CHAPTER V

SUMMARY AND CONCLUSION

India is internationally recognized for spices. Spices are added to foods in small amounts but they make important contribution to the sensory qualities due to presence of volatile and fixed oils. In addition to contributing taste and aroma to foods, spices also contain a variety of bioactive substances which are of considerable use from the standpoint of food science and technology and diet related health function.

Garlic (Allium sativum L.) is a bulbous perennial plant of the lily family, Liliaceae and it is a common food spice used widely in many parts of the world. It has been cultivated for centuries all over the world on account of its culinary and medicinal properties. It is used in several food preparations like chutneys, pickles, curry powders, curried vegetables, meat preparations, tomato ketchup, etc. The raw garlic can also be used in the manufacturing of garlic powder, garlic salt, garlic vinegar, garlic potato chips, garlic bread, etc. Besides the culinary usages, garlic is also well known for having numerous valuable medicinal properties. It is used in treatment of diseases like running cold, saliva formation, chronic bronchitis, respiratory problems, whooping cough, bronchitic asthma, influenza, chronic diarrhea, pulmonary tuberculosis, rheumatism, impotence, etc. It can also fight infection, reduce cholesterol, protect against heart diseases and stroke, control diabetes, and prevent cancer. It is one of the most effective antimicrobial herbs, as it has anti-bacterial, anti-fungal, anti-viral and antiseptic properties. Many recent studies have provided strong evidence that most of these biological functions of garlic are attributed to allicin.

Garlic oleoresin is a naturally occurring mixture of an oil and a resin extracted from garlic bulbs by solvents and the active components present in it are allicin and disulphide which have wide spread application as a flavouring agent in foods, beverages, and medicines. It can replace whole/ground spices without impairing any flavour and aroma characteristics. Unlike the essential oils, oleoresins contain natural
antioxidants of the corresponding spices, which make them more stable. Oleoresins provide a better distribution in the finished products and require less storage space than the corresponding spices. However, spice oleoresins exhibit sensitivity to light, heat and oxygen, and have short storage lives if not stored properly which is due to the result of oxidative and polymeric changes involving the fatty oil component and monoterpinic hydrocarbons. Some chemical and organoleptic changes also occur in the oleoresin during prolonged storage. Destruction of several pigments occurs under exposure to oxygen wherein the hydroxylic groups are converted into unstable ketones. These in turn decompose into colourless compounds with a shorter carbon skeleton. This can be overcome by microencapsulation technology.

Microencapsulation is a technique by which liquid droplets, solid particles or gas compounds are entrapped into thin films of a food grade microencapsulating agent to form small capsules and build a barrier between the component in the particle and the environment. The core may be composed of just one or several ingredients and the wall may be single or multi-layered.

Although many encapsulation techniques such as spray drying, spray chilling, fluidized bed coating, extrusion, co-extrusion, co-acervation, liposome, molecular inclusion, co-crystallization, lyophilization, emulsification etc., have been developed to encapsulate food ingredients, spray drying is the most common technology used in food industry due to good reconstitutional characteristics, low water activity, low cost, available equipment, wide choice of carrier solids, good stability of the finished product, suitable for heat sensitive components, suitable for transport and storage, and large-scale production in continuous mode. Microencapsulation by spray-drying has been successfully used in food industry for several decades and this process is one of the oldest encapsulation methods used since the 1930s.

The selection of wall material for each core material is important as the efficiency of the protection, flow properties and morphology of powders are mainly
depends on the composition and physical stability of the encapsulating material used. This wall could act as a barrier and it may protect against oxygen, water, light or could avoid contact with other ingredients. Numerous wall materials have been studied and used for their suitability as encapsulating agents in spray-drying. Wall material for microencapsulation by spray-drying should possess good properties of emulsification, film forming, high water solubility, low viscosity, a bland taste, and drying properties. It should also be non-reactive, protect the aroma from oxidation and available at low cost. Typical wall material for spray-drying are mono- and disaccharides, maltodextrin, corn syrup solids, modified starches, gums, milk or soy proteins, hydrolysed gelatin and combinations thereof.

Currently, Maltodextrin is one of the common drying aids for spray drying owing to its beneficial role as an encapsulating agent in increasing the stability of active compounds, reasonably cheap and commercially available. Therefore, based on a thorough review of literature and preliminary studies conducted, this research work was taken up to study the effect of process parameters such as core (garlic oleoresin) and wall (maltodextrin) materials at various concentrations and spray drying inlet air temperature on emulsion characteristics and spray dried powder in order to optimize the operating conditions for encapsulation of garlic oleoresin by spray drying with respect to the product quality. The optimally produced microencapsulated garlic oleoresin powder was further assessed based on their sensory, physical and micro structural characteristics.

