CHAPTER V
SUMMARY AND CONCLUSIONS

5.1 Summary

India is ‘The Land of Spices’ and the glory of Indian spices are known throughout the world. Spices have high unit price, it is important commodity throughout the world. There are about 80 spices grown in different parts of the world. Most of these spice grown in India. India has been a leading spice producing and exporting country of the world. Total production of spices of India in year 2015 according to DSDA is 5833870 tones under the area of cultivation 3145610 ha. Turmeric is of the most important and ancient spices of India and traditional item of export. Among them turmeric production is 1092628 tones under the area of cultivation of 207570 ha. Tamilnadu, Telangana, Gujarat, Karnataka and Andhra Pradesh mostly produced turmeric. Largest turmeric produced state is Tamilnadu, producing nearly 461990 tonnes under the area 76983 ha.

Spices are well-known as appetisers and are considered volatile in the culinary art all over the world. Spices add a tang and flavour to otherwise insipid or bland foods. Some of them are also possess antioxidant properties, while others are used as preservatives in some foods like pickles and chutneys. Some spices are also possessing strong anti-microbial activities. Many of them possess medicinal properties and have a profound effect on human health.

Proximate composition of turmeric contains 8.5 per cent of protein, 69.9 per cent of carbohydrate and 6.8 per cent of the ash content. Turmeric is a rich source of dietary fibre, minerals and vitamins. A 100 g of turmeric provides around 390 Kcal of energy. Volatile oil content in dried turmeric is nearly 4-6 per cent. Volatile oil is major component of spices; it adds flavour and aroma in food. Major component essential oil of turmeric oil is Curlone, Tr-Turmerone, Turmerone and Tr-Curcumin.

Grinding is a very important step in the post-harvest processing of spices requiring special attention in order not to lose the aroma and flavour compounds
present in them. In conventional grinding of spices, frictional heat is generated in the
grinder due to high oil content. During grinding, the temperature of the product rises
to a level in the range of 42-95°C, which varies with the oil and moisture content of
the spices, but spices lose a significant fraction of their volatile oil or flavouring
components due to this temperature rise. The loss of volatile oil can be significantly
reduced by cryogenic grinding technique. Extremely low temperature in the grinder,
solidifies oils so that the spices become embrittled; so that they crumble and easily
permitting finer grinding and more consistent particle size. By circulating water or air
around the mill, temperature reduction can possible, but it is not that much effective.
A cryogenic grinding technique is very costly. So another method is to grind spices at
a temperature near about 0°C. This can be happen by using the cooling system by
using refrigerant around the grinding mechanism. This would be low-cost technique
than cryogenic grinding. Low temperature grinding technique can also easily
available for small mills than cryogenic grinding. In view of the above, the present
study was undertaken to develop a low temperature grinding mill for grinding of
spices. For cutting of turmeric in small pieces pin mill was also designed and
developed.

Physical and mechanical properties of turmeric was determined at different
moisture content relevant for the design of pin mill and development of low
temperature grinding mill namely size, bulk density, true density, porosity, angle of
repose coefficient of friction and rupture force. Properties were determined in
laboratory by standard procedures with available facilities.

On the basis of engineering properties the pin mill was designed and
fabricated. Grinding mill was procured from local market. During design of low
temperature grinding mill, Firstly design of cooling coil (evaporator) was done by
considering dimension of grinding chamber. It was fixed on the grinding chamber.
Then cooling load was calculated. On the basis of this refrigeration load, selection of
refrigerant and compressor, design of capillary tube and condenser was done.

Performance evaluation of grinding mill was done by grinding turmeric at
three different temperatures and at three different moisture contents of turmeric
rhizome. Following parameter were observed, time to set required temperature inside
grinding chamber, temperature profile of grinding chamber during grinding,
temperature inside the grinding chamber at the end of grinding, time of grinding, flour temperature and milling loss. Also biochemical analysis of low temperature ground turmeric and ambient ground turmeric was done. Volatile oil, true protein, total carbohydrate, fat content and ash content were analyzed.

The data obtained from performance evaluation and biochemical analysis was statistically analysed, using factorial completely randomized design (SAS Software) and it was compared with ambient grinding (control treatment).

Sensory analysis of ground turmeric at various treatments and ambient ground turmeric was done. Economics of operation of low temperature grinding mill (including pin mill) was also worked out and compared with the cost of grinding without cooling system. The payback period was worked out.

