CHAPTER 5

SUMMARY AND CONCLUSIONS

The aim of the present investigation was to develop process technology for flaxseed fortified extruded snack food and cookies. Flaxseed variety NL-260 was selected for the study. Before fortifying into food products, optimization of microwave roasting was carried out by RSM to reduce cyanogenic glycosides (CG) under permissible limits. Microwave roasted flaxseed flour was fortified with rice flour and refined wheat flour to develop extruded product and cookies respectively. Extruded product was optimized by using RSM and cookies were optimized by studying the effect on its physical, textural and sensory characteristics after fortifying with roasted flaxseed flour. Optimized both products were analyzed for its proximate composition and fatty acid profile for comparison and to check the enhancement of nutritional characteristics. Optimized products storage study in two different packaging materials were conducted to track the changes occurred and to suggest most suitable packaging material. 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 Microwave roasting of flaxseed

5.2 Development of roasted flaxseed flour fortified extruded snack food product by using RSM

5.3 Development of roasted flaxseed flour fortified cookies

5.4 Proximate composition and fatty acid profile of developed products

5.5 Storage study of extruded product in two packaging material laminates

5.6 Storage study of cookies in two packaging material laminates

5.7 Conclusions

5.8 Future scope
5.1 Microwave roasting of flaxseed

Optimization of microwave roasting of flaxseed was carried out by RSM considering CG content (expressed as HCN content) as response. CG content is negatively related with the linear effect of microwave power and time of heating (p<0.01). As microwave power and time of heating increased, CG content reduced. When higher microwave power and time of treatment are used, flaxseed found to be burned. Therefore, numerical optimization was carried out to find optimum heating time and microwave power. 60% microwave power and 300 seconds of treatment found to be optimized as it reduced HCN content from 190 ±2.13 mg/kg to 36.4 ± 0.9 mg/kg which was in line with the permissible limits given by FSSA, 2006. HCN removal rate of 80.84% was achieved.

Proximate analysis and fatty acid profile of raw and optimized microwave roasted flaxseed were carried out to investigate the effect of microwave treatment. The moisture content of roasted flaxseed significantly reduced as compared with raw flaxseed. Significant increase in the ash and lipid content can attributed to the increase in the total solids content of roasted flaxseed. A small but insignificant reduction in the protein, crude fiber and carbohydrate content was observed. Traces of palmitolic acid, arachidic acid and other unknown fatty acids had disappeared after roasting of flaxseed. Slight increase in palmitic acid and linolenic acid was observed. Increase in linolenic acid content was observed from 54.28% to 55.37%. Overall there were no major changes in proximate composition and fatty acid profile caused by microwave treatment.

5.2 Development of roasted flaxseed flour fortified extruded snack food product by using RSM

In the present investigation, RFF (roasted flaxseed flour) fortification level (%), moisture content (%) of extruder feed material, temperature (°C) of extruder barrel and extruder screw speed were varied to develop extruded food. The responses used for optimization were expansion ratio, bulk density, breaking strength and overall acceptability score. The experimental results indicated that as RFF fortification increased, ER and OAA score of extruded product decreased while BS and BD increased. As the
moisture content of extruder feed material increased from 12 to 16%, ER and OAA score increased while BS and BD decreased. As the extruder barrel temperature increased, ER and OAA decreased. No significant effect on BS was observed while BD increased as barrel temperature increased. ER and BS was found to be positively related with quadratic effect of screw speed at p<0.01 and p<0.05 respectively. BD was found to be negatively related with quadratic effect of screw speed. The interaction effect of moisture content and screw speed found to be negatively correlated with BS of the product at p<0.01. No significant linear effect of screw speed was observed. Flaxseed fortification level was found to be more significant variable followed by moisture content of extruder feed and then barrel temperature.

