VALUE ADDITION OF CULINARY BANANA (*MUSA* ABB)

ABSTRACT

The thesis primarily focuses value addition of culinary banana which is an underutilized vegetable of Assam, India having immense local importance. In the process the investigation aimed to identify the various nutritional and bioactive compounds present in pulp and peel at different stages of growth and development of the vegetable. Based on the highest activity of a particular chemical constituent during the growth of the vegetable, some of the compounds were isolated viz. starch from pulp, cellulose from peel and antioxidant from both pulp and peel. The starch isolated was further modified to resistant starch and incorporated into brown bread with the aim to deliver nutritionally rich vis-à-vis low glycemic index food. The study revealed that peel of culinary banana is a potential source of cellulose and therefore attempt was made to utilize the peel, which is otherwise considered as waste and discarded. High performance cellulose nanopaper was subsequently developed from the isolated cellulose of peel, adding high value to this agro-waste. Finally, the vacuum drying parameters for drying of culinary banana pulp and peel have been optimized using ANN/GA model, which might be useful for low moisture food industry where culinary banana could promote its industrialization as high valued flour. Moisture sorption isotherm of flour obtained at optimized condition and its antioxidant stability during storage have also been studied.

The thesis is divided into seven chapters which are briefly discussed below:

Chapter 1 highlights the general introduction about plantains and banana, its production and utilization. It covers the entire introduction of objectives and theme of the thesis regarding utilizing underutilized and neglected culinary banana of Assam which is having immense local importance. The glimpse on effect of vegetable growth and ripening on various biochemical attributes is also highlighted. The potential health benefits of this crop and its utilization in developing high value added functional foods is explained. It also highlights the potential of peel to be used in the field of nanotechnology. Preserving the active compounds present in banana by encapsulation or stability of its flour as a whole by drying is also focused. This chapter has been

supported by literature survey which consequently provides the aim of the work being presented, the objectives being set, and the prescriptions forwarded.

Chapter 2 presents the study on changes in biochemical and nutritional properties of culinary banana at various stages of maturity from 20 DAE (days after emergence of banana inflorescence) to 80 DAE. The amount of particular compound of interest at its optimum level at particular maturity stage has been identified, and the optimum stage for harvesting is also determined. The nutritional compositions significantly affected by various growth stages have been recorded. The study revealed that culinary banana has potential applications of developing number of value added products. The high amount of antioxidant present during early ripening stage makes culinary banana an excellent ingredient for developing high value added products enriched with bioactive compounds. Furthermore, it also concludes that an increased accumulation of starch rendered mature tissue a potential source for extraction (of starch) commercially, and also presence of considerable amount of amylose could help in developing products which can be subjected to high temperature.

Chapter 3 deals with the isolation, characterization and modification of culinary banana starch. It discusses about the isolation of starch and further modification into resistant starch (RS) using hydrothermal as well as debranching enzyme methods. The physicochemical characterization revealed that culinary banana starch is a mixture of A and B type polymorphs and functional groups present evinced typical bands of C-type starch with a mixture of spherical and elliptical granules. In partial replacement of wheat flour with resistant starch and culinary banana flour (KF) for developing brown bread revealed that replacement of wheat flour with 10% RS and 10% KF is the best combination from the standpoint of various quality parameters for making brown bread. The effect of fortification on quality attributes of brown bread suggests that incorporation of RS and KF up to 10% in substituting wheat flour resulted high quality attributes in the bread in terms of nutrients, yield, texture, colour and sensory analysis with highest score of consumer acceptance. The study justifies that culinary banana is an excellent source of RS and may be utilized as an alternative source of neutraceutical ingredient for preparing low glycemic functional foods.

Chapter 4 discusses that culinary banana peel is an interesting source of biomaterial for the production of cellulose nanofiber (CNF). In this chapter chemically purified cellulose is being isolated using chemical treatment followed by individualization of CNF employing high-intensity ultrasonication at various output power levels which helped in homogenization, tailoring and size reduction of each CNF. The CNF got reduced with the gradual increase in the output power of ultrasonic treatment. Finally the cellulose nanopaper (CNP) was developed using isolated CNF. The developed CNP possesses high crystallinity, thermal, mechanical and electrical stability. The presence of thinner and finer webs of CNF has been confirmed by TEM images with individual crystallite size in the range of 2.53-3.09 nm with partial formation of nanotubes. The high purity of cellulose in developed CNP is evidenced by FT-IR and ^{13}C NMR of cellulose I. Thus CNP has credible evidence for the production of high performance biocomposites and may be considered as one of the potent renewable reinforcement agents for use in the field of food packaging industries.

