Chapter-7

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Carica papaya is an herbaceous plant that is renowned for its nutritional and culinary value, and it thrives in various regions globally. Different components of the plant contain enzymes, minerals, vitamins, alkaloids, phenolic compounds, and flavonoids, which contribute to its traditional and contemporary uses. Currently, the fruit of the papaya is utilized in the production of a range of processed items like jam, jelly, pickle, candied fruit, puree, concentrate, and canned slices or chunks. Following the extraction of the fruit pulp, the papaya peel and seeds are typically considered waste and discarded. Moreover, the discarded fruit peel has applications in food, pharmaceuticals, cosmetics, wastewater treatment, biofuel production, animal feed, and ceramics as a binder. However, our ongoing research indicates that the papaya peel contains valuable bioactive compounds that can be transformed into high-value products.Different novel extraction techniques were compared to identify the best method which extracts the bioactive components from the peel. The major finding of the study was that the total phenolic content was maximised when ultrasound-assisted extraction and enzyme pre-treatments were used together. On the other hand, enzyme was isolated using ATPS and after analyzing all the results, it was observed that 10% PEG 6000 along with 18% $(NH_4)_2SO_4$ gave a better extraction of papain enzyme from the papaya peel. It can be inferred that the papaya peel holds promise as a viable resource for functional food ingredients, and furthermore, it has the potential to undergo additional processing to create therapeutic functional food products.This study demonstrated the phenolic compound extract was a suitable, easy-to-use, and effective food product to deliver bioactive compounds when used for enrichment in spray-dried powder and isolated enzyme was used as meat tenderization.

Lastly, the elucidated idea of waste utilization is of practicality and viability, paving way to explore the untapped potential of industrial wastes and marketing these cheap value added sources as nutraceuticals to enhance human wellness.

From the study following inferences has been drawn:

1. Efficient extraction of polyphenols and antioxidant compounds from papaya peel was achieved using an eco-friendly technique, with significant operational factors being pretreatment and solvent type.
2. Kinetic experiments revealed that the E-W pretreatment yielded better results compared to other methods, and the data fitting using second order and Langmuir models showed excellent performance (R^2 = 0.9996).
3. Water was identified as an excellent solvent for extracting total polyphenols, aligning with the principles of green extraction. Ultrasonication was explored as a viable method to enhance extraction efficiency, resulting in improved kinetics and higher yields (98.90 mg GAE/100g) compared to non-ultrasound methods.
4. HPLC analysis confirmed the suitability of the phytochemical extract from papaya peel for food product development, highlighting its potential to enrich phytochemical compounds in other food products. Furthermore, the freeze-dried phytochemical compounds offer a potential source for the development of food products.
5. Aqueous two-phase system (ATPS) partitioning of papain from papaya peel was investigated, and a specific composition of 10% PEG 6000 and 18% $(NH_4)_2SO_4$ demonstrated the best results in terms of protease activity (1.43), purification factor (4.08).
6. A comparison was made between ATPS and conventional ethanol extraction techniques, revealing that ATPS exhibited higher protease activity compared to the conventional method.
7. The protease activity and protein content from the best ATPS condition were analyzed using SDS-PAGE and Gel Chromatography, which provided further evidence of the effectiveness of ATPS in extracting papain.
8. The spray drying process applied to juice samples had both positive and adverse effects on the quality and antioxidant activity of the final product. The physiochemical properties of spray-dried watermelon powder (SWP) were significantly influenced by drying temperature and maltodextrin concentration. Higher maltodextrin concentration and increased inlet/outlet temperature resulted in a significant decrease in lycopene content, which is an important indicator of antioxidant activity ($p \leq 0.05$).

9. Among the various drying conditions tested, juice dried at 140°C with 3% maltodextrin concentration yielded the best results compared to other dried powder variants. This combination of drying temperature and maltodextrin concentration was identified as the best condition for obtaining a high-quality SWP.
10. The best condition SWP was further enriched with a phytochemical extract from papaya peel (FPP). It was observed that the total phenolic content and antioxidant activity of the SWP increased with higher concentrations of FPP. This enrichment process enhanced the nutritional and functional properties of the powder.
11. Sensory evaluation indicated significant differences in taste, mouthfeel, and overall acceptance between the enriched SWP samples. Based on panel preferences, it was suggested that concentrations up to E3 (1.5%) of the phytochemical extract were acceptable for enrichment. Additionally, storing the powder under vacuum conditions could potentially improve its stability over time, ensuring a longer shelf life for the product.
12. Papain enzyme was extracted from ripe papaya peel using APTS (aqueous two-phase system) and utilized to enhance the tenderness of meat. The enzyme was found to significantly improve the functional properties of both chicken and mutton meat cuts when dipped in papain solution.
13. Texture profile analysis revealed that increasing the concentration of papain and the treatment duration resulted in a significant weakening of the meat structure. However, sensory evaluation indicated that a concentration of 0.05% papain was accepted for chicken meat cuts, while a concentration of 0.125% papain was preferred for mutton meat, as compared to the control samples. Notable differences in tenderness were observed ($p > 0.05$).
14. It is recommended to use papain doses as low as possible to avoid excessive tenderization and the production of meat with an overly soft structure and low resistance to mastication. Implementing this technology could benefit meat producers and processors by enabling them to produce meat products that meet consumer expectations.

The current study reveals that papaya peels, often discarded as waste, harbor a diverse range of bioactive compounds that can be extracted and utilized in various beneficial ways. The food industry recognizes the value of peels, appreciating their natural flavorings, dietary fiber content, and nutritional benefits. Extracting and utilizing bioactive compounds from peels not only brings economic value but also supports waste reduction and embraces a more circular approach to resource management. Among the extraction methods investigated, ultrasound proves to be highly efficient in extracting polyphenols, making it an appealing option for large-scale industrial processes involving papaya peel. The aqueous two-phase system (ATPS) stands out as a superior method for the separation and purification of papain enzyme, surpassing conventional techniques in terms of efficiency and effectiveness. The study further demonstrates the potential application of extracted bioactive compounds in the development of functional food, enhancing nutritional value and promoting health benefits and papain derived from papaya peel for meat tenderization, leveraging previous findings on protein breakdown in various meats. Papain, a potent protease, exhibits remarkable specificity in breaking down peptide bonds within proteins, resulting in enhanced meat tenderness, flavor, and juiciness.

Ultimately, this research highlights the underutilized potential of papaya peels and their bioactive compounds in the food industry, while also promoting sustainability and efficient resource utilization.

Future scope

The food industry is actively seeking prospects to create and market functional food products by utilizing valuable ingredients derived from by-products and waste of fruits and vegetables. This approach not only offers health advantages but also serves as a natural food additive to enhance the shelf life of food products. Moreover, the utilization of these resources helps alleviate the environmental pollution burden.

1. Further, to fully utilize papaya peel and commercialize food products with natural food additives, it is essential to conduct pilot plant trials for their complete valorization and simultaneously study consumer acceptability.
2. In addition, it is necessary to evaluate the bioaccessibility and bioavailability of the bioactive compounds present in the papaya peel through in vitro and in vivo studies.
3. The extracted papain enzyme can be used in the preparation of minced meat product such as kebab, meat balls, and sauces, for softening of meat.