# RELATIVE NUTRITIONAL AND PHYTOCHEMICAL COMPOSITION OF CITRUS FRUIT COMPARTMENTS- A CASE AGAINST WASTING CITRUS PEELS

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## ABSTRACT

**Citrus fruits are known to contribute towards health considering their nutritional composition as well as bioactive ingredients. Although utilized at the industrial level, household-level consumption of citrus peel is not a common concept. The current study was conducted to compare the composition of different citrus fruits as well as to compare their peels and pulps composition.**

**Three samples of citrus fruits (oranges (Citrus Sinensis) [sample O], lemons (Citrus Limons) [sample L], and grapefruits (Citrus Paradisi) [sample G]) were selected. Two variables; type of fruit with three categories (O vs L vs G) and part of the fruit with two categories (peel vs pulp) were studied. Proximate contents (AOAC methods), antioxidant activity (modified DPPH bleaching), Ferrous ion chelating activity, and total phenol content (Folin- Ciocalteu method) were determined for each sample. One-way ANOVA and post hoc analysis was run to note down differences among various samples.**

**Except for moisture and fat, all other proximate components showed significantly higher amounts in peels compared with pulp. Fiber and ash contents were significantly higher in peels compared with pulps for all three fruits with a mean difference of L=10.1g, O= 9.29g, G= 10.19g for fiber and L= 0.18g, O=0.37g, G=0.10g for ash. Protein and carbohydrate were found in higher quantity in peels of Samples O and L (mean difference L=0.38g, O=0.15g for protein and L=8.1g, O=13.86g) while significantly lower in the peel of sample G (mean difference protein=1.14g, carbohydrate=0.98g). Antioxidant capacity, total phenolic content and chelating activity were found to be significantly higher in peels of L, O, and G though these contents were not significantly correlated ($p>0.05$) to one another.**

**The findings of this study show that citrus fruits are a rich source of nutrients as well as phytochemicals. The peels of citrus fruits can serve as better sources of antioxidants, phenolic content, chelating properties, and some nutrients than their pulps. This study provides evidence for the benefits of utilizing peels at the household level while reducing food waste.**

***Keywords: phytochemicals, citrus fruits, citrus peels, non-nutrients, health, functional foods***

## INTRODUCTION

**Citrus plants belong to the family Rutaceae and are among the most important fruit crops grown in tropical as well as in subtropical regions (Al-Juhaimi, 2014). They not only add color, flavor, aroma, and variety to the diets (Zou, Xi, Hu, Nie, & Zhou, 2016) but also make significant nutritional and functional contributions to the diet. Particularly rich in phytochemicals and other bioactive components, citrus fruits offer anti-inflammatory, anti-oxidant, anti-aging and anti-carcinogenic properties (Ke et al., 2015; Zhang et al., 2015). Flavonoids, antioxidants and phenolic compounds have been studied to protect against several metabolic disorders including glucose intolerance, carcinomas, cardio-metabolic disorders, and neurodegenerative diseases(Ramful, Bahorun, Bourdon, Tarnus, & Aruoma, 2010). Thus, the therapeutic and preventive properties of these bioactive plant components have given rise to a special interest in studying the nutritional and non-nutritional composition of various parts of fruits and vegetables.**

**With the advent of industrialization, citrus fruits, like other foods, have also witnessed a shift in consumption patterns from fresh produce towards processed items. Citrus processing has resulted in the production of a large bulk of products and waste materials (Parashar et al., 2014). Although, citrus peel and pulp extracts are utilized by cosmetic, nutraceutical, and food industries, household-level usage usually involves discarding the non-edible portions of fruit. Nutraceutical formulations derived from natural products and used as supplements or formulae are an essential means by which to promote the therapeutic and preventive properties of bioactive components (Fang & Bhandari, 2010). However, these pharmacological preparations are usually expensive. The utilization of citrus pulp and peels for their health-promoting properties not only serve as a low-cost solution but also contributes towards the waste**

**management approach. The current study was conducted to determine and compare the composition of three major citrus fruits (oranges, lemons, and grapefruits) as well as to compare the composition of peels and pulps. This study would provide information about the composition of various parts of local varieties of citrus fruits and can encourage the household consumers as well as industrialists in exploring safe and effective methods of utilizing all parts** of the fruits.

