Chapter-8

Summary, Conclusions and Future scope

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The study demonstrated the value addition of haritaki pulp extract encapsulated as a functional ingredient for the creation of a value-added product. Engineering properties of haritaki were calculated, which would be helpful in the design of instruments including hoppers, chutes, sorters, and grading machines for the fruits. The engineering properties are helpful in providing academics and enterprises with extensive knowledge for haritaki fruit post-harvest activities. From the findings, it can be inferred that while the rate of drying increased with temperature, the degradation of the phytochemicals also did so, and that temperature had the greatest impact on vitamin C. Therefore, the ideal drying temperature should be chosen based on the final quality requirements for a minimum drying time. To estimate the parameter of supercritical fluid extraction of phytocompounds from haritaki pulp, the ANN-GA was demonstrated to be a key instrument. The pulp obtained by combining microwave and ultrasound was subjected to SFE extraction and evaluated for pH and thermal stability, with bioactive characteristics decreasing as pH and temperature increased. This study demonstrated the encapsulated haritaki pulp extract was a suitable, easy-to-use, and effective food product to deliver bioactive compounds when used in functional yoghurt. The major finding of the study was that the total phenolic content was maximised when ultrasound and microwave treatments were used together. Nowadays, due to the increasing awareness of consumers and the demand for alternatives to synthetic ingredients, the encapsulated haritaki pulp extract could be a solution for the functional food, nutraceuticals, chemical, and pharmaceutical industries.

Following points of conclusions from the thesis are summarised below:

Chapter 1 presents a brief explanation of the many bioactive substances found in haritaki fruit and their pharmacological properties. It also goes into more detail about the many conventional and cutting-edge techniques used to extract the bioactive substances. The chapter also discusses several biopolymers used in the encapsulation of bioactive substances for food use in light of encapsulating methodologies. The chapters conclude by summarising the many functional foods used for various physiological aspects as well as the knowledge gap and justification for the study.

Haritaki is a versatile plant with a wide range of pharmacological and therapeutic properties, as summarised in Chapter 2. The unique source of a diverse spectrum of compounds with various chemical structures is this adaptable medicinal plant. It is a potent herbal remedy that is employed in the treatment of a number of diseases, including cancer. Additional pharmacological study is still required to properly comprehend how fruit can be employed as food additives, safety precautions, and nutraceuticals because of its amazing features and chemical composition. Equipment for the fruits, such as hoppers, chutes, sorters, and grading machines, will be designed using the calculated fruit engineering qualities. New technology-assisted extractions yield more bioactive chemicals than standard and unconventional extraction techniques. Combining cutting-edge technologies might make it easier to create extraction processes that are more physiologically active. There are many advantages, including comfort, safety, and speed. Heat-sensitive compounds can be extracted (at various solvent ratios). High extraction yields and high-quality extracts are the result of these features (with a high concentration of interesting compounds). In general, these methods may be used to extract caffeine, flavonoids, carotenoids, phenolic compounds, and a variety of other beneficial components.

Chapter 3 summarised that different mathematical models were used to fit the data, and it was discovered that approximation diffusion models fit the data the best. The activation energy was discovered to be 47.87 kJ/mol, and the drying rate constant "k" increased with increasing temperature, demonstrating the process's significant temperature sensitivity. Following first-order kinetics, phytochemicals degraded and changed colour, and the rate of decomposition accelerated with rising temperature. The higher "Ea" value for vitamin C indicates that it degraded faster during drying than TPC and TFC and was also more temperature dependent. The findings can be summarised as follows: whereas the rate of drying rose with temperature, the degradation of the phytochemicals also increased, and temperature had the greatest impact on vitamin C. The isotherms were type III according to BET classification. Over the range of water activity and study temperature, the Peleg model provided the best fit to the experimental sorption data.

