5. DISCUSSION

The traditional dairy products play an important role in the economic and social life of Indian population in addition to significant contribution to nutritional status. The manufacturing and marketing of these products have been in the hands of petty traders and halwais who generally use the batch method for product preparation without placing any reliance on raw milk quality, hygienic considerations, and right type of suitable packaging which result in inferior and unsafe products to consumers. In this investigation, emphasis has been laid upon the characterization of sensory, rheological and physico-chemical properties and the use of appropriate packaging technique for extending the shelf-life of paneer a most popular traditional dairy product. Accordingly experiments were carried out to extend the shelf life of paneer in three phases by the application of microwave heating, MAP and microwave heating followed by MAP and the results obtained during the study are discussed in this chapter.

5.1. Process optimization for microwave processing of paneer

Paneer was packaged in two different packaging materials viz., PET/PE (P1) and PET/PE/Metellosine/PE (P2) and was subjected to microwave heating in a continuous microwave processor. The parameters such as time-temperature combination, conveyor speed at 2450 MHz wavelength and 1 kW power level were optimized without affecting the sensory quality of the product.

5.1.2. Microwave treatment on sensory quality of paneer

The effect of microwave power level on temperature raise of paneer packed in different packaging materials is presented in Table-1. The paneer processed at lower conveyor speed (1.0 m/min) led to greater exposure time (60 sec) to microwave and thereby increasing the temperature of paneer to 84-86°C in P1 and P2 packages significantly. At higher conveyor speed (2.0 m/min), the paneer attained lower temperature (52-54°C). The conveyor speed of 1.5 m/min yielded a satisfactory temperature rise of 73-74°C in both the packaging materials P1 and P2 (Table-1).

The paneer exposed to higher temperature developed pronounced cooked flavour, very hard and compact body and texture with localized yellow colour than control, which was a not preferred trait (Table-2). The production of sulfhydral groups, loss of moisture, melting and solidifying of fat on the surface at higher temperature might have been responsible for these changes. The same phenomenon was also
observed in In-can sterilization of paneer with pronounce cooked flavour by Sachdeva (1983).

The paneer evaluated on 9-point Hedonic scale revealed that the control paneer secured significantly higher flavour score of 8.7 as it retained mild acidic sweet nutty flavour than microwave treated paneer in P1 and P2 packages but the body and texture and overall acceptability scores of microwave treated paneer was 8.7 and 8.8, respectively and was higher than control. Further, the overall acceptability scores of microwave treated paneer in P1 and P2 packages were 8.7 and 8.6 out of 9.0 respectively, than control (Table-3). The results of the present investigation are in line with Sieber (1996) who observed volatilization of flavour compounds from milk when exposed to microwave heat treatment at higher temperature. The improvement in the body and texture and overall acceptability of microwave treated paneer may be due to heat induced changes associated with slight reduction in moisture content in paneer. Accelerated heating of products in microwave oven resulted in higher quality of products due to shorter heating time, lack of hot contact surfaces and avoidance of case hardening (Mullin, 1995)

5.2. Effect of microwave treatment and packaging materials on the quality of paneer

5.2.1. Chemical quality of paneer

5.2.1.1. Fresh paneer

The untreated paneer (M1) had significantly higher moisture (52.77 %) than microwave treated paneer (M2), which had 52.34 % moisture (Table-4). The decrease in moisture content in M2 paneer may be associated with slight evaporation caused by microwave heating. Young and Jolly (1990) reported that microwave penetrates the food material allowing direct heating of the interior, and causing a possible vapour-pressure gradient from the interior to the surface, thereby accelerating moisture transfer. Though, there was a change in fat, protein, acidity, SN (soluble nitrogen) and FFA (free fatty acid) contents of M1 and M2 paneer, these changes were found to be statistically non-significant. The values obtained for chemical composition of fresh paneer in this study are almost similar to the values reported by various researchers for cow milk paneer (Sachdeva et al., 1991; Desai, 1988; Singh and Kanawajia, 1988).

5.2.1.2. Stored paneer
5.2.1.2.1 Changes in paneer at ambient temperature

Storage of paneer at ambient temperature (Table-5) revealed statistical difference in moisture, acidity, pH, SN and FFA except fat and protein contents between M1 and M2 paneer on day 1 and 2. The untreated paneer (M1) had significantly higher moisture (52.38 %), acidity (0.30%), SN (0.215%) and FFA (0.838 μ.equil./g) and lower pH (5.28) than the microwave treated paneer (M2). The increase in the acidity, SN, FFA and decrease in pH in M1 paneer which may be ascribed to proliferation of microorganism (Table-11 ) and associated changes brought there in. The reduction in the moisture content in M2 paneer may be associated to the evaporation of moisture from paneer when exposed to microwave. Further, the lower values in soluble chemical constituents in M2 paneer may be due to lower bacterial load that resulted through heat destruction when the product is exposed microwave (Table-11). The paneer samples in package P2 showed significantly lower acidity, SN and FFA contents and higher pH than the paneer in P1 package on day 1 and 2. Since packaging material P2 (PET/PE/Metellosine/PE) had constituted more number of polymer layers with thickness of 78 μm than P1 (PET/PE) which had 66 μm would have improved barrier properties (O₂, water vapour transmission rate etc) of P2 than P1 and thereby the growth of various microbes. The interaction effect between microwave and package was non-significant that indicated no reaction occurred between them.

The untreated paneer in package P1 and P2 remained well for 1 day when stored at 30±1º C. Similar findings have been reported Bhattacharya et al. (1971) for paneer packaged in polyethylene bags and stored at ambient temperature.

The storage stability of microwave treated paneer in package P and P2 was evaluated on 3rd day at 30±1º C (Table-6). The paneer packaged in P2 had 0.40 % acidity, 0.325 % SN, 1.003 μ.equil./g FFA and 4.69 pH which were lower than paneer in P1 package. The increase in the above chemical parameter might be associated with microbial growth (Table-12 ). However, microwave treated paneer samples in P1 and P2 packages were acceptable up to 2 days of storage at 30±1º C. Singh et al. (1989) observed 2 days of shelf-life of paneer when treated with sorbic acid stored at room temperature.

5.2.1.2.2 Changes in paneer at refrigeration temperature
The untreated (M1) and the microwave treated (M2) paneer samples as well as paneer in P1 and P2 packages did not show any statistical differences w.r.t. moisture, fat and protein even after 7 and 14 days of storage (Table 7). However, the acidity, SN and FFA contents of untreated paneer (M1) and the paneer in P1 package increased gradually on 7th and 14th day and were significantly higher than microwave treated paneer (M2) as well as paneer in P2 package. The significant increase in the above chemical parameters in untreated paneer (M1) might be ascribed to increase in the bacterial population (Table 13) and the associated changes caused by them. The chemical changes of paneer in the present study are in agreement with the findings of Pal (1998) and Sachdeva and Singh (1990b).

The untreated paneer (M1) in P1 and P2 packages were found acceptable up to 7 days when stored 7±1°C. Vishweshwaraih and Anantakrishnan (1985) recorded a keeping quality of 7 day for paneer stored at 5°C in polyethylene bags.

The storage studies on microwave treated paneer in package P1 and P2 on 21st day (Table 8) revealed that moisture, fat and protein contents did not have any statistical difference between packages. However, the paneer packed in P2 had significantly lower acidity (0.27 %), SN (0.146 %) and FFA (0.810 μ.equil./g) and higher pH (5.43) when compared to the P1 paneer after 21 days of storage. On 28th day similar trend in the chemical changes in paneer in P1 and P2 packages was observed. The moisture contents of paneer in P1 and P2 decreased drastically and the surface drying of product started. This may be ascribed to initial evaporation of moisture when paneer was exposed to microwave and subsequent loss during storage of product. The lower acidity, SN, FFA and higher pH in P2 paneer may be due to differences in the bacterial load (Table 14) and higher barrier property provided by the package. The results of the present findings are in line with Jha and Bargale (1999).