## METHODS

**Three fruits belonging to the citrus class i.e. oranges (citrus Sinensis) [sample O], lemons (citrus limons) [sample L] and grapefruits (Citrus paradisi) [sample G] were selected for this study. Two variables; type of fruits (three categories O vs. L vs. G) and part of the fruit (peel vs pulp) were studied in this research. Ripened and freshly harvested fruits were bought from the local market of Lahore, Pakistan, and washed with distilled water. The peels of all selected citrus fruits were removed. These peels and pulps were dried separately in a hot air oven for 24 hours and then converted into fine powdered form. Proximate analysis was carried out using the dried powdered form of selected citrus fruits peels and pulps while extract was prepared for determining the antioxidant, phenol and chelating activity of fruits.**

**The extracts for both peels and pulps dried samples were prepared in methanol by adding 0.01 g of sample in 10ml of solvent in clean, sterilized test tubes and placed in an incubator at 27oC overnight to extract the antioxidant component of the sample effectively. The test tubes with their contents were sealed and stored at 4˚C accompanying occasional stirring and agitation until used for the DPPH, ferrous iron chelation, and total phenolic content assay.**

**Proximate analysis of selected citrus fruits i.e. carbohydrate, protein, fat, ash, fiber, and moisture content was carried out according to standard methods of AOAC (2012). Total energy content (kcal) was determined through the product of grams of fats, proteins and carbohydrates with factors 9, 4, and 4 (Yadang et al., 2009).**

**A slightly modified method of DPPH bleaching assay was used to determine the antioxidant activity of extracts.**

**The ferrous ion chelating activity of methanolic extracts of samples and standards was determined according to the method described by Kumaran, A., & Karunakaran, R. (2007).**

**The total phenol content of the extract was determined using the modified Folin-Ciocalteu method (Wolfe, K., Wu, X. & Liu, R., 2003).**

**Results were presented as Means ± SD. One Way ANOVA and Post Hoc Analysis was performed to find out the difference in nutritional and phytochemical composition of peels and pulps of selected citrus fruits. All the data were analyzed by using SPSS (version 21.0).**

## RESULTS

**Proximate composition of fruit peel and pulp was found to be significantly different for all three fruits. As shown in Table 1, fiber and ash contents were found to be significantly greater in peels of all three fruits compared to their respective pulps. The number of proteins and carbohydrates was found to be significantly higher in peels of Sample O and L but not in Sample G. Moisture content was significantly greater in pulps as compared to their peels. The comparison of composition among various fruits showed that among macronutrients, carbohydrates were found in the highest amounts in orange peel, proteins in grapefruit pulp, and fats in the lemon pulp, fiber in grapefruit peel, and ash in orange peel (Table 1).**

**Table 2 indicates the phytochemistry of fruit peels and pulps. Antioxidant, total phenol content, and chelating activity were found to be highest in lemon peels (Table 2). The mean scores of antioxidant activity of lemon peels (M=97.91±0.47), orange peels (M=82.48±0.36), and grapefruit peels (M=73.29±0.16) were greater than lemon pulps (M=82.63±0.37), orange pulps (M=74.59±0.26), and grapefruit pulps (M=69.61±0.47) which shows that citrus fruits peels have greater antioxidant activity than their pulps. It was also revealed that mean scores of total phenol content of lemon peels (M=68.46±0.30), orange peels (M=62.55±0.31) and grapefruit peels (M=30.33±0.28) are greater than lemon pulps (M=34.20±0.20), orange pulps (M=28.64±0.35), and grapefruit pulps (M=25.69±0.18) showing that citrus fruits peels have higher total phenol content than their pulps. Similarly, the mean scores of chelating activity of peels and pulps indicate significantly higher activity in peels (L= 60.93±0.65; O=32.07±0.47; G=**

