Amaranth (*Amaranthus* spp.) is a nutritious grain because of its unique composition. The awareness in peoples about their health is increasing and amaranth can meet their daily nutrition requirement being higher in nutritional value than common cereal grains (corn, rice and wheat). It is a good source of protein and amino acids, the present protein does not form gluten when amaranth flour hydrates with the water. Hence, amaranth can be recommended for people with celiac disease. Amaranth is a good source of important minerals like calcium, magnesium and iron that are deficient in gluten-free products. Despite the nutritional potential of the amaranth grain it also contains some antinutritional factors which limit their food application. Germination is an inexpensive and effective way to improve the nutritional value and reduce antinutritional factors. The use of germinated flour is the natural way to fortify and enrich gluten-free foods.

In India popped amaranth grains are used in making laddu on Hindu fasting days when people do not consume food from cereal and legume sources. Amaranth flour blended with other flour shows applicability in foods includes items like bread, biscuits, cakes and pasta. But there is very less research on whole amaranth flour product preparation. In addition to its nutritional characteristics, amaranth plants have agronomic features identifying it as an alternative crop which might increase the use of marginal lands i.e. dry soil, high altitude and high temperature, where cereal and vegetable cannot be grown making it more environmental friendly. Amaranth could play an important role in Indian context because it produces high quality grain which can improve daily diet. Keeping in view the above, the present study has been undertaken for optimization of the processing parameters of raw and germinated amaranth grains for flour preparation.
Further raw and germinated amaranth flour has been characterized for various nutritional aspects and to develop wholesome cookies and pasta from whole raw and germinated amaranth flour. Both products (cookies and pasta) were analyzed for their quality characteristics and storage study.

The optimization of germination process was carried out for amaranth grains. The optimal conditions for germination of amaranth grain were: germination time (22 h) and germination temperature (35.86°C). Under these optimal germination conditions, amaranth grain showed higher nutritional and lower antinutritional value e.g. protein (16.53 %), total dietary fibre (11.84%), antioxidant activity (13.63 %), phytic acid (0.70 g/100 g) and tannin (0.45 mg/100g). Further, the process for the preparation of flour from raw and germinated amaranth grains was optimized by using two mills viz. stone mill and cyclotech mill at different moisture content (10, 12, 14, and 16%). The average particle size and functional properties (WAI, WSI, OAC, BD, TD and porosity) were determined. On the basis of average particle size and functional properties cyclotech mill was found best to produces a finer particle size and improved functional properties of raw and germinated amaranth flour, at 12% moisture content.

The amaranth flour (raw and germinated) obtained by cyclotech mill were characterized for its proximate composition, color value, functional component, mineral composition, fatty acid profile, amino acid profile, morphological characteristics, pasting properties, and antinutritional factors. Germinated amaranth flour shows significantly increase in \( p \leq 0.05 \) ash, protein, crude fibre, reducing and total sugars (3.4%, 17.4%, 5.70%, 4.12% and 8.60%) than raw amaranth flour (2.91%, 15.15%, 4.80%, 3.07% and 5.90%) while significantly lower value for fat, carbohydrate, and starch content (4.7%, 60.7% and 32.68%) than raw amaranth flour (6.68%, 62.41% and 40.11%) were observed. The color analysis depicted that germinated amaranth flour was darker in color as
indicated by its lower L* value (77.85) than raw amaranth flour (80.20) that might be due to the presence of high phenolic content in the germinated amaranth flour. The results of functional components revealed that germinated amaranth flour exhibited significant (p≤0.05) higher value for antioxidant activity (14.71g/100g), total dietary fibre (12.9g/100g), total phenol content (49.20 mg GAE/100g extract), and total flavanoid content (7.12 mg CE/100g extract) than raw amaranth flour (10.23g/100g; 9.52g/100g; 47.07 mg GAE/100g extract; and 6.90 mg CE/100g extract). Among minerals (calcium, magnesium, sodium, iron, potassium, and zinc) were analyzed. The mineral content increased significantly after germination viz. calcium, magnesium, sodium, potassium, and zinc (170.27 to 189.27mg/100g; 117.75 to 129.17 mg/100g; 195.02 to 216.94 mg/100g; 77.86 to 165.22 mg/100g; 2.76 to 4.86 mg/100g). However, germinated amaranth flour showed lower values for iron (10.62 mg/100g) than raw amaranth flour (13.1 mg/100g). The results of fatty acid profile showed that linoleic was the dominant fatty acid, while palmitic acid was found as a minor fatty acid in amaranth flour. After germination an increase was noticed in oleic acid and linoleic acid from 1.84 to 1.99% and 1.94 to 2.30% respectively, while the decrease was noticed in palmitic acid from 1.06 to 1.00%.

