CONCLUSION
6. CONCLUSION

Investigations related to starch characteristics were carried out using small millets viz., proso (var. CO3), foxtail (var. TNAU83), barnyard (var. K2), kodo (var. APK 1) and little (var. IPM 1164) millets.

Starch content of the small millets varied from 62.5 to 69.4 per cent which is comparatively lower than other millets and cereals. The absolute amylose content varied from 17.2 to 20.02 per cent which is comparable with other millets and cereals.

Soluble starch (expressed as per cent of total starch) was high in foxtail millet and low in proso millet. Soluble amylopectin (relative) was significantly higher in foxtail millet and much lower in proso millet. Soluble amylose levels (relative) ranged between 40.89 and 46.56 per cent.

The fibre content of the decorticated grain of small millets were higher when compared to other millets and cereals. Total dietary fibre content was higher in little millet and lower in foxtail millet. Barnyard millet contained higher content of soluble dietary fibre among the five small millets studied.

Changes in the dry matter content and carbohydrate profile during seed germination and development were also studied in the small millets.

The dry matter loss was relatively high for the first four days of germination. The dry matter loss after seven days was comparatively higher in barnyard millet and lower in little millet. Total carbohydrate, starch, amylose and amylopectin decreased during
germination which is accompanied by an increase in the total sugars. The increase in the fermentable sugars during malting due to the action of α- and β-amylases is advantageous to improve sensory properties of traditional food preparation and also for its utilization for brewing and malting industries.

During development, in proso, foxtail and little millets, the dry matter content of the grains increased rapidly up to 25 DAF and thereafter only very little increase was noticed. In barnyard and kodo millets, the increase was faster up to 28 DAF and thereafter slowed down. The starch content increased in all the small millets during maturation and reached maximum on 30 DAF in proso, little and foxtail millets and on 42 DAF in barnyard and kodo millets. Increase in the amylose content was noticed throughout the developmental period. During grain development, amyllopectin showed increasing trend in all the small millets. Total sugar content was decreased during the development in all the small millets.

Pure starch was isolated from each small millet and the enzymic degradation of starch by porcine pancreatic α-amylase were examined with and without gelatinisation. Gelatinised starch of barnyard millet showed minimal hydrolysis and that of proso millet showed maximum hydrolysis of starch by porcine pancreatic α-amylase. Gelatinised starch was highly susceptible to enzymic digestion when compared to ungelatinised starch. The extent of starch degradation varied from 71 to 85 per cent in gelatinised starch and 10 to 18 per cent in ungelatinised sample. The per cent hydrolysis of gelatinised and ungelatinised starch by porcine pancreatic α-amylase are in the following order. Proso millet > foxtail millet > little millet > kodo millet > barnyard millet. The per cent hydrolysis of ungelatinised and gelatinised starch was negatively correlated with absolute amylose content.
Scanning electron microscope (SEM) pictures of small millet starches were recorded at 2000, 5000 and 7500 times magnification. Small millet starch granules showed more number of large polygonal and few number of small spherical or polygonal granules. The granules of small millets resemble those of rice starch granules. The size of the starch granules ranged from 0.8 - 10 μm. The size of the granules was high in barnyard millet and low in proso millet. The ratio of large granules to small granules was high in foxtail millet (40:10) and low in kodo millet (40:1). Several granules showed deep indentations caused by protein bodies. All small millet starches had hard endosperm.

SEM of 24 h germinated kodo millet starch showed an increased proportion of smaller starch granules and pitting or pinholes at some points due to the attack of amylases (preferentially on bigger molecules). SEM of kodo millet starch during maturation (28 DAF) showed, maximum synthesis of starch during that period. SEM of treated barnyard millet starch after one and five autoclaving-cooling cycles showed disappearence of granular structure and irregularly shaped particles with a continous spongy like porous network. In SEM of resistant starch isolated from barnyard millet (oven dried and vacuum dried) porous structure was disappeared due to the action of heat stable α-amylase.

Brabender viscoamylograph studies were carried out to find out the gelatinisation temperature and viscosity characters of small millet starches. The gelatinisation temperature of small millet starches ranged from 75.8°C to 84.9°C. The gelatinisation temperature was higher for barnyard and kodo millet when compared to other small millets. Barnyard millet possesses low amylograph viscosity (375 BU) minimum break down (20) and relative break down value (0.02) when compared to other small millets which suggests a lower susceptibility to enzymes. This observation is well correlated with in vitro hydrolysis experiment carried out on starch by porcine pancreatic α-amylase.
The chain length of amylose varies from 275-340 glucose units. The chain length of amylopectin varies from 18-25 glucose units.

Resistant starch content of small millets was comparatively higher both in native and treated starch when compared to rice. Among the small millets resistant starch content was lower in proso millet and higher in barnyard millet.

Native starch extracted from rice and small millets when subjected to five autoclaving and cooling cycles contained more amount of resistant starch than native starch.

Rat feeding experiments were carried out to understand the effect of RS on faecal bulking capacity and blood glucose, serum cholesterol and triacylglycerol levels. Rice was used to formulate control diet.

Diet A (native starch of rice and small millets) diet B (treated starch of rice and small millets) and diet C (treated starch of rice and small millets with antibiotics) were fed to three groups of male albino rats (6 rats/diet) for 2 weeks.

Rats fed with treated starch showed a six fold increase in faecal wet weight than rats fed with NS. Higher faecal dry weight was obtained for the rats which received diet A, B and C from barnyard millet. Increase in faecal volumes paralleled increases in faecal weight. The digestibility of RS was high in rats fed with diet from rice and low in rats fed with barnyard millet. Reduction in blood glucose was considerably higher in the rats which received NS and TS (with and without antibiotics) of small millets than control diet. Rats fed with native and treated starch from barnyard millet showed significant reduction in
serum cholesterol than control diet. Diet A, B and C from barnyard millet showed higher reduction in serum triacylglycerol.

Glycemic index was calculated by feeding native and treated starch of rice and small millets to normal human volunteers and non-insulin dependent diabetes mellitus (NIDDM) patients. The glycemic index was lower in the groups fed with treated starch of small millets when compared to the groups fed with native starch of small millets. Same trend was noticed in NIDDM patients also. Both in normal and NIDDM patients, groups fed with treated starch of barnyard millet showed lower glycemic index which may be due to the higher content of resistant starch. Regression analysis showed glycemic index was negatively correlated with \textit{in vitro} resistant content of rice and small millets.

Based on the data on dietary fibre, \textit{in vitro} hydrolysis of starch by porcine pancreatic $\alpha$- amylose, viscoamylograph studies, feeding experiments in rats and human beings, barnyard millet may be considered as an effective faecal bulking, hypoglycemic and hypolipidemic agent which could be recommended for better control of chronic diseases such as diabetes, cardiovascular diseases and cancer.