# *Summary and Conclusion*

# CHAPTER V

# SUMMARY AND CONCLUSION

Millets, and specifically finger millet (*Eleusine coracana*), have gained recognition as essential crops in the context of food security, especially in developing countries where reliance on staple grains like rice and wheat poses sustainability and nutritional challenges. Finger millet also has a nutritional profile that makes it particularly valuable: it contains a high amount of dietary fiber, essential amino acids, and minerals such as calcium, which is present at levels unmatched by other common cereals.

While finger millet holds substantial nutritional promise, its natural composition includes various anti-nutritional factors that limit the full bioavailability of its nutrients. These factors include tannins, and phytic acid, which interferes with the absorption and digestibility of crucial vitamins, minerals, and proteins. These factors underscore the importance of processing methods that can reduce anti-nutritional compounds while preserving the rich nutrient profile of finger millet.

Various traditional methods are employed to reduce antinutritional factors in finger millet, including soaking, fermentation, decortication, and germination. However, traditional processing methods have certain limitations. To overcome these limitations, novel non-thermal processing methods are being explored. Among the novel techniques, Cold plasma (CP) technology has shown particular promise in processing millet. Its ability to inactivate antinutritional factors like tannins and phytates without significant heat application sets CP apart from traditional methods.

In this regard, the research entitled “Application of atmospheric pressure cold plasma on the quality attributes of finger millets” was performed with the following objectives: i) To determine physico-chemical, functional, nutritional and antinutritional properties of finger millets (full grain, dehusked, and flour). ii) To develop an optimized process protocol for the reduction of antinutrients and enhancement of quality of finger millets (full grain, dehusked and flour). iii) To conduct storage studies of the CP treated millet.

A multi-pin dielectric barrier discharge atmospheric pressure plasma system (Ingenium Technologies, Odisha, India) was employed in this study for plasma treatment. The specifications of CP set up includes: 200 - 250 V, single phase, 50 Hz, 40 kV- 50 kV output voltage with 72 pins and a discharge area of 2840 $cm^2$.

The experiment design employed in this study was Box Behnken design created using design expert software (version 12.0.3.0). The process parameters selected were voltage (10 to 20 kV), treatment time (10 to 20 min), and electrode distance (8 to 10 cm) and the responses selected were tannin content and phytic acid content.

The quality parameters of finger millet samples under optimised conditions were analysed. The properties such as color, Water absorption capacity ($W_{AC}$), oil absorption capacity ($O_{AC}$), water solubility index ($W_{SI}$), emulsifying capacity ($E_C$), foaming capacity ($F_C$) was determined in the optimized samples.

The storage study was conducted on control and CP-treated finger millet samples under optimized conditions. Both treated and control samples were packed in LDPE packets and laminated pouches. Quality parameters were assessed at room temperature (28±3°C) every 7 days for 18 weeks.

**The results of the above experiments are summarized as following:**

The moisture content showed slight variations, with full-grain and dehusked samples containing 8.62% and 8.67%, respectively, while the flour form exhibited a higher moisture level at 11.56%. Color analysis revealed distinctions among the different forms, with the flour showing a significantly higher L* value compared to the full-grain and dehusked forms. The dehusked form displayed a higher redness (a*) value, whereas the flour had the lowest a* value. Regarding macronutrient composition, carbohydrate was found to be relatively high across full-grain, dehusked, and flour. Protein content was fairly consistent, with full-grain finger millet containing 7.8%, dehusked millet 7.1%, and flour 7.4%. Fat and ash contents showed minor fluctuations, with values around 1.1–1.6% for fat and 2.3–2.9% for ash. The levels of antinutritional factors—phytic acid and tannin—differed notably across the forms. Phytic acid was highest in the flour form at 616 mg/100 g, followed by the dehusked and full-grain forms, which had similar levels around 362 mg/100 g. Tannin content was lowest in case of dehusked grain than full grain and flour. Total phenolic content was fairly consistent across all forms, averaging around 270–283 mg/100 g. $W_{AC}$ was highest in the flour (0.666 g/g). Also, $O_{AC}$ was also greater in the flour (0.277 g/g), indicating its suitability for products with oil-based ingredients. The $W_{SI}$ followed a similar trend, with the flour form displaying the highest value at 30.81 g/100 g. The $F_C$ and $E_C$ were also most prominent in the flour, at 9.3% and 25.3%, respectively.

