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CHARACTERIZATION OF ESSENTIAL OIL OF GRAPEFRUIT (*CITRUS PARADISI*) BY GAS CHROMATOGRAPHY-MASS SPECTROMETRY (GC-MS) AND ITS ANTIOXIDANT ACTIVITY BY 2,2-DIPHENYL-1-PICRYL-HYDRAZYL FREE RADICAL

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ABSTRACT

The essential oil from the fresh peels of grapefruit (*Citrus paradisi*) was extracted through the hydro-distillation method by using Dean Stark apparatus. The extracted essential oil was dried by using anhydrous sodium sulfate, resulting in a 0.2% yield. Gas Chromatography-Mass Spectrometry (GC-MS) analysis was conducted to identify the constituents present in the essential oil. The study showed presence of Limonene 88.15%, 5-Caranol,(1S,3R,5S,6R)-(-) 3.04%, 2-Furanmethanol 5-ethenyltetrahydro-α,α,5-trimethyl-,cis- 1.44%, 1,6-Octadien-3-ol3,7-dimethyl- 1.43%, Caryophyllene 1.03%, 2-Isopropenyl-5-methylhex-4-enal 0.98%, Terpinen-4-ol 0.94%, Naphthalene1,2,4a,5,8,8a-hexahydro-4,7-dimethyl-1-(1-methylethyl)-,[1S-(1a,4aβ,8aα)]- 0.60%, ethyl2-(5-methyl-5-vinyltetrahydrofuran-2-yl)propan-2-yl 0.57%, 2-Naphthalenemethanol 1,2,3,4,4a,5,6,7-octahydro-α,α,4a,8-tetramethyl-,(2R-cis)- 0.52%, n-Hexadecanoic acid 0.51%, alfa-Copaene 0.31%, 9,12-Octadecadienoic acid (Z,Z)- 0.27%

and D-Limonene 0.11%. The antioxidant activity of essential oil was determined by 2,2-diphenyl-1-picryl-hydrazyl (DPPH) free radical and it was concentration dependent. The antioxidant activity of 56.5% was observed at a concentration of 100 µL of essential oil.

KEYWORDS: Grapefruit; Peel; Hydrodistillation; Essential oil; GC-MS; Antioxidant; DPPH.

INTRODUCTION

Grapefruit (*Citrus paradisi*) belongs to the *Rutaceae* family which is commonly recognized as the Citrus family. The Rutaceae family stands as the largest fruit family comprising 158 genera and 2100 species (Appelhans *et al.*, 2021). Pakistan is producing different varieties of citrus fruits. These citrus fruits have been divided into various groups. These groups include Oranges, Lemon, Grapefruit, and Mandarin (Butt *et al.*, 2004; Cheema & Jamali, 2020). In Pakistan, it is known as "Chakotrah". Pakistan is an agricultural country and it produces 116 million tons of total crops of agriculture, involving a total fruit production of 7.01 million tons and the output of citrus fruit amounts to around 2.4 million tons constituting 35.2% of total amount of fruit produced. The grapefruit contributes only 0.1% of the total citrus produced in Punjab province (Siddique & Garnevska, 2018).

The grapefruit is an abundant reservoir of various bioactive components including limonene, ascorbic acid, pectin, flavonoids, phenolic contents, and organic acids. These components have a significant part in facilitating potential well-being benefits because of having nutritional, antiallergic, anticarcinogenic, antioxidant, and antimicrobial characteristics (Kawaii *et al.*, 1999). After the utilization of citrus fruits, the peels from the citrus fruits are produced in large amounts, these peels are discarded as agricultural and industrial waste. They provide a way to recycle discarded waste as a source of producing oils. On the industrial scale, after the utilization of the fruit the flavonoids, pulp, pectin, and other byproducts are also produced that enhance the worth of grapefruit.

The peel is recognized as a natural substance that has the potential to serve as an economic and exceptional source of antioxidants. After the processing and utilization of fruit, the peels of grapefruit play a substantial part in the formulations of health supplements or act as pharmacological substances in a variety of both in vivo and in vitro therapeutic applications (Castro-Vazquez *et al.*, 2016). Over the recent years, the need for the plant's essential oils has enhanced because of their recognized sustainability and pharmacological attributes. These properties included anti-inflammatory characteristics, bacteriostatic effects, free radical scavenging, and inhibiting malignant tumors or cancer-causing cell proliferation (Burt, 2004; Edris, 2007; Sahay, 2015; Shaaban *et al.*, 2012).

