CHAPTER 5

SUMMARY AND CONCLUSION

Foam mat drying allows the dehydration of heat sensitive, high sugar content and viscous foods that are difficult-to-dry and sticky under relatively mild conditions without compromising the quality. The foam-mat drying is a process in which the liquid product is whipped to form stable foam with the addition of food foaming and stabilizing agents and subsequently dried by thermal means to form a thin porous honeycomb mat which is disintegrated to yield a free-flowing powder.

5.1 COMPARISON OF FOAMING RESULTS

In the present study, three different foaming agents such as Egg albumen (5-15%), Soy Protein Isolate (5-15%), and Whey Protein Concentrate (2 – 6%) and carboxy methylcellulose (0 - 1%) as stabilizer were selected based on the previous literatures. The levels of the foaming agent and stabilizer were selected based on the preliminary experiment. The response selected for study were foam density, foam drainage volume and foam expansion. The density of fresh pulp before whipping was found to be 0.68 g cm$^{-3}$. The foam density for the series of samples treated with egg albumen, soy protein isolate and whey protein concentrate were varied from 0.351 to 0.614 g cm$^{-3}$, 0.502 to 0.709 g cm$^{-3}$ and 0.314 to 0.499 g cm$^{-3}$ respectively. It was observed from literature that 0.3 to 0.6 g cm$^{-3}$ was the suitable range of foam density.
density associated with foam mat drying. The foam expansion for egg albumen, SPI and WPC treated samples varied from 10 – 90, 35.29 -55.65, and 20.5 - 87.9 %, respectively. Among the three foaming agents, egg albumen and whey protein concentrate were found to produce foam density within the recommended range. Whey protein concentrate tend to form more cohesive film at the air-water interface than soy protein isolate. Also higher foam expansion was obtained by whey protein concentrate than soy protein isolate. Liquid separation was well observed in the samples without carboxymethylcellulose and indicated that influence of foam stabilizer on the foam stability. The liquid separation was found to be almost zero when stabilizing agent was used irrespective of the concentration of foaming agents. However, when stabilizing agent was not used, the liquid separation was considerably low in case of whey protein concentrate than egg albumen and soy protein isolate. The gravitational drainage was faster in soy protein isolate. The optimized foaming parameters were selected at minimum foam density and foam drainage volume with maximum foam expansion. The optimized values of EA (11.59% of EA, 0.59% of CMC and 3.97 min of WT) SPI (8.95% of SPI, 0.53 of CMC and 5.02 min of WT) and WPC (4.42% of WPC, 0.55 of CMC and 4.09 min of WT) treated sample were further selected for performing drying studies.
5.2 COMPARISON OF DRYING RESULTS

The drying of the pulp was carried out as thin layer drying in hot air dryer at a temperature of 50°C, 60°C and 70°C. The same drying procedure was carried for the fresh unfoamed muskmelon pulp. The fresh muskmelon pulp had an average initial moisture content of about 92.35% w.b. The drying process was preceded till the product reached final moisture content of 2.5 – 3% w.b. From the drying experiment, it was inferred that unfoamed muskmelon pulp took higher drying period and yielded a less porous sticky product. However, all foam dried muskmelon powders yielded a free flowing powder and also dried in a shorter period compared to unfoamed pulp. This was due to the air bubbles incorporated in foamed pulp during whipping process which facilitated the drying rate at a rapid rate in all foamed pulp. Soy protein isolate treated pulp presented better drying characteristics than unfoamed pulp, it took more time than egg albumen and whey protein concentrate treated pulp. Due to the lower foam density and higher foam expansion, egg albumen and WPC treated muskmelon pulp represented the open-pore structure than soy protein isolate treated products. In terms of vegetarian source, WPC resulted in better foaming properties and produced highly porous texture.

