CHAPTER 5
SUMMARY AND CONCLUSIONS

The aim of this study was to investigate the most suitable ripening stage of banana for preparation of acceptable quality clarified banana juice. Three advanced maturity stages of banana viz. stage 5 (yellow with a trace of green), stage 6 (all yellow) and stage 7 (all yellow with a brown speckles) were selected and experiments were conducted to optimize the enzymatic conditions for clarification of banana pulp for each selected stage. Clarified juices thus obtained with optimized enzymatic conditions were studied for their physico-chemical characteristics and evaluated for sensory attributes. This chapter deals with the summary of the present investigation and also brings out the conclusion that can be drawn on the basis of findings of current research project. The chapter is divided into following headings

5.1 Changes in banana fruits at advanced stages of maturity during ripening
5.2 Enzymatic clarification of banana pulp at different stages of maturity
5.3 Effect of optimized enzymatic combinations and ripening stages on physico-chemical characteristics of clarified banana juices
5.4 Sensory evaluation of clarified banana juices
5.5 Study of inhibition of browning of clarified banana juice

5.1 Changes in Banana Fruits at Advanced Stages of Maturity During Ripening

As the ripening progressed, banana passes through various ripening stages. Among the three selected advanced maturity stages of banana (stage 5, 6 and 7) considerable changes with respect to their physico-chemical and mechanical properties were observed. Ripening transformed inedible mature fruit into a both visually attractive and edible one. Changes occurred both in the peel and pulp. Green colour of the peel decreased and attained full yellow with brown spots at fully ripened stage i.e. at stage 7. Whereas whitish pulp changes to yellowish creamy. As the ripening progressed (stage 5 to 7), pulp to peel ratio was increased. Maximum PPO activity was observed at stage 5 which was gradually decreased during ripening.
Significant compositional differences were observed in banana pulp of all the ripening stages. Constituents in banana pulp viz. moisture, fat, titratable acidity, total sugar and total soluble solids were found to be increased from ripening stage 5 to 7 whereas ash, protein, pectin and starch content were decreased during ripening. The major compositional changes in the pulp were observed in the carbohydrates. At maturity stage 5, banana pulp content 7.05 g starch per 100 g of pulp which was continuously decreased and reached to 1.56 g per 100 g of pulp at maturity stage 7. Starch hydrolysis leads to increase in total sugar and TSS content in the pulp during ripening of banana from maturity stage 5 to stage 7.

In advancement of stages of ripening, mechanical properties of fruits viz. firmness, cohesiveness, chewiness, fracture force and stiffness were observed to be decreased.

### 5.2 Enzymatic Clarification of Banana Pulp at Different Stages of Maturity

Due to pulpy nature and high viscosity of banana, it was difficult to extract and clarify juice from pulp without pectic enzyme treatment. In the present investigation, different enzymatic treatment conditions viz. enzyme concentration, incubation temperature and time were applied for banana pulp clarification and optimized separately for each of the selected maturity stages. The responses used for optimization were viscosity of treated pulp, yield and clarity of prepared clarified juices. The experimental results indicated that concentration of pectinase enzyme play an important role in influencing the yield, clarity and viscosity of juices at all the stages of ripening. Increased in enzyme concentration was found to increase the yield and clarity of prepared juices and decreased the viscosity of treated pulp. Banana pulp at all the ripening stages showed maximum enzymatic activity at incubation temperature in the range of 35 - 40°C. Increased in incubation temperature above 40°C decreased the yield and clarity of juices whereas increased the viscosity of enzymatic treated pulp. Incubation time for effective clarification of pulp was observed to be mainly dependent on concentration of enzyme. Increased enzyme concentration decreased the time for clarification.

Enzymatic treatment conditions for the preparation of clarified banana juices at different stages of ripening were optimized by using RSM. Increased in ripening
Summary and Conclusions

Stage was observed to decrease requirement of enzyme dose. The enzymatic conditions optimized for stage 5 were 0.15% enzyme concentration, 35.0°C temperature, 180 minute time; whereas 0.12% enzyme concentration, 40.0°C temperature for 135 minute time for stage 6 and; 0.11% enzyme concentration, 40°C temperature for 145 minute for stage 7. Juices obtained at ripening stages 5, 6 and 7 with their optimized combination exhibited different responses. The responses for stage 5 were yield (49.28%), viscosity (539.19 cps), clarity (62.31%); for stage 6, yield (64.76%), viscosity (450.20 cps), clarity (84.56%) and for stage 7, yield (75.11%), viscosity (372.00 cps), clarity (94.05%).