Numerical optimization in Design software was adopted to find the best combination of variables. RFF fortification level of 15% at 16 % moisture content, 120°C extruder barrel temperature and 330 extruder screw speed was found to be optimized. At this optimized condition, the product had ER of 3.08, BS of 0.53 kgf, BD of 0.106 g.cm$^{-3}$ and overall acceptability score of 7.86

5.3 Development of roasted flaxseed flour fortified cookies

Roasted flaxseed flour (RFF) was fortified with the replacement of refined wheat flour at 5%, 10%, 15%, 20%, 25% and 30% in the development of cookies. As RFF level increased, thickness and diameter of cookies increased. Lowest thickness of 50±0.76 mm and diameter of 286.75±0.96 at 5% RFF cookies while highest thickness of 69.33±1.15 mm and diameter of 321.25±0.96 at 30% RFF were observed in cookies. As the RFF level increased, spread ratio for different treated cookies gradually decreased from 5.70 ± 0.07 to 4.63 ± 0.06. This reduction in spread ratio might be due to increase in protein and dietary fiber percentage with increasing level of flaxseed flour.

Color score decreased gradually as RFF level increased. Cookies were found be more dark brown at higher RFF level. No significant change in Taste score was observed and flaxseed pleasant nutty taste was liked by the panel members up to 15% RFF level. Beyond 15%, significant reduction in taste score was observed and higher flaxseed nutty taste was disliked by panel members. Texture score values also showed decrease trend as RFF level in cookies increased. Texture score of 8.1 at 5% RFF level
decreased to texture score of 4.6 at 30% RFF level. Overall acceptability score of 7.8 at 5% RFF level decreased to 4.3 at 30% RFF level. Significant reduction in the overall acceptability score was observed at 20% and above RFF level. Overall acceptability score of 7.5 did not significantly affected up to 15% RFF level as compared to the control cookies.

Hardness and fracturability of cookies showed increasing trend when RFF level increased from 0 to 15%. Higher dietary fiber and protein content of flaxseed flour imparted higher hardness and fracturability. However, at 20% and above RFF level, both these textural attributes were found to decrease. The hardness of 1364 g and fracturability of 0.67 mm at 15% RFF level, decreased to the hardness of 1217 g and 0.54 mm at 30% RFF level. Flaxseed flour also contains higher amount fat which imparted lubricating action and also disturbed the protein network resulted in lower hardness and fracturability of cookies. Consequently, crispiness of cookies decreased which also affected texture and overall acceptability score negatively. Therefore, 15% RFF fortified cookies were found to be optimized and acceptable.

5.4 Proximate composition and fatty acid profile of developed products

Proximate analysis of extruded products showed significant increase in the moisture, ash, fat, protein and crude fiber content in the optimized flaxseed fortified product as compared with control extruded product. Desirable nutrients specifically crude fiber and protein content increased approximately by 3 and 1.3 times as compared with the control. Fatty acid profile of extruded products showed that saturated fatty acids i.e. mainly palmitic and oleic acid content decreased while polyunsaturated fatty acids i.e. α-linolenic acid (ALA - omega-3 fatty acid) increased from 24.28% to 46.51% in flaxseed incorporated extruded product. ALA content almost doubled in the flaxseed fortified extruded product as compared with the control product. Increase in fiber, protein and ALA content can attributed due to the addition of roasted flaxseed powder which contains 12.33% crude fiber, 21.10% and 55.37% ALA content.

Proximate analysis and fatty acid profile of cookies also showed significant increase in the moisture, ash, protein, crude fiber and ALA content. About 1.5
times more the protein content, 9 times more fiber content and 25 times more ALA content in the optimized cookies as compared with the control cookies were observed. This confirmed that the nutritional enhancement can be achieved with the fortification of flaxseed flour in food products without affecting its sensory quality.

