6.0 SUMMARY AND CONCLUSIONS

- The juice yield from different mango cultivars in this study ranges from 385.3 to 581.4 (mL/Kg). Of all the cultivars studied, *Neelam, Totapuri, Mulgoa, Raspuri* and *Sindhura* (385.3, 424.5, 480.8, 486.2 and 495.6 mL/Kg, respectively) were of low juice yield, whereas, *Banginapalli*, *Alphonso* and *Rumani* were of high juice yield (581.4, 574.7 and 562.4 mL/Kg, respectively).

- There was a significant ($P \leq 0.05$) in the juice yield of all cultivars studied by increasing the irradiation dose and ranged from 398.5 to 597.6 (mL/Kg). The highest juice yield was obtained at 3 kGy irradiation dose in all cultivars studied.

- The pH was unchanged up to 1 kGy dose level but a higher dose (3 kGy) produced a significant ($P \leq 0.05$) increase of pH in all the mango cultivar juices studied except *Raspuri* and *Totapuri* cultivars, where the pH was unchanged in irradiated juice samples also.

- Total soluble solids (TSS) of the all cultivars of mango juice were not affected at all by the applied irradiation doses.

- Titratable acidity (TA) was remained unchanged up to 0.5 kGy but a significant decrease was observed at 1 and 3 kGy irradiation doses in all the mango juices studied except *Raspuri* and *Totapuri* cultivars, where the TA was unchanged in all irradiated juice samples.

- The major organic acids found in all cultivars of mango juice samples are citric, tartaric, succinic and malic acids. The content of citric, tartaric, succinic and malic acids in all cultivars of control mango juice ranged from 0.23 to 0.34, 0.07 to 0.13, 0.074 to 0.083 and 0.75 to 0.86 (g/100 mL), respectively. The lowest content of citric, tartaric, succinic and malic acids were found in Cv. *Banginapalli*, *Raspuri*, *Sindhura* and and *Banginapalli* juices and highest contents were in Cv. *Neelam*, *Banginapalli*, *Alphonso* and *Neelam* juices, respectively. In this study, different doses of γ-irradiation had no or

negligible effect on the content these organic acids in all cultivars of mango juice samples.

- Total sugar (TS) content did not change in all cultivars of the mango juice samples at all the applied irradiation doses. However, compared to the control, slight variations were observed among different dose levels for the reducing sugar (RS) content. The amount of RS varied differently at all applied irradiation doses (0.5, 1 and 3 kGy).

- Glucose, fructose and sucrose were detected in the all cultivars of mango juice samples. The lowest content of glucose, fructose and sucrose was found in Cv. *Mulgoa* juice samples and highest content was in Cv. *Alphonso*, *Banginapalli* and *Banginapalli* juices, respectively. In all cultivars of mango juice samples, glucose content was significantly ($P \leq 0.05$) increased by increasing irradiation dose. However, fructose and sucrose contents were significantly ($P \leq 0.05$) increased in 3 kGy irradiated samples and no significant differences between 0.5 and 1 kGy juice samples of all mango cultivars studied.

- Mango juice colour indices showed significant statistical differences among the control and irradiated juice samples of all cultivars studied.

- The highest total bacterial counts (TBC) were observed in *Alphonso* and lowest in *Neelam* juice samples. However the highest yeast and mold counts (YMC) were observed in *Banginapalli* and lowest in *Mulgoa* juice samples. The initial TBC and YMC of all cultivars of mango juice samples were significantly ($P \leq 0.05$) reduced by γ-irradiation at 0.5 kGy or above and no TBC and YMC were observed at an irradiation dose of 3 kGy. Thus improvement in microbiological quality of mango juice by radiation processing was evident by the dose dependent reduction in TBC and YMC.

- There was a slight decrease in the pH from mango juice to wine. The pH of the different types of mango wine was significantly ($P \leq 0.05$) decreased in irradiated wine samples, when the irradiation was dose increased.

- At the irradiation doses of 0.5 and 1 kGy, there was a significant ($P \leq 0.05$) increase in the soluble solids of the most of the mango wine samples studied, but there is no significant difference between 1 and 3 kGy wine samples.

