



Assessment of Biochemical Components, Mid-Infrared Fingerprints and X-Ray Diffraction Patterns of Ripe and Raw Papaya Fruit Parts

Sailendra Kumar, Anamta Rizvi and Sangeeta Saxena*

Department of Biotechnology, Babasaheb Bhimrao Ambedkar University, Lucknow-226 025, India

*E-mail: dr_sangeeta_saxena@yahoo.com

Abstract: The comparative investigations between ripe and raw papaya fruit pulp, peel and seeds extracts were done including qualitative analysis of bioactive components, morphological analysis and element profile. Alkaloids, polyphenols, tannins and flavonoids were examined in all the papaya samples. Mid-infrared spectroscopy revealed a wide range of functional groups linked with phytochemicals belonging to diverse types of organic chemicals, including alkaloids, polyphenols, amino acids, sulphur, and nitrogen compounds. X-ray diffraction patterns of both ripe and raw pulp extracts showed their amorphous nature. Peel extract of ripe papaya and seed extracts of both ripe and raw papaya showed crystalline nature. Further, the microscopic analysis at 1000X magnification showed reduced tissue integrity in ripe papaya tissues. Additionally, the higher percentage of sodium, phosphorus and potassium were observed in raw papaya pulp. On the contrary, magnesium and sulphur were found in higher concentrations in ripe papaya pulp.

Keywords: Papaya, Fourier transform infrared spectroscopy, Energy dispersive X-ray spectroscopy, X-ray diffraction

The *Carica papaya* is one of the plants with great human health attributes. Although, it is native to Southern Mexico and Central America, it is a popular crop grown all over the world in majorly in tropical and sub-tropical climates. India is the largest producers of papaya followed by Dominican Republic and Mexico. According to Food and Agriculture Organization (FAO), 13.8 million metric tonnes was total annual production of papaya in the world in year 2022 and India alone contributed approx. 38% of the total world production (FAOSTAT, 2024). Papaya fruit contains substantial amounts of vitamins (A, B-complex, C, E and K), minerals, carbohydrates, dietary fiber, lipids and other bioactive phytochemicals. The vitamins-A, C and K provide the fruit excellent antioxidant properties (Nayak et al., 2007, Aravind et al., 2013). Papaya seeds contain phenolic compounds such as glucosinolates, cryptoxanthin carotenoids and isothiocyanates and among fatty acids oleic acid, palmitic acid, linoleic acid are the major constituents (Kermanshai et al., 2001, van Breemen and Pajkovic 2008). The leaves are rich in dietary fiber, polyphenols including, flavonoids, tannins, saponins, anthocyanins and isothiocyanates (Vuong et al., 2013). Besides these key elements, papaya also contains papain a proteolytic enzyme that helps in digestion, treatment of traumatized tissues, sport injuries and allergies (Vij and Prashar 2015). Some studies have also investigated the presence of other industrially important proteolytic enzymes such as chymopapain that also possess anti-viral, antibacterial, antifungal, anti-malarial (Bhat and Surolia 2001, Vij and

Prashar 2015). The parts of the whole *Carica papaya* plant such as leaves, roots, fruits, stem and seeds contain important bioactive phytochemicals which may exert various therapeutic effects and can be used as biomedicines. The present study aims to characterize the various parts of papaya fruits including, pulp, peel and seeds of both raw and ripened forms. In addition to the biochemical analysis, microscopic and spectroscopic analysis including mid-infrared spectroscopy (FT-IR), X-ray diffraction (XRD) and energy dispersive X-ray spectroscopy (EDS) were also performed. With a particular emphasis on spectroscopic and microscopic features, the work offers insights on biochemical paradigms that could be useful for future research.

MATERIAL AND METHODS

Fruit collection and extract preparation: Ripe and raw papaya fruits were collected from the local market (26°46'N, 80°55'E), peeled off and sliced into smaller pieces and kept for drying. The dried papaya pulp slices were then ground with mortar and pestle to prepare fine powder and stored. 20 grams of air-dried powders of ripe and raw papaya fruits were soaked in 200 mL of 80% methanol solution (v/v). The prepared suspensions were then homogenized and sonicated (LABMAN Probe Sonicator PRO650) so that most of the phytochemicals can be extracted in the solvent. The prepared suspensions were then kept for 72 hours in shaking incubator for the proper extraction of phytochemicals into the solvent. After 72 hours the prepared suspensions were filtered using grade 1 Whatman qualitative filter papers and

collected the filtrates in fresh vessel. The collected filtrates were then subjected to evaporation in a rotary vacuum evaporator. Then dried extracts were collected and stored at -20°C for further analyses (More and Makola 2020).

Qualitative tests for the presence of bioactive components: The presence of alkaloids, tannins, flavonoids and phenols in the prepared papaya extracts was determined by previously described methods (Ugochukwu et al., 2013, Auwal et al., 2014, Ramya et al., 2015, Pena et al., 2023). The presence of glycosides, steroids and proteins was determined by using previously described methods (Chaudhary et al., 2010).