The essential oils are broad natural systems that are comprised of primarily terpenes along with numerous other non-terpene components (Edris, 2007). The essential oils derived from peels of citrus fruits contribute about one to third of the worldwide production of essential oils (Li *et al.*, 2021) and are extensively utilized in perfume, beauty products, medicinal, and foodstuff industries (Fisher & Phillips, 2009; Hardin *et al.*, 2010; Kaur & Kaur, 2015). They are extracted by various methods including cold pressing, hydrodistillation, solvent extraction, expression, supercritical carbon dioxide extraction, and maceration (Ashurst, 2012; Njoroge *et al.*, 2006; Venkateshwarlu & Selvaraj, 2000). Factors that affect composition of essential oil included storage conditions, ripening of fruits, soil quality, climate and geography, extraction methods, varieties and species of plant used, and cultivation process (Poonkodi, 2016). The evaluation of natural sources of antioxidants has been increased because of the removal of synthetic antioxidants from the various applications of food (Iqbal, 2018). Over the past few decades, various studies have been conducted to show that the waste of citrus fruits can serve as a natural reservoir of antioxidants that provide a way to utilize these byproducts (Bocco *et al.*, 1998; Llorach *et al.*, 2003; Manthey & Grohmann, 2001; Wolfe *et al.*, 2003). The essential oil of grapefruit are extracted by hydrodistillation method which is then further characterized by GC-MS to elaborate constitutes. This study shows the presence of major contents of limonene, d-limonene, terpinene-4-ol, n-hexadecanoic acid, etc.

Studies have been conducted on the extraction of essential oils from peels of citrus fruits and determining their chemical constituents by GC-MS. The several characteristics of essential oils including antioxidant, anticancer, antifungal, and antibacterial activity were also investigated (Achimón *et al.*, 2022; Deng *et al.*, 2020; Okunowo *et al.*, 2013; Saleem *et al.*, 2008; Shahzad *et al.*). The current research was designed to extract the essential oil from the discarded peels of grapefruits and determine its chemical composition by GC-MS and antioxidant activity by DPPH free radical.

MATERIALS AND METHOD

Collection of Material

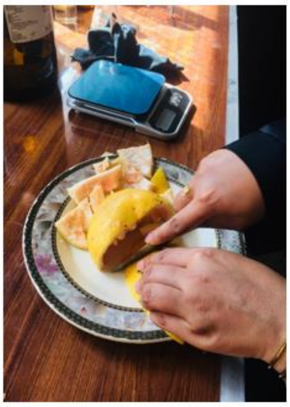
The fresh grapefruits were collected from the local fruit market of Lahore division, Punjab Pakistan.

Chemicals

The chemicals included anhydrous sodium sulphate, methanol and 2,2-diphenyl-1-picryl-hydrazyl (DPPH) were of analytical grade and purchased from the local market of Lahore Division, Punjab Pakistan.

Extraction of Essential oil

Fresh peels of grapefruit were separated manually and weighed 3.2 kg. These peels were chopped into small pieces by using a knife and then subjected to the hydrodistillation to extract essential oil by using a Dean-Stark apparatus for a duration of 10 hours(Shahzad *et al.*, 2009). Essential oil was separated in a separating funnel and then dried by using anhydrous sodium sulphate, which yields a light yellow-colored oil after the removal of solvent. The oil was stored in an airtight bottle at 4°C in the fridge for further studies.



Cutting of Peels → Hydrodistillation Method → Storing Essential oil

GC-MS studies of essential oil

The analysis was carried out by using an Agilent 5973-6890 gas chromatograph-mass spectrometry system that was equipped with a split-splitless injector and operated in EI mode at 70 eV. The helium was used as carrier gas at a flow rate of 1 ml/min. A DP-5MS (30 m × 0.25 mm internal diameter, 0.25 µm film thickness) capillary column was utilized.

The injector temperature was set at 220°C. The initial oven temperature was at 60°C with a hold time of 4 min which was programmed to increase to 260°C at the rate of 10°C/min. A sample volume of 2 μL was injected into the column. Other MS operating parameters included quadruple temperature 120°C, ion source temperature 230°C, solvent delay 4 minutes, and scan range 50-700 amu. Interpretation of potential components was done by comparing their retention indices, and mass spectra with those in the library of the National Institute of Standards and Technology (NIST).

