CHAPTER 5

SUMMARY AND CONCLUSION

Nowadays, the focus has been shifted to the production of non-traditional crops that are capable to cope up with the unfavourable climatic as well as soil conditions and do not depend much on fertilizers and irrigation. The present work was carried out to study physical property of *C. quinoa* seed followed by preparation of flour (using appropriate mill) and its characterization. Process standardization for isolation of starch from *C. quinoa* and its characterization for various properties was also carried out followed by optimization for development of products from both flour and starch. The developed products were then evaluated for various quality parameters, storage stability and *in vitro* digestibility.

Quinoa seeds were analysed for various physical properties like size, thousand kernel weight, density, porosity, angle of repose and coefficient of friction with increase in moisture content from 5 to 25%. Varying moisture content can also lead to flow problems in silos, such as arching, segregation and irregular flow. Moisture content showed the significant effect on all engineering properties (except sphericity) with some properties showing a negative correlation with moisture and vice-versa. Results revealed that both the quinoa varieties showed smaller variation in physical properties with V2 being slightly higher in principal dimensions, bulk density and thousand seed weight than V1. However, V1 showed higher angle of repose and coefficient of friction.

Selection of appropriate mill for preparation of flour from *C. quinoa* seeds was done by using two mills (stone mill and cyclotec mill). The flour obtained from both the mills was analysed for particle size, color and various functional properties like water absorption index, water solubility index and oil absorption capacity. Suitable mill was then selected on the basis of particle size and functional properties of flour. Smaller particle size has been related with the proper binding of the product and is suitable for pseudocereals which are devoid of
gluten. Results revealed that the cyclotec mill resulted in the flour of brighter appearance, smaller and more uniform particle size with better functionality hence was selected for conversion of quinoa seed to flour.

The *C. quinoa* flour was then analyzed for physico-chemical, functional, pasting, morphological and structural properties. Quinoa flour showed high starch content and good nutritional composition. Quinoa flour from both the varieties showed typical A-type diffraction pattern, lower relative crystallinity and lower setback viscosity. Lower viscosity of quinoa flour may be due to its high protein and fibre content which hinder the development of paste. Morphological properties revealed the presence of many irregular chunks with the starch granules being either scattered or embedded within a dense matrix of fibre, protein or other constituents. Fatty acid profile showed the abundance of linoleic acid contributing about 47 -58.23 % of lipid fraction. Insoluble dietary fibre was present in higher amount and contributed about 86.39 to 86.93 % of total dietary fibre. Among the varieties used in present study V2 showed higher foaming capacity, foam stability, emulsifying capacity and emulsion stability owing to its higher protein content. Antioxidant activity, total phenolic content and total flavonoid content was higher for V2 than V1. Antioxidant activity was found to be 17.46% for V1 and 19.24 % for V2. Presence of antinutritional components is the major drawback of this super food. These components can have negative health effects when used as primary dietary energy source and some of these factors can impart bitterness to quinoa thereby limiting its use. For removal of the antinutritional components quinoa seeds were soaked and rubbed in water prior to preparation of flour. Soaking and rubbing the seeds in water resulted in effective reduction of antinutritional components than soaking alone. Soaking was selected for removal of antinutritional components as the main antinutritional component in quinoa is saponin and it is water soluble. Further, the treatment is simple and inexpensive. Soaking along with rubbing reduced the saponin content from 2.95 to 0.31 % for
V1 and from 3.22 to 0.52 % for V2. Soaking along with rubbing reduced the phytate content from 510 mg/100 g to 417 mg/100 g for V1 and 652 to 544 mg/100 g for V2.

Demand for starch is growing at a faster pace as the new food processing industries are increasingly dependent on both native and modified starches for the manufacture of various fabricated foods. Process for isolation of starch from quinoa was standardised by using seed as well as flour for isolation purpose and also by varying the alkali concentration (0.20-0.30%). Process standardisation for isolation of starch was followed with a target to obtain the product of higher yield and purity. Results revealed that higher yield and purity was obtained from flour instead of whole seed at an alkali concentration of 0.25%. Higher alkali concentration resulted in the formation of mucilaginous starch layer on the surface after centrifugation posing the difficulty in starch separation thereby leading to reduced starch yield. Starch isolated by standard process was examined for physicochemical, morphological, thermal and pasting properties. Among the selected varieties V1 showed higher starch yield, viscosity profile and amylose content than V2. In contrast to quinoa flour quinoa starch showed higher viscosity profile. Morphological analysis revealed that the starch granules from both varieties were irregular, angular and polygonal in shape. Quinoa starch from both the varieties showed typical A-type X-ray diffraction pattern with varying crystallinity. Results from starch extraction and characterization revealed that both varieties can be explored for commercial starch production and the starch can be used for various food (thickener, stabilizer, and weaning foods) and non-food (pharmaceuticals, textiles) applications. The swelling power of both the starches place them in category of highly restricted-swelling starch which is desirable for products like noodles and composite blends.