Evaluation of functional groups through Fourier transform infrared (FT-IR) spectroscopy: Determination of the nature of chemical bonds and probable functional groups that may in turn correlate to the probable phytochemicals/secondary metabolites in PFEs was done by Fourier transform infrared FT-IR spectroscopic analysis. Each powdered extract was independently mixed with potassium bromide (KBr in 1:10 ratio) in mortar and pestle and gently macerated. The mixtures were then palleted by using a hydraulic press. The translucent pallets were used to read and record the absorption spectra in mid infra-red region from wave number $4000-400\text{ cm}^{-1}$ (Sharif et al., 2022) (Model: Nicolet TM 6700, Thermo Fisher Scientific, USA).

Assessment of X-ray diffraction patterns: X-ray diffraction patterns were analysed to determine the amorphous or crystalline nature of the papaya samples. X-ray diffractometer (Bruker, D8 Advance Eco, Germany) was used to analyse the samples. The samples were measured between 10° and 50° angles (2θ) with 0.02° step size. The papaya samples were analysed at a rate of 1 step/second.

Scanning electron microscopic (SEM) examination and energy dispersive X-ray diffraction analysis: For the morphological and elemental analysis, scanning electron microscopy (SEM) and energy dispersive X-ray spectroscopy (EDS) were performed respectively. For sample preparation, fresh ripe and raw papaya fruits were washed, peeled off and sliced. The fresh papaya peels and pulps were cut into smaller pieces. For SEM and EDS analysis, the smaller slices of papaya pulp, peel and seeds were dipped into 2.5% glutaraldehyde solution and kept at 4°C for primary fixation, for at ~ 5 hours. Then to remove the primary fixative, the slices were washed thrice with 0.1M phosphate buffer for 15 minutes each at 4°C . Further the slices were dipped in 1% osmium tetrachloride solution for 2 hours. Again, washed with 0.1M phosphate buffer thrice (15 minutes each). The thin papaya flesh and peel slices were then sequentially dehydrated by dipping in 30, 50, 70, 90 and 95% (v/v) and absolute acetone for 30 minutes in each of the

given concentration of acetone (Rizvi et al., 2024). The prepared dehydrated slices were then mounted on black carbon tape on aluminium stubs and kept in vacuum desiccator for further dehydration. The prepared slices were then kept in sputter coater for coating with platinum to make the samples conductive (Auto Fine Coater, JFC 1600, JEOL, Japan). Papaya peels and pulps were visualized by scanning electron microscope (JEOL JSM 6490 LV, Tokyo, Japan) at 1000X magnification.

RESULTS AND DISCUSSION

Biochemical components: Alkaloids, tannins, proteins, flavonoids and phenols were identified in pulp, peels and seeds of both ripe and raw papaya fruit. Glycosides were observed in every part of ripe papaya but in case of raw papaya fruit glycosides were only in peels. Terpenoids were in both ripe and raw papaya fruits except raw papaya peels. Plant based bioactive compounds have great biochemical significance including various medicinal properties. Alkaloids, tannins, terpenes, flavonoids, phenols and glycosides possess various health benefits and therapeutic effects against critical diseases (Table 1).

Annotation of Fourier transform infrared (FT-IR) peaks: Absorbance of the papaya samples were measured and all potent peaks were labelled (Fig. a-c). In ripe papaya pulp, peel and seeds 11, 11 and 12 peaks were observed in mid-infrared region respectively. In raw papaya pulp, peel and seeds exhibited 10, 9 and 10 significant peaks respectively in mid-infrared region (Table 2). The functional groups were assigned to all detected FT-IR peaks corresponding to the range they fell in (AM 2014, Singh et al. 2022). Most of the spectral peaks of both ripe and raw papaya samples were falling in the same spectral ranges but with different absorption intensities. The most prominent peaks of both ripe and raw papaya fruit samples were falling in $3550-3200\text{ cm}^{-1}$ range indicating O-H stretch and in turn the presence of alcohols or phenols. Each of the papaya sample was observed to have at least one spectral peak in $3300-2500$ and $3000-2800$ range indicating the presence of O-H stretch of carboxylic acid and N-H stretch of amine salts respectively. These ranges might be indicating the presence of amino acids in all the papaya samples. Peaks observed between $2000-1650$ and $1750-1735\text{ cm}^{-1}$ corresponded to the tentative presence of aromatic compounds and esters respectively. Between $1550-1500\text{ cm}^{-1}$, 1543.3 was the only peak in ripe papaya seeds which was corresponding to the presence of nitro compounds in the seeds. In range $1662-1626$, $1650-1600$ and $1650-1566\text{ cm}^{-1}$ alkenes, conjugated alkene and cyclic alkenes were predicted, respectively. Carboxylic acids and alcohols were further predicted in $1440-$

1395, 1420-1330 cm^{-1} range. Fluoro compounds with C-F stretch and amines with C-N stretch were predicted in all the samples between 1400-1000 and 1250-1020 cm^{-1} range respectively. The absorbance in the range of 1070-1030 indicated the presence of S=O stretch that might be related to presence of sulphoxides in the samples. Although no peak was observed in ripe papaya seeds in this range, 921.1 was the only peak observed between 950-910 cm^{-1} in ripe papaya pulp that corresponded to O-H bend related to carboxylic

acids. The fingerprinting regions of both ripe and rawpapayapulp, peel and seeds indicated the presence of C-Cl stretch (850-550), C=C bend (840-790) and C-Br stretch (690-515) and in turn the presence of halo-compounds and alkenes (Sharif et al., 2022, Singh et al., 2022). The absorption intensity of peaks in the papaya samples were different but most of them were falling in similar spectral ranges indicating the presence of similar kind of functional groups but in different concentrations.