Paneer in P1 and P2 packages remained acceptable up to 21 day when stored at 7±1°C. Jha and Bargale (1999) demonstrated that the shelf-life of soy- paneer could be extended to 15 days at refrigeration by submerged heating of paneer in polyethylene to 75°C for 30 min in a water bath.

5.2.2 Microbiological quality of paneer

5.2.2.1 Fresh paneer
The fresh untreated paneer (M1) in P1 and P2 packages had coliforms 1.46 and 1.44 log_{10} cfu/g (Table-9). In fresh microwave treated paneer (M2), coliforms were absent. Pal (1998) reported presence of coliforms in freshly prepared paneer. One possible explanation for the absence of coliforms in M2 paneer in P1 and P2 packages may be that when using 0.5 kW microwave source, the organisms were subjected to heat, resulted in greater destruction (Tochman et al., 1985).

The effect microwave treatment on microbial quality of paneer revealed significant difference (Table-10). The microwave treated paneer had 2.73 log_{10} cfu/g of SPC and the 1.69 log_{10} cfu/g of YMC which were significantly lower than the untreated paneer. There was 1.11 log reduction of SPC and 0.44 log reduction in YMC for the microwave treated paneer than untreated one. A non-significant difference was found in the above microbial counts of paneer packaged in P1 and P2. Villamiel et al. (1996) showed that microwave pasteurization of milk resulted in lower microbial counts.

5.2.2.2. Stored paneer

5.2.2.2.1. Changes in paneer at ambient temperature

The effect of packaging materials on the coliform counts of M1 paneer in P1 and P2 during storage at 30±1° C and at 7±1° C (Table –9) revealed that up on storage the paneer in P2 had significantly lower counts of 1.76 log_{10} cfu/g on day 1 and increased to 2.10 log_{10} cfu/g on day 2 than P1. Sachdeva and Singh (1990a) reported an increase in the coliform counts during storage of paneer at ambient temperature. The coliform count increased on 7th and 14th day in both the packages, however the count was lower in paneer packed in P2 than the P1. This increase in the count could be due to the difference in the overall barrier properties such as O_2, CO_2 and water vapour transmission rates of the packaging materials (difference in number of polymer layers and thickness of packaging material) that would have supported the growth of microorganisms. The untreated paneer in packages P1 and P2 remained well up to 1 day and 7 days at 30±1° C and at 7±1° C respectively.

A significant increase in the SPC and YMC was recorded in untreated (M1) than the microwave treated paneer (M2) at the end of 1 and 2 days of storage (Table-11). Between packages the P1 showed higher counts of SPC and YMC than P2 on 1st and
2nd day also reflecting highly significant difference between the packages. The difference in the above microbial counts are attributed to the difference in the initial counts (microwave exposed paneer had lower counts initially) than untreated paneer and also the differences in the barrier properties of packaging materials. The present finding is in accordance with Tochman et al. (1985) who recorded increase in the microbial counts in microwave treated cottage cheese during storage at 25°C. The untreated paneer in packaging materials P1 and P2 spoiled after 1 day of storage at 30±1°C.

The microwave treated paneer in package P1 and P2 were further stored up to 3 days at 30±1°C (Table-12). The paneer in P1 package had 5.63 and 3.91 log_{10} cfu/g SPC and YMC respectively and was relatively higher than paneer packaged in P2. However, the paneer in both the packaging materials spoiled on 3rd day of storage due to higher counts.

5.2.2.2.2. Changes in paneer at refrigeration temperature

The SPC and the YMC of untreated paneer on 7th day storage were 4.01 and 2.24 log_{10} cfu/g respectively which were significantly higher than M2 paneer After 14 days the SPC and YMC increased to 5.44 and 3.16 respectively and was significantly higher than M2 paneer (Table-13). Pal (1998) observed increase in the total plate counts and yeast and mould counts during storage of paneer at refrigerated temperature. Between packages, the paneer in P2 showed significantly lower SPC and YMC than P1 paneer on both 7 and 14 days of storage. Though the untreated paneer in P2 had lower bacterial count, the paneer in P1 and P2 spoiled after 7 days of storage at 7±1°C.

The effect of packaging materials on the quality of microwave treated paneer revealed statistical difference between packages (Table-14). After 21 day, the paneer in P1 had higher SPC and YMC, of 4.79 and 2.77, log_{10} cfu/g, respectively than paneer in P2. The difference in the nature of packaging materials and their barrier properties might have contributed to the difference in the microbial count in P1 and P2. After 28 days of storage, the SPC and YMC increased in both packages and the product spoiled on 28th day. However, the paneer in P1 and P2 packages remained acceptable up to 21 day when stored at 7±1°C.

5.2.3. Rheological quality of paneer
5.2.3.1. Fresh paneer

The rheological characteristics of microwave treated paneer are presented in Table –15. The microwave treated paneer (M2) had significantly higher hardness (9.170 N), cohesiveness (0.712) and chewiness (5.419 N) than untreated paneer (M1). However, the microwave treated paneer had lower springiness (0.830) than untreated paneer (0.873). The increase in the hardness, cohesiveness, chewiness and decrease in the springiness in microwave treated paneer may be due to significant decrease in the moisture content (Table-5) as well as other heat induce changed brought in the protein network in the sample. The findings of this study related to untreated paneer are in accordance with Desai et al. (1991) who studied the rheological properties of market paneer. Paneer in P1 and P2 packages did not show any statistical difference.

5.2.3.2. Stored paneer

5.2.3.2.1. Changes in paneer at ambient temperature

The hardness, springiness, cohesiveness and chewiness of M1 paneer were 6.380 N, 0.759, 0.525 and 2.542 N, respectively which was significantly lower than M2 paneer after 1 day of storage at 30±1°C (Table-16). The above rheological characteristics of M1 paneer further decreased on 2nd day storage and were significantly lower than M2 paneer. After 1 day storage, the paneer in P1 had hardness of 7.512 N and chewiness of 3.611N which were appreciably lower than paneer in P2 package. Similar trend was observed in paneer packed in P1 and P2 after 2 days of storage for the above rheological parameters. The decrease in the above rheological characteristics in untreated paneer as well as in P1 paneer may be associated with increased microbial population (Table- 9 and 11) that might have brought more proteolysis as indicated by increase in the soluble nitrogen (SN) contents (Table - 5). The results of the present study are in agreement with Pollard et al. (2003) who reported that the cheese firmness, springiness and cohesiveness decreased with increased storage period. The untreated paneer in packageP1 and P2 spoiled after 1 day of storage at 30±1°C.

The microwave treated paneer in P1 and P2 packages stored for 3 days at 30±1°C resulted decrease in hardness, springiness, cohesiveness and chewiness in both the paneer samples (Table –17). The decrease in the rheological characteristics may be due to further hydrolysis of protein and release of more and more soluble nitrogen that could not contribute to the protein network integrity. The decrease was greater in
paneer packed in P1 package than paneer in P2. However, both paneer samples spoiled on 3rd day.