Garlic oleoresin and maltodextrin were used as core and wall material, respectively. The physico-chemical characteristics of raw materials were determined based on the standard methods. The emulsions were prepared with 40, 50 and 60% maltodextrin concentration with 10, 20 and 30% of garlic oleoresin concentration. The emulsion characteristics such as pH, total soluble solids, colour, viscosity and stability index were determined and the statistical analysis was performed using two factors at three levels central composite response surface design. The second order polynomial
model was generated to understand the interaction between independent and dependent parameters. Based on the high coefficient of determination value in emulsion experiment, this study was further carried out to encapsulation process.

The emulsions prepared were spray dried in a laboratory model tall type spray dryer which has water evaporation capacity of 3 l h\(^{-1}\) with 0.7 mm diameter nozzle. The pressure of compressed air flow of the spray was adjusted to 350 kPa. The inlet temperature was varied as 180, 200 and 220°C and the outlet temperature was maintained at 96±2°C. The resultant microencapsulated garlic oleoresin powder was packaged in self-sealing aluminium foil pouches and stored in desiccator containing calcium chloride to prevent moisture absorption until further analysis. The statistical analysis, three factors and three levels Box-Behnken Design was used to understand the interaction between the independent and dependent parameters (bulk density, moisture content, redispersion time, water activity, colour, encapsulation efficiency and allicin content), to generate second order polynomial model, coefficient of determination, adequacy of the models and diagnostic plots.

The Derringer’s desired function methodology was followed for optimizing the various responses involved in the microencapsulation process and the optimized conditions were validated experimentally. The additional quality analyses such as total ash content, pH, total antioxidant activity, water solubility index, micro structural characteristics and sensory evaluation were carried out for optimally produced microencapsulated garlic oleoresin powder. The cost economics was calculated to produce one kg of microencapsulated garlic oleoresin powder. This study will be useful to cater to the needs of middle and large scale oleoresin industries.

The conclusions of the study are summarized below:

1. The density and specific gravity of the fresh garlic oleoresin were 1.187 g cm\(^{-3}\) and 1.19, respectively. The allicin content was 92.67% against standard allicin.
The Hunter values were 23.67; 2.27; 1.37 for “L”, “a” and “b” in that order. It is high viscous, 6005 cP with obnoxious odour.

2. The pH and moisture content of the garlic oleoresin was 3.36 and 8.81% d.b correspondingly. Hence it can assume to be that the garlic oleoresin is safe to use and free from pathogenic micro organism. The total soluble solids was 81°Brix and the total antioxidant activity was 68.2% by DPPH radical scavenging activity method.

3. The moisture content, water activity, pH and bulk density of the maltodextrin was 2.97% d.b., 0.47, 6.47 and 0.429 g cm⁻³, respectively. The hunter colour value was L = 93.67±1.53; a = -0.52±0.04; b = 4.05±0.05. It is confirmed that maltodextrin can be used as wall material as it possess less moisture content, low water activity, a bland taste, a smaller amount of bulk density and produces colourless solution.

4. The emulsion pH varied from 3.67 to 4.35 with respect to varied level of garlic oleoresin and maltodextrin concentration, which confirmed that maltodextrin was not much influenced in the emulsion pH. The total soluble solids (TSS) of the emulsion varied from 37.4 to 58.2°Brix. It was observed that TSS increased when maltodextrin concentration increased which may be due to increase in solid content of the raw materials.

5. The Hunter “L” and “a” value were notably affected with increase in the concentration of raw materials. With increase in maltodextrin concentration, the Hunter “L” value was increased and Hunter “a” value was decreased, as maltodextrin is white and garlic oleoresin is dark in colour.

6. The emulsion stability index varied from 0.50 to 0.85. When the emulsion prepared with higher oil content, the less stable was observed which may be due
to the lower amount of emulsifying agent available to cover the oil droplets, which leads to faster droplets coalescence.

7. The emulsion viscosity ranged from 13.8 to 78.5 cP. It was noted that with increase in maltodextrin concentration, the emulsion viscosity was drastically increased, since maltodextrin making them more viscous in nature.

8. While analyzing the emulsion characteristics statistically, the very small p value (<0.0001) and high coefficient of determination (0.999, 0.999, 0.995, 0.994, 0.990, and 0.999 for pH, TSS, Hunter L value, Hunter a value, stability index and viscosity) showed that the quadratic polynomial model was significant and sufficient to represent the actual relationship between the independent and dependent parameters.

9. The bulk density of microencapsulated garlic oleoresin powder ranged from 0.315 to 0.505 g cm\(^{-3}\). With increase in garlic oleoresin and maltodextrin concentration, the bulk density increased mainly due to increase in the solid content present in the raw materials. The less bulk density (0.315 g cm\(^{-3}\)) was observed in 10% garlic oleoresin concentration, 40% maltodextrin concentration and 200°C drying inlet air temperature.