5.2 Conclusions

The following conclusions were drawn from the study

1. Physical properties for turmeric rhizome measured. It was found that length, breadth and thickness of rhizome were increased when moisture content was increased. Average length, breadth and thickness of turmeric rhizome increased from 54.46±2.34 to 55.79±2.38 mm, 12.48±0.45 to 13.21±0.31 mm and 11.32±0.39 to 11.65±0.27 mm, respectively with increasing moisture content from 6 to 10 per cent.
2. Bulk density ($\rho_b$) of turmeric rhizome was increased from 555.25±0.94 to 563±2.65 kg/m$^3$, with increasing moisture content from 6 to 10 per cent.
3. True density ($\rho_t$) of turmeric rhizome increased with increasing moisture content from 6 to 10 per cent, from 1337±2.88 to 1359±1.13 kg/m$^3$.
4. Porosity of turmeric rhizome was increased from 58.47±0.00 to 58.57±0.00 per cent, with increasing moisture content from 6 to 10 per cent.
5. Angle of repose of turmeric rhizome was increased from 35.87±0.01º to 37.42±0.04º per cent, with increasing moisture content from 6 to 10 per cent.
6. Coefficient of friction of turmeric rhizome increased with increasing moisture content from 6 to 10 per cent, from 0.24±0.002 to 0.271±0.002.
7. Rupture force of turmeric rhizome was decreased from 183.22±5.54 to 83.18±11.60 kg, with increasing moisture content from 6 to 10 per cent.
8. Designed and developed pin mill had capacity of 25-27 kg/hr. Pin mill cut whole turmeric rhizome into small pieces which had the average length, width and thickness of 9.10±0.51, 6.37±0.29 and 4.72±0.32 mm, respectively. It was observed that bulk density of cut rhizome pieces was 725.1±0.00 kg/m³.

9. Ambient temperature before grinding was measured it was observed to be 24 to 25°C.

10. Time to set temperature 0°C, 10°C and 20°C inside the grinding chamber were 19 min, 12.20 min and 6.12 min, respectively. i.e. when temperature set around the grinding chamber was lowered, time to set temperature inside the grinding chamber was increased.

11. Temperature profile of grinding chamber was measured. It was observed that, temperature was increased during grinding for ambient grinding (Control treatment) and also for low temperature treatment. But there was significant difference between temperature increasing rate during ambient grinding and during various low temperature treatments. Temperature increasing rate was slow during low temperature grinding as compared to ambient grinding.

12. Temperature increasing rate was also decreased with increasing moisture content of rhizome. This was due to higher moisture present cause evaporative water cooling effect during grinding.

13. Temperature inside the mill at the end of grinding of ambient grinding (control treatment) was 62°C, while it ranged from 39 to 52°C in low temperature grinding sample depending on the experimental conditions.

   Temperature inside the mill at the end of grinding decreased with increasing moisture content of rhizome this was due to evaporative cooling effect. Grinding of turmeric at low temperature decreased temperature inside the mill at the end of grinding.

   The minimum temperature inside the mill at the end of grinding 39°C was found for grinding temperature 0°C and moisture content of turmeric rhizome 10 per cent whereas maximum of it 52°C was found for grinding temperature 20°C and moisture content of turmeric rhizome 6 per cent.

14. Time of grinding of ambient grinding (control treatment) was 390 sec, while it ranged from 320 to 431 sec in low temperature grinding sample depending on the experimental conditions.
Time of grinding increased with increasing moisture content of rhizome and it was also increased with increasing grinding temperature.

The minimum time of grinding 320 sec was found for grinding temperature 0°C and moisture content of turmeric rhizome 6 per cent whereas maximum of it 431 sec was found for grinding temperature 20°C and moisture content of turmeric rhizome 10 per cent.

15. Flour temperature of ambient grinding (control treatment) was 54.4°C, while it ranged from 29.1 to 44.5°C in low temperature grinding sample depending on the experimental conditions.

Flour temperature decreased with increasing moisture content of rhizome because higher moisture present cause evaporative water cooling effect during grinding. Flour temperature was decreased with decreasing grinding temperature.

The minimum flour temperature 29.1°C was found for grinding temperature 0°C and moisture content of turmeric rhizome 10 per cent whereas maximum of it 44.5°C was found for grinding temperature 20°C and moisture content of turmeric rhizome 6 per cent.

16. Milling loss of ambient grinding (control treatment) was 11.07 per cent, while it ranged from 7.98 to 10.08 per cent in low temperature grinding sample depending on the experimental conditions.

Milling loss decreased with increasing moisture content of turmeric rhizome and grinding temperature not significantly affect on milling loss.