Table 1. Presence of bioactive compounds in ripe and raw papaya pulp, peel and seeds

| Bioactive components | Ripe papaya | | | Raw papaya | | | Biochemical activities |
|----------------------|-------------|------|------|------------|------|------|---|
| | Pulp | Peel | Seed | Pulp | Peel | Seed | |
| Alkaloids | + | + | + | + | + | + | Cardioprotective, anti-inflammatory, anti-cancerous (Heinrich et al., 2021) |
| Glycosides | + | + | + | - | + | - | Cardioprotective, antithrombotic, analgesic, antidiabetic (Khan et al., 2021) |
| Steroid | + | + | + | + | - | + | Antiseptic, anti-plasmodial, antimalarial, anti-cancerous (Cox-Georgian et al., 2021) |
| Tannins | + | + | + | + | + | + | Antimicrobial (Farha et al., 2021) |
| Flavonoids | + | + | + | + | + | + | Cardioprotective, anti-inflammatory, antiviral, antioxidant, anti-cancerous, neuroprotective (Ullah et al., 2021) |
| Phenols | + | + | + | + | + | + | Antioxidant, anti-inflammatory, anti-hypertensive (Rana et al., 2021) |
| Proteins | + | + | + | + | + | + | Building blocks, enzymes |

- Absent, + Present

Table 2. Functional group annotation to the FT-IR spectral peaks of ripe and rawpapaya pulp, peel and seeds

| Frequencies observed (cm^{-1}) | | | | | | Range | Stretch / bend | Tentative functional groups |
|---|-------------------|-------------------|------------|-------------------|-------------------|-----------|--------------------|-----------------------------|
| Ripe papaya | | | Raw papaya | | | | | |
| Pulp | Peel | Seeds | Pulp | Peel | Seeds | | | |
| 3378.2 | 3418.0 | 3373.0 | 3411.3 | 3396.5 | 3407.6 | 3550-3200 | O-H stretch | Alcohol / phenol |
| 2927.5 | 2923.7, 2855.9 | 2924.9, 2855.4 | 2924.9 | 2923.0, 2855.9 | 2925.3, 2857.2 | 3300-2500 | O-H stretch | Carboxylic acid, |
| | | | | | | 3000-2800 | N-H stretch | Amine salts |
| 1738.0 | 1734.9 | 1744.8 | 1740.1 | 1735.2 | 1740.9 | 2000-1650 | C-H bend | Aromatic compound, |
| | | | | | | 1750-1735 | C=O stretch | Esters, δ -lactone |
| 1626.1 | 1635.7 | 1648.6 | 1632.6 | 1640.8 | 1633.2 | 1662-1626 | C=C stretch | Alkene, |
| | | | | | | 1650-1600 | C=C stretch | Conjugated alkene, |
| | | | | | | 1650-1566 | C=C stretch | Cyclic alkene |
| - | - | 1543.4 | - | - | - | 1550-1500 | N-O stretch | Nitro compounds |
| 1419.5 | 1418.3 | 1455.5, 1379.8 | 1419.6 | 1415.7 | 1412.6 | 1440-1395 | O-H bend | Carboxylic acid, |
| | | | | | | 1420-1330 | O-H bend | Alcohol, |
| | | | | | | 1500-1400 | C-C stretch | Aromatic compound |
| 1253.5 | 1319.2, | 1237.5, | 1244.0, | 1243.2, | 1244.4, | 1400-1000 | C-F stretch | Fluoro compound, |
| 1061.6 | 1238.5, 1065.3 | 1157.3, 1104.8 | 1063.8 | 1060.8 | 1060.2 | 1275-1200 | C-O stretch | alkyl aryl ether, |
| | | | | | | 1250-1020 | C-N stretch | Amine, |
| | | | | | | 1280-1240 | C-O stretch | Epoxides, |
| | | | | | | 1255-1240 | Skeletal vibration | t-butyl in hydrocarbons |
| 1061.6 | 1065.3 | - | 1063.8 | 1060.8 | 1060.2 | 1085-1050 | C-O stretch | Primary alcohol, |
| | | | | | | 1070-1030 | S=O stretch | Sulphoxide |
| 921.1 | - | - | - | - | - | 950-910 | O-H bend | Carboxylic acid |
| 820.9 | 777.6, | 614.7 | 819.4, | 608.9 | 774.3, | 850-550 | C-Cl stretch | Halo compound, |
| 775.4 | 610.4 | | 775.1, | | 605.5 | 840-790 | C=C bend | Alkene |
| 628.6 | | | 598.2 | | | 690-515 | C-Br stretch | Halo compound |