**29.00±1.05) as compared to pulps (L= 55.80±0.51; O=24.97±0.83; G= 22.85±0.96) as shown in Table 2.**

**Table 1 Proximate analysis of selected citrus fruits per 100gm**

| Components (g) | Lemon pulp M±S.D | Lemon peel M±S.D | Orange pulp M±S.D | Orange peel M±S.D | Grapefruit pulp M±S.D | Grapefruit peel M±S.D | *ANOVA* *F ( 5,13)* | P |
|---|---|---|---|---|---|---|---|---|
| **Energy (kcal)** | 34.53 ±0.51[a] | 47.6 ±0.53[b] | 47.55 ±0.25[b] | 97.20 ±0.20[c] | 42.73 ±0.25[d] | 22.44 ±0.22[e] | 15625.83 | <.001 |
| **Moisture (g)** | 88.53 ±0.31[a] | 0.00 ±0.00[b] | 87.21 ±0.23[c] | 0.00 ±0.00[b] | 89.72 ±0.34[d] | 0.00 ±0.00[b] | 164776.26 | <.001 |
| **CHO (g)** | 8.46 ± 0.25[a] | 16.56 ±0.25[b] | 11.36 ±0.11[c] | 25.22 ±0.22[d] | 10.24 ±0.04[e] | 9.26 ±0.51[f] | 3775.32 | <.001 |
| **Protein (g)** | 0.70 ±0.10[a] | 1.08 ±0.07[b] | 0.93 ±0.04[c] | 1.08 ±0.07[b] | 1.14 ±0.04[d] | 0.00 ±0.00[e] | 141.16 | <.001 |
| **Fat (g)** | 0.77 ±0.04[a] | 0.33 ± 0.05[b] | 0.23 ± 0.04[c] | 0.21 ±0.01[c] | 0.12 ± 0.02[d] | 0.13 ± 0.05[d] | 95.89 | <.001 |
| **Fiber (g)** | 2.16 ±0.05[a] | 11.26 ±0.11[b] | 2.33 ±0.02[a] | 11.62 ±0.02[c] | 2.36 ±0.15[a] | 12.55 ±0.10[d] | 9608.11 | <.001 |
| **Ash (g)** | 0.41 ±0.01[a] | 0.59 ±0.03[b] | 0.45 ±0.01[a] | 0.82 ±0.02[c] | 0.32 ±0.01[d] | 0.42 ±0.01[a] | 240.55 | <.001 |

***Means with different letters within the same rows are significantly different from each other (p < 0.05).***

**Table 2 Antioxidant, Total Phenol Content and Chelating Activity of Citrus Fruits (N=6)**

| **Parameters** | **Citrus Fruits** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Lemon pulp M (SD)** | **Lemon peel M (SD)** | **Orange pulp M (SD)** | **Orange peel M (SD)** | **Grapefr uit pulp M (SD)** | **Grapefr uit peel M (SD)** | ***ANOVA*** **F(2,4)** | ***P*** |
| **Antioxidant** | 82.63[a*] (0.37) | 97.91[b] (0.47) | 74.59[c] (0.26) | 82.42[a] (0.36) | 69.61[d] (0.47) | 73.29[e] (0.16) | 2317.98 | *<0.001* |
| **TPC** | 34.20[a] (0.20) | 68.46[b] (0.30) | 28.64[c] (0.35) | 62.55[d] (0.31) | 25.69[e] (0.18) | 30.33[f] (0.28) | 13682.75 | *<0.001* |
| **FICA** | 55.80[a] (0.51) | 60.93[b] (0.65) | 24.97[c] (0.83) | 32.07[d] (0.47) | *22.85[e] (0.96)* | *29.00[f] (1.05)* | 1354.82 | *<0.001* |

*Means with different letters within the same rows are significantly different from each other (p < 0.05).