Chapter 4 explores how, in terms of response prediction, the RSM model outperformed the ANN model. This was demonstrated by comparing the statistical characteristics of the two models. As a result, both RSM and ANN techniques are somewhat successful in anticipating answers, though performance varies depending on a variety of factors such as the precise process, the number of tests performed, the independent and dependent parameters used, and so on. Additionally, the RSM-DF, RSM-GA, and ANN-GA desirability functions and genetic algorithms were employed to optimise the SFE process using the RSM and ANN models. Additionally, in this instance, it was found that the RSM-DF and RSM-GA models performed better than the ANN-GA model, which was the goal of optimization. In conclusion, it can be said that both RSM and ANN models can be used to anticipate answers with a high degree of accuracy, but to achieve the best results, one must choose the right model for the job at hand. Similar to optimization, all of the approaches produced generally satisfactory results; nevertheless, each approach must be used in order to meet the unique requirements for optimization.

In chapter 5, various drying techniques and pre-treatments were used to investigate the bioactive components of haritaki pulp. Fresh haritaki pulp was employed for extra pre-treatment because the majority of the beneficial elements in haritaki pulp were severely reduced after drying. The highest bioactive properties are provided by the combination pre-treatment of ultrasound at 50% amplitude, microwave at 360 W, and enzyme at 400 U. Of all the pre-treatment techniques, microwave-assisted ultrasonic extraction extracts the most bioactive compounds. The amount of bioactive compounds extracted from haritaki is increased when ultrasound and microwave treatments are combined. The pulp produced by mixing microwave and ultrasound was extracted using SFE, and its pH and thermal stability were assessed. As pH and temperature rose, so did the level of bioactivity in the pulp.

Chapter 6 summarised that haritaki extract was successfully encapsulated employing the various starch and zein combination through freeze-drying. To encapsulate the bioactive molecule, various ratios of starch:zein were attempted. Based on yield, encapsulation effectiveness, and powder density, 100% starch encapsulations performed better than the other ratios. Encapsulates possessed a rough and erratic morphology, which was confirmed by the SEM study. The TGA investigation showed that the combination of 70% starch and 30% zein saw the most mass loss, while 100% zein experienced the least amount of mass loss. The greatest onset point and peak point were shown by 50:50 (starch:zein) encapsulates, while the minimum onset point and peak point were shown by 70:30 (starch:zein) encapsulates, according to DSC curves.100% starch encapsulates had the highest endpoint, whereas 30:70 (starch:zein) encapsulates had the lowest endpoint. According to FTIR spectra, 100% starch encapsulates had very little stretching and weak bond intensities, but 100% zein encapsulates exhibited maximum stretching and vibrations. There was no sharpness in the encapsulates other than 50:50, as shown by the XRD pattern (starch:zein). The chemical interaction of the composite wall components (starch and zein) in amorphous form resulted in the encapsulation of haritaki in microcapsules, as demonstrated by FTIR and XRD.

In Chapter 7, encapsulated haritaki extract and haritaki extract combined with guar gum had a significant effect on yoghurt quality attributes. Encapsulated haritaki extract showed improved phenolics and antioxidant activity when compared to haritaki extract, making it a better option for yoghurt fortification. According to the results of the physicochemical investigations, acidity rose and pH fell as storage duration increased. Yogurt containing (1.5%) guar gum exhibited syneresis, but it was shown that syneresis declined with increasing storage time. Yoghurt that had been supplemented with guar gum up to 0.5% was found to have sensory quality that was comparable to the control sample and, in some cases, even better. Guar gum had a concentration dependent effect on the rheology of the yoghurt. Based on these findings, fortified yoghurts would be of great interest to the pharmaceutical and functional food industries.

Future scope

1. The future scope of the present research would be to identify the chemical compounds affected by the drying treatment.
2. *In-vivo* study of a functional product to assess the physiological effects.
3. Assessment of the immuno-modulatory effect of the haritaki extract or isolated compounds.
4. The pharmaceutical and functional food businesses would be very interested in the technology of supercritical fluid extraction since it could be scaled up from laboratory to pilot scale for the extraction of bioactive components from haritaki fruit pulp. These encapsulations could be employed to create functional food products or as nutraceuticals.