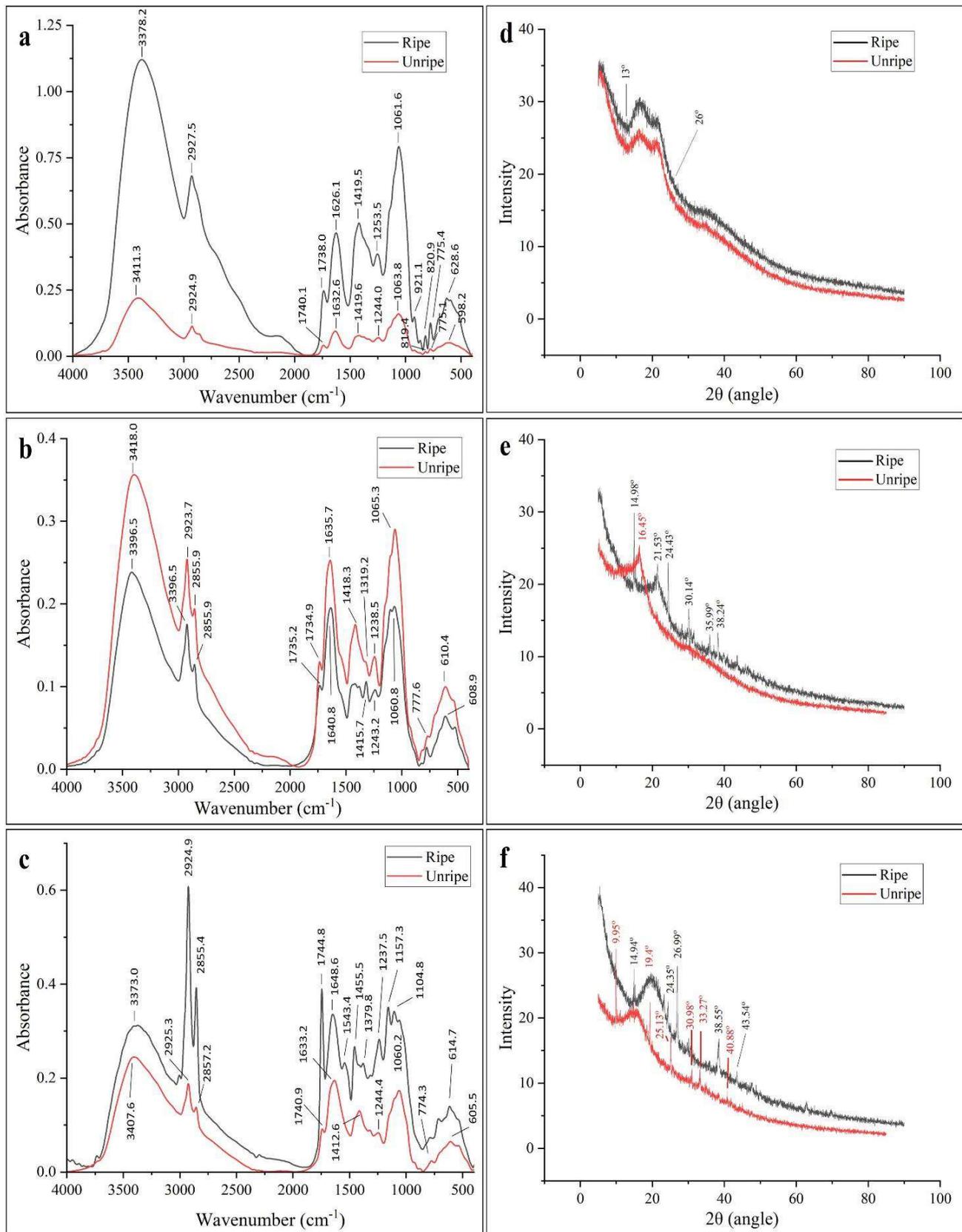


Fig. 1. Comparative analysis of mid-infrared spectra of ripe and raw papayapulp (a), peel (b), seed (c) and X-ray diffractograms of ripe and raw papaya pulp (d), peel (e) and seed (f)

Analysis of XRD: XRD determines the degree of crystallinity of a given sample and identifies its crystalline or amorphous characteristics. The diffractograms of ripe and raw papaya pulp showed “M” type patterns between 13° and 26° (Fig. 1d) with broad peaks indicating the high degree of amorphous structures present in them. Inverted “V” type pattern diffractograms were observed in both ripe and raw papaya peel. The XRD analysis of ripe papaya peel showed significantly sharp peaks at 14.98° and 24.43° depicting its slightly crystalline nature whereas the raw papaya peel extract showed a single broad peak at 16.45° showing its amorphous characteristics (Fig. 1e). “A” type pattern of diffractograms were observed in both ripe and raw papaya seed extracts with various sharp peaks between 10° and 50° (Fig. 1f). In ripe papaya seed extract sharp angles of diffraction were observed at 14.94° , 26.99° and 38.55° whereas in raw papaya seeds extract the diffraction angles were observed at 9.95° , 19.4° and 25.13° indicating the crystalline nature that might be induced by some specific compounds present in both seed samples. The sharp peaks that were observed in the samples might be due to the presence of starch as the crystalline nature of starch varies with the crystalline region and the crystal size (Kim et al., 2005). The crystal size depends on the angle of diffraction and the intensity. If the angle of diffraction is larger while intensity is smaller, the crystal size will be smaller (Singh et al., 2007).