- TA of all irradiated wine samples tested remained the same as the non-irradiated mango wine as the dose of irradiation increased. This showed that the acids, which also contribute to the flavor of wine, were not positively or negatively affected by γ-irradiation. It also showed that the study's fermentation process was up to standard and there was no rancidity and no contamination in the entire process.

- Volatile acidity (VA) was significantly ($P \leq 0.05$) decreased in all the irradiated wine samples, compared to non-irradiated controls and 3 kGy irradiated wine samples having lowest VA statistically.

- The citric, tartaric, succinic and malic acids were also found in all mango wine samples. Different doses of γ-irradiation had no or negligible effect on the content of these organic acids in all mango wine samples.

- The residual sugars (ReS) content of all irradiated mango wine samples remained the same as the non-irradiated samples as the dose of irradiation increased.

- The percent alcohol in control wines (non-irradiated) produced from eight cultivars of mangoes was in the range of 11.2-13.3 %. The highest ethanol production was found in *Rumani* and lowest was in *Neelam* wines, respectively. The alcohol content did not show any change upon irradiation in all mango wine samples, so there were no effects on the alcohol content of mango wine by γ-irradiation.

- The higher alcohols (HA) range of the control (0 kGy) mango wines was between 201.8 and 345.4 mg/L, the lowest HA content was found in the *Mulgoa* and highest was in *Banginapalli* wines, respectively. There was a significant ($P \leq 0.05$) increase in the HA content in all irradiated mango wine samples up to 1 kGy and no significant differences between 1 and 3 kGy irradiated wine samples.

- The total esters (TE) range of the control (0 kGy) mango wines was between 22.3 and 45.6 mg/L, the lowest TE content was found in the *Mulgoa* and highest was in *Banginapalli* wines, respectively. There was a significant ($P \leq 0.05$) increase in the TE content in all irradiated mango wine samples by increasing the irradiation dose, and the highest TE content was observed in all 3 kGy irradiated mango wine samples.

- The Hunter colour *L** value (brightness) was significantly ($P \leq 0.05$) decreased in all irradiated mango wine samples up to 1 kGy irradiation dose and there was no significant differences between 1 and 3 kGy wines samples. The Hunter colour *a** value (redness) and *b** value (yellowness) were found to be significantly ($P \leq 0.05$) increased in all irradiated mango wine samples by increasing the irradiation dose. The chroma (C*) value was also significantly ($P \leq 0.05$) increased in all irradiated mango wine samples by increasing the irradiation dose. The hue angle (h°) was significantly ($P \leq 0.05$) decreased by increasing the γ-irradiation dose in all mango wine samples.

- The cell numbers in the total bacterial count of all mango wines were also significantly ($P \leq 0.05$) reduced by γ-irradiation at 0.5 kGy or above. At an irradiation dose of 3.0 kGy no bacterial counts were detected in all mango wine samples subjected to radiation processing. There was also a significant ($P \leq 0.05$) reduction in the yeast and mold counts (total fungal counts) of all mango wine samples and complete elimination was observed at irradiation doses above 1.0 kGy. Thus improvement in microbiological quality of mango wine by radiation processing was evident by dose-dependent reduction in total bacterial count, yeast, and mold counts.

- A significant ($P \leq 0.05$) reduction in ascorbic acid (AA) was observed in all the irradiated mango juice samples with increase in irradiation dose and lowest content of AA was found in the juice samples treated at 3 kGy. However dehydroascorbic acid (DHAA) content was stable in irradiated mango juice samples, when compared to non-irradiated controls of all cultivars studied.

- In the present study a significant ($P \leq 0.05$) increase in the total polyphenolic content (TPC) and total flavonoiod contents (TFC) in all cultivars of irradiated mango juice and

wine samples when compared to non-irradiated controls was observed. At an irradiation dose of 3 kGy, highest TPC and TFC were found all mango juice and wine samples.

- A total 15 polyphenolic compounds (gallic acid, protocatechic acid, p-OH benzoic acid, vanillic acid, chlorogenic acid, syringic acid, caffeic acid, p-coumaric acid, m-coumaric acid, ferulic acid, synapic acid, ellagic acid, rutin, (+)-catechin, quercetin) were identified in both non-irradiated and irradiated mango juice and wine samples. These include different classes of phenolic acids and flavanoids. A significant ($P \leq 0.05$) increase in the concentration of majority of the phenolic acids studied with exception ferulic and synapic acids wherein a significant ($P \leq 0.05$) decrease in the concentration with increase in irradiation dose was noted.