High enzyme dose was required for clarification of banana pulp at stage 5 followed by those for maturity stage 6 and stage 7. This was attributed to the higher pectin and starch content in banana pulp at initial stages of ripening compared to those of later stages.

5.3 Effect of Optimized Enzymatic Combinations and Ripening Stages on physico-chemical characteristics of clarified banana juices

Optimized enzymatic combination of each ripening stage was applied to other stages and clarified juices were prepared to study the effect of enzymatic treatments and ripening stages on their physico-chemical parameters. In general, both these factors were found to be affected the physico-chemical properties of prepared juices but the effect of ripening stages was found be more pronounced. Enzymatic combinations with higher enzyme concentration yielded clarified juices with higher TSS, total sugar, reducing sugar and titratable acidity; and lower sugar to acid ratio and pectin content as compared to treatments with lower concentration of enzyme. In advancements of stages of ripening (stage 5 to stage 7) significantly marked increased in TSS, total sugar, reducing sugar and titratable acidity; and decreased in sugar to acid ratio and pectin content of prepared juices were observed.

5.4 Sensory Evaluation of Clarified Banana Juices

Sensory panel assessment of the clarified juices at different stages of ripening indicated that banana fruits at 7th stage of ripening are the most suitable for commercial production of clarified banana juices with acceptable quality. Dark brown
colour attained by the clarified juices due to the problem of browning was not preferred by the panelist.

5.5 Study of Inhibition of Browning of Clarified Banana Juice

To avoid the problem of discoloration, two anti-browning treatments viz. addition of ascorbic acid (200 to 1200 ppm) and heat treatment (at 90°C at different time intervals) were applied to banana pulp at 7th stage of ripening during the course of pulp clarification process. Pretreatment of pulp with 1000 ppm of ascorbic acid or heating at 90°C for 6 minute was observed to retain the natural colour of prepared clarified juices without marked changes during storage at room temperature. Juices obtained from both these pretreatments were analyzed for their quality characteristics. The results indicated that yield, clarity, titratable acidity, total soluble solids and total sugar content of juices prepared from ascorbic acid treated pulp were significantly higher compared to juices from preheated pulp. Preheating of banana pulp was observed to cause slightly cooked flavour and altered the original taste of the clarified juices. Whereas 1000 ppm of ascorbic acid yielded banana juices with their natural colour and having typical banana flavour and good sweet taste.

Conclusions

By the end of this study, following conclusions can be made:

1) Bananas of three advanced stages of maturity viz. stage 5, 6 and 7 differ significantly with respect to their mechanical properties and physico-chemical parameters; though the slight changes observed in terms of peel colour.
2) The optimum enzymatic combinations for clarification of banana pulp were
   a. 0.15% Enzyme concentration, 35°C Temperature, 180 minute Time *(For Stage 5)*;
   b. 0.12% Enzyme concentration, 40°C Temperature, 135 minute Time *(For Stage 6)*;
   c. 0.11% Enzyme concentration, 40°C Temperature, 145 minute Time *(For Stage 7)*;

when the optimization criteria used was to maximize yield and clarity and minimize viscosity of pulp.
Summary and Conclusions

3) Maximum juice yield of about 75% with 94% clarity could be obtained using the bananas at maturity stage 7; clarified with their optimized enzymatic combination.

4) Commercial pectinolytic enzyme i.e. Pectinex Ultra SP-L and cellulase enzyme i.e. Celluclast 1.5L can be effectively used for clarification of banana pulp without significant differences in the major parameters required for qualitative banana juice preparation.

5) In banana pulp clarification process, requirement of enzyme concentration decreases as ripening progressed.

6) Clarified banana juices prepared with different enzymatic treatments and stages of maturity differ significantly with respect to their physic-chemical parameters like TSS, sugar to acid ratio, titratable acidity, reducing sugar and pectin content.

7) Banana fruits at 7th stage of ripening are the most suitable for commercial production of clarified banana juices with acceptable quality.

8) Pretreatment of banana pulp with 1000 ppm of ascorbic acid is the most suitable method to produce clarified juice with natural yellow colour and acceptable flavour.

Scope For Future Work

Scale-up of this technology provides an excellent scope for the development of non-conventional products from banana. The extracted clarified juice after a dilution is ready to serve as nectar and/or after carbonation as a drink. Banana juice also can be used for the production of banana wine by fermentation, which has a lot of commercial value.