SEM and EDS: Scanning electron micrographs of both ripe and raw papaya epicarp, mesocarp and seeds were obtained at 1000X magnification to analyze the fruit texture, morphological details and the changes during ripening were observed. No significant differences were observed in the image replicates of each sample. With maturity stages, the degradation of tissues becomes more progressive and apparent. Figure 2a shows loosely arranged parenchymatous cells in mesocarp (pulp) which however were compactly arranged of in epicarp (peel) of the ripe papaya (Fig. 2b). Loosely arranged cells having flaky structures were seen in SEM micrographs of ripe papaya seeds (Fig. 2c). Ripe papaya pulp showed less flaky structures than the raw one. Distinguishable cellular structures were seen in mesocarp of raw papaya (Fig. 2d), however cellular structures in ripe papaya pulp were not distinguishable and the reduced cellular integrity indicated the reduction in firmness of the pulp. In raw papaya peel, cells were densely arranged showing a high degree of compactness (Fig. 2e). The parenchymatous tissues in ripe papaya became loosely arranged and softened that might be occurred due to the degradation of middle lamella that is made up of magnesium pectate and hence the level of magnesium was observed to be high in ripe papaya as it was freely available and detected through EDS. However, in raw papaya pulp, cells were densely arranged showing a specific compactness and membrane integrity (de Oliveira and

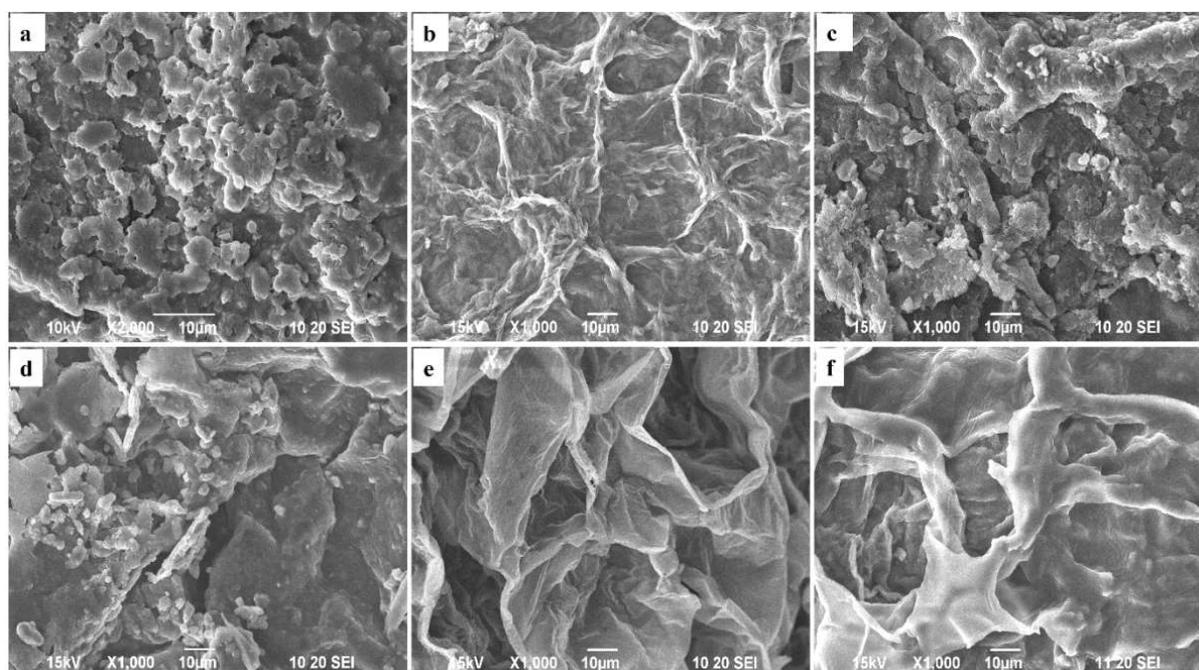


Fig. 2. Scanning electron micrographs of ripe papaya pulp (a), peel (b), seed (c) and raw papaya pulp (d), peel (e) and seed (f)

Vitória 2011, Lara-Abia et al., 2021). The tissues of raw papaya seeds were seemed to be compact with large intercellular spaces (Fig. 2f). The loss of cellular integrity and large intercellular spaces werereported in apple (Quiles et al., 2004) and persimmons (Salvador et al., 2007) during ripening stages.