5.2.3.2.2. Changes in paneer at refrigeration temperature

The rheological changes in paneer during storage at 7±1°C also revealed. Significant differences between untreated (M1) and microwave treated paneer (M2) (Table-18). The M1 paneer had significantly lower hardness (9.097 N), springiness (0.719), cohesiveness (0.613,) and chewiness (4.410 N) than M2 paneer on 7 days of storage. The above rheological parameters further decreased in M1 paneer when stored after 14 day and differed significantly from M2 paneer. The decrease in the above rheological characteristics in untreated paneer may be ascribed to higher proteolysis (Table-7) brought by more bacterial numbers (Table-13). The microwave treated paneer showed increase in the above rheological properties up to 14 days and the increase may be due to lower proteolysis (Table -7) contributed by lower microbial colonies (Table –13). Kanawajia and Singh (1996) studied textural profile of paneer and revealed that all textural properties of refrigerated paneer such as hardness, cohesiveness, springiness and chewiness initially increased up to 15 days. The package difference was found to be non-significant at 7 and 14 days as well. The untreated paneer in P1 and P2 were found acceptable up to 7 days when stored under refrigeration temperature.

The results on rheological characteristics of 21 and 28 days stored paneer revealed statistical difference (Table-19). The P2 paneer had significantly higher hardness (10.071N), cohesiveness (0.670) and chewiness (5.391N) than P1 on 21st day. The hardness, and chewiness increased drastically which might be attributed to more evaporation of moisture during microwave heating and subsequent loss during storage of M2 paneer in both the packages (Table – 8). Kanawajia and Singh (1996) reported decrease in the rheological characteristics when stored beyond 15 days under refrigeration there after the rheological properties increased. The springiness on 21st day did not show any difference between paneer in P1 and P2 packages. On 28th day the rheological characteristics was greatly affected by more dehydration of product in P1 than P2 paneer (Table – 8). Both the paneer samples were unacceptable on 28th day when stored at 7±1°C and rheologically considered better up to 21 days of storage.
5.2.4. Sensory quality of paneer

5.2.4.1. Fresh paneer

The effect of microwave treatment and the type of packaging material on the sensory scores of fresh paneer is presented in Table - 20. The flavour score of untreated paneer (M1) was 45.9 which was significantly higher than the microwave treated paneer (M2) which had 44.5, whereas the M2 paneer had significantly higher body and texture score (33.5) than M1 (31.0). The total score of M2 paneer was 91.7 and was significantly higher than M1 paneer, which secured 90.5. The higher flavour score in M1 paneer may be associated with pleasant mild acidic and nutty flavour. Nayak and Bector (2001) reported higher flavour score in freshly prepared paneer. The reduction in flavour score of M2 paneer may be due to loss of nutty flavour when exposed to microwave. The lower body and texture score in untreated M1 paneer may be due to less compactness, while the microwave treated paneer had more compact body and texture which might be ascribed to loss of moisture (Table - 4) and heat induced association between protein networks due to exposure to microwave.

5.2.4.2. Stored paneer

5.2.4.2.1. Changes in paneer at ambient temperature

The sensory changes in paneer stored at 30±1° C are presented in the Table – 21. The flavour, body and textural and total scores of M1 paneer were 37.8, 30.2 and 81.5 respectively and were significantly lower than M2 paneer after 1 day of storage. The above sensory scores of M1 declined further on 2nd day and also significantly differed including colour and appearance from M2 paneer which had higher scores for above sensory attributes. The decrease in the flavour, body and texture and total score of M1 paneer after 1 day may be ascribed to increase in the soluble constitutes such as acidity, soluble nitrogen and free fatty acid contents (Table- 5). The colour and appearance score of M1 paneer was 11.5, which was significantly lower than M2 paneer, which scored 12.5 out of 15. The lower colour and appearance score in M1 might be due to development of dullness in the product. Further, signs of visible mould growth were also notice. The paneer in P1 had significantly lower flavour (39.3) and body and textural (30.8) scores than P2 paneer on 1st and 2nd day also. The lower sensory scores of paneer in P1 may be due more bacterial growth and other physico-chemical changes brought in the product. The present results are in line with Singh et al. (1991) who recorded decrease in sensory scores for paneer treated with sorbic acid and also
reported that the bacterial population showed continuous multiplication with time of storage and the product spoiled after 1 day of storage at 25-35°C. The untreated paneer in P1 and P2 spoiled on 2\textsuperscript{nd} day and remained acceptable up to 1 day when stored at 30±1°C.

The storage studies of microwave treated paneer in package P1 and P2 was continued for 3 days to study the stability of paneer at 30±1°C (Table-22). The Flavour, body and texture, colour and appearance and total scores continued to decrease in the both paneer in P1 and P2 package as compared to 2\textsuperscript{nd} day. The paneer surface was slightly dried and had dull appearance on 3\textsuperscript{rd} for both the packages. The paneer in P1 and P2 packages secured less than 72 % for each attribute. The results of the study indicated that the product is unfit for consumption as it secured less than 72% in each attribute. Patil and Gupta (1986) recommended that the product must score more than 72 % of its maximum score in each sensory attribute for its acceptance. The microwave treated paneer in P1 and P2 spoiled on 3\textsuperscript{rd} day and remained well up to 2 days at 30±1°C.

5.2.4.2.2. Changes in paneer at refrigeration temperature

The sensory changes in paneer during storage at 7±1°C. presented in the Table-23. The M2 paneer had 43.1, 32.9 and 89.2 for flavour, body and texture and total scores respectively, which were significantly higher than M1 paneer after 7 days of storage. On 14\textsuperscript{th} day the sensory scores continue to decline and the decline was greater in untreated paneer M1. The higher sensory scores in the M2 paneer may be attributed to the lower formation of lactic acid, amino compounds and free fatty acids by different microbes, yeast and moulds than the M1 paneer (Table- 7 and 13). Paneer in P2 had significantly higher score for flavour (38.1) and body and texture (27.9) than P1 on 14\textsuperscript{th} day. The higher and lower scores in P2 and P1 paneer might be related to the extent of biochemical changes that have taken place during storage. The untreated paneer in P1 and P2 package spoiled on 14\textsuperscript{th} day and were found acceptable up to 7 days at 7±1°C.

The storage studies were continued for microwave treated paneer in package P1 and P2 to study the stability of paneer (Table-24). The sensory scores of paneer in P1 and P2 declined and the paneer packaged in P2 had significantly higher flavour, body
and texture and total scores of 38.3, 28.6 and 79.1 respectively than P1 after 21 days of storage. The lower sensory scores might be attributed to higher acidity, FFA and lower pH (Table -8). The sensory scores continued to decline on 28 day and the product spoiled due to excessive acidity and FFA and development of other off-flavours. The surface discoloured, dull became hard and dry. Tochman et al. (1985) subjected cottage cheese to microwave treatment and reported that during refrigeration storage the sensory quality of cottage cheese decreased as the storage period increased. The paneer in P1 and P2 were acceptable up to 21 days when stored at 7±1°C.

5.2.5 Rheological characteristics of fried and cooked paneer

At times raw paneer is deep fried before being cooked along with vegetables for increasing the acceptability of paneer. The rheological qualities of fried and cooked paneer made from stored untreated paneer (1 day at 30±1°C and 7 at 7±1°C) and microwave treated (2 day at 30±1°C and 21 at 7±1°C) paneer samples in P1 and P2 packaging materials were studied in order to know whether, the stored paneer is able to withstand the frying and cooking conditions. Further, the rheological characteristics of experimental samples were also compared with the fried and cooked paneer made from FC (fresh control) paneer.