The eighteen amino acids were identified and quantified by HPLC, which includes His, Ile, Leu, Lys, Met, Phe, Thr, Trp and Val as essential amino acids, Cys, Tyr, Gly, Arg, and Pro as conditionally essential and Asp, Glu, Ala and Ser as non-essential. Germinated amaranth flour revealed the higher values for His, Ile, Leu, Lys, Phe, Thr, Arg, Tyr, Pro, Glu, Ala, Ser and Asp however, a decrease was noticed in Met, Try, Val, Cys, and Gly as shown in Table 4.11.

The SEM micrograph showed the structural differences between raw and germinated amaranth flours. Raw amaranth flour exhibited intact starch granules embedded in a very dense protein matrix. Conversely, starch granules had been degraded
in the germinated amaranth flour. The results of pasting profile revealed that germination significantly affects pasting properties of amaranth flour as it decreased the values of peak viscosity, breakdown, setback, final viscosity and pasting temperature. Germinated amaranth flour showed substantially lower peak (93.32 RVU), trough (62.58 RVU), breakdown (10.66), final viscosity, (82.33 RVU), setback (12.16 RVU) than that of raw amaranth flour (124.26, 98.0, 26.0, 115, 17.6 RVU) respectively. Germinated amaranth flour showed a significant lower value of phytic acid and tannin, (0.70 g/100g and 0.45 g/100g,) than raw amaranth flour (1.42 g/100 g and 0.69 g/100 g).

Cookies and pasta were prepared from raw and germinated amaranth grain flour. The prepared cookies and pasta were analyzed for various quality characteristics. For cookies, several parameters such as physical properties (weight, thickness, diameter and spread ratio), color characteristics, textural properties, sensory properties were analyzed. It was observed that raw amaranth flour cookies exhibited higher spread ratio (7.95) followed by germinated amaranth flour cookies (7.44) and wheat flour cookies (7.21). The result indicates that germinated flour cookies showed lowest hardness (42 N) than the raw (50.53 N) and control cookies (92.25 N). The color analysis depicted that germinated amaranth flour cookies were darker in color as indicated by its lower $L^*$ value (61.7) than raw (63.25) and control (65.2) cookies that might be due to the darker color of germinated flour. On the basis of sensory analysis, it was observed that cookies prepared from germinated amaranth flour were superior over that of raw as well control.

Amaranth flour pasta was prepared with addition of different gums (guar gum, gum acacia, and gum tragacanth) at different proportion 0.5 and 1.0% and analyzed for various properties viz. color, cooking characteristics (cooking time, water uptake, and cooking loss), TPA, and sensory analysis. Pasting properties of amaranth flour with different gums were also analyzed before pasta preparation. Data revealed that the guar gum was found
most effective in improving the pasting properties of raw and germinated amaranth flour. Germinated amaranth flour blends shows a significant lower values for all pasting properties than raw amaranth flour blends. The color analysis shows a significant difference in color values of raw and germinated amaranth flour pasta samples than the control pasta. Germinated amaranth flour pasta showed the lowest $L^*$ value < raw amaranth flour pasta < control pasta. All formulations of germinated amaranth flour pasta exhibited lowest cooking time (3.06 to 3.23 min.) < raw amaranth flour pasta (3.26 to 4.14 min.) < control (6.10 min.). Germinated amaranth flour pasta also shows the highest water uptake ranging from 186.41 to 225.62 g/100 g > raw amaranth flour pasta (161.29 to180.60 g/100g) > control pasta (144.78 g/100g). Similarly, germinated amaranth flour pasta showed a significant highest cooking loss in range 10.5 to 18.1% > raw amaranth flour pasta formulations (8.5 g – 17.3 g /100 g), > control pasta (7.4g/100g). Among amaranth pasta formulations, raw amaranth flour pasta with 1.0 % guar gum showed minimum cooking loss (8.5 g/100 g) whereas germinated amaranth flour pasta with 0.5% gum acacia showed maximum cooking loss (18.1 g/100 g).