Central composite rotatable design was used to optimize the levels of process conditions (baking temperature and time) and ingredients (sugar and fat) on the selected responses for development of cookies. Cookies represent the largest category of snacks in
bakery industry and can serve as effective vehicle of nutrient supply to consumer. Analysis revealed that the selected independent process variables had a dominant effect on responses. The optimal conditions obtained for development of cookies were fat content, sugar content, baking temperature and baking time of 41.83 %, 33.95 %, 181 °C and 18 min, respectively. Experimentally determined values for responses under such optimum conditions were color 53.05, spread factor 7.16, hardness 47.05, antioxidant activity 20.67 (% DPPH inhibition) and overall acceptability 7.61. Increase in fat and sugar content increased spread factor and decreased the hardness of cookies, while an increase in baking temperature and time decreased spread factor and increased hardness. Formation of Maillard reaction products during baking improved the antioxidant activity.

For development of noodles, modification of quinoa starch was done to observe its effect on properties of starch as well as the noodle quality. As, the quality of noodles depends on physico-chemical, functional and pasting properties of the starch. Modification was done by two methods heat moisture treatment and gum addition. The results revealed that quinoa starch has a great potential for noodle preparation, while as, the modification techniques were ideal for improving the quality of noodles. Both the modifications successfully improved the properties of quinoa starch and noodle quality with hydrocolloid modification being more desirable than HMT. Cooking loss for modified noodles (HMT-QS- 6.17 g/100g; GM-QS-5.25 g/100g) was lower than native starch noodles (7.18 g/100g). Cooking time of noodles was higher for HMT-QS (4.07 min) followed by GM-QS (3.11 min) and native (3.04 min). Among all the samples gum added quinoa starch resulted in the noodle sample with best cooking, textural and sensory characteristics.

The developed quinoa cookies were then stored in two different packaging materials like low density polyethylene (LDPE) and laminate pouches of metalized polyester polyethylene (MET-PPE) for 120 days at a temperature and relative humidity of 30±2 °C and
65±5% respectively. Stored packed samples were then withdrawn periodically every 15 days for analysis of various parameters. With increase in storage duration moisture content and water activity of the packed samples increased with LDPE showing the significant effect. Peroxide value, free fatty acid and microbial count was also higher in case of cookies packed in LDPE. While as, Yeast and mold count was absent in both the packaged samples throughout the storage study period. Sensory score reduced drastically in case of cookies packed in LDPE in comparison to cookies packed in MET-PPE. Results revealed that the quinoa cookies packed in MET-PPE were shelf stable up to 120 days under studied conditions.

The developed quinoa starch noodles were stored in two different packaging materials like low density polyethylene and biaxially oriented polypropylene for 180 days at a temperature and relative humidity of 30±2 °C and 65±5% respectively. Stored packed samples were then withdrawn periodically every 30 days for analysis of various quality parameters. Sensory score showed a slight decline in case of both the packaging materials with LDPE showing comparatively higher decline. Results revealed that the noodles packed in both the packaging materials were shelf stable up to 180 days under studied conditions.

Digestibility of protein is considered as an important characteristic of its nutritional quality. Developed flour based product showed higher in vitro protein digestibility than the corresponding flour. Results revealed that the processing conditions like baking can improve the protein digestibility of the food due to unfolding of protein at higher temperatures. Starch digestibility has been divided into three fractions; readily digestible, slowly digestible, and resistant starch. Product developed from starch showed lower readily digestible starch (53.75%) and higher slowly digestible starch (33.42%) in comparison to that of the starch from which it was developed. While as, the product developed from flour (cookies) showed slightly higher RDS (31.51%) and lower SDS (20.58%) in comparison to the flour from
which it was developed. However, the difference was marginal in case of cookies. From the results of *in vitro* starch digestibility it can be predicted that quinoa flour and cookies could be considered as an ideal resistant starch material due to their low slowly and readily digestible starch in comparison to the starch, whereas the noodles could be more suitable as a slowly digestible starch material. Further, retrogradation makes starch more resistant to enzymatic hydrolysis and hence retrograded starches can be used for preparation of low-calorie or low glycemic index foods.
Future scope of study

*C. quinoa* is gluten-free has wide adaptability and immense nutritional potential and thus can be commercially grown on a larger scale especially in India. Suitable equipment for proper dehulling of *C. quinoa* seeds to remove the antinutritional components can be designed based on the physical properties. Quinoa seeds being higher in protein can be explored for isolation, characterization and utilization of proteins. Scaling-up of development process of *C. quinoa* cookies could be explored and can be beneficial for people suffering from celiac disease. The study can be extended to the utilization of quinoa flour for development of some other ready to eat snacks apart from cookies. Native and modified starches from quinoa obtained in the present investigation can be utilized in diverse range of food products. Apart from the modifications used in present investigation quinoa starch can be modified by some other means like irradiation, acetylation and cross-linking to observe the effect of these modifications on functional properties of the starch and end-product.