The minimum milling loss 7.98 per cent was found for grinding temperature 0°C and moisture content of turmeric rhizome 10 per cent whereas maximum of it 10.08 per cent was found for grinding temperature 20°C and moisture content of turmeric rhizome 6 per cent.

17. Volatile oil percentage of ambient grinding (control treatment) was 2.85 per cent, while it ranged from 3.02 to 3.52 per cent in low temperature grinding sample depending on the experimental conditions.

Volatile oil content increased with increasing moisture content of turmeric rhizome because higher moisture present cause evaporative water cooling effect, it lowers temperature during grinding. Volatile oil increased with decreasing grinding temperature.
The maximum volatile oil percentage 3.52 per cent was found for grinding temperature 0°C and moisture content of turmeric rhizome 10°C whereas minimum of it 3.02 per cent was found for grinding temperature 20°C and moisture content of turmeric rhizome 6 per cent.

18. Moisture content of ambient grinding (control treatment) was 5.99 per cent, while it ranged from 6.11 to 10.66 per cent in low temperature grinding sample depending on the experimental conditions.

Moisture content of ground turmeric increased with increasing moisture content of rhizome. For same moisture content of rhizome maximum percentage of moisture content of ground turmeric was obtained at grinding temperature of 0°C and minimum at 20°C.

The maximum moisture content 10.66 per cent was found for grinding temperature 0°C and moisture content of turmeric rhizome 10 per cent whereas minimum of it 6.11 per cent was found for grinding temperature 20°C and moisture content of turmeric rhizome 6 per cent.

19. True protein percentage of ambient grinding (control treatment) was 5.30 per cent, while it ranged from 5.72 to 6.40 per cent in low temperature grinding sample depending on the experimental conditions.

True protein content increased with increasing moisture content of rhizome because higher moisture present cause evaporative water cooling effect, it lowers temperature during grinding. True protein was increased with decreasing grinding temperature.

The maximum true protein 6.40 per cent was found for grinding temperature 0°C and moisture content of turmeric rhizome 10 per cent whereas minimum of it 5.72 per cent was found for grinding temperature 20°C and moisture content of turmeric rhizome 6 per cent.

20. Total carbohydrate percentage of ambient grinding (control treatment) was 60.05 per cent, while it ranged from 61.04 to 63.56 per cent in low temperature grinding sample depending on the experimental conditions.

Total carbohydrate content increased with increasing moisture content of rhizome because higher moisture present cause evaporative water cooling effect, it lowers temperature during grinding. Carbohydrate increased with decreasing grinding temperature.

The maximum total carbohydrate content 63.56 per cent was found for grinding temperature 0°C and moisture content of turmeric rhizome
10 per cent whereas minimum of it 61.04 per cent was found for grinding temperature 20°C and moisture content of turmeric rhizome 6 per cent.

21. Fat percentage of ambient grinding (control treatment) was 6.663 per cent, while it ranged from 7.41 to 8.05 per cent in low temperature grinding sample depending on the experimental conditions.

Fat content increased with increasing moisture content of rhizome because higher moisture present cause evaporative water cooling effect, it lowers temperature during grinding. Fat content increased with decreasing grinding temperature.

The maximum fat content 8.05 per cent was found for grinding temperature 0°C and moisture content of turmeric rhizome 10 per cent whereas minimum of it 7.41 per cent was found for grinding temperature 20°C and moisture content of turmeric rhizome 6 per cent.

22. Ash percentage of ambient grinding (control treatment) was 6.890 per cent, while it ranged from 6.310 to 6.610 per cent in low temperature grinding sample depending on the experimental conditions.

Ash content decreasing with increasing moisture content of rhizome and it increases with increasing grinding temperature.

The maximum ash content 6.610 per cent was found for grinding temperature 20°C and moisture content of turmeric rhizome 6 per cent whereas minimum of it 6.310 per cent was found for grinding temperature 0°C and moisture content of turmeric rhizome 10 per cent.

23. Gas chromatography analysis of volatile oil reported that, retention of volatile oil compounds was higher in low temperature ground turmeric sample than ambient ground sample.

24. Sensory analysis of ground turmeric at various treatments and ambient ground turmeric was reported that, low temperature ground at higher moisture content gives better colour, odour, flavour, appearance and taste compared to ambient ground powder.

25. The cost of grinding without cooling system of 1 kg of turmeric was found to be ₹ 10.84 while with cooling system was ₹ 12.12. Thus increased cost of grinding per kilogram was only ₹ 1.28. The payback period was found to be 277.18 hr for grinding mill without cooling system (including cost of pin mill) and payback period was found to be 310.17 hr for grinding mill with cooling system (including cost of pin mill).