SUMMARY AND CONCLUSION
5. SUMMARY AND CONCLUSION

Summary of the results obtained from the experiments carried out to evaluate the “studies on the factors influencing the stability of processed meat and meat products” has been given in this chapter. The various conclusions drawn from the results of the study have been summarised as follows:

A. Role of sugar amino acid interaction products (MRPs) as antioxidants in a methyl linoleate model system.
   ▶ Early MRPs exhibited good antioxidative potential in the methyl linoleate model system.
   ▶ Out of the five different amino acid combinations studied, lysine and glycine in combination with glucose produced antioxidative MRPs capable of inhibiting lipid peroxidation.
   ▶ Concentration, temperature and time for the preparation of the MRPs played an important role in assessing the retardation effects of MRPs on the oxidation of lipids.
   ▶ MRPs prepared at 60mM concentration heated at 100-110°C for 2h in all combinations exhibited better antioxidant activity in methyl linoleate model system.
   ▶ 60mM/2h at 100-110°C of glucose + lysine exhibited the most antioxidative effect.
   ▶ Early MRPs generated from basic amino acids produced highest antioxidant potential followed by neutral, aromatic, sulphur containing and acidic being the lowest.
   ▶ The parameters employed to assess the antioxidant activity of these MRPs (methyl linoleate degradation by GLC, peroxide value and TBARS) gave a clear picture of the antioxidant ability and its variation with respect to the treatment.
   ▶ From the investigation it was revealed that the percentage of antioxidant activity was in the order 60mM/2h > 60mM/1h > 30mM/2h > 30mM/1h for the treatments glucose + lysine > glucose + glycine > glucose + tryptophan > glucose+mehionine> glucose + aspartic acid, respectively.
Since the studies were carried out in methyl linoleate, which is a primary substrate for evaluating the oxidation in meat the most antioxidant MRPs of glucose + lysine and glucose + glycine could be employed as natural antioxidants for controlling the development of warmed over flavour (WOF) as well as rancidity in precooked refrigerated stored meat and meat products.

B. Antioxidant assay of MRPs by DPPH radical scavenging activity β-carotene-linoleate assay and reducing power.

- Different MRPs exhibited a concentration and time dependent DPPH radical scavenging activity, β-carotene-linoleate assay and reducing power.
- Out of the different groups (30mM/0h, 30mM/1h, 30mM/2h, 60mM/0h, 60mM/1h and 60mM/2h) 60mM/2h exhibited good DPPH radical scavenging activity β-carotene-linoleate assay and reducing power in all the treatments.
- Between the different combinations glucose with lysine and glycine exhibited best DPPH β-carotene-linoleate assay and good reducing powder indicating the maximum antioxidant potential within the treatments.
- Statistical analysis indicated that at a concentration of 60mM/2h there was a strong correlation between the reducing activity and DPPH radical scavenging activities ($r^2 = 0.945$). A positive correlation was observed between the reducing power and the antioxidant activity in β-carotene-linoleate assay. ($r^2 = 0.876$).
- The investigation w.r.t these three experiments revealed the order of DPPH radical scavenging assay, β-carotene-linoleate activity and reducing power was 60mM/2h > 60mM/1h > 30mM/2h > 30mM/1h > 60mM/0h > 30mM/0h and glucose + lysine > glucose + glycine > glucose + tryptophan > glucose + methionine > glucose + aspartic acid.
- From the studies it was revealed that the DPPH radical scavenging assay, β-carotene-linoleate activity and reducing power evaluation of different MRPs can be used to determine the antioxidant potential variation.
The result obtained in this investigation was in accordance with the findings from the methyl linoleate model system studies.

C. Evaluation of the UV – visible spectra of 60mM/2h glucose + lysine MRPs

- UV – visible spectrum shows a strong absorption at 294nm and a weak shoulder at 350nm.
- Presence of carbonyl groups shows two absorptions, \( \pi - \pi^* \) corresponding to lower wave length and \( n - \pi^* \) for a higher wave length.
- The observation in the UV – visible spectrum is matching with the presence of a carbonyl group. Hence the compound could be a deoxy ketose.