The rheological quality of fried and cooked made from 30±1°C and 7±1°C stored at untreated paneer in P1 (M1P1) and P2 (M1P2) packages (Fig-1 and 3) and microwave treated paneer in P1 (M2P1) and in P2 (M2P2) packages (Fig -2 and 4) were recorded. Irrespective of packaging material and storage temperature, all the experimental fried and cooked paneer had considerably lower hardness and chewiness than the fried and cooked paneer made from FC. However, the springiness and cohesiveness were found to be equal to the FC. Between treatments, the microwave treated fried and cooked paneer in P1 and P2 packages had slightly more hardness and chewiness than made from untreated paneer in P1 and P2 packages. The hardness and chewiness were higher in fried and cooked paneer made from the one stored at refrigeration temperature than the room temperature store. Though the hardness and chewiness decreased, the springiness and cohesiveness of M1P1 and M1P2 paneer were comparable to FC paneer. The decrease in the above rheological factors is attributed to the proteolysis and weakening of protein network during storage of raw paneer. However, frying and cooking regained the rheological characteristics of paneer especially, the paneer in P2 package. The rheological characteristics of Microwave treated paneer in P2 package was better than rest of the experimental sample and was comparable to FC. All the experimental paneer samples withstood the frying and cooking conditions. The results of the present study are in agreement with Desai et al. (1991) who reported that the hardness and chewiness of fried and cooked paneer decreased.

5.2.6 Cost of manufacturing of microwave treated paneer

The cost of manufacturing for 18 kg paneer which is the output of 100 kg milk was calculated separately for control paneer (CP) and microwave treated paneer (MTP). The total production cost was
slightly higher for MTP at Rs. 87.94 per kg of paneer, whereas the corresponding for CP was Rs. 85.99. The difference in the cost was accounted primarily by the fixed cost as capital investments on equipment for MTP when compared to CP. There was also a difference w.r.t. operating cost specifically with regard to the cost of power. The power cost was worked out to Rs. 12.0 in MTP and Rs. 4.5 in CP. The difference in the cost of production of MTP was 2.2% higher than the CP. The MTP involves additional capital investment cost of Rs. 6,25,000 which has a life period of 10 years. Though the capital investment was higher, the corresponding benefit was quit substantial in terms of shelf-life improvement. The shelf-life of MTP was 2 days and 21 days as against CP which had only 1 day and 7 days at 30±1°C and 7±1°C, respectively.

5.3. Effect of modified atmosphere and packaging materials on the quality of paneer

5.3.1. Chemical quality of paneer

5.3.1.1. Fresh paneer

The effect of modified atmosphere (MA) and the type of packaging materials on the chemical composition of fresh paneer was evaluated (Table – 26). The fresh paneer samples packed under different gas atmospheres did not differ in their chemical composition from the control paneer (G1). The paneer in P1 and P2 packages also showed non-statistical difference between them for the various chemical parameters studied. The non-statistical differences indicated that neither the MA nor the packaging materials had any influence on the chemical quality of fresh paneer. The chemical compositions of paneer in this study are equivalent to the composition cow milk paneer reported by Singh and Kanawajia (1988).

5.3.1.2. Stored paneer

5.3.1.2.1 Changes in paneer at ambient temperature

The chemical changes in paneer stored at 30±1°C are given in the Table - 27. The moisture, fat and protein contents on day 1 and 2 showed non-significant differences among treatments as well as between packages. After 1 day storage, the control paneer (G1) had higher acidity (0.31%), SN (0.211%) and FFA (0.821 μ.equil./g) and lower pH (5.27) than that of paneer under different MA, G2 (100% N₂), G3 (50% N₂+50%CO₂) and G4 (100%CO₂). The above chemical constituents continued to increase in G1 on day 2 and the values are higher than the paneer samples in various MA. Among paneer under different MA, G4 had lower acidity, SN and FFA, which were 0.25%, 0.176% and 0.731 μ.equil./g respectively on day 1 and increased to 0.28% acidity, 0.205% SN and 0.766 μ.equil./g FFA after 2 days of storage. After 1 day of storage, paneer in P1 package had higher SN (0.196%) and
FFA (0.755 μ. equl./g) contents than in P2 paneer and increased to 0.253% and 0.844 μ. equl./g FFA on day 2. The higher contents of above soluble chemical constituents in control paneer may be ascribed to higher microbial numbers (Table-37 ). The results of the present study are in line with the findings of Sachdeva and Singh (1990b). Pawan Kumar and Bactor (1991) also reported increase in acidity, SN and FFA during storage of paneer at ambient temperature. The control paneer in P1 and P2 packages were found acceptable for 1 day of storage at 30±1º C.

The paneer samples under different MA in P1 and P2 package were stored for 3 days to evaluate the quality of paneer at 30±1º C (Table –28). All the paneer samples showed increase in acidity, SN and FFA contents and decrease in pH after 3 days of storage. The increase in the above chemical constituents is directly related with the increase in the microbial load (Table- 38). All paneer samples under various MA and package materials spoiled on 3rd day.

5.3.1.2.2. Changes in paneer at refrigeration temperature

Paneer stability under various MA at 7±1º C was investigated and the results are given in the Table - 29. The moisture contents of all paneer samples decreased, while the fat and protein contents increased slightly as the storage period increased. However, the changes in the above chemical constituents did not show any statistical difference among paneer kept under different MA as well as between the paneer in P1 and P2 packaging materials even after 7 and 14 days of storage. This indicated that neither MA gases nor packaging materials had any adverse effect on the above chemical composition of paneer. However, the acidity, SN and FFA contents of G1 paneer were 0.30%, 0.141 % and 0.821 μ.equl/g respectively after 7 days storage and increased to 0.38%, 0.190 and 0.923 respectively on 14th day. The increase in the above soluble chemical compounds in G1 paneer was appreciable at each storage interval than rest of the paneer samples in different MA. The higher contents of acidity, SN and FFA in control G1 paneer may be ascribed to higher glycolysis, proteolysis and lipolysis brought about by more number of different microbes (Table- 39). Among MAP paneer, G4 (100% CO₂) had lower acidity (0.21%), SN (0.119%), FFA (0.573 μ. equl./g) and higher pH (5.83 ) after 7 days of storage and continued to increase and reached values of 0.23%, 0.122% and 0.583 μ. equl./g FFA on day14. Though there was an increase in the soluble constituents in G4 paneer, it was similar to that of G3 paneer on 14th day.
Pal (1998) stored paneer at refrigerated temperature and recorded an increase in various chemical parameters such as acidity, pH and soluble nitrogen. Rosenthal et al. (1991) preserved fresh Quarg and Cottage cheeses with CO₂ and observed that the pH was continued to decline. No difference was observed statistically in chemical compositions between paneer in packages P1 and P2 on day 1. After 2 days of storage, paneer in P1 package had higher acidity (0.28%), SN (0.145%), FFA (0.689µ. equl./g ) and lower pH (5.52) than paneer in P2. The increase in the acidity, SN, FFA and decrease in pH in P1 paneer may be associated with the initial load of micro-organism and their activity (Table- 37). Fandos et al. (2000) studied the physico-chemical changes of Cameros cheese packaged under MAP and reported the cheese packaged under 100 % CO₂ showed slower rate of increase in SN and FFA than the cheese under 50% N₂+50% CO₂ which is in support of present study. The control sample spoiled on 14th day in P1 and P2 was found acceptable up to 7 days at refrigeration storage.

The storage was continued for paneer samples in various MA in package P1 and P2 and the change in moisture, fat and protein contents are given in the Table – 30. All paneer in various MA as well as paneer in P1 and P2 packages stored at 21, 28 and 35 days did not differ from each other in their moisture, fat and protein contents despite slight decrease or increase in the respective constituents. The non-significant difference indicated that the treatments under study had no adverse effect on these chemical compounds.