5.2.1 Comparison of thin layer drying models

The moisture ratio values were fitted into selected drying models to determine the best fitting model. Midilli-Kucuk model was found to be a suitable fitting model which was followed by Wang and Sling model for all the experiments except whey protein concentrate treatments. The drying of whey protein concentrate treated muskmelon pulp was well represented by Page model followed by Logarithmic and Midilli-Kucuk model. In all the
unfoamed and foamed muskmelon pulp using different foaming agents, the values of $R^2$ of the above two models was found to be greater than 0.95. The effective moisture diffusivity and activation energy was determined for all the samples. And it was inferred that in all the treatments, drying temperature had a predominant effect on moisture diffusivity. The higher drying temperature revealed high moisture diffusivity because at high temperature more energy was being provided for drying which increased the activity of water molecules and also the drying rate. Similarly, the foaming process improved the moisture diffusivity in all the foamed samples compared to unfoamed samples. This might due to the increased surface area of the bubbles due to whipping which facilitated the increased moisture removal from foamed muskmelon pulp. The activation energy was found to be 44.85, 22.40 and 33.75 kJ/mol for muskmelon samples treated with egg albumen, soy protein isolate and whey protein concentrate, respectively. The activation energy was found to be higher in case of foamed samples than unfoamed sample (16.34 kJ/mol) and the values were within the recommended range for food and agricultural materials.

5.3 COMPARISON OF POWDER PROPERTIES

The various physical and chemical properties of muskmelon powders were studied and the results were also correlated using statistical analysis. The properties like water activity, bulk and tapped density, Hausner ratio and Carr index, water solubility index, hygroscopicity, colour, ascorbic acid and beta carotene were studied. Also the infrared analysis and microstructure analysis of the powder were performed. From this study, it was inferred that WPC exhibited better powder properties and also confirmed that foam mat drying is a promising technique for the production of powdered products from fruit pulp. It was also concluded by incorporating the
Specific conclusions drawn from the investigation are as follows:

i) The optimized foaming parameter for egg albumen, soy protein isolate and whey protein concentrate treated samples are 11.59% EA, 0.59 % CMC and 3.97 min of whipping, 8.95 % SPI, 0.53 % CMC and 5.02 min of whipping and 4.42 % WPC, 0.55 % CMC and 4.09 min of whipping, respectively.

ii) Drying of foamed and unfoamed muskmelon pulp is carried in hot air dryer to reduce from the initial moisture content of 92.35 % w.b to 2.5 – 3 % w.b.

iii) The effective moisture diffusivity foamed samples are higher than unfoamed muskmelon samples, which might be due to the formation of air bubbles in the pulp due to whipping. Whey protein concentrate treated foam at all temperatures shows a higher moisture diffusivity value than other treatments which might be due to their lower foam density. The activation energy is found to be higher in foamed muskmelon samples (44.85, 22.40 and 33.75 kJ/mol) than unfoamed samples (16.34 kJ/mol).

iv) The physical and chemical properties of foamed and muskmelon powder also represented good characteristics compared to unfoamed muskmelon samples. Foamed powder using soy protein isolate and whey protein concentrate showed good flowability. Water solubility is found to be higher in egg albumen and whey protein concentrate.
treated samples. Egg albumen treated powders showed extremely hygroscopic nature compared to other samples.

v) The sensory evaluation of ice cream and muffin incorporated with muskmelon pulp and muskmelon powder shows near equal preference in terms of sensory attributes such as colour, aroma, taste, texture and overall acceptability. Among the two products, ice cream was associated with higher consumer acceptability.

vi) From the above experimental results, it is concluded that egg albumen and whey protein concentrate treated muskmelon showed better foaming ability and produced low density stable foams. Similarly, muskmelon pulp treated with egg albumen and whey protein concentrate dried at 60°C showed better properties.

vii) The approximate cost of production of foam dried muskmelon powder is about Rs. 745.98 per kg of muskmelon powder.

viii) Egg albumen being non-vegetarian source, it is not preferred by vegetarians when added in ice creams or muffins. Hence whey protein concentrate is highly suitable for the production of muskmelon powder.

5.4 SCOPE FOR FUTURE STUDY

Thus the present study has positively revealed that foam mat drying will be suitable for the production of muskmelon powder with better properties. Further continuation of this research can be made in the following direction:
The hot air drying of foamed muskmelon pulp itself produced free flowing powder. Hence, an extensive study can be performed in using vacuum drying, microwave drying and freeze drying which may yield highly acceptable muskmelon powder. Based on the batch processing of muskmelon powder, a continuous type foam mat dryer suitable for the production of muskmelon powder may be designed.