Pearson Product Moment Coefficient of Correlation (Table 3) was calculated to find the relationship of DPPH with TPC and chelating property. No significant correlation was found in any of the six variants of samples studied.

**Table 3 Pearson correlation between antioxidant activity, iron chelating activity and total phenolic contents of Peels and Pulps of selected citrus fruits**

| **Correlation** | **Lemon pulp r(p)** | **Lemon peel R(p)** | **Orange pulp r(p)** | **Orange peel r(p)** | **Grapefruit pulp r(p)** | **Grapefruit peel r(p)** |
|---|---|---|---|---|---|---|
| **DPPH and TPC** | -.269 (.827) | .697 (.509) | .527 (.647) | -.500 (.667) | 1.000 (.014) | 0.074 (.953) |
| **DPPH and Chelating** | -.530 (.644) | .995 (.065) | .963 (.174) | .962 (.175) | .915 (.264) | .378 (.753) |

## DISCUSSION

**The present study was conducted to compare the nutritional composition, antioxidant activity, total phenol content, and chelating activity of peels and pulps of various indigenous citrus fruits.**

**Nutritional analysis of the dry weight of citrus fruits reported in Table 1 showed a difference in the proximate nutritional composition of peels and pulps with significantly higher fiber and ash contents in peels than pulps. Ash content obtained in orange peels was greater than lemon and grapefruit peels. These results were incomparable to the literature as no published data was available regarding the proximate analysis of peels and pulps of selected indigenous citrus fruits. Fruits and vegetables are generally considered a rich source of dietary fiber. Considering the health benefits of fibers, citrus fruit peels may serve as an important contributor to nutraceutical supplements or household usage. However, in this study, the detailed fiber assay was not run, therefore, the type of dietary fibers extracted could not be found. The DPPH assay is often used to evaluate the ability of antioxidants to scavenge free radicals which are known to be a major factor in biological damages caused by oxidative stress (Kim et al., 2013). In the current study, antioxidant activity was higher in lemon peels at 97.91% than orange at 82.42%, and grapefruit peels at 73.29%. Antioxidant activity in lemon pulps 82.63% was found to be greater than orange 74.59% and grapefruit pulps 69.61% (Table 2). Result reveals that antioxidant activity was significantly higher in lemon peels and pulps than in oranges and grapefruits peels and pulps. In all three citrus fruits, the antioxidant activity was significantly higher in citrus fruit peels than in pulps ($p< 0.05$). These results are following (Gorinstein et al., 2001) who also reported the same results that the highest antioxidant activity was in lemon peels and their peels in contrast to grapefruit peels and pulps which showed the lowest antioxidant activity ($p$ ranges < 0.01–0.05). Free radical scavenging activity, metal chelation, and total phenol content sum up the antioxidant potential of these citrus fruits (Lim et al., 2007).**

**In the current study, the maximum phenol compounds (68.46 mg GAE/100 g) were obtained from lemon peel followed by orange peel (62.55 mg GAE/100 g). The content of the studied phenol acids was significantly higher in lemon pulps and their peels than in oranges, grapefruits pulps, and peels, respectively. The results of the current study are per the findings of Gorinstein et al., (2001). The overall content of total phenols in citrus fruit peels was significantly higher than in citrus fruit pulps ($P< 0.05$ in all cases). These results are also supported by the findings of Belitz et al., (1999) and Moosavy et al. (2017).**

**The results of the present study also suggest that the peels of these three citrus fruits were slightly better sources of phenol compounds than their pulps. The bioactive compounds such as phenol compounds are responsible for the valuable antioxidant potential of citrus fruit extracts and these are regarded as health beneficial constituents (Al-Juhaimi & Ghafoor, 2013; AL-Juhaimi et al., 2014). The use of phenol has also been reported for lowering and preventing obesity and prevention oxidative stress (Dalar et al., 2014).**