Antioxidant activity of essential oil

The antioxidant activity of grapefruit's essential oil was analyzed by DPPH free radical by using the method given by (Dawidowicz *et al.*, 2012). Various concentrations of essential oil specifically 25µL, 50µL, 75µL, and 100µL, were mixed with 3 ml methanol-containing DPPH solution. Then, after 30 minutes of incubation at room temperature, the absorbance of resulting solutions and blank (comprising only DPPH) was measured at a wavelength of 517 nm utilizing a UV-Vis spectrophotometer (Shimadzu UV-1700 Pharma-Spec).

Percentage inhibition of essential oil of grapefruit was determined by using the equation below.

$$\% \text{ Inhibition (DPPH)} = \frac{Absorbance\ of\ DPPH\ solution - Absorbance\ of\ sample}{Absorbance\ of\ DPPH\ solution} \times 100$$

RESULTS AND DISCUSSIONS

Chemical Composition of Essential Oil by GC-MS

The essential oil extracted from the fresh peels of grapefruit was light yellow colored and 0.2% yield of oil was obtained which was lower than the yield reported by (Uysal *et al.*, 2011), (Ahmad *et al.*, 2006) and (Ahmad *et al.*, 2016) that might be due to the difference in the variety of fruit, soil type, environmental and harvesting conditions.

The chemical composition of the essential oil of grapefruit was determined by GC-MS which showed the presence of various volatile components. The essential oil of grapefruit was found to contain 14 different components that are represented in Table 1.

Table 1: Chemical Composition of Essential Oil.

Peak #	Components	Retention time(min)	%age
1	Limonene	4.889	88.15
2	D-Limonene	5.948	0.11
3	2-Furanmethanol, 5-ethenyltetrahydro-α,α,5-trimethyl-,cis-	6.762	1.44
4	Ethyl 2-(5-methyl-5-vinyltetrahydrofuran-2-yl)propan-2-yl carbonate	6.822	0.57
5	1,6-Octadien-3-ol, 3,7-dimethyl-	6.904	1.43
6	Terpinen-4-ol	7.433	0.94
7	5-Caranol, (1S,3R,5S,6R)-(-)-	7.783	3.04
8	2-Isopropenyl-5-methylhex-4-enal	8.551	0.98
9	alfa-Copaene	9.453	0.31
10	Caryophyllene	10.056	1.03
11	Naphthalene, 1,2,4a,5,8,8a-hexahydro-4,7-dimethyl-1-(1-methylethyl)-,[1S-(1a,4aβ,8aα)]-	11.278	0.6
12	2-Naphthalenemethanol,1,2,3,4,4a,5,6,7-octahydro-α,α,4a,8-tetramethyl-,(2R-cis)-	12.572	0.52
13	n-Hexadecanoic acid	16.411	0.51
14	9,12-Octadecadienoic acid (Z,Z)-	17.770	0.27

These components represented presence of six different groups of hydrocarbons in essential oil including monoterpenes, sesquiterpenes, oxygenated monoterpenes, monoterpenoids, saturated fatty acids and polyunsaturated fatty acid. The monoterpenes account for 90.18% that include Limonene, D-limonene, Terpinen-4-ol, and 2-Isopropenyl-5-methylhex-4-enal. The oxygenated monoterpenes comprises 3.44% that include 2-Furanmethanol, 5-ethenyltetrahydro-α,α,5-trimethyl-,cis- which is commonly known as cis- Linalool oxide, 1,6-Octadien-3-ol, 3,7-dimethyl- known as linalool and Ethyl 2-(5-methyl-5-vinyltetrahydrofuran-2-yl)propan-2-yl carbonate. The monoterpenoids makeup 3.04% which include 5-Caranol, (1S,3R,5S,6R)-(-)-. Naphthalene 1,2,4a,5,8,8a-hexahydro-4,7-dimethyl-1-(1-methylethyl)-,[1S-(1a,4aβ,8aα)]- which is commonly known as β-Cadinene, Caryophyllene, alfa-Copaene, and Naphthalene, 1,2,4a,5,8,8a-hexahydro-4,7-dimethyl-1-(1-methylethyl)-,[1S-(1a,4aβ,8aα)]- constitute 2.46% sesquiterpenes. While n-hexadecanoic acid known as palmitic acid constitutes 0.51% saturated fatty acid, and 9,12-Octadecadienoic acid (Z, Z)- called linoleic acid constitutes 0.27% polyunsaturated fatty acid.