The changes in the acidity, pH, SN and FFA contents are shown in the Table -31. Among paneer under different MA, on 21st day G2 (100% N₂) had higher acidity, SN and FFA of 0.29 %, 0.162 %, 0.712µ. equil./g respectively, which increased to 0.35 %, 0.237 %, 0.840 µ. equil./g, respectively on 35th day. While, the G4 (100% CO₂) paneer had the lowest acidity (0.24 %), SN (0.140 %), FFA (0.631µ. equil./g) on 21st day and increased to 0.28% acidity, 0.177 %SN, 0.712 µ. equil./g FFA on 35th day. Between packages, paneer in P1 had showed higher acidity, SN, FFA and lower pH than P2 at all storage intervals. Alves et al. (1996) stored mozzarella cheese under various MA environments and reported that the soluble nitrogen increased with increase in the storage period, while Maniar et al. (1994) observed increase in acidity in cottage cheese stored under different MA conditions, wherein cheese under 100% CO₂ showed lower
rate of increase in acidity. The paneer packaged under 100% $N_2$ in package P1 spoiled on 35\textsuperscript{th} day and remained well up to 28 days at 7\pm 1\degree C.

The chemical quality of paneer stored for 42 days is shown in the Table -32. Though there is a variation in the moisture, fat and protein contents among treatments, the differences were statistically non significant indicating that the gas and package combination had no influence on the major chemical composition of paneer. The G2P2 paneer (100 % $N_2$ in package two) had higher acidity (0.38\%), SN (0.257 \%), FFA (0.865 $\mu$ equl./g) and lower pH (4.99) than rest of the paneer under different MA. The G4P2 paneer (100 % $CO_2$ in package two) had the lowest acidity, SN, FFA and highest pH of 0.31\%, 0.179\%, 0.757 $\mu$ equl./g and 5.60 respectively than other paneer samples. Among gas and package combinations, the paneer G2P2 was spoiled on 42\textsuperscript{nd} day and was acceptable up to 35 days when stored under refrigeration.

The chemical quality of 49 days stored paneer is presented in the Table-33. The data revealed that, even though the storage period increased, there was no appreciable change in the moisture, fat and protein contents except some minor decrease or increase in the above constituents as indicated by non-significant differences in the parameters under study. Between paneer samples in various MA, the G3 (50% $N_2$ + 50% $CO_2$) paneer had higher acidity, SN, FFA and lower pH which were 0.36\%, 0.226\%, 0.858 $\mu$ equl./g and 5.15, respectively than G4(100%$CO_2$). Between Packages, paneer in P1 package showed higher acidity (0.36\%), SN(0.218\%), FFA(0.838 $\mu$ equl./g) and lower pH (5.16) than paneer in P2 package. The interaction effect was found to be non-significant as the gas and pack may be inert to each other. Piergiovanni \textit{et al.} (1993) reported that Taleggio cheese stored under nitrogen and carbon-dioxide showed an increase in the acidity and soluble nitrogen contents during storage of cheese. The paneer under 50\%$N_2$+ 50\%$CO_2$ in P1 package remained well up to 42 days at 7\pm 1\degree C.

The results of 56 days stored paneer are shown in the Table-34. The gas and pack combinations did not influence the major chemical compositions of paneer stored for 56 days which was evident from the non-significant differences among treatments w.r.t. moisture, fat and protein. Among gas and pack combinations, G4P2 paneer showed lower acidity, SN, FFA and higher pH which were 0.35 \%, 0.222 \%, 0.833 $\mu$ equl./g and 5.22 than rest of the paneer. The observation of the present study is in agreement with Piergiovanni \textit{et al.} (1993) who studied the effect of nitrogen and carbon-dioxide
on Taleggio cheese and recorded an increase in the acidity and soluble nitrogen contents during storage. The G3P2 paneer remained acceptable up to 49 days when stored under refrigeration.

The paneer packaged under 100% CO\textsubscript{2} in P1 and P2 packages was investigated on 63\textsuperscript{rd} day and the data are presented in the Table 35. Both the G4P1 and G4P2 paneer continued to show increase in the acidity, SN, FFA and decrease in pH on 63\textsuperscript{rd} day as compared to 56\textsuperscript{th} day. However the both the paneer spoiled and were acceptable up to 56 days when stored at 7\textdegree\pm 1\textdegree C.

5.3.2 Microbiological quality of paneer

5.3.2.1 Fresh paneer

The fresh control and gas packed paneer in P1 and P2 package as well as stored paneer were evaluated immediately for standard plate counts (SPC), coliform counts (CFC) and yeast and mould counts (YMC). The results are shown in Table- 36. The SPC ranged from 3.24 (G4) to 3.62 (G1), CFC from 1.27 (G4) to 1.34 (G1) and YMC from 2.15(G4) to 2.24 (G1) log\textsubscript{10} cfu/g. Though there was a difference in the above microbial counts, it was found to be non-significant between control G1 and rest of the paneer samples under different MA as well as between P1 and P2 paneer. This indicated that neither the treatment nor the packaging material had any adverse effect on the above microbial counts as for as fresh paneer is concerned. The results of the present study is in accordance with Eliot et al. (1998) who have studied the stability of shredded Mozzarella cheese under various MA environments and reported that the yeast and mould counts of fresh control cheese and the cheese under different MA remained almost similar on zero day. The interaction effect between gas and packages was non-significant and indicated no reaction between them.

5.3.2.2 Stored paneer

5.3.2.2.1 Changes in paneer at ambient temperature

The microbial quality of paneer during storage at 30\textdegree\pm 1\textdegree C is presented in the Table -37. After 1 day of storage, the control paneer (G1) had significantly higher SPC, CFC and YMC of 4.32, 1.74 and 2.54 log\textsubscript{10} cfu/g respectively than remaining gas packaged paneer. The above microbial counts continued to increase on day 2 also. Among gas packaged paneer, the G4 had lower SPC, CFC and YMC of 3.39, 1.20 and 2.11 respectively and differed from G2 but was similar to G3 paneer after 1 day
After 2 days of storage, the SPC, CFC and YMC increased in all samples and the G4 paneer had lower SPC (3.88), CFC (1.18) and YMC (2.23) than G2 paneer, but was similar to G3. The increase in the above microbial counts in control G1 paneer in P1 package may be due to availability of more oxygen (Fig-A, Appendix-II) for their growth. Further, the decline in the oxygen, nitrogen (as air contains 78% nitrogen) and carbon-dioxide contents (Fig-A, B and C, Appendix-II) on day 2 in G1P1 and G1P2 are evident for the growth of aerobic as well as anaerobic micro-organisms and yeast and moulds. The decrease in the SPC, CFC and YMC of gas packed paneer on day 1 as compared to fresh paneer might be non-availability of oxygen in case of G2P1 and G2P2 paneer as well as the inhibitory effect on carbon-dioxide in case of G3P1, G3P2, G4P1 and G4P2 paneer on the above micro-organisms. The extent of inhibition increased with increase in the carbon-dioxide per cent in the package (Fig-C, Appendix-II). Rosenthal et al. (1991) studied the change in the micro flora of Quarg and Cottage under CO₂ atmosphere during storage at 32°C and reported that the yeast and mould counts increased with increase in storage time; however the increase was slower at higher CO₂ levels. The results are also in line with Chen and Hotchkiss (1991). Paneer in P1 and P2 did not show any difference in the SPC, CFC and YMC on day 1. After 2 days of storage, all microbial counts increased and the P1 paneer had higher SPC, CFC and YMC of 4.21, 1.53, 2.49 log₁₀ cfu/g respectively than P2 paneer. The higher counts of above micro-organisms may be attributed to the differences in the headspace gas composition where in the P1 package had greater decrease of nitrogen and carbon-dioxide than the P2 package (Fig-B, and C, Appendix -II) and also differences in the barrier properties between them. Pawan Kumar and Bector (1991) reported that paneer treated with various preservatives showed increase in total plate counts, coliform and yeast and mould counts during storage at 25°C. The control G1 paneer in P1 and P2 packages remained acceptable up to 1 day when stored at 30±1°C.