- γ-Irradiation significantly ($P \leq 0.05$) increased the free radical scavenging activities (DPPH, FRAP, NO, ABTS and DMPD) in all cultivars of mango juice and wine samples. The increased activities observed could be due to the synergistic action of antioxidant compounds occurring in mango juice and wine such as polyphenolic compounds, flavanoids and carotenoids.

- Mango juice was found to be rich source of antioxidants and possessed strong *in vitro* radioprotective ability, even after exposure to dose of 3 kGy. Further, mango wine was also shown to protect DNA damage induced by hydroxyl radicals and γ-irradiation. Hence it can be concluded that application of γ-irradiation to mango juice and wine has manifold benefits.

- In general, irradiation only induced quantitative changes in some of the volatile compounds, and the effect of irradiation on production of volatile compounds depended on radiation dose.

- The isomers of monoterpenes ($C_{10}H_{16}$) and sequiterpenes ($C_{15}H_{24}$) dominated the major volatiles of mango juice, and their flame ionization detector relative peak area (FID RPA) reached 67% in control juice samples. The major terpene hydrocarbons present in mango juice samples were δ-3-carene, limonene, terpinolene, *m*-cymene, α-terpinene, γ-terpinene, α-phellandrene and α-humulene. The total RPA of the terpene hydrocarbons

was significantly ($P \leq 0.05$) increased in irradiated mango juice samples. The contents of δ-3-carene and limonene were significantly ($P \leq 0.05$) increased, however terpinolene was slightly increased by increasing the irradiation dose in mango juice samples.

- The next class in importance after the terpene hydrocarbons was that of the esters and their FID RPA reached 15% in control juice samples. The major esters present in mango juice samples were ethyl acetate, ethyl butanoate, ethyl-(Z)-9-hexadecenoate, ethyl hexadecanoate, ethyl linoleate, ethyl linolenate and ethyl oleate. The total RPA of the esters was significantly ($P \leq 0.05$) increased in irradiated mango juice samples. The contents of ethyl acetate, ethyl butanoate, ethyl hexadecanoate, ethyl linoleate and ethyl linolenate were significantly ($P \leq 0.05$) increased, however ethyl-(Z)-9-hexadecenoate and ethyl oleate were significantly ($P \leq 0.05$) decreased by increasing irradiation dose in mango juice samples.

- The total RPA of the lactones was slightly increased in irradiated mango juice samples. The lactones identified in mango juice samples were γ-octalactone, γ-decalactone, δ-decalactone, γ-undecalactone and γ-dodecalactone and their content was slightly altered in irradiated mango juice samples.

- The major carbonyls identified in mango juice samples were hexanal, trans-2-hexenal, pentadecanal, p-tolualdehyde, 2,5-dimethyl-4-methoxy-3(2H)-furanone, (E)-β-ionone and β-damascenone. The total RPA of the aldehydes was significantly ($P \leq 0.05$) increased, however the total RPA of the ketones was slightly increased in irradiated mango juice samples. The presence of (E)-β-ionone, a product of carotenoid oxidation, which has been described as having a violet-like aroma with an odor detection threshold of 0.007 ppb, might be an important contributor to the overall aroma of the studied mango juice.

- The major alcohols identified in mango juice samples were (*Z*)-3-hexenol, 3-methyl-butanol, 2-methyl-butanol and 2-ethyl-1-hexanol. The total RPA of the alcohols was significantly ($P \leq 0.05$) increased in irradiated mango juice samples.

- Acids probably contribute little to the aroma, because they generally have high odor detection thresholds. A total of 7 acids were identified and hexadecanoic acid was the major one in mango juice samples. The total RPA of acids significantly ($P \leq 0.05$) decreased in irradiated mango juice samples.

- In the present study the amount of acetaldehyde, an off-flavor, was slightly increased in mango wine samples as γ-irradiation dose increased.

- Alcohols are quantitatively the largest groups of all the volatiles, with RPA accounting for more than 50% for both control and irradiated mango wine samples. The major polyols, such as 1-propanol, 1-pentanol, 2-methyl-butanol, and 3-methyl-butanol (often considered to bad, greasy mouth feel in wines) were decreased and 2-phenyl ethanol, which is considered to have a rose fragrance, was increased as γ-irradiation dose increased in mango wine samples.

