-58.

6. Sahoo U K, Jeeceelee L, Lalliinrawna S, Muthukumaran R B. Effect of citrus reticulata Blanco leaf extract on seed germination and initial seedling growth parameters of five home garden food crops. Journal of Experimental Biology and Agricultural Sciences. 2015; 3(6):517-28. doi: 10.18006/2015.3(6).517.528

7. Espina L, Somolinos M, Loreen S, Conchello P, Garcia D, Pageen R. Chemical composition of commercial Citrus fruit essential oils and evaluation of their antimicrobial activity acting alone or in combined processes. Food Control. 2011; 22: 896-902. doi: 10.1016/j.foodcont.2010.11.021

8. Okwu D E. Citrus fruits: a rich source of phytochemicals and their roles in human health. Int. J. Chem. Sci. 2008;6(2):451-71.

9. Sidana J, Saini V, Dahiya S, Nain P, Bala S. A review on Citrus-"The Boon of Nature". Int. J. Pharm. Sci. Rev. Res. 2013;18(2):20-27.

10. Rekha S.S, Bhaskar M. In vitro screening and identification of antioxidant activities of orange (citrus sinesis) peel extract in different solvents. International Journal of Pharma and Bio Sciences. 2013;4:405-12.

11. Zhang Y, Sun Y, Xi W, Shen Y, Zhong L, Ye X, et al. Phenolic compositions and antioxidant capacities of Chinese wild mandarin (citrus reticulata Blanco) fruits. Food Chemistry. 2014;145: 674-80. doi: 10.1016/j.foodchem.2013.08.012

12. Tao N, Jia L, Zhou H. Anti-fungal activity of Citrus reticulata Blanco essential oil against Penicillium italicum and Penicillium digitatum. Food Chemistry 2013;153: 265-71. doi: 10.1016/j.foodchem.2013.12.070

13. AOAC (Association of Analytical Chemists).Official methods of Analysis .15th edition, Washington DC. USA. 2005:1121-80.

14. Dubois M, Gilles KA, Hamilton JK, Rebers PA, Smith F. Calorimetric method for determination of sugars and related substances. Analytical Chemistry 1956;28(3)**:** 350-56. doi: 10.1021/ac60111a017

15. Justin JS, Milton A, Natesan G. Phytochemical evaluation of peel of citrus reticulata Blanco using various solvent extracts. Int. J. Pharm. Sci. Bus. Manag. 2014;2(9):26-35.

16. Viuda-Martos M, Lopez-Marcos MC, Fernandz-Lopez J, Sendra E, Lopez-Vargas JH, Perez-Alvarez JA. Role of fiber in cardiovascular diseases: A review. Comprehensive Reviews in Food Science and Food Safety. 2010;9:240-58. doi: 10.1111/j.1541-4337.2009.00102.x

17. Tu MNT, Onishi Y, Choi HS, Kondo Y, Bassore SM, Ukeda H. Characteristic odor components of citrus sphaerocarpa Tanaka (Kabosu) cold-pressed peel oil. J Agric Food Chem. 2002;50(10):2908-13. PMID: 11982418

18. Kamal GM, Ashraf MY, Hussain AI, Shahzadi A, Chughtai MI. Antioxidant potential of peel essential oils of three Pakistani citrus species: citrus reticulata, citrus sinensis and citrus paradisii. Pak J Bot. 2013;45(4):1449-54.

19. Hamden DI, Mohamed ME, El-Shazly AM. Citrus reticulata Blanco cv. Santra leaf and fruit peel: A common waste products, volatile oils composition and biological activities. J Med Plant Res. 2016;10(30):457-67. doi: 10.5897/JMPR2016.6139

20. Minh Tu NT, Thanh LX, Une A, Ukeda H, Sawamura M. Volatile constituents of Vietnamese pummelo, orange, tangerine and lime peel oils. Flavour Fragr J. 2002;17: 169-74. doi: 10.1002/ffj.1076

21. Sun J. D-Limonene: safety and clinical applications. Alternative Medicine Review. 2007;12(3):259–64.

22. Crowell PL, Kennan WS, Haag JD, Ahmad S, Vedejs E, Gould MN. Chemoprevention of mammary carcinogenesis by hydroxylated derivatives of d-limonene. Carcinogenesis. 1992;13:1261–64.