The control pasta showed maximum hardness (3.85N) than all raw and germinated amaranth flour pasta. Among all the amaranth flour pasta samples, germinated amaranth flour pasta with 1.0% guar gum showed highest hardness (2.96N), followed by raw amaranth flour pasta having 1.0% guar gum (2.59N). Likewise, the control pasta showed lowest adhesiveness (-58.37) as compared with raw amaranth flour pasta. Among all the amaranth flour pasta, raw amaranth flour pasta with 1.0% guar gum showed least adhesiveness (-36.31) whereas, germinated amaranth flour pasta having 0.5 % gum acacia indicated highest adhesiveness (-10.63). The control pasta showed highest value of chewiness (223.73) as compared to amaranth flour pasta. Germinated amaranth flour pasta prepared with 1.0% guar gum addition showed maximum chewiness (188.58) as compared
with other amaranth flour pasta formulations. Microscopic examination of uncooked raw amaranth flour pasta revealed a compact structure with visible starch granules deeply embedded in the protein matrix. The protein network forms a more uniform layer over the starch matrix and starch was less degraded in raw amaranth flour pasta. While in germinated flour pasta, starch and protein granules had been degraded. Furthermore, cooked pasta shows structural changes in starch and protein. Sensory score indicates that 1.0% guar gum improved the sensory characteristics of both pasta samples. Results revealed that raw amaranth flour was more suitable than germinated amaranth flour for pasta preparation.

Cookies and pasta prepared from amaranth flour (raw and germinated) were stored for 90 and 180 days at ambient storage conditions (27±2°C and 58±2% R.H.). During the storage period cookies were evaluated for different characteristics (moisture content, water activity, free fatty acid value, peroxide value, hardness, and overall acceptability) at a time interval of 0, 15, 30, 45, 60, 75, and 90 days. Likewise, pasta was analyzed for different characteristics viz. moisture content, water activity, cooking loss, and overall acceptability at a time interval of 0, 30, 60, 90, 120, 150, and 180 days. It was found that moisture content of the raw and germinated amaranth flour cookies stored for 90 days were in the permissible limits. However, more increase in the moisture content was observed in germinated amaranth flour cookies (2.72 to 3.20%) as compared with raw amaranth flour cookies (2.20 to 2.61%). The values of water activity for germinated amaranth flour cookies were slightly higher (0.33 to 0.44) than raw amaranth flour cookies (0.21 to 0.33). Results indicate that the water activity of the raw and germinated amaranth flour cookies was in the microbiologically safe limits up to 90 day. Germinated amaranth flour cookies presents slightly higher values of peroxide value (5.22 to 6.35 meq.peroxide/Kg) than raw amaranth flour cookies (4.13 to 4.67 meq.peroxide/Kg).
Similarly, the values of FFA for germinated amaranth flour cookies were slightly higher (0.60 to 0.77 mg KOH/g) than raw amaranth flour cookies (0.33 to 0.51 mg KOH/g). But the FFA value of both cookies were according to ISI specification (IS: 7487) in which the acidity of fat as 1.5% (maximum) for high protein biscuits. Furthermore, there was a significant decrease in hardness values of raw and germinated amaranth flour cookies stored up to 90 days. Germinated amaranth flour cookies showed lower hardness (42.44 to 34.10 N) than raw amaranth flour cookies (50.37 to 45.11 N). Sensory analysis shows that there was no significant change in overall acceptability of stored cookies (raw and germinated amaranth flour) up to 90 days. Data showed that all the quality parameters are within the permissible limits up to 90 days storage period.

The results of storage study of pasta revealed that the moisture content of raw and germinated amaranth flour pasta increased from 6.10 to 6.52% and 6.20 to 6.74% up to 180 day of storage. Similarly, a significant change was noticed in water activity of raw and germinated amaranth flour pasta stored up to 180 days. Germinated amaranth flour pasta showed higher water activity increase from 0.37 to 0.42 than raw amaranth flour pasta ranging from 0.33 to 0.38. Further, there was no significant change in cooking loss and overall acceptability of raw and germinated amaranth flour pasta up to 180 days of storage. Data shows that both raw and germinated amaranth flour pasta could be stored up to 180 days at ambient condition without changing their quality characteristics.

The results about nutritional evaluations indicates that germinated amaranth flour cookies documented the higher values of all parameters like moisture (2.75%), ash (0.97%), protein (11.18%), crude fiber (0.69%), antioxidant activity (21.43%) and total dietary fibre (13.97%) than raw amaranth and wheat flour cookies. Likewise, data shows that germinated amaranth flour pasta expressed higher value for all parameters ash
(1.70%), protein (16.38%), crude fibre (5.42%), antioxidant activity (14.56%) and total dietary fibre (9.12%), except fat (4.08%) than raw and control pasta.

Furthermore, our results indicate considerable variations in chemical composition of the amaranth flour by germination. So, germinated amaranth flour could be used to provide more nutritional benefits, not only for celiac patients, but also for the general population. Our studies show that raw as well as germinated amaranth flour represents great nutritional profile for manufacture of nutrient-rich gluten-free products.