D. Antioxidant potential of synthetic and natural antioxidants and its effect on warmed – over flavour in different species of meat

- The studies revealed variation in the antioxidant potential of various synthetic and natural antioxidants in three common domestic species (sheep, beef and pork).
- The importance of early MRPs from glucose + lysine, as natural antioxidants and their potential to control WOF, lipid oxidation and inhibition in the release of non-heme iron, equivalent to TBHQ, in all the three species of meat, has been established in the study.
- MRPs, cloves and ascorbic acid could well be used as substitutes for the synthetic antioxidants, TBHQ, BHA and PG, respectively to control the WOF development in these meat species.
- Individual antioxidant potentials of natural and synthetic antioxidants were established with reference to the three species and correlation with WOF profile and non-heme iron catalysis.
- WOF and non-heme iron could be taken as markers for the evaluation of antioxidant activity.
- The data obtained for the non-heme iron and WOF have illuminated the inhibition mechanisms of the antioxidants in the oxidation of lipids during refrigerated storage of these meat species.
Regression analysis of the data on antioxidant activity with WOF and non-heme iron revealed exponential fit equations for beef and pork and a polynomial equation for sheep.

The susceptibility of these species to lipid oxidation was in the order, pork > beef > sheep and the order of antioxidant activity for the natural antioxidants was MRPs > cloves > ascorbic acid > cinnamon; for synthetic antioxidants, it was TBHQ > BHA > PG.

E. Effect of natural antioxidants on the lipid stability of fluidised bed dried mutton.

Freeze thaw and fluidised bed drying (FT/FBD) process could be successfully employed in the development of dehydrated meat products for civilians and services.

Study signifies the effectiveness of incorporating natural antioxidants like MRPs, ascorbic acid and spices in inhibiting the oxidation of lipids and extending the shelf life of dehydrated meat products.

The oxidative rancidity markers like TBARS, total carbonyls and non-heme iron evaluation clearly established the variation in the antioxidant effect of various treatments initially and during storage.

The results revealed an individual as well as synergistic, antioxidant potential of natural antioxidants in enhancing the shelf life of FT/FBD mutton samples.

MRPs, ascorbic acid and spices played a significant role in controlling the release of non-heme iron, thus inhibiting its catalytic activity.

The critical water content and water activity were found to be crucial for the stability of dehydrated products and it was found to be 7.8g/100g and 0.47 respectively.

Out of the different combinations tried, the product with spices, MRPs and ascorbic acid exhibited good shelf stability in terms of its oxidation profile and Organoleptic characteristics, establishing the synergistic antioxidant potential of the natural antioxidants.

All the parameters evaluated in this study for FT/FBD mutton exhibited the order of antioxidative effect, MRP + spices + ascorbic acid > MRPs > spices > ascorbic acid.
With the incorporation of natural antioxidants, the product shelf life could be extended to more than six months without any deterioration in lipids and sensory characteristics.

Non linear correlation regression analysis between non-heme iron, TBARS and total carbonyls indicated a reciprocal logarithmic fit equation with correlation coefficients of 0.93, 0.931 for TBARS and total carbonyls.

F. Effect of irradiation on differential scanning calorimetric (DSC) profile of fluidised bed dried mutton.

Studies revealed the importance of thermal properties like glass transition temperature (Tg) melting temperature (Tm) and change in enthalpy (ΔH) in evaluating the physical characteristics with respect to irradiation.

Findings endorsed the view that the variation in Tg, Tm and ΔH is having a positive correlation with irradiation dosage.

The percentage of crystallinity change during thermal analysis can be correlated with the physical status of the product.

Investigation revealed dose dependent crystallinity increase in irradiated fluidised bed dried mutton samples.

Both isothermal mode and scanning mode could be successfully utilised to evaluate the thermal property parameters and to assess the physical status of the dehydrated meat products with reference to irradiation.

Alterations in the textural and reconstitution characteristics after irradiation can be correlated with the crystallinity changes and variation in ΔH, Tg and Tm.

The extent of denaturation that is taking place due to process abuse in meat products can be correlated with the percentage of crystallinity and enthalpy change (ΔH).
G. Evaluation of the antioxidant potential of natural and synthetic antioxidants in chicken.

- Studies revealed a good antioxidant potential for MRPs and TBHQ in cooked chicken meat during storage.
- Ascorbyl-6-palmitate, the ester derivative of ascorbic acid possessed a greater antioxidant activity than ascorbic acid in controlling the lipid oxidation during refrigerated storage.
- Studies revealed a higher susceptibility for lipid oxidation for chicken species compared to other species as reported earlier.
- Ascorbyl-6-palmitate exhibited a similar antioxidant activity of BHA in controlling the lipid oxidation in cooked chicken meat.
- The order of antioxidant activity was TBHQ > MRPs > cloves > Ascorbyl-6-palmitate > BHA > Ascorbic acid > PG > cinnamon.

H. Effect of MRPs and ascorbyl-6-palmitate (ascorbyl ester) on the lipid oxidative profile of Hurdle processed, irradiated chicken legs.