- After alcohols, esters were clearly the dominant constituents, with RPA accounting for more than 10% for both control and irradiated mango wine samples. The amount of ethyl acetate, which is considered to have a fruit fragrance and 2-phenylethyl acetate, which is considered to have a rose fragrance were increased as γ-irradiation dose increased. However, two other fragrant compounds of mango wine like ethyl lactate and isoamyl acetate, which were also considered to have fruit fragrance in wines, showed little change in amount after γ-irradiation.

- A total of 7 acids were identified, among which hexadecanoic acid, dodecanoic acid, tetradecanoic acid and hexanoic acid were the most abundant in mango wine samples. The total RPA of the acids was significantly ($P \leq 0.05$) decreased in irradiated mango wine samples.

- Among the 9 terpenes detected trans-linalool oxide, limonene, (E)-nerolidol, and (E, E) farnesol were the most abundant in mango wine samples. The total RPA of the terpenes was significantly ($P \leq 0.05$) increased in irradiated mango wine samples.

- Among the 5 identified aldehydes and 4 ketones, acetaldehyde, nonanal, decanal, acetophenone and benzophenone were the most abundant in mango wine samples. The total RPA of the carbonyl compounds was significantly ($P \leq 0.05$) increased in irradiated mango wine samples.

- Variation in relative percentage (Area) of some of the volatile constituents upon irradiation as, observed in the present study, could presumably be due to the radiation sensitivity of these compounds at the dose employed. It is therefore, of interest in the future to determine the effect of γ-irradiation on pure compounds to know the fact during irradiation.

- Panelists found that the overall sensory scores of the irradiated and control samples were not significantly different in all cultivars of mango juice samples. In case of mango wine samples, the taste was improved as the dose of γ-irradiation increased and panelists found that no significant differences in overall sensory scores of the irradiated and control wine samples from different mango cultivars. So γ-irradiation improved some mango wine defects and produced higher taste quality in the wine at a suitable dose (1 kGy).

- The serum glucose levels and total proteins were increased in EtOH-treated rats and remained unaltered in other groups, compared to PFC group.

- The serum bilirubin, urea, uric acid and creatinine (mg/dl) concentrations were significantly increased in EtOH treated group; however there were no significant differences observed in other groups when compared to PFC.

- A significant ($P \leq 0.05$) induction in triglycerides concentrations in EtOH-treated group when compared with PFC and other groups.

- The serum total cholesterol levels were significantly ($P \leq 0.05$) increased in EtOH-treated rats and no significant increase in the remaining other groups, when compared to PFC rats.

- The serum HDL-C concentrations were increased in all the experimental groups when compared to PFC, however the highest concentration was found in GMJ group.

- The serum LDL-C concentrations were decreased in all the experimental groups when compared to PFC, however the lowest concentration was found in GMJ group.

- Significantly increased levels of serum marker enzymes viz., AST, ALT, ALP, GGT, LDH and AMY have been observed in EtOH-treated group when compared to other groups.

- A significant ($P \leq 0.05$) increase in both liver and kidney TBARS levels of EtOH-treated rats and no significant differences in remaining other groups, compared to PFC rats.

- A significant decrease in SOD, CAT, GPx, GR, and GST activities in both liver and kidney of EtOH-treated group; similarly there was also a significant reduction in the non-enzymatic antioxidants viz., reduced glutathione and vitamin C.

- The histological studies revealed that significant degeneration and congestions were observed in liver and kidney slides of EtOH-treated group.

- The present study reveals noticeable improvements of several hepatic and kidney parameters by following non-irradiated and γ-irradiated mango juice (GMJ) and mango wine (GMW) consumption in contrast with the rats with similar ethanol intake. This striking difference may be related to the nonalcoholic components of juice and wine and highlights the importance of considering the biological matrix other than alcohol while evaluating the effects of alcoholic beverage intake.

- Gamma irradiated mango products can be considered safe as it did not cause any lethality or adverse changes in the general behavior and also no detrimental effects caused by these irradiated beverages in biochemical and histopathological changes in rat model was observed. This shows the non-toxic nature of the GMJ and GMW. Thus these may be safely administered for further *in vivo* studies to study their antioxidant activities in humans.