The stability of gas packed paneer in P1 and P2 paneer was evaluated and the data are shown in the Table-38. All gas packed paneer in P1 and P2 packages showed increase in SPC, CFC and YMC after 3 days of storage. The decline in the N₂ contents in G2P1 and G2P2 paneer (Fig-B, Appendix-II), decrease in N₂ as well a CO₂ contents (Fig-B and C, Appendix -II) in G3P1 and G3P2 paneer (CO₂ one of the end products during growth of microbes) and decrease in the CO₂ contents in G4P1 and G4P2 paneer (Fig-C, Appendix -II) are responsible for increase in microbial numbers. Though the
extent of increase is lower in G4P2 (100% CO₂ in packaging material two) and G3P1 paneer (50% N₂+50%CO₂ in packaging material one) all the paneer samples in package P1 and P2 spoiled on 3rd day and were found acceptable up to 2 days when stored under room temperature.

5.3.2.2.2. Changes in paneer at refrigeration temperature

The changes in the microbiological quality of paneer under various MA in P1 and P2 packages were also evaluated under refrigeration temperature and the results are shown in Table - 39. The control G1 paneer had higher SPC, CFC, and YMC of 4.00, 1.74 and 2.33 log₁₀ cfu/g respectively than rest of the paneer samples in various MA after 7 days of storage. Among paneer under different MA, the G2 (100% N₂) paneer had the highest counts of SPC, CFC and YMC than G3 (50%N₂+50%CO₂) and G4 (100% CO₂), while the G4 had the lowest counts for the above micro-organism. However, the counts of above micro-organisms were lower in these paneer samples when compared to fresh paneer under different MA. The SPC, CFC and YMC continued to increase on 14th day in control as well as paneer under different MA. The greater increase in the above micro-organisms in control G1 paneer may be ascribed to increase availability of oxygen in the package as compared to paneer in various MA (Fig-D, Appendix -II). The lower microbial counts in G3 and G4 paneer than G2 paneer is ascribed to the inhibitory effect of CO₂ on microbes especially where the CO₂ concentration is higher and also non-availability of oxygen in case of N₂ packed paneer in P1 and P2. Alves et al. (1996) reported that the psychrotrops and yeast and mould counts increased in the MAP Mozzarella cheese during refrigerated storage and the increase was slower in cheese packed under 100% CO₂ and 50%N₂+50%CO₂ than in 100%N₂. Paneer samples in P1 and P2 packages did not show any difference in SPC, CFC and YMC even after 7 days of storage. This may be due to equal inhibitory effect brought in by different gas composition irrespective of packaging materials. However, the SPC and YMC continued to increase and the paneer in P1 package had higher SPC and YMC 3.83 and 2.40 log₁₀ cfu/g, respectively than P2 paneer. The CFC was similar in both P1 and P2 paneer. The differences in the counts may be associated with the differences in the headspace gas composition between packages as the P2 package showed lesser extent of decrease in the headspace compositions. The control paneer (G1) in P1 and P2 packages showed higher counts and was found to be spoiled on 14th day and remained acceptable up to 7 days when stored at 7±1°C.
The storage study was continued for the paneer samples under various MA in P1 and P2 packages and the microbiological changes are presented in the Table -40. After 21 days of storage, the G2 (100% N₂) paneer showed higher SPC, CFC and YMC of 3.81, 1.25 and 2.36 log₁₀ cfu/g of respectively than G3 and G4 paneer. All paneer under different MA continued to show increase in the SPC, CFC and YMC as the storage period proceeded and differed from each other. The G2 paneer continued to have higher SPC, CFC and YMC, whereas the G4 paneer had the lowest number of these micro-organisms on 28th and 35th day. The increase in SPC, CFC and YMC is attributed to the fact that the reduction in the headspace gas compositions (Fig- E and F, Appendix -II) that supported the growth of different aerobic and anaerobic microbes including yeast and moulds. Pintado and Malcata (2000) studied the effect of modified atmosphere packaging of Portuguese whey cheese and recorded an increase in the coliform and yeast and mould counts during storage of cheese at 4°C. Further, they observed that the cheese under 100% CO₂ showed slower growth rate, followed by the cheese under 50%N₂+50%CO₂ atmosphere. Between, packages, P1 paneer had higher SPC (3.60), CFC (1.29) and YMC (2.35) than P2 paneer on 21st day. These microbial counts continued to increase on 28th and 35th day of storage and the paneer in P1 showing the higher counts than P2 paneer. The lower increase in these microbial counts in P2 paneer packed under different MA may be due to lower decrease or increase in the N₂ and CO₂ concentration than P1 package (Fig-E and F, Appendix -II). The interaction effect between gas and package was non-significant. The G2 (100% N₂) paneer in package P1 was found to be spoiled on 35th day and remained acceptable up to 28th day when stored at 7±1°C.

As one of the levels G1P1 has spoiled, the storage study was further continued for rest of the paneer and the results of 42 days stored paneer are shown in the Table- 41. The G2P2 (100% N₂ in packaging material two) paneer had higher SPC, CFC and YMC of 4.62, 1.62 and 2.68 log₁₀ cfu/g of respectively than other paneer. The G3P1, G4P1, G3P2 and G4P2 paneer samples were similar to each other in their SPC, CFC and YMC. The overall increase in the microbial counts during storage period may be due to reduction in the headspace gas composition of the different MAP paneer in P1 and P2 (Fig -E and F, Appendix-II). The highest increase in microbial counts in G2P2 paneer may be associated with decrease in the N₂ concentration and production of
carbon-dioxide in the package (Fig -E and F, Appendix-II). Alves et al. (1996) noticed a steady increase in the psychrotrophic as well as yeast and mold counts in sliced Mozzarella cheese under different MA environments for up to 31 days of storage, thereafter the counts stabilized. The paneer G2P2 spoiled on 42nd day and was considered acceptable up to 35 days when stored under refrigeration.

As one of the levels G2P2 has spoiled, the storage study was further continued for rest of the paneer and the changes in the microbial counts on 49th day are presented in the Table- 42. The G3 paneer had higher SPC (4.40), CFC (1.50) and YMC (2.61) log 10 cfu/g than G4 paneer. The higher counts of G3 in P1 and P2 package are ascribed to the decrease in the headspace gas composition especially N₂ and CO₂ than that of G4 paneer in P1 and P2 packages (Fig-E and F, Appendix -II). Between packages, paneer in P1 had higher SPC, CFC and YMC of 4.22, 1.49 and 2.62 log 10 cfu/g than P2 paneer. The higher counts in P1 paneer may be associated to decrease in the concentration of CO₂ in P1 than P2 paneer (Fig E and F, Appendix-II). The interaction between gas and packaging material was found to non-significant indicated that no reaction between gas and the packaging material has taken place. The G3P1 (50% N₂+50% CO₂ in packing material two) was spoiled on 49th day and was acceptable up to 42 days.