Among these components, limonene 88.15%, 5-Caranol,(1S,3R,5S,6R)-(-)- 3.04%, 2-Furanmethanol, 5-ethenyltetrahydro-α,α,5-trimethyl-,cis- 1.44%, 1,6-Octadien-3-ol, 3,7-dimethyl- 1.43%, and Caryophyllene 1.03% were the major components found in the essential oil of grapefruit. While other components found in essential oil having percentage less than 1% were 2-Isopropenyl-5-methylhex-4-enal, Terpinen-4-ol, Naphthalene 1,2,4a,5,8,8a-hexahydro-4,7-dimethyl-1-(1-methylethyl)-,[1S-(1a,4aβ,8aα)]-, ethyl 2-(5-methyl-5-vinyltetrahydrofuran-2-yl)propan-2-yl carbonate, 2-Naphthalenemethanol, 1,2,3,4, 4a,5,6,7-octahydro-α,α,4a,8-tetramethyl-,(2R-cis)-, n-Hexadecanoic acid, alfa-Copaene, 9,12-Octadecadienoic acid (Z, Z)- and D-Limonene. Various studies showed the makeup of essential oils extracted from citrus peels, with constituents such as limonene, copaene, D-limonene α-Caryophyllene, etc. (Okunowo *et al.*, 2013; Uysal *et al.*, 2011) that are similar to reported results.

The GC-MS mass spectra of different components of essential oil were obtained and have been elaborated as follows.