23. Duke JA, Beckstrom-Sternberg SM. Hand book of medicinal mints (aromathematics) phytochemicals and biological activites. Washington.CRC press. 2001;402.

24. Wu Z, Li H, Yang Y, Zhan Y, Tu D. Variation in the components and antioxidant activity of Citrus medica L. var. sarcodactylis essential oils at different stages of maturity. Industrial Crops and Products. 2013;46:311–16. doi: 10.1016/j.indcrop.2013.02.015

25. Haung B, Ban X, He J, Tong J, Tian J, Wang Y. Comparative analysis of essential oil components and antioxidant activity of extracts of Nelumbo mucifara from various areas of China. J. Agric. Food Chem. 2010; 58 (1):441-48. doi: 10.1021/jf902643e

26. Kour R, Rastogi A, Sharma RK, Kumar A, Raghuwanshi P. Chemical composition, anti-oxidative activity and in vitro dry matter degradability of Kinnow mandarin fruit waste. Veterinary World 2014; 7(10):803-806. doi: 10.14202/vetworld.2014.803-806

27. Lansky EP, Newman RA. Punicagranatum (Pomegranate) and its potential for prevention and treatment of inflammation and cancer. J Ethnopharmacol. 2007;109:177-206.Doi:https://doi.org/10.1016/j.jep.2006.09.006

28. Javed S, Javaid A, Nawaz S, Saeed MK, Mahmood Z, Siddiqui SZ et al . Phytochemistry, GC-MS analysis, antioxidant and antimicrobial potential of essential oil from five Citrus species. J Agric Sci. 2014;6(3):201-08. doi:10.5539/jas.v6n3p201

29. Prakesh D, Gupta C, Sharma G Importance of Phytochemicals in Nutraceuticals. Journal of Chinese Medicine Research and Development. 2012;1(3):70-78

30. Dillard CJ, German JB. Review Phytochemicals: nutraceuticals and human health. J. Sci. Food Agric. 2000;80:1744-56. doi:https://doi.org/10.1002/1097-0010(20000915)80:12%3C1744::AID-JSFA725%3E3.0.CO;2-W

31. Boughendjioua H, Boughendjioua Z. Chemical composition and biological activity of essential of Mandarin (Citrus reticulata) cultivated in Algeria. Int. J. Pharm. Sci. Rev. Res. 2017; 44(1):179-84.

32. Junior MRM, Rocha e Silva TAA, Franchi GC, Nowill A, Pastore GM,Hyslop S. Antioxidant potential of aroma compounds obtained by limonene biotransformation of orange essential oil. Food Chemistry. 2009;116:8–12. doi: 10.1016/j.foodchem.2009.01.084

33. Yang SA, Jeon SK, Lee EJ, Shim CH, Lee IS. Comparative study of the chemical composition and antioxidant activity of six essential oils and their components. Nat Prod Res. 2010; 24 (2):140-151. doi: 10.1080/14786410802496598

34. Malhotra S, Suri S, Tuli R. Antioxidant activity of Citrus cultivars and chemical composition of Citrus karna essential oil. Planta Medica. 2009;75:62-64. doi: 10.1055/s-0028-1088363

35. Roberto D, Micucci P, Sebastian T, Graciela F, Anesini C. Antioxidant activity of limonene on normal murine lymphocytes relation to H2O2 modulation and cell proliferation. Basic Clin Pharmacol Toxicol. 2009;106:38–44. doi: https://doi.org/10.1111/j.1742-7843.2009.00467.x

36. Dai J, Zhu L, Yang L, Qiu J. Chemical composition, antioxidant and antimicrobial activities of essential oil from Wedelia Prostrata. EXCLI J. 2013;12:479-90.

37. Boudries H, Loupassaki S, Ladjal Ettoumi Y, Souagui S, Bachir Bey M, Nabet N et al. Chemical profile, antimicrobial and antioxidant activities of Citrus reticulata and Citrus clementina (L.) essential oils. Int Food Res J. 2017;24:1782-92.