The effect of process parameters (voltage, treatment time, electrode distance) on tannin and phytic acid content was analysed. The conditions of the process parameters for minimising tannin and phytic acid content were optimised using RSM. For full grain finger millet, the optimal conditions, were determined to be 20 kV of voltage, 18 min of treatment time with an electrode distance of 10 cm. Under these optimal conditions, the values for the dependent parameters such as tannin and phytic acid content were 124.09 and 545.97 mg/ 100 g. In case of dehusked finger millet, optimal conditions were achieved at a voltage of 20 kV, a treatment duration of 19 min, and an electrode distance of 10 cm. Under these conditions, the tannin and phytic acid contents were measured at 68.74 and 266.12 mg/100 g, respectively. For finger millet flour, optimal processing conditions were identified as 20 kV, treatment time of 20 min, and an electrode distance of 9 cm. Under these optimal conditions, tannin and phytic acid contents were recorded as 101.97 mg/100 g and 351.77 mg/100 g, respectively. It was found that CP treatment reduced tannin content by 24.4%, 15.37% and 27% in finger millet full grain, dehusked and flour, respectively. While, phytic acid content was decreased by 30%, 19.39%, 43% in finger millet full grain, dehusked and flour, respectively.

Furthermore, characterization of finger millet samples was conducted at optimized condition and compared with untreated millet sample. Optimized sample had improved functional properties such as $W_{AC}$, $O_{AC}$, $W_{SI}$, $E_C$, and $F_C$. Additionally, FTIR spectra indicated functional group concentration changes, while SEM showed surface cracks post-CP treatment. Also, CP helps in achieving over a 4-log reduction in bacterial count and a 3-log reduction in yeast/mold.

The storage study was conducted on finger millet (full grain, dehusked, and flour) control samples and those treated with CP under optimized conditions. The samples were packaged in LDPE packets and laminated pouches. The quality attributes such as phytic acid, tannin content, total phenolic content, moisture content, pH, free fatty acid content of the samples was evaluated every 7 days over 18 weeks at room temperature (28±3°C). The storage study indicated that treated samples of full-grain, dehusked, and finger millet flour stored in laminated pouches exhibited minimal quality changes over 18 weeks compared to other samples.

**Following conclusions were derived based on the findings:**

- CP treatment effectively reduces antinutritional factors, including tannin and phytic acid content in full grain, dehusked, and flour of finger millet.
- Functional properties of finger millet improved following CP treatment.
- CP treatment is effective in lowering microbial counts, enhancing the grain's safety and storage potential.
- FTIR spectral analysis and SEM micrographs revealed changes in surface morphology post-treatment.
- Optimized samples stored in laminated pouches retained quality for up to 18 weeks, showing minimal changes.
- These findings suggest that finger millet treated under optimized conditions and stored in laminated pouches holds promising for industrial applications due to its reduced anti-nutritional factors and enhanced functional properties.
- CP technology thus holds significant potential for improving finger millet's suitability for consumption and extended storage.

**Scope of future work**

- Future research should explore CP’s effects under different atmospheric conditions and gas compositions to further understand its application.
- Additionally, long-term storage studies would be beneficial to assess the stability of CP-treated millet's enhanced properties over time.
- Integrating CP with other non-thermal methods could offer synergistic effects, potentially enhancing both nutritional and sensory properties while extending shelf life.
- Research could also focus on scaling up CP technology for commercial applications to make millet products more accessible and affordable for consumers, contributing to sustainable and health-focused food systems.
- Finally, studying CP’s impact on other antinutritional factors and its interactions with bioactive compounds could expand the understanding of CP’s role in food processing and support further innovation in plant-based food treatments.