CHAPTER 4

CONCLUSION

In today’s era of healthy eating, the awareness on chemical preservatives and their side effects is spreading rapidly. Therefore, the challenge faced by the food processing industries across the world is the increased demand for food products which are minimally processed and free from synthetic chemical preservatives. Spices play a major role in the development of safe and effective food preservation. They are found to be the potential natural sources of antimicrobial and antioxidant properties and have the ability to produce multidimensional flavours and aroma in food.

Studies conducted in the last decade found that the growth of food pathogens like gram positive, negative bacteria, mold and yeast can be inhibited by the spices like cinnamon, cloves, garlic and others. It was observed in this study that the leachate of *Syzygium aromaticum* has significantly higher phenolic content, flavonoid content and antioxidant activity compared to other spice leachates. The leachate of *Syzygium aromaticum* has higher inhibition zone diameters when compared with other spice leachates. Mathematical model was developed for optimizing the leaching process under different leaching parameters. The leaching efficiency increased with the decrease in particle size, which was due to the fact that smaller size particles provided a larger lateral surface area for their contact with the solvents. Leaching yields increased with the
increasing solvent-solid ratios. Solvent-solid ratio of 1:50 exhibited more leaching efficiencies due to higher diffusion rates.

For *S. aromaticum*, a higher effective diffusivity value of $36.01 \times 10^{-10}$ m$^2$/s was achieved during leaching and for *C. cassia*, it was $26.78 \times 10^{-10}$ m$^2$/s at the solvent-solid ratio of 50:1. For *Origanum vulgare* and *Brassica nigra*, the values were observed to be $12.390 \times 10^{-8}$ cm$^2$/s and $10.581 \times 10^{-8}$ cm$^2$/s at the solid-solvent ratio of 50:1. Spice leachates were analysed for their ability to extend the shelf-life of raw chicken meat at refrigerated storage. Natural antioxidants from spice leachates appear to retard lipid oxidation during the storage period and reduce the final microbial load. The spice leachates contain a large amount of essential oil compounds, as well as phenolic acids, which can control foodborne pathogens and inhibit lipid oxidation. The addition of combination of spice leachates (T-W-SA+T-W-CC+T-W-OV) was very effective against microbial growth and oxidative reactions. Furthermore, the addition of spice leachates showed higher CIE $a^*$ values and lower TBARS values ($P < 0.05$) than the control samples, along with improvement in color and odor. Due to health benefits of these highly effective natural leachates, their usage in the meat industry may be very valuable and desirable.

In the shelf life modeling of spice leachates on raw chicken meat, parameters derived from Gompertz models were estimated to compare the effects of temperatures on microbial growth. It was found that the increase in temperature showed an increase in the maximal growth rate ($\mu_{max}$). The results indicated that the meat samples treated with spice leachates had highest $\mu_{max}$ values for *Enterobacteriaceae* at various temperatures and particularly for T-SA
samples stored at 20°C, when compared with LAB counts. In the case of lactic acid bacteria, it showed the lowest $\mu_{\text{max}}$ values in the meat samples, especially in T-SA-CC-OV samples stored at 4 °C.

Through Arrhenius equation, the effect of temperature on specific microbial growth and lag phase duration values were modeled, determining the corresponding activation energies. Lactic acid bacteria exhibited the highest value of activation energy ($E_a$) for the specific growth rate in raw chicken meat samples treated with *O. vulgare* leachates (T-OV) and the highest values of activation energy for the adaptation period ($E_{1/LPD}$) were found for *Enterobacteriaceae* in the T-SA-CC-OV samples. According to the results of the present study, the combination of spice leachates (SA+CC+OV) can be used as an alternate preservative to synthetic preservatives in raw chicken meat to improve and increase the hygiene quality of the chicken meat.

Edible films were developed from corn starch with spice (clove and cinnamon) leachates at various concentrations. Antimicrobial activity of the CS films was observed against 7 bacterial strains by varying essential concentrations from 0.5% - 3%. CS films incorporated with 3% of clove or cinnamon essential oil had highest antimicrobial activity. The effect of CS films coated with spice leachates was measured for the extension of shelf life of raw chicken meat. Incorporation of clove and cinnamon leachates in CS films at 3% level significantly reduced the microbial population and TBARS values in raw meat during refrigerated storage with good color values. The experimental results provided an approach to develop antimicrobial packaging with less concentration
of spice leachates. This fact is of paramount importance from the point of view of food safety and food organoleptic properties.

Packaging material used for the study has low water vapour transmission rate, oxygen transmission rate and carbon dioxide transmission rate. It has got enough strength to withstand machine handling. The overall migration residue (Water extractives) was below the acceptable limit for food contact application. Headspace gas analysis proved an expected trend in gas concentrations. In meat stored under air an increase in microbial growth resulted in increased CO$_2$ concentration whereas in meat stored under MAFC, the initial decrease was due to absorption of CO$_2$ in meat and after that microbial growth resulted in increased CO$_2$ concentration. Decrease in O$_2$ concentration was mainly due to respiration of bacteria.

The multiplicative factor (MF) is the mathematical predictive model used to propagate the contamination through the production phase. The MF is essentially a “multiplier” that allows the contamination to be propagated through the model. If a selection increases the contamination, the multiplier will be greater than 1; if a selection decreases the contamination, the multiplier will be between 0 and 1. These multipliers are calculated by obtaining the contamination level at the input and output of the step from the experimental data in the literature.

In order to consider the uncertainty associated with the multiplicative factors (MF), the MFs are in the form of a distribution. Although the MFs are assumed to follow a lognormal distribution, no prior knowledge of the parameters of the distribution is assumed. For each MF distribution, non-informative uniform prior distributions are assumed for both the mean and standard deviation. Using
data from the literature, multipliers are calculated for each option from the level of contamination at the input and output of a step. The Gompertz equation is used to describe the effect physical condition of extracts with MAP system on the growth of *E. coli* O157:H7 during the preservation and distribution phase. Distributions for the Gompertz equation parameters B, M, and C are estimated using a Bayesian approach similar to the one described for the multiplicative factors. Again, a lognormal distribution is assumed for each of the Gompertz parameters (i.e., B, M, and C), as these parameters describe bacterial survival. Data for B, M, and C are obtained from the literature, and this data serves as the likelihood in the Bayesian updating process. The Bayesian updating results in posterior distributions of the mean and standard deviation of the Gompertz parameters.

The risk model developed will provide a more systematic approach to food safety problems, and also deals with the relationships and dependencies between basic elements. The engineering-based risk assessment methodology adapts routes for characterizing and propagating uncertainty about the mathematical models and the model parameters. The validation of the dose-response relationship makes confidence and credibility to the results of the model. This model can be used as an absolute assessment of the risk and a relative measurement of the effectives of mitigation with control strategies. The successful application of the engineering-based risk assessment for contamination in meat products suggests that these adapted methodologies and techniques can be applied to food safety problems in future.