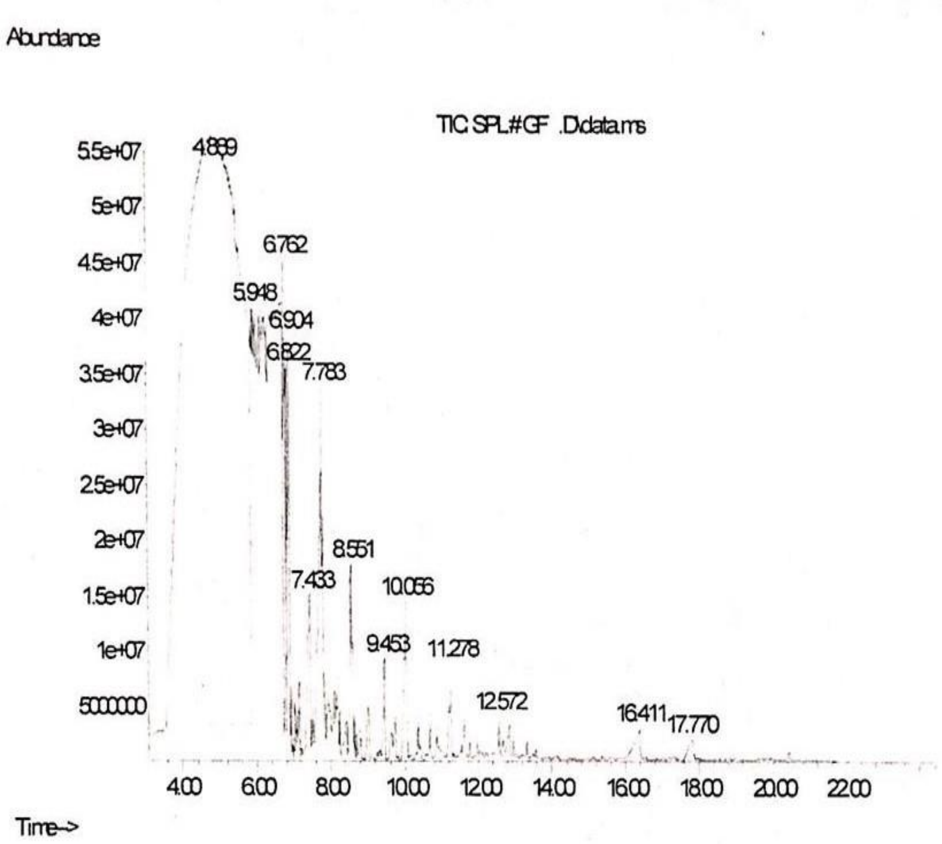


Fig 1: GC-MS Spectra of Essential oil of grapefruit (Citrus paradisi). Retention time corresponds to (4.889) Limonene, (5.948) D-Limonene, (6.762) 2-Furanmethanol, 5-ethenyltetrahydro-α,α,5-trimethyl-,cis-, (6.822) Ethyl 2-(5-methyl-5-vinyltetrahydrofuran-2-yl)propan-2-yl carbonate, (6.904) 1,6-Octadien-3-ol, 3,7-dimethyl-, (7.433) Terpinen-4-ol, (7.783) 5-Caranol, (1S,3R,5S,6R)-(-)-, (8.551) 2-Isopropenyl-5-methylhex-4-enal, (9.453) alfa-Copaene, (10.056) Caryophyllene, (11.278)

Naphthalene, 1,2,4a,5,8,8a-hexahydro-4,7-dimethyl-1-(1-methylethyl)-,[1S-(1a,4aβ,8aα)]-, (12.572) 2-Naphthalenem- ethanol,1,2,3,4,4a,5,6,7-octahydro-α,α,4a,8-tetramethyl-,(2R-cis)-, (16.411) n-Hexadecanoic acid and (17.770) 9,12-Octadecadienoic acid (Z,Z).

Antioxidant activity of Essential oil

The antioxidant activity of the essential oil is because of the presence of greater concentrations of phenolic contents including limonene, d-limonene, terpinen-4-ol, etc. These phenolic contents can neutralize free radicals that can harm the body, thereby lowering the risk of various diseases like cancer, Alzheimer's disease, and heart disease (Aadil *et al.*, 2013). Because they possess a high redox potential, thus they can act as radical scavengers as well as hydrogen donors (Corzo-Martínez *et al.*, 2007). The results elaborated that essential oil having a concentration of 100 µL showed % inhibition of 56.5, a concentration of 75 µL showed % inhibition of 46.8, concentration of 50 µL showed % inhibition of 38.9 and concentration of 25 µL showed % inhibition of 29.5 as shown below graph.

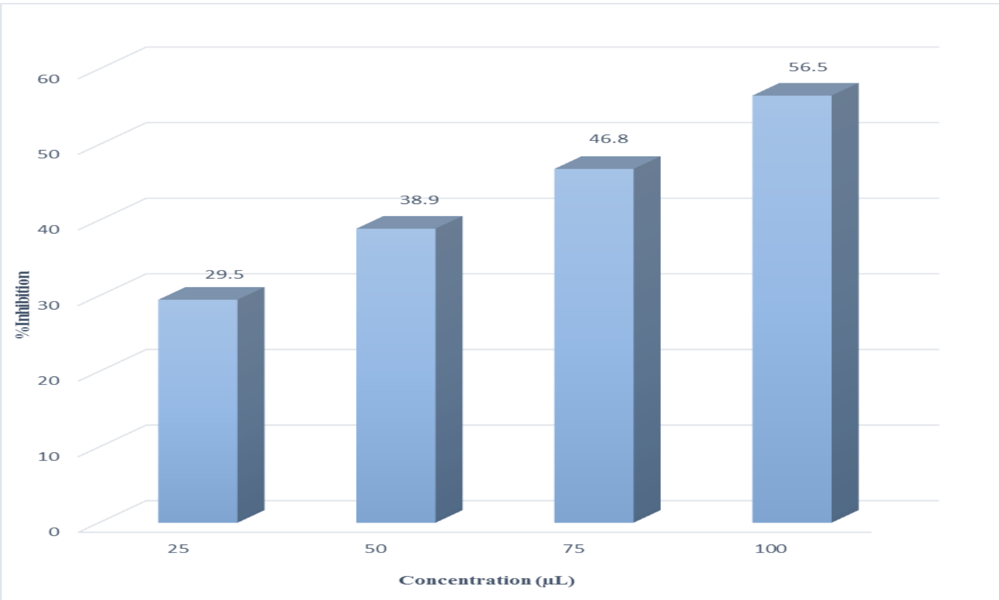


Fig 2: Antioxidant activity of Grapefruit Essential oil.