Energy dispersive X-ray spectroscopy (EDS) is a quantitative analysis which identifies inorganic elements present in a targeted area in the prepared samples in the form of peaks. The peak height increases with the increase in concentration of the elements present. The EDS revealed the richness of ripe papaya pulp in magnesium and sulphur

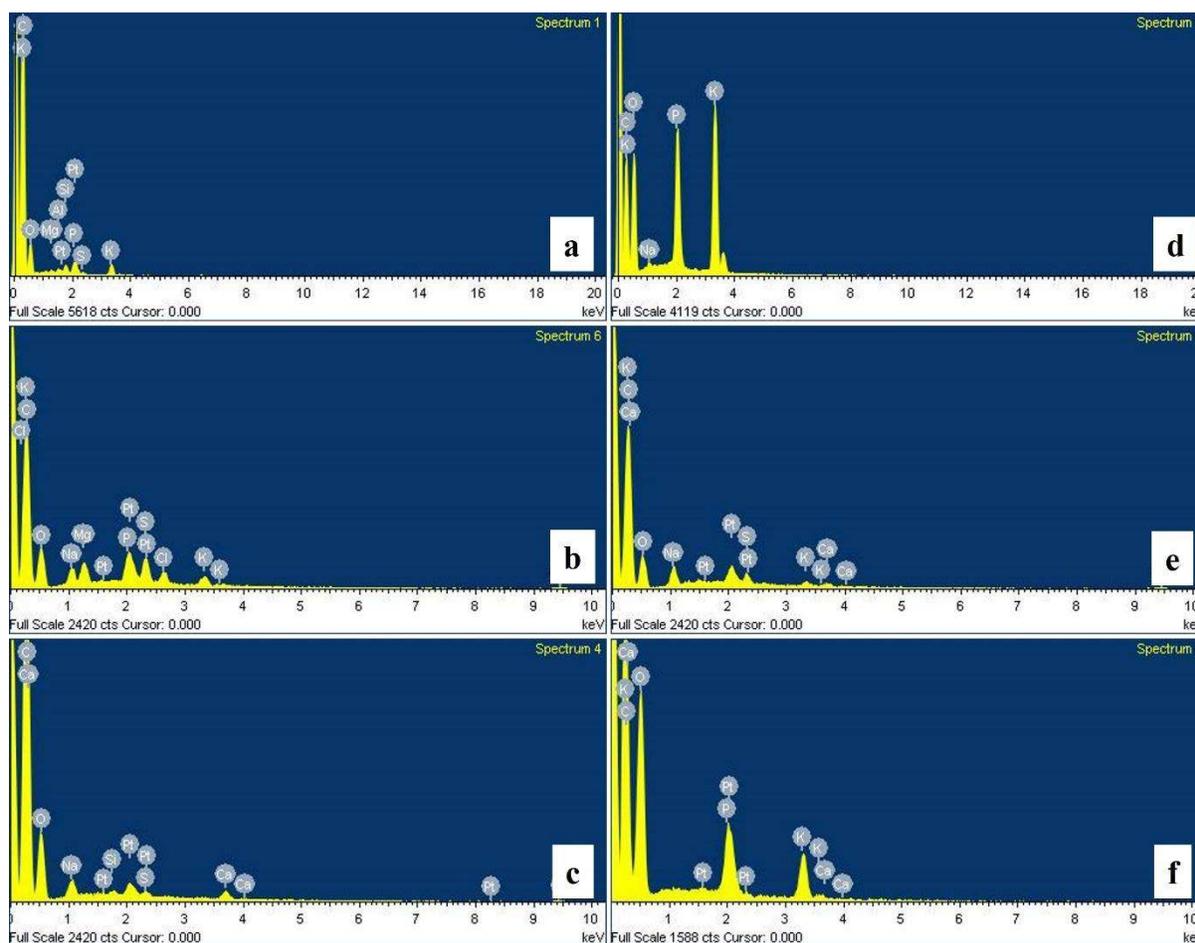


Fig. 3. Energy dispersive X-ray spectra of ripe papaya pulp (a), peel (b), seed (c) and raw papaya pulp (d), peel (e), seed (f)

Table 3. Weight percentage of elements present in ripe and raw papaya fruit pulp, peel and seeds

| Elements (weight %) | Ripe papaya | | | Raw papaya | | |
|---------------------|-------------|-------|-------|------------|-------|-------|
| | Pulp | Peel | Seed | Pulp | Peel | Seed |
| Carbon (C) | 64.19 | 58.60 | 66.17 | 23.74 | 56.51 | 37.19 |
| Oxygen (O) | 29.90 | 27.85 | 30.31 | 52.10 | 32.93 | 54.14 |
| Sodium (Na) | ND* | 1.99 | 1.25 | 0.41 | 3.63 | ND* |
| Phosphorus (P) | 0.80 | 1.80 | ND* | 9.05 | ND* | 2.03 |
| Potassium (K) | 1.53 | 1.03 | ND* | 14.70 | 0.61 | 2.76 |
| Magnesium (Mg) | 0.27 | 1.92 | ND* | ND* | ND* | ND* |
| Sulphur (S) | 0.19 | 2.43 | 0.26 | ND* | 1.53 | ND* |
| Chloride (Cl) | ND* | 1.26 | ND* | ND* | ND* | ND* |
| Calcium (Ca) | ND* | ND* | 0.52 | ND* | 0.65 | 0.04 |