10. The moisture content of microencapsulated garlic oleoresin powder varied from 2.07 to 5.82% d.b. The minimum moisture content was found when the drying inlet air temperature increased to greater level which may be due to the higher rate of heat transfer into particles, causing faster water removal.

11. The redispersion time of the microencapsulated garlic oleoresin powder ranged from 34.9 to 47.6 s. The maximum redispersion time was found in 10% garlic oleoresin concentration, 50% maltodextrin concentration and 180°C drying inlet air temperature. The minimum redispersion time was noticed in 30% garlic oleoresin concentration, 40% maltodextrin and 200°C drying inlet air
temperature. It was seen that the microencapsulated garlic oleoresin powder produced with more concentration of garlic oleoresin, the lesser was redispersion time, since only the maltodextrin gets solubilized in water.

12. The water activity of the microencapsulated garlic oleoresin powder ranged from 0.197 to 0.511 which shows the product is microbiologically stable. The least water activity was observed in 10% garlic oleoresin concentration, 50% maltodextrin concentration and 220°C drying inlet air temperature. Also it was noticed that there was decrease in water activity with increase in the level of maltodextrin which act as a drying aid.

13. The maximum Hunter “L” value, 72.8 was measured in 10% garlic oleoresin concentration, 60% maltodextrin concentration and 200°C drying inlet air temperature. The minimum Hunter “a” value, 5.55 was recorded in 20% garlic oleoresin concentration, 60% maltodextrin concentration and 180°C drying inlet air temperature.

14. The encapsulation efficiency (EE) of microencapsulated garlic oleoresin powder varied from 64.7 to 82.1%. The EE was found to increase with increase in drying inlet air temperature from 180 to 200°C and further increase in drying inlet air temperature from 200 to 220°C, EE was decreased drastically. The maximum EE was noticed in 10% garlic oleoresin concentration, 60% maltodextrin concentration and 200°C drying inlet air temperature. The EE was higher when maltodextrin concentration was increased to elevated level which can be related to the effect of wall solids concentration on the formation of surface core prior to the formation of crust around the drying droplets.

15. The maximum allicin content, 94.21% was presented in 10% garlic oleoresin concentration, 60% maltodextrin concentration and 200°C drying inlet air temperature and the minimum value, 75.3% was recorded in 30% garlic
oleoresin concentration, 50% maltodextrin concentration and 220°C drying inlet air temperature.

16. While statistically analysing the quality parameters, the adequacy of model summary indicates that the quadratic model is found to be the most suitable model for the present encapsulation process. The data points on diagnostic plot lie reasonably close to the straight line and indicated that an adequate agreement between real data and the data obtained from the developed models.

17. Based on Derringer's desired function methodology, the optimum conditions obtained for microencapsulation of garlic oleoresin was found to be 10% garlic oleoresin concentration as core material, 60% maltodextrin concentration as wall material and drying inlet air temperature of 200°C with overall desirability value of 0.819.

18. The optimized conditions were validated experimentally and the mean value of the triplicate for all the quality analyses were compared with the predicted values obtained from the second order polynomial model to calculate error percentage which was varied from -0.337 to 1.145% which indicates that it could be effectively used for microencapsulation of garlic oleoresin by spray drying technology.

19. Total ash content, 1.05 ±0.2% ; pH, 3.84 ±0.01; total antioxidant activity by DPPH radical scavenging activity, 62.8±0.3% and water solubility index, 33.2±0.1% were recorded for optimally produced microencapsulated garlic oleoresin powder.

20. The micro structural characteristics was observed to be 10.67 to 35.42 μm size, smooth, spherical shape and without dents which indicates good encapsulation efficiency and retention of active compounds.
21. Sensory evaluation by triangular test for garlic flavoured hung-curd as product was conducted to assess the quality of microencapsulated garlic oleoresin powder. The results indicated that 90% of the panel member thought S3 sample was the odd one out which was incorporated with raw garlic extract. This result supports that microencapsulation technique has been used not only to retain the active compounds, but also to mask the original core (pungency of garlic) taste.

22. The cost of production of microencapsulated garlic oleoresin powder was estimated to be Rs. 852 /kg.

Suggestions for future work

1. The microencapsulated garlic oleoresin powder may be incorporated into different food products such as milk powder, health mix, garlic meals, etc., to find releasing mechanisms and acceptability of the product.

2. The study may be carried out by changing the homogenization pressure and analyze how it’s influenced the encapsulation efficiency.

3. The study may be carried out by implementing the multi-matrix model and the stability of encapsulated powder must be investigated.