Chapter 5 deals with encapsulation by cocrystallization of natural antioxidant from both pulp and peel of culinary banana at early developmental stage (20 DAE) at various concentrations (3, 5 and 10 g). The study revealed that cocrystals obtained has high entrapment yield, yielded desirable characteristics such as low water content and water activity, high solubility, low hygroscopicity and very good flowability. The encapsulation process is proved to be successful in entrapment of major polyphenolic compounds as confirmed by HPLC chromatographs. The cocrystals also demonstrate the typical bands of sucrose molecules in FT-IR spectroscopy which is further confirmed by DSC endothermic peak at around 191^{o}C and shown a typical melting point of sucrose. The results of XRD also proved similar type of x-ray crystalline pattern of sucrose. Scanning electron micrographs illustrated basic porous structures which correspond to typical cluster like agglomerates with void spaces and irregular cavities. The cocrystallization process resulted in a good alternative to preserve and handle antioxidant for further application in food products. The result supports the present study for value addition of natural antioxidant especially for formulation of functional foods.

Chapter 6 deals with drying characteristics and optimization of process parameters in vacuum drying of culinary banana. The study evinced that Wang and Singh and modified Page models were most suitable models for describing thin layer drying kinetics of both culinary banana pulp and peel. Comparison of the performances of ANN and RSM with their modeling, prediction and optimization for vacuum dehydration process revealed that ANN models are capable of better predictions for responses (rehydration ratio, scavenging activity, nonenzymatic browning and hardness) compared to RSM. Maximization of responses of rehydration ratio and scavenging activity percentage and minimization of nonenzymatic browning and hardness were obtained through ANN modeling followed by GA optimization process. Therefore, ANN is proved to be a useful tool for correlation and simulation of vacuum drying parameters of culinary banana. Both drying temperature and pretreatment have positive effect on rehydration ratio and the effect of drying temperature is most significant. It also illustrates that a drying temperature at 76^{o}C with citric acid pre treatment (1% concentration) and a sample thickness of 6 mm should be used for vacuum drying of culinary banana slices. In case of peel vacuum drying, it suggests drying temperature of 71^{o}C, with 1% citric acid pretreatment and paste thickness of 4 mm.

The study on moisture sorption isotherm of culinary banana flour developed at optimized vacuum drying conditions evinced the sigmoid shape, which resembles type II isotherm for typical of food material. The experimental sorption data is suitably fitted in four-parameter Peleg model with highest R^2 and lowest R_d values and indicates good stability at usual storage conditions. The net isosteric heat of sorption of culinary banana flour revealed decrease in increasing moisture content which suggests endothermic reaction in the region of lower moisture content. Results of this study further revealed that culinary banana flour could be stored at 25^{o}C up to 120 days with minimal degradation of phenolics and antioxidant activity.

Chapter 7 concludes the study carried out with specific objectives, salient findings and future scopes of the present investigations. It is concluded that both pulp and peel of culinary banana are excellent sources of many functionally important nutrients and bioactive compounds which could be potentially utilized for the benefit of society in terms of health and nutrition by delivering functional foods. Peel an agro-waste is abundantly available but currently adds no value. Therefore the present study was primarily focused to find an alternative approach for value addition of culinary banana peel as a potentially rich source of cellulosic nanofibers for developing cellulose nanopaper (CNP) that could be utilized in a proper and better way as reinforcement in biocomposites. Both pulp and peel has maximum amount of antioxidant compounds during early developmental stages and are extracted and encapsulated in supersaturated solution of sucrose by cocrystallization. The detailed characterization of cocrystals encapsulated antioxidants from both pulp and peel were carried out. Additionally, study on drying of culinary banana is carried out, where the process parameters (viz. drying temperature, sample thickness and pretreatment) for vacuum drying of culinary banana have been optimized with the help of ANN/GA. ANN proved to be an useful tool for correlation and simulation of vacuum drying parameters of culinary banana. Finally, moisture sorption isotherm was done for the flour developed from optimized drying conditions and its antioxidant stability during storage up to 120 days was also performed.

The future scope of the present investigation included culinary banana to be the potential source of many functionally important nutrients and bioactive compounds. The isolation of other important compound of interest could be carried out at particular stage which could be further incorporated into high value foods. The brown bread developed in the present investigation might be explored further in terms of detailed glycemic index study in diabetic as well as healthy animals and humans. The stability of developed CNP packaging material during storage might be explored. The incorporation of antioxidant cocrystals and its stability might be studied in products like jam, jelly, candy and other sugar enriched foods.