Literature showed that the antioxidant potential is directly proportional to the phenolic content, as their effect is concentration-dependent. The essential oil extracted from the peels of grapefruit possesses greater antioxidant activity because the phenolic contents are present in larger amounts as compared to the other parts of pulp and seeds (Ghasemi *et al.*, 2009; Molina-Quijada *et al.*, 2010; Sir Elkhatim *et al.*, 2018). Studies have demonstrated a strong correlation between the phenolic content and antioxidant potential of fruits and vegetables (Li *et al.*, 2006). The results were higher than the results reported by (Vincenzo *et al.*, 2018) which showed % inhibition of 35.25% and 46.08% for the star ruby variety of grapefruit and the marsh variety of grapefruit respectively. These results were similar to those reported by (Iqbal, 2024; Jang et al., 2010; Xi et al., 2015; Zhang et al., 2018) who investigated that the peels of various varieties of citrus fruits possess higher antioxidant activity as compared to that of pulp because of higher phenolic content.

CONCLUSION

The essential oil from peels of grapefruit (*Citrus paradisi*) was extracted through hydrodistillation. The extracted essential oil was dried by using anhydrous sodium sulfate, resulting in 0.2% yield. GC-MS was conducted to identify the constituents of essential oil. The major constitutes were Limonene 88.15%, 5-Caranol,(1S,3R,5S,6R)-(-) 3.04%, 2-Furanmethanol 5-ethenyltetrahydro-α,α,5-trimethyl-,cis- 1.44%, 1,6-Octadien-3-ol3,7-dimethyl- 1.43%, and Caryophyllene 1.03%. Its antioxidant activity was determined by DPPH free radical. The antioxidant activity of 56.5% was observed at a concentration of 100 μL of essential oil. So, it can be used as a natural source of antioxidants for therapeutic purposes.

REFERENCES

1. Aadil, R. M., Zeng, X.-A., Han, Z., & Sun, D.-W. (2013). Effects of ultrasound treatments on quality of grapefruit juice. *Food chemistry*, *141*(3): 3201-3206.
2. Achimón, F., Leal, L. E., Pizzolitto, R. P., Brito, V. D., Alarcón, R., Omarini, A. B., & Zygadlo, J. A. (2022). Insecticidal and antifungal effects of lemon, orange, and grapefruit peel essential oils from Argentina. *AgriScientia*, *39*(1): 71-82.
3. Ahmad, M., Rehman, S.-u., Tahir, M., Qureshi, T., Nadeem, M., & Asghar, M. (2016). *VARIABILITY IN PEEL COMPOSITION AND QUALITY EVALUATION OF PEEL OILS OF CITRUS VARIETIES*. https://doi.org/10.13140/RG.2.2.25607.85922
4. Ahmad, M. M., Iqbal, Z., Anjum, F. M., & Sultan, J. I. (2006). Genetic variability to essential oil composition in four citrus fruit species. *Pakistan Journal of Botany*, *38*(2): 319.
5. Appelhans, M. S., Bayly, M. J., Heslewood, M. M., Groppo, M., Verboom, G. A., Forster, P. I., Kallunki, J. A., & Duretto, M. F. (2021). A new subfamily classification of

the Citrus family (Rutaceae) based on six nuclear and plastid markers. *Taxon*, *70*(5): 1035-1061.