**Table 2 reveals that lemon peels and pulps had the highest ferrous ion chelating activity (FICA) at 60.93% and 55.80% as compared to grapefruit peels and pulps 29.00% and 22.85% which showed the lowest concentration of FICA. Considering that no data of a similar type is currently available from the literature, it is not possible to compare these findings with other reports.**

**The correlation between total phenol contents and antioxidant activity has been widely studied in different foodstuffs such as fruit and vegetables (Hashemi et al., 2017; Moosavy et al. 2017; Chen et al., 2019). The study at hand analyzed that there was no correlation between antioxidant activity and the total phenol contents of the selected citrus fruits except grapefruit pulp. In general, extracts with a high antioxidant activity show a high phenol content as well but in the present study, a direct correlation between antioxidant activity and phenol content of the selected samples has not been found by Pearson Product Moment Analysis. This lack of relationship is in agreement with other literature (Ghasemi et al., 2014).**

**In contrast to the above findings, it also has been reported that the higher the total phenol content, the greater is the antioxidant activity (Liu et al., 2018). A striking correlation between total phenol and antioxidant capacity of citrus extracts was noted by Ramful et al., (2010). They reported that the extracts with the highest phenol contents had the highest antioxidant potential while the extracts characterized by low total phenol levels exhibited poor antioxidant capacities. These results are also following others who indicated that peels are an important source of phenol (Bocco et al., 1998). Correlation between antioxidant activity and total phenol content was also in partial disagreement between different studies.**

**Differences in results in many pieces of research might be due to various factors such as genotypic differences, geographical and climatic conditions, cultural practices, harvest time, and extraction methods amongst others (Łysiak, Michalska-Ciechanowska, & Wojdyło, 2020).**

**The difference in nutritional as well as the non-nutritional composition of pulps and peels help the consumers, industrialists, and health professionals to shift their focus from the pulp towards peels which are not usually considered edible. Peels of citrus fruits, owing to their functional properties, can function as an economical alternative to many nutraceutical preparations used for health promotion.**

## CONCLUSION

**The findings of the present study show that citrus fruits are a rich source of nutrients as well as phytochemicals. The peels of citrus fruits can serve as better sources of antioxidant, phenol, and chelating properties. This opens future research directions for the promotion and utilization of citrus peels by individual consumers as well as food and nutraceutical industries. Through this approach, in addition to the optimization of health benefits of these phytochemicals, waste management of citrus peels can also be achieved.**

## REFERENCES


Al-Juhaimi, F. Y., & Ghafoor, K. (2013). Bioactive compounds, antioxidant and physicochemical properties of juice from lemon, mandarin, and orange fruits cultivated in Saudi Arabia. Pak. J. Bot, 45(4), 1193-1196.

Al-Juhaimi, F.Y. (2014). Citrus fruits by-products as sources of bioactive compounds with antioxidant potential. Pak. J. Bot, 46(4): 1459-1462.

Association of Analytical Chemists. (2012) Official Methods of Analysis of AOAC International. Virginia, USA: Association of Analytical Chemists.

Bocco, A., Cuvelier, M.E., Richard, H., and Berset, C. (1998). Antioxidant activity and phenolic composition of citrus peel and seed extracts. Journal of agricultural and food chemistry, 46(6):2123-2129.

Chen, G. L., Fan, M. X., Wu, J. L., Li, N., & Guo, M. Q. (2019). Antioxidant and anti-inflammatory properties of flavonoids from lotus plumule. Food Chemistry, 277, 706-712.

Dalar, A., and Konczak, I. (2013). Phenolic contents, antioxidant capacities, and inhibitory activities against key metabolic syndrome relevant enzymes of herbal teas from Eastern Anatolia. Industrial Crops and Products, 44: 383-390.