Since the G3P1 paneer spoiled, the storage study was continued for rest of the paneer and the microbiological quality of 53 days stored paneer is given in the Table- 43 . The G3P2 paneer had the highest counts of SPC, CFC and YMC of 4.29, 1.66 and 2.70 log 10 cfu/g than G4P1 and G4P2 paneer. The above microbial counts were similar for G4P1 and G4P2 paneer. The higher counts in the G3P2 may be due to the difference in the head space gas. The G3P2 paneer spoiled on 53rd day and was acceptable up to 49 days when stored at refrigeration temperature.

The storage was continued for G4P1 and G4P2 and the microbiological quality of 63 days stored paneer is shown in the Table- 44. Both the paneer showed increase in the SPC, CFC and YMC on 63 days than 56 days. However, these paneer samples spoiled on 63rd days and remained well up to 53 days at 7±1°C.

5.3.3. Rheological quality of paneer

5.3.3.1. Fresh paneer
The results of the effect MA and packaging materials on the rheological characteristics of fresh paneer are presented in the Table - 45. The hardness springiness, cohesiveness and chewiness of the paneer under various MA were similar to control paneer (G1) as indicated by non-significant difference for the treatment under study. Similarly, the package difference was also found to non-significant w.r.t above rheological characteristics. This indicated that neither gas nor the packaging was able to influence any adverse effect on the rheological parameters. The results pertaining to rheological parameters in present study are in agreement with the findings (Desai 1988; Dharm Pal and Garg, 1989a)

5.3.3.2. Stored paneer

5.3.3.2.1. Changes in paneer at ambient temperature

The effect of MA and packaging materials on the rheological changes in paneer stored at 30±1°C are presented in the Table-46. The control G1 paneer had lower hardness and chewiness which were 6.317 N and 2.515 N respectively after 1 day of storage, and subsequently decreased to 5.628 N and 1.861 N respectively on day 2. However, the springiness and cohesiveness were similar to G2 (100 % N₂) on day 1 and 2. All gas packed paneer differed significantly with each other in hardness, springiness, cohesiveness and chewiness on day 1. The G4 paneer (100 % CO₂) had highest hardness, springiness, cohesiveness and chewiness that were respectively 6.616 N, 0.784, 0.562 and 2.915 N on day 1 and further decreased to 6.739, 0.762, 0.564 and 2.896 N on day 2. However, after 2 days, though there was decrease in the above rheological characteristics, the G3 (50 % N₂ +50 % CO₂) was similar to G4 paneer. The P1 paneer had lower hardness, springiness, cohesiveness and chewiness which were 6.435 N, 0.760, 0.531 and 2.595 respectively than P2 paneer after 1 day of storage. The above rheological characteristics further continued to decrease on day 2 also. The interaction effect between gas and package was non-significant. The decrease in the hardness, springiness, cohesiveness and chewiness may be associated with hydrolysis of protein as indicated by increased soluble nitrogen contents of paneer brought about by different kinds of micro-organisms. The higher decrease in the above rheological parameters in control paneer G1 than paneer under different MA may be associated with the reason as mentioned above (Table-27). Fedrick and Dully (1984) who reported a negative correlation between proteolysis and cheese textural parameters. The higher reduction in the hardness, springiness, cohesiveness and chewiness in paneer in P1
packages may be due to the differences in the extent of proteolysis (Table-27) contributed more bacterial and yeast and mould population (Table-37). The control paneer in package P1 and P2 remained acceptable for 1 day of storage at 30±1°C.

5.3.3.2.2. Changes in paneer at refrigerated temperature

The effect of MA and packaging materials on the rheological changes of paneer is given in the Table-48. After 7 days of storage, the control G1 paneer showed lower hardness (8.962 N) springiness (0.786) and chewiness (4.040N) than G4 paneer. The springiness of G4 paneer was highest and the hardness and chewiness of all gas-packaged paneer were similar. As the storage period increased to 14 days, the hardness, springiness, cohesiveness and chewiness of control paneer G1 decreased appreciably to 8.219N, 0.789, 0.601 and 3.897 N respectively than paneer samples under various MA. The hardness and springiness of all paneer in different MA were similar, while the G4 had highest chewiness than other gas-packaged paneer on 14th day. The study revealed that the storage temperature and duration had marked effect on rheological properties of paneer. The decrease in the rheological properties of control paneer may be exhibited by more proteolysis than the paneer samples under various MA. The results are in accordance with Walstra and Van Vliet (1982) who studied the rheology of cheese and recorded that decrease in the rheological properties of cheese during storage because of the breakdown products of casein that are largely water-soluble and can not contribute to the protein matrix. Paneer in P1 and P2 packages did not show any statistical differences in hardness, springiness, cohesiveness and chewiness on 7th as well as on 14th day. This indicated that no appreciable chemical changes had taken in paneer packed in P1 and P2 packages. The rheological data pertaining to control paneer is in conformation with the report of Awadhwal and Singh (1985). The interaction effect between gas and package were non-significant for both storage days reflected inertness of gas towards package. The control G1 paneer in P1 and P2 packages remained well up to 7 days when stored at 7±1°C.

The paneer under different MA in P1 and P2 packages were further subjected to storage studies and data are presented in the Table-49. The G2 paneer (100% N₂) exhibited lowest hardness and chewiness which were 8.711N and 4.270 N respectively, while the cohesiveness of G3 (50% N₂+50% CO₂) was lower 0.541 than rest of the paneer samples in various MA on 21st day. The above rheological parameter continued
to decrease in all paneer kept under different MA as the storage advanced, but the decrease was highest in G2 than G4 paneer. The G4 paneer (100% CO$_2$) had more hardness (8.597N), springiness (0.809), cohesiveness (0.590) and chewiness (4.103N) than rest of the paneer. The observations of the present study is in agreement with Koca and Metin (2004) investigated the textural properties of full and low-fat Kashar cheese during storage and reported that the full fat cheese showed decrease in hardness, springiness and cohesiveness. Between package P1 and P2, a non-significant difference existed on 21$^{st}$ day. However, of P1 paneer showed lower the hardness, springiness, cohesiveness and chewiness which were 8.516N, 0.804, 0.580 and 3.984 N respectively on 28$^{th}$ day and decreased to 8.302N, 0762, 0.567 and 3.586N respectively on 35$^{th}$ day than P2 paneer. The lower rheological parameters in the P1 paneer may be associated with the greater degree of hydrolysis (Table-30) of protein in the sample contributed by more bacterial population (Table-40). The G2 paneer in package P1 remained acceptable for up to 28 days when stored under refrigeration condition.

As one of the levels G1P1 paneer has spoiled, the storage study was conducted for rest of the paneer and the data on 42$^{nd}$ day are presented in Table- 50. The data revealed that the G2P2 paneer had lowest hardness, springiness, cohesiveness and chewiness, which were 7.928 N, 0.700, 0.513 and 2.846 N respectively than G3P1, G4P1 and G3P2. Among rest of the paneer, G4P2 exhibited highest hardness (8.430 N) and cohesiveness (0.578) and chewiness (3.766N). Lowest rheological properties in G2P2 may be attributed more increase in the soluble nitrogen that led to weakening of protein matrix. The observations of the present study are agreeing with Visser (1991) who reported that proteolysis is at least one of the parameter partly responsible for the reduction in the various rheological properties of cheese during storage.