6. Ashurst, P. R. (2012). *Food flavorings*. Springer Science & Business Media.
7. Bocco, A., Cuvelier, M.-E., Richard, H., & Berset, C. (1998). Antioxidant activity and phenolic composition of citrus peel and seed extracts. *Journal of agricultural and food chemistry*, *46*(6): 2123-2129.
8. Burt, S. (2004). Essential oils: their antibacterial properties and potential applications in foods—a review. *International journal of food microbiology*, *94*(3): 223-253.
9. Butt, S. J., Khan, M., & Anwar, R. (2004). Citrus production in Pakistan. Proceedings of the Ist International Conference on Citriculture in Pakistan. University of Agric. Faisalabad.
10. Castro-Vazquez, L., Alañón, M. E., Rodríguez-Robledo, V., Pérez-Coello, M. S., Hermosín-Gutierrez, I., Díaz-Maroto, M. C., Jordán, J., Galindo, M. F., & Arroyo-Jimenez, M. d. M. (2016). Bioactive flavonoids, antioxidant behaviour, and cytoprotective effects of dried grapefruit peels (Citrus paradisi Macf.). *Oxidative Medicine and Cellular Longevity*, *2016*.
11. Cheema, I. A., & Jamali, H. K. (2020). Growth of citrus fruits in Pakistan. *Amazonia Investiga*, *9*(35): 74-81.
12. Corzo-Martínez, M., Corzo, N., & Villamiel, M. (2007). Biological properties of onions and garlic. *Trends in food science & technology*, *18*(12): 609-625.
13. Dawidowicz, A. L., Wianowska, D., & Olszowy, M. (2012). On practical problems in estimation of antioxidant activity of compounds by DPPH method (Problems in estimation of antioxidant activity). *Food Chemistry*, *131*(3): 1037-1043.
14. Deng, W., Liu, K., Cao, S., Sun, J., Zhong, B., & Chun, J. (2020). Chemical composition, antimicrobial, antioxidant, and antiproliferative properties of grapefruit essential oil prepared by molecular distillation. *Molecules*, *25*(1): 217.
15. Edris, A. E. (2007). Pharmaceutical and therapeutic potentials of essential oils and their individual volatile constituents: a review. *Phytotherapy Research: An International Journal Devoted to Pharmacological and Toxicological Evaluation of Natural Product Derivatives*, *21*(4): 308-323.
16. Fisher, K., & Phillips, C. (2009). The mechanism of action of a citrus oil blend against Enterococcus faecium and Enterococcus faecalis. *Journal of Applied Microbiology*, *106*(4): 1343-1349.

17. Ghasemi, K., Ghasemi, Y., & Ebrahimzadeh, M. A. (2009). Antioxidant activity, phenol and flavonoid contents of 13 citrus species peels and tissues. *Pak J Pharm Sci*, *22*(3): 277-281.
18. Hardin, A., Crandall, P. G., & Stankus, T. (2010). Essential oils and antioxidants derived from citrus by-products in food protection and medicine: an introduction and review of recent literature. *Journal of Agricultural & Food Information*, *11*(2): 99-122.
19. Iqbal, Z. (2018). Essential oil from the aerial roots of Ficus elastica and their antioxidant activity. *Int J Adv Res*, *6*(1): 137-140.
20. Iqbal, Z. (2024). Antioxidant activity of Methanolic Extracts of Sweet Lime (Citrus lemitta) Peel, Pulp, and Seed by 2, 2-diphenyl-1-picryl-hydrazyl free radical. *Research Prospects in Natural Sciences (RPNS): 2*(1): 5-8.
21. Jang, H.-D., Chang, K.-S., Chang, T.-C., & Hsu, C.-L. (2010). Antioxidant potentials of buntan pumelo (Citrus grandis Osbeck) and its ethanolic and acetified fermentation products. *Food chemistry*, *118*(3): 554-558.
22. Kaur, J., & Kaur, G. (2015). An insight into the role of citrus bioactives in modulation of colon cancer. *Journal of Functional Foods*, *13:* 239-261.
23. Kawaii, S., Tomono, Y., Katase, E., Ogawa, K., & Yano, M. (1999). Quantitation of flavonoid constituents in citrus fruits. *Journal of agricultural and food chemistry*, *47*(9): 3565-3571.
24. Li, B., Smith, B., & Hossain, M. M. (2006). Extraction of phenolics from citrus peels: I. Solvent extraction method. *Separation and Purification Technology*, *48*(2): 182-188.
25. Li, G., Xiang, S., Pan, Y., Long, X., Cheng, Y., Han, L., & Zhao, X. (2021). Effects of cold-pressing and hydrodistillation on the active non-volatile components in lemon essential oil and the effects of the resulting oils on aging-related oxidative stress in mice. *Frontiers in Nutrition*, *8:* 689094.
26. Llorach, R., Espín, J. C., Tomás-Barberán, F. A., & Ferreres, F. (2003). Valorization of cauliflower (Brassica oleracea L. var. botrytis) by-products as a source of antioxidant phenolics. *Journal of agricultural and food chemistry*, *51*(8): 2181-2187.
27. Manthey, J. A., & Grohmann, K. (2001). Phenols in citrus peel byproducts. Concentrations of hydroxycinnamates and polymethoxylated flavones in citrus peel molasses. *Journal of agricultural and food chemistry*, *49*(7): 3268-3273.
28. Molina-Quijada, D., Medina-Juárez, L., González-Aguilar, G., Robles-Sánchez, R., & Gámez-Meza, N. (2010). Phenolic compounds and antioxidant activity of table grape (Vitis vinifera L.) skin from northwest Mexico. *CyTA-Journal of Food*, *8*: 57-63.