Ghasemi Pirbalouti, A., Siahpoosh, A., Setayesh, M., and Craker, L. (2014). Antioxidant activity, total phenolic, and flavonoid contents of some medicinal and aromatic plants used as herbal teas and condiments in Iran. Journal of medicinal food, 17(10), pp.1151-1157.

Gorinstein, S., Martín-Belloso, O., Park, Y.S., Haruenkit, R., Lojek, A., Ĉíž, M., Caspi, A., Libman, I. and Trakhtenberg, S. (2001). Comparison of some biochemical characteristics of different citrus fruits. Food Chemistry, 74(3): 309-315.

Hashemi, S. M. B., Khaneghah, A. M., Barba, F. J., Nemati, Z., Shokofti, S. S., & Alizadeh, F. (2017). Fermented sweet lemon juice (Citrus limetta) using Lactobacillus Plantarum LS5: Chemical composition, antioxidant and antibacterial activities. Journal of Functional Foods, 38, 409-414.

Ke, J.Y., Kliewer, K.L., Hamad, E.M., Cole, R.M., Powell, K.A., Andridge, R.R., Straka, S.R., Yee, L.D., and Belury, M.A. (2015). The flavonoid, naringenin, decreases adipose tissue mass and attenuates ovariectomy-associated metabolic disturbances in mice. Nutrition & metabolism, 12(1): 1

Kim, M.Y. (2013). Free radical scavenging and ferrous ion chelating activities of citrus fruits derived from induced mutations with gamma irradiation. Life Sci J, 10: 401-3.

Kumaran, A., & Karunakaran, R. J. (2007). In vitro antioxidant activities of methanol extracts of five Phyllanthus species from India. LWT-Food Science and Technology, 40(2), 344-352.

Lim, Y.Y., Lim, T.T., and Tee, J.J. (2007). Antioxidant properties of several tropical fruits: A comparative study. Food Chemistry, 103(3): 1003-1008.

Liu, Y., Chen, H., Chen, W., Zhong, Q., Zhang, G., & Chen, W. (2018). Beneficial effects of tomato juice fermented by Lactobacillus Plantarum and Lactobacillus casei: Antioxidation, antimicrobial effect, and volatile profiles. Molecules, 23(9), 2366.

Łysiak, G. P., Michalska-Ciechanowska, A., & Wojdyło, A. (2020). Postharvest changes in phenolic compounds and antioxidant capacity of apple cv. Jonagold growing in different locations in Europe. Food Chemistry, 310, 125912.

Moosavy, M. H., Hassanzadeh, P., Mohammadzadeh, E., Mahmoudi, R., Khatibi, S. A., & Mardani, K. (2017). Antioxidant and antimicrobial activities of essential oil of Lemon (Citrus limon) peel in vitro and a food model.

Journal of food quality and hazards control, 4(2), 42-48.
Parashar, S., Sharma, H., and Garg, M. (2014). Antimicrobial and antioxidant activities of fruits and vegetable peels: A review. Journal of Pharmacognosy and Phytochemistry, 3(1).
Ramful, D., Bahorun, T., Bourdon, E., Tarnus, E., and Aruoma, O.I. (2010). Bioactive phenolics and the antioxidant propensity of flavedo extracts of Mauritian citrus fruits: Potential prophylactic ingredients for functional foods application. Toxicology, 278(1): 75-87.
Wolfe, K., Wu, X., and Liu, R.H. (2003). Antioxidant activity of apple peels. Journal of agricultural and food chemistry, 51(3): 609-614.
Zhang, H., Xi, W., Yang, Y., Zhou, X., Liu, X., Yin, S., Zhang, J., and Zhou, Z. (2015). An on-line HPLC-FRSD system for rapid evaluation of the total antioxidant capacity of Citrus fruits. Food Chemistry, 172: 622-629.
Zou, Z., Xi, W., Hu, Y., Nie, C., and Zhou, Z. (2016). Antioxidant activity of Citrus fruits. Food Chemistry, 196: 885-896.