5.5 Storage study of extruded products in two packaging material laminates

Two packaging material laminates namely METPET/Al/LD laminate and PP/LD laminate were used in the present investigation. WVTR and OTR of METPET/Al/LD laminate was observed to be lower as compared with PP/LD laminate. Control and flaxseed fortified extruded products were packed in two laminates and analyzed at 15 days interval up to 90 days at ambient temperature. Moisture content, breaking strength and OAA score were taken as responses during storage study of extruded product.

Significant effect of packaging material on the extruded product moisture content, breaking strength and OAA was observed. PP/LD laminate products gained more moisture content as compared with METPET/Al/LD laminate product. Consequently, breaking strength and OAA score reduced more for PP/LD Laminates. Comparison between products showed that flaxseed fortified extruded products had more tendency to absorb moisture as compared to the control and consequently they lost their breaking strength and OAA score. Storage period also significantly affected moisture content, breaking strength and OAA score. After 30 days of storage, breaking strength significantly reduced. Moreover, after 45 days of storage, OAA score significantly reduced.

5.6 Storage study of cookies in two packaging material laminates

The above mentioned two laminates were also used in storage study of cookies for 90 days at ambient temperature. Moisture content, peroxide value and OAA score were taken as responses during storage study of cookies.

Significant effect of packaging material laminate was observed on moisture content, peroxide value and OAA score. Highest moisture content and peroxide
value were observed in the cookies packed in PP/LD laminate while highest OAA score was observed in the cookies packed in METPET/Al/LD laminate. Moisture content was significantly affected by storage period. Peroxide value and OAA score was not significantly affected up to 45 days and 60 days respectively. After wards, significant effect was observed in both parameters. Flaxseed fortified cookies were observed to gain higher moisture content and peroxide value as compared to the control cookies. Lower moisture content and peroxide value along with higher OAA score confirmed that METPET/Al/LD laminate performed better in preserving the wholesomeness of cookies.

5.7 Conclusions

- Microwave power of 60% and heating time of 300 seconds optimized for microwave roasting of flaxseed to reduce cyanogenic glycosides under permissible safe limit.
- Microwave roasting of flaxseed did not significantly affect on proximate and fatty acid composition. Therefore, microwave roasting can be adopted to reduce anti-nutritional factors in flaxseed.
- Roasted flaxseed flour fortification at 15% with rice flour gave the most desirable product at processing conditions of 16% moisture content of extruder feed, 120°C extruder barrel temperature and 330 extruder screw speed. The optimized product had Expansion Ratio of 3.08, Breaking Strength of 0.53 kgf, Bulk Density of 0.106 g.cm\(^{-3}\) and overall acceptability score of 7.86.
- Roasted flaxseed flour fortification at 15% with refined wheat flour resulted the optimized cookies without affecting its organoleptic characteristics. The optimized cookies had sensory taste, texture and overall acceptability score of 7.4, 7.2 and 7.5 respectively on 9-point hedonic scale.
- Desirable nutrients specifically protein, ALA and fiber content increased by about 1.3 times, 2 times and 3 times more respectively as compared with control in extruded product while about 1.5 times, 25 times and 9 times more respectively as compared with control in cookies. Proximate composition of both developed products confirmed the nutritional enhancement of desirable components like protein, fiber and ALA content.
(essential omega-3 fatty acid) can be achieved by the fortification of flaxseed in the food products.

- METPET/Al/LD laminate performed better than PP/LD laminate to preserve the wholesomeness of both products during 90 days of storage at ambient temperature.
- Flaxseed fortified products showed more susceptibility towards moisture gain, loss of crispiness and oxidation during storage. With the increase in storage period, sensory score of flaxseed fortified products decreased rapidly compared with the control.

5.8 Future Scope

- Different fractions of flaxseed (i.e. flaxseed oil, defatted flaxseed meal) can also be explored in the development of food products.
- Different cereals, millets and pulses combination with flaxseed flour can also be explored in the development of food products.
- Storage study of developed products in the present investigation can be continued for enhancing shelf life.
- Effect of anti-oxidant on the shelf life of flaxseed fortified products can be carried out.