29. Njoroge, S. M., Mungai, H. N., Koaze, H., Phi, N. T. L., & Sawamura, M. (2006). Volatile constituents of mandarin (Citrus reticulata Blanco) peel oil from Burundi. *Journal of Essential Oil Research*, *18*(6): 659-662.
30. Okunowo, W. O., Oyedeji, O., Afolabi, L. O., & Matanmi, E. (2013). Essential oil of grape fruit (Citrus paradisi) peels and its antimicrobial activities.
31. Poonkodi, K. (2016). Chemical composition of essential oil of Ocimum basilicum L.(Basil) and its biological activities-an overview. *Journal of Critical Reviews*, *3*(3): 56-62.
32. Sahay, S. (2015). A review on pharmacological uses of essential oil. *Int. J. Curr. Pharm. Rev. Res, 6:* 71-79.
33. Saleem, M., Mahmud, S., Waheed, A., Akhtar, M., & Iqbal, Z. (2008). Volatile constituents of Citrus aurantifolia variety" Kaghzi Nimbu".
34. Shaaban, H. A., El-Ghorab, A. H., & Shibamoto, T. (2012). Bioactivity of essential oils and their volatile aroma components. *Journal of Essential Oil Research*, *24*(2): 203-212.
35. Shahzad, K., Nawaz, S., Ahmad, R., Akram, N., & Iqbal, Z. Evaluation of antbacterial, antifungal and antioxidant activity of essentail oil of Citrus reticulata fruit (tangerine fruit peel).
36. Shahzad, K., Nawaz, S., Ahmad, R., Mahmud, S., Iqbal, Z., & Saeed, K. (2009). Evaluation of antioxidant and antimicrobial activity of essential oil of Tangerine fruit peel. *Pak J Biochem Mole Bio*, *42:* 4-7.
37. Siddique, M. I., & Garnevska, E. (2018). Citrus value chain (s): A survey of Pakistan citrus industry. *Agric. Value Chain*, *37:* 37-58.
38. Sir Elkhatim, K. A., Elagib, R. A., & Hassan, A. B. (2018). Content of phenolic compounds and vitamin C and antioxidant activity in wasted parts of Sudanese citrus fruits. *Food science & nutrition*, *6*(5): 1214-1219.
39. Uysal, B., Sozmen, F., Aktas, O., Oksal, B. S., & Kose, E. O. (2011). Essential oil composition and antibacterial activity of the grapefruit (Citrus Paradisi. L) peel essential oils obtained by solvent-free microwave extraction: comparison with hydrodistillation. *International journal of food science & technology*, *46*(7): 1455-1461.
40. Venkateshwarlu, G., & Selvaraj, Y. (2000). Changes in the peel oil composition of Kagzi lime (Citrus aurantifolia Swingle) during ripening. *Journal of Essential Oil Research*, *12*(1): 50-52.

41. Vincenzo, S., Pellicanò, T., Giuffrè, A., Zappia, C., Capocasale, M., & Poiana, M. (2018). *Physical chemical properties and antioxidant capacities of grapefruit juice (Citrus paradisi) extracted from two different varieties*.
42. Wolfe, K., Wu, X., & Liu, R. H. (2003). Antioxidant activity of apple peels. *Journal of agricultural and food chemistry*, *51*(3): 609-614.
43. Xi, W., Zhang, G., Jiang, D., & Zhou, Z. (2015). Phenolic compositions and antioxidant activities of grapefruit (Citrus paradisi Macfadyen) varieties cultivated in China. *International journal of food sciences and nutrition*, *66*(8): 858-866.
44. Zhang, H., Yang, Y.-F., & Zhou, Z.-Q. (2018). Phenolic and flavonoid contents of mandarin (Citrus reticulata Blanco) fruit tissues and their antioxidant capacity as evaluated by DPPH and ABTS methods. *Journal of Integrative Agriculture*, *17*(1): 256-263.