ND* is not detected

contents (0.27 and 0.19% respectively) than that of raw papaya (Fig. 3a). Higher level of sulphur in ripe papaya fruit pulp might be due the degradation of various structural proteins via denaturation of their disulphide bonds and thus making it freely available. Although in raw papaya, elements like potassium, phosphorus and sodium (14.70, 9.05, 0.41% respectively of total weight percentage) were present in higher concentrations (Fig. 3d). The EDS spectra of ripe papaya peel (Fig. 3b) showed the presence of potassium and sulphur in higher concentration than the raw papaya peel (Fig. 3e). However, sodium was in higher concentrations in raw papaya. Additionally, phosphorus, magnesium and chlorine were detected in ripe papaya although calcium was not detected which was present in raw papaya peel. Sodium and sulphur were present in ripe papaya seeds (Fig. 3c) whereas these elements were not detected in raw papaya seeds (Fig. 3f). Phosphorus and potassium were in higher concentrations in raw papaya seeds but not detected in ripe papaya seeds. Although calcium was detected in ripe papaya seeds but not in raw papaya seeds. During preparing the samples for SEM-EDS analysis the samples were subjected to platinum coating in the sputter coater and that why the peaks of platinum (Pt) can be seen in the EDS spectra (Table 3).

CONCLUSION

The present study showed the presence of bioactive components in ripe and raw papaya samples. However, in raw papaya pulp and seeds glycosides were not detected. The FT-IR analysis also showed the occurrence of similar kind of functional groups in both ripe and raw papaya samples but in different concentrations. The XRD analysis showed the amorphous nature of pulp extracts whereas the crystalline nature of seeds extracts of both ripe and raw papaya. SEM analysis showed the gradual change in the morphology of pulp, peel and seeds during ripening of the fruit. The elemental profile of the both papaya fruits' pulp, peel and seed revealed that occurrence of various elements in different weight percentage. Further analytical studies can identify the beneficial phytochemicals present in papaya. Morphological studies of the fruit at different ripening stages should be endorsed to understand its mechanism and then to hypothesize strategies to delay the fruit ripening and increase the shelf life of the fruit.

ACKNOWLEDGEMENTS

Authors would like to acknowledge Ministry of Social Justice and Empowerment for providing National Fellowship for Other Backward Classes (NFOBC) to Sailendra Kumar and Department of Science and Technology for providing

INSPIRE fellowship to Anamta Rizvi. We would also like to acknowledge Department of Biotechnology and University Sophisticated Instrumentation Centre (USIC), Babasaheb Bhimrao Ambedkar University for providing essential infrastructural and instrumentation facilities.

REFERENCES

- AM M 2014. Proximate analysis, antioxidant and antiproliferative activities of different parts of *Carica Papaya*. *Journal of Nutrition & Food Sciences* **4**(2): 1000267.
- Aravind G, Bhowmik D, Duraivel S and Harish G 2013. Traditional and medicinal uses of carica papaya. *Journal of Medicinal Plants Studies* **1**(1): 7-15.
- Auwal MS, Saka S, Mairiga IA, Sanda KA, Shuaibu A and Ibrahim A 2014. Preliminary phytochemical and elemental analysis of aqueous and fractionated pod extracts of *Acacia nilotica* (Thorn mimosa). *Veterinary Research Forum* **5**(2): 95-100.
- Bhat GP and Suroliya N 2001. In vitro antimicrobial activity of extracts of three plants used in the traditional medicine of India. *American Journal of Tropical Medicine and Hygiene* **65**(4): 304-308.
- Chaudhary S, Negi A and Dahiya V 2010. The study of in vitro antimicrobial activity and phytochemical analysis of some medicinal plants in Chamoli Garhwal Region. *Pharmacognosy Journal* **2**(12): 481-485.
- Cox-Georgian D, Ramadoss N, Dona C and Basu C 2019. Therapeutic and medicinal uses of terpenes, In: *Medicinal Plants: From Farm to Pharmacy*, 333-359.
- de Oliveira JG and Vitória AP 2011. Papaya: Nutritional and pharmacological characterization, and quality loss due to physiological disorders: An overview. *Food Research International* **44**(5): 1306-1313.
- Farha AK, Yang QQ, Kim G, Li HB, Zhu F, Liu HY, Gan RY and Corke H 2020. Tannins as an alternative to antibiotics. *Food Bioscience* **38**: 100751.
- Heinrich M, Mah J and Amirkia V 2021. Alkaloids used as medicines: Structural phytochemistry meets biodiversity—An update and forward look. *Molecules* **26**(7): 1836.
- Kermanshah R, McCarry BE, Rosenfeld J, Summers PS, Weretilnyk EA and Sorger GJ 2001. Benzyl isothiocyanate is the chief or sole anthelmintic in papaya seed extracts. *Phytochemistry* **57**(3): 427-435.
- Khan H, Amin S and Patel S 2018. Targeting BDNF modulation by plant glycosides as a novel therapeutic strategy in the treatment of depression. *Life Sciences* **196**: 18-27.
- Kim EHJ, Xiao DC and Pearce D 2005. Effect of surface composition on the flowability of industrial spray-dried dairy powders. *Colloids and Surfaces B: Biointerfaces* **46**(3): 182-187.
- Lara-Abia S, Lobo-Rodrigo G, Welti-Chanes J and Pilar Cano M 2021. Carotenoid and carotenoid ester profile and their deposition in plastids in fruits of new papaya (*Carica papaya* L.) varieties from the Canary Islands. *Foods* **10**(2): 434.
- More GK and Makola RT 2020. In-vitro analysis of free radical scavenging activities and suppression of LPS-induced ROS production in macrophage cells by *Solanum sisymbriifolium* extracts. *Scientific Reports* **10**: 6493.
- Nayak BS, Pereira LP and Maharaj D 2007. Wound healing activity of *Carica papaya* L. In experimentally induced diabetic rats. *Indian Journal of Experimental Biology* **45**(8): 739-743.
- Pena DCM, Anguiano ACR, Casillas MC, Ramírez APV, Fonseca MMF, Armas MAD, Larroca ALC and Ramírez SFV 2023. Qualitative identification of secondary metabolites and determination of the toxicity of extracts obtained from the flower of *Kalanchoe Pinnata*. *Annals of Advances in Chemistry* **7**(1): 68-73.
- Quiles A, Hernando I, Pérez-Munuera I, Llorca E, Larrea V and