- The negative effect of irradiation on the lipid deterioration of chicken samples by producing free radicals was observed in this investigation.
- A dose dependent increase in oxidative rancidity parameters were seen in this study w.r.t irradiated chicken samples.
- Incorporation of preformed MRPs from glucose + lysine and ascorbyl – 6 – palmitate clearly inhibited/retarded the oxidative deterioration of hurdle processed chicken samples during irradiation and storage.
- Oxidative rancidity parameters like TBARS, total carbonyls and peroxide value gave a clear picture of the effect of irradiation dosage on lipid oxidation the presence of antioxidants.
- A positive correlation ($r^2 = 0.98$) existed between peroxide value and other oxidative rancidity parameters.
- Evaluation of the increase in non-heme iron as in the earlier studies, exhibited the extent of catalytic effect in the presence of antioxidants during irradiation and storage.
- Non-heme iron values can be taken as a marker for the evaluation of lipid oxidation profile in irradiated meat samples.
MRPs and ascorbyl – 6 – palmitate showed good inhibition in the lipid deterioration at all doses of irradiation as indicated by the values of TBARS, total carbonyls, PV and non-heme iron.

MRPs and ascorbyl ester treatment coupled with irradiation significantly reduced (p < 0.01) the values of FFA, indicating the effect of these additives.

Total fatty acid profile by GLC reveals the presence of saturated, mono-unsaturated and poly-unsaturated fatty acids in hurdle processed irradiated chicken samples.

Out of the saturated fatty acids myristic and lauric are present in very small quantities while palmitic and stearic contributed the major saturated fatty acids percentage.

From the studies it was observed that saturated fatty acids did not show any significant difference (p > 0.05) throughout the storage period at all the three irradiation dosages of 1, 2 and 3KGy.

MUFAs and PUFAs up to 1KGy exhibited good stability during irradiation and storage.

2KGy and 3 KGy irradiation without antioxidants produced deterioration in the MUFAs and PUFAs values reflecting the effect of higher irradiation dosage on the unsaturated fatty acids.

Effect of MRPs and ascorbyl – 6 – palmitate in protecting the unsaturated fatty acids during irradiation and storage, was clearly reflected this investigation.

Total volatile evaluation of the irradiated chicken samples revealed the production of irradiated volatiles and its correlation with the irradiation dosage.

Loss of irradiated volatiles was observed during storage of irradiated hurdle processed chicken samples.

MRPs and ascorbyl ester treatment significantly reduced (p < 0.01) the irradiated volatiles production.
I. Effect of natural antioxidants on the lipid stability of Freeze-dried chicken pieces.

- Investigation strengthened the view that lipid oxidation is a major problem in dehydrated meat products limiting the shelf stability and acceptability.

- Incorporation of preformed MRPs, ascorbic acid and spices before freeze-drying did have a beneficial effect in controlling the lipid oxidation, WOF development while cooking and catalytic activity of non-heme iron.

- The parameters studied for the evaluation of rancidity parameters showed positive correlation ($r^2 = 0.968$) indicating the effectiveness of these parameters in judging and interpreting the results of this investigation.

- The product with out antioxidants, exhibited lipid deterioration within 3 months of storage and was unacceptable.

- By incorporating antioxidants the lipid stability problem in F.D chicken samples could be solved and the shelf life could be extended to more than 6 months at ambient temperature ($25 \pm 2^\circ C$).

- Investigation again strengthened the importance of non-heme iron as a marker in assessing the catalytic activity and thus lipid oxidation, occurring in this type of dehydration techniques.

- All the natural antioxidants exhibited individual and synergistic antioxidation potential in F.D chicken samples.

- The product treated with MRPs, spices and ascorbic acid exhibited maximum stability.

- The synergistic potential of these antioxidants in controlling the development of hydrolytic rancidity was reflected in this study with respect to F.D chicken pieces.

- The critical water content and water activity was important to maintain a good shelf stability along with antioxidants.

- Volatile evaluation of the F.D chicken product revealed a significant change ($p < 0.05$) in the volatile characteristics after freeze drying. But during storage the volatile loss was not significant in samples treated with MRPs, spices and ascorbic acid.
Antioxidants effect in retaining the volatile characteristics during storage of F.D chicken product by inhibiting the oxidation of pigments, vitamins and fat is established in this study.

Freeze drying did not make any impact in the total fatty acid profile as analysed by GLC.

Samples with MRPs in synergism with spices and ascorbic acid exhibited good stability for all the saturated and unsaturated fatty acids during storage. But other samples exhibited variation in the fatty acids concentration.

To conclude MRPs individually and in synergism with other natural antioxidants exhibited good antioxidant potential in retarding rancidity development in dehydrated, hurdle processed and irradiated meat and poultry samples.