CHAPTER V
SUMMARY AND CONCLUSIONS

The pigeon pea (*Cajanus cajan* L.) grain is considered as most difficult for dehulling as compared to other pulses. Seed coat is more firmly attached with the cotyledons through a layer of gum and mucilage. Due to the presence of gummy layer and hard seed coat, it is difficult to mill. Pre-milling treatments are generally employed to loosen the seed coat to remove husk without losing any edible portion. In milling method various approaches to remove hulls, namely wet and dry milling, CFTRI method, Pantnagar process, CIAE method and IIPR method for pigeon pea milling. Generally, there are many pre-milling treatments, with respect to different milling methods, to facilitate before dehulling for loosening of seed coat of pigeon pea grains. All of the above mentioned treatments are time consuming and overall the complete milling of pigeon pea requires 4 to 7 days. At present, the consumer’s requirements are that the dhal should be cooked well in minimum possible time and have a good taste and flavour. This necessitated the suitable pre-treatment for pigeon pea milling that can shorten the processing time and improve the product quality.

It is necessary to have special pre-treatment to dissolve the glue that binds the cotyledons of pigeon pea grains to the seed coat. It is evident that dehulling quality is highly dependent on physical properties of grains and pre-treatments. Enzymatic pre-treatments have shown increased recovery and quality of pigeon pea dhal.

In view of above, it was felt necessary to develop a suitable enzymatic pre-treatment which could be helpful in easy dehusking giving higher recovery of better nutritional, milling and cooking quality of dhal. Hence, the present research work was undertaken with the following objectives.

1. To study the proximate composition of pigeon pea grains
2. To determine the effect of enzymatic pre-treatments on dehulling efficiency, protein content and cooking quality of dhal
3. To optimize the enzymatic process parameters for better recovery and quality of dhal
The experiments mainly consisted of chemical properties of pigeon pea grains, enzymatic pre-treatments on milling quality, protein content and cooking time. The proximate composition of pigeon pea grains at 12.45 % m.c was found to be 20.09 ± 0.06 % protein, 54.50 ± 0.11 % carbohydrate, 02.17 ± 0.02 % fat, 07.20 ± 0.07 % crude fibre and 03.20 ± 0.05 % ash. Enzymatic pre-treated and control samples 1 kg weight having about 12.45 % moisture content (w.b.) were milled using laboratory dehusking machine/dhal mill. Samples were milled at the standard setting of the machine, i.e., 1420 rpm operating speed and 64 kg/h feed rate. The different fractions of the milled product were separated for calculation of hulling efficiency. Generally, the dry method is followed throughout the Indian subcontinent for milling of pigeon pea. Hence, for the comparison of enzymatic pre-treatment, the dry milling method was considered as control.

Selection of enzymes was based on the chemical composition and binding substances present between husk and cotyledon of pigeon pea grain. The xylanase, cellulase and pectinase are the key enzymes that rupture the binding materials leading to increase the dehulling efficiency. The effects of four enzymatic hydrolysis parameters viz., enzyme concentration (20, 27.5, 35, 42.5, 50 mg/100 g dry sample), incubation time (4, 6, 8, 10 and 12 h), incubation temperature (35, 40, 45, 50 and 55 °C) and tempering water pH (4.0, 4.5, 5.0, 5.5 and 6.0) on hulling efficiency, protein content and cooking time were optimized using response surface methodology.

The optimum condition obtained through response surface analysis was verified by conducting the experiment. The value of dehulling efficiency, protein content and cooking time were considered for the validation.

Based on the inferences drawn from the results obtained during the study, the following conclusions could be drawn.

1. The proximate composition of pigeon pea grains, viz., moisture content 12.45 ± 0.068 % (w.b.), protein 20.09 ± 0.065 %, carbohydrate 54.50 ± 0.11 %, fat 02.17 ± 0.026 %, crude fibre 07.20 ± 0.072 %, and ash 03.20 ± 0.050 %.

2. The value of hulling efficiency, protein content and cooking time of oil treated pigeon pea grains were found to be 66.36 %, 18.74 % and 18 min, respectively.
3. The hulling efficiency varied from 67.20 to 82.56 % obtained at different combination of variables. The minimum hulling efficiency was found in treatment number 21 having the combination of enzyme concentration of 35 mg/100g dry matter, 8 h incubation time, 55 °C incubation temperature and 5 tempering water pH, while the maximum hulling efficiency found in treatment number 7 having the combination of enzyme concentration of 42.5 mg/100g dry matter, 6 h incubation time, 40 °C incubation temperature and 5.5 tempering water pH.