- Ángeles Lluch M 2004. The effect of calcium and cellular permeabilization on the structure of the parenchyma of osmotic dehydrated "Granny Smith" apple. *Journal of the Science of Food and Agriculture* **84**(13): 1765-1770.
- Ramya I, Arunadevi S and Vidhya A 2015. Screening of Phytochemicals and Testing the Antimicrobial Activity of Different Parts of *Erigeon* sp and its Essential Oil. *International Journal of Current Microbiology and Applied Sciences* **4**(8): 372-378
- Rana A, Samtiya M, Dhewa T, Mishra V and Aluko RE 2022. Health benefits of polyphenols: A concise review. *Journal of Food Biochemistry* **46**(10): e14264.
- Rizvi A, Kumar S, Sharma M, and Saxena S 2024. Functional and antioxidant potential of beetroot, mustard and radish microgreens using spectroscopic techniques. *Agriculture (Pol'nohospodarstvo)* **70**(2): 53-71.
- Salvador A, Arnal L, Besada C, Larrea V, Quiles A and Pérez-Munuera I 2007. Physiological and structural changes during ripening and destringency treatment of persimmon fruit cv. "Rojo Brillante." *Postharvest Biology and Technology* **46**(2): 181-188.
- Sharif M, Ansari F, Ul Hassan N, Sultana K and Ali Q 2022. Explore the antiproliferative phytochemicals from ethanolic extracts of *Citrus paradisi* against liver cancer cell line by chemical analysis using TLC and FT-IR spectroscopy. *Brazilian Journal of Biology* **82**: e256856.
- Singh L, Yadav N, Kumar AR, Gupta AK, Chacko J, Parvin K and Tripathi U 2007. Preparation of value added products from dehydrated bathua leaves (*Chenopodium album* Linn.). *Natural Product Radiance* **6**(1): 6-10.
- Singh PK, Singh J, Medhi T and Kumar A 2022. Phytochemical screening, quantification, FT-IR analysis, and in silico characterization of potential bio-active compounds identified in hr-lc/ms analysis of the polyherbal formulation from Northeast India. *ACS Omega* **7**(37): 33067-33078.
- Ugochukwu SC, Arukwe UI and Ifeanyi O 2013. Preliminary phytochemical screening of different solvent extracts of stem bark and roots of *Dennetiatripetala*. *Asian Journal of Plant Science and Research* **3**(3): 10-13.
- Ullah A, Munir S, Badshah SL, Khan N, Ghani L, Poulson BG, Emwas AH and Jaremko M 2020. Important flavonoids and their role as a therapeutic agent. *Molecules* **25**(22): 5243.
- van Breemen RB and Pajkovic N 2008. Multitargeted therapy of cancer by lycopene. *Cancer Letters* **269**(2): 339-351.
- Vij T and Prashar Y 2015. A review on medicinal properties of *Carica papaya* Linn. *Asian Pacific Journal of Tropical Disease* **5**(1): 1-6.
- Vuong QV, Hirun S, Roach PD, Bowyer MC, Phillips PA and Scarlett CJ 2013. Effect of extraction conditions on total phenolic compounds and antioxidant activities of *Carica papaya* leaf aqueous extracts. *Journal of Herbal Medicine* **3**(3): 104-111.