4. The response surface equation for hulling efficiency was obtained as given below

\[
\text{Hulling efficiency (\%)} = 79.21 - 0.91X_1 - 0.87X_2 - 1.34X_3 + 2.43X_4 - 0.60X_1X_2 - 0.032X_1X_3 - 0.44X_1X_4 + 0.80X_2X_3 - 0.65X_2X_4 - 0.10X_3X_4 - 1.33X_1^2 - 1.01X_2^2 - 2.16X_3^2 - 1.09X_4^2
\]

Where, \(X_1, X_2, X_3\) and \(X_4\) are the coded factors of enzyme concentration (mg/100g dry matter), incubation time (h), incubation temperature (°C) and tempering water pH, respectively.

5. The protein content of enzyme treated pigeon pea dhal varied from 17.90 to 22.77 %. The minimum protein content was found in treatment number 12 having the combination of enzyme concentration of 27.5 mg/100g dry matter, 6 h incubation time, 50 °C incubation temperature and 4.5 tempering water pH, while the maximum protein content was found in treatment number 25 having the combination of enzymatic concentration of 35 mg/100g dry matter, 8 h incubation time, 45 °C incubation temperature and 5 tempering water pH.

6. The response surface equation for protein content was obtained as given below

\[
\text{Protein Content (\%)} = 21.53 + 0.064X_1 - 0.11X_2 - 0.018X_3 + 0.32X_4 + 0.33X_1X_2 + 0.27X_1X_3 - 0.078X_1X_4 + 0.29X_2X_3 - 0.066X_2X_4 + 0.12X_3X_4 - 0.61X_1^2 - 0.33X_2^2 - 0.80X_3^2 - 0.57X_4^2
\]
Where, $X_1$, $X_2$, $X_3$ and $X_4$ are the coded factors of enzyme concentration (mg/100g dry matter), incubation time (h), incubation temperature (°C) and tempering water pH, respectively.

7. The cooking time varied from 14 to 17.24 min for different enzyme treated dhal samples. The minimum cooking time was found in treatment number 25 having the combination of enzyme concentration of 35 mg/100g dry matter, 8 h incubation time, 45 °C incubation temperature and 5.0 tempering water pH, while the maximum cooking time found in treatment number 17 having the combination of enzymatic concentration of 50 mg/100g dry matter, 8 h incubation time, 45 °C incubation temperature and 5 tempering water pH.

8. The response surface equation for cooking time was obtained as given below

\[
\text{Cooking time (min)} = 14.43 - 0.41X_1 - 0.090X_2 - 0.16X_3 - 0.13X_1X_2 - 0.12X_1X_3 + 0.15X_1X_4 - 0.00314X_2X_3 + 0.24X_2X_4 - 0.23X_3X_4 + 0.50X_1^2 + 0.44X_2^2 + 0.44X_3^2 + 0.20X_4^2
\]

Where, $X_1$, $X_2$, $X_3$ and $X_4$ are the coded factors of enzyme concentration 31.62 (mg/100g dry matter), incubation time (h), incubation temperature (°C) and tempering water pH, respectively.

9. The response surface quadratic model optimized the pre-treatment as enzyme concentration 31.62 mg/100g dry matter, incubation time 7.34 h, incubation temperature 44.70 °C and tempering water pH 5.34 which gave the predicted values of hulling efficiency 80.95 %, protein content 21.42 % and cooking time 14.64 min.

10. The hulling efficiency, protein content and cooking time of oil treated (control) sample were found 66.36 %, 18.74 %, 18 min, respectively while the observed values of hulling efficiency, protein content and cooking time at the optimum conditions of enzymatic pre-treatment variables was 78.85 %, 21.24 %, 14.72 min, respectively. Hence there was an increase in hulling efficiency of 15.84 %, protein content 11.77 % and decrease in cooking time 22.28 % over oil treated sample.
11. The predicted value of hulling efficiency, protein content and cooking time obtained from equation showed 2.59, 0.84, and 0.54 % deviation from the experimental values, respectively.

12. From the above study, it could be recommended that higher recovery and better quality of pigeon pea dhal could be obtained by enzymatic pre-treatment of enzyme concentration of 31.62 mg/100 g dry matter, incubation time 7.34 h, incubation temperature 44.70 °C and tempering water pH 5.34 which gave the predicted values of hulling efficiency 80.95 %, protein content 21.42 % and cooking time 14.64 min. The quantities of enzymes required have been estimated considering the 12.45 % (w.b.) moisture content of pigeon pea normally used by the pulse mills. The suggested method could save time, energy consumption and labour to a great extent and beneficial to the pulse milling industry.