Since one of the paneer samples G2P2 (100%N$_2$ in package two) spoiled, the storage study was carried out for rest of the paneer and the result on 49 days stored paneer is given in the Table -51. The G3 (50% N$_2$:50%CO$_2$) paneer showed lower hardness, springiness, cohesiveness, and chewiness that were 7.973 N, 0.678, 0.536 and 2.896N respectively than G4 (100% CO$_2$) paneer. Between packages, P1 paneer had lower hardness (8.017 N), springiness (0.705), cohesiveness (0.535) and chewiness (3.029N) than P2 paneer.
The rheological quality of 56 days stored paneer is presented in the Table -52. The G3P2 paneer had the lowest hardness (7.824 N), springiness (0.658), cohesiveness (0.518) and chewiness (2.667 N) than of G4P1 (100% CO\textsubscript{2} in package one) and G4P2 (100% CO\textsubscript{2} in package two). This may be due to higher hydrolysis in G3P2, (Table-34) the protein structural integrity has been lost. The product become spoiled on 56 days and was acceptable up to 49 days at refrigeration temperature.

The rheological quality of G4P1 (100% CO\textsubscript{2} in package one) and G4P2 (100% CO\textsubscript{2} in package two) 63 days stored paneer is shown in Table -53. The hardness, springiness, cohesiveness and chewiness continued to decline as the storage period increased in both G4P1 and G4P2 paneer. The decrease in rheological parameters are ascribed to the degree of proteolysis occurred in paneer samples during storage (Table-35). Though the decline of rheological characteristics is lower in G4P2 paneer, both the paneer were spoiled on 63\textsuperscript{rd} day and were acceptable up to 56 days when stored at 7±1\textdegree C.

5.3.4. Sensory quality of paneer

5.3.4.1. Fresh paneer

The effect of MA and packaging materials on the sensory quality of fresh paneer is given in the Table- 54. The flavour, body and texture, colour and appearance and total scores of all paneer under different MA were similar to control paneer (G1) as indicated by non-significant difference for the treatment studied. The difference between packages was also found to be non-significant for the above sensory characteristics. The data indicated neither gas nor the packaging material had influence on the organoleptic quality of fresh paneer. The results obtained in this study are corroborating with the results obtained by Rao et al. (1984) for the organoleptic characteristic of paneer. The interaction effect between gas and package was also found non-significant and this could be due to inertness of gas towards packaging material.

5.3.4.2. Stored paneer

5.3.4.2.1. Changes in paneer at ambient temperature

The sensory changes in paneer during storage at 30±1\textdegree C are presented in the Table -55. The control G1 paneer had lowest flavour, body and textural and the total
scores of 37.6, 28.9 and 78.9 respectively than paneer under different MA after 1 day of storage and further declined to 33.7, 23.4 and 68.6 respectively after 2 days of storage. Among gas packaged paneer, G4 (100% CO₂) had the highest flavour (42.9), body and texture (32.6) and total (89.1) scores than G2 (100% N₂) and G3 (50% N₂ +50%CO₂) paneer and continued to decrease on day 2. The flavour, body and texture and total scores of G3 paneer were similar to G4 on day 2. The colour and appearance did not show any statistical difference between control and paneer in different MA as all the samples looked like light cream in colour and uniform appearance on day 1 there after the G1 control paneer had lowest colour and appearance score of 11.5 than paneer samples under various MA. The highest decrease in the flavour and body and texture and scores of control paneer G1 may be due to loss of freshness and deterioration of rheological characteristics (Table-46). The higher flavour, body and texture scores of paneer in different MA, especially G4 (100% CO₂) is ascribed to the retention of freshness and also formation of moderate amount of soluble nitrogen and FFA (Table -27) and lower rheological changes (Table-46 ) in these paneer. Between packages, P1 paneer had lower body and textural and total scores of 31.0 and 84.6 respectively than P2 paneer. However, flavour and colour and appearance did not have any difference as the paneer in both packages retained freshness and the uniform light cream colour and appearance after one day of storage. The flavour, body and texture, total scores decline in P1 paneer on day 2 than P2 paneer. The decrease in the above sensory attributes may be associated with differences in the acidity and FFA contents (Table -27) and also due to variation in the microbial load (Table-37). The control paneer G1 had the lowest score for different sensory attributes than rest of the paneer samples under various MA and may be associated with surface slime formation, poor appearance, production of musty off-flavour along with sourness and the body became more soft, little pastry after 2 days of storage. Vishweshwaraiah and Anantakrishnan (1985) observed a decline in the sensory scores of paneer stored at room temperature in polyethylene bags and reported that the freshness was lost after 1 day and there after surface discoloration and development of off-flavours in paneer. The control paneer G1 in package P1 and P2 remained well up to 1 day when stored at 30±1° C

The sensory scores of 3 days stored paneer in various MA are presented in the Table-56 The flavour score ranged from 29.0 (G3P1) to 31.7 (G4P2), body and texture score from 29.2(G3P1), colour and appearance score from 11.7 (G2P1) and total score
from 65.5 (G2P1) to 73.5 (G4P2). However, all the paneer samples had developed off-flavour, weak body and textural characteristics and surface discoloration and secured less than 70% of total scores in each sensory attributes. According to Patil and Gupta (1986), for acceptance of paneer, each attribute must score a minimum of 72% in their individual sensory characteristics. All the paneer samples were spoiled on 3rd day and remained acceptable for up to 2 days when stored at 30±1°C.

5.3.4.2.2. Changes in paneer at refrigeration temperature

The effect of MA and packaging materials on the sensory changes in paneer during storage at 7±1°C is presented in the Table -57. The control G1 paneer had 41.4 and 86.1 for flavour and total scores respectively which were considerably lower than the rest of the MAP paneer after 7 days of storage. These scores progressively decreased and attained values of 33.1, 28.9, 11.5 and 73.5 on 14th day. Among paneer samples in different MA, G4 (100% CO₂) had the lowest decrease in the flavour, body and texture and total scores on 7th day which were respectively 45.9, 33.6, and 92.2. The above sensory scores declined on 14th day in G4 paneer and remained higher than rest of the paneer under various MA. The decrease in above sensory attributes in control G1 may be ascribed progressive decline in the mild acidic, sweet nutty flavour followed by weakening of body and texture contributed by more proteolysis (Table-29) on 7th day. The higher decrease in the sensory attributes on 14th day in control may be due to production of staleness, flat flavour with little pasty body and texture followed by discoloration, dull and dry surface of the product. The lower degree of decrease in organoleptic characteristics of G4 paneer may be associated with slower rate of glycolysis, proteolysis and lypolysis in the samples (Table-29). Between packages, P1 had lower flavour score of 44.0 than P2 paneer and might be due little loss of mild acidic sweet nutty flavour on 7th day. The body and texture, colour and appearance and total scores had non-significant differences for the packages under study after 7 day storage. This may be associated to lower hydrolysis that might have taken place in paneer of both packages and the existence of more uniform colour and appearance in these paneer. After 14 days of storage, the flavour and total scores of P1 has further reduced to 39.9 and 83.8 respectively which were lower than P2 paneer, whereas non-significant difference was recorded for body and texture and colour and appearance. The decrease in flavour scores may be associated with more and more loss of inherent flavour of paneer (mild acidic sweet nutty flavour) and subsequent development of
other related flavors by respective microbes. The refrigerated paneer in polyethylene lost the freshness after 3 days and showed decrease in the flavour, body and texture and colour and appearance scores after 7 days (Vishweshwaraiah and Anatakrishnan, 1985). The control G1 paneer in P1 and P2 packages remained acceptable up to 7 day when stored at 7±1° C.

The storage stability paneer in various MA was evaluated and the values are presented in the Table - 58. After 21 days of storage the G2 (100% N₂) paneer had lowest flavour, body and texture and total scores of 39.3, 30.4 and 82.0 respectively and continued to decrease as the period increased and attained scores of 34.2, 26.4 and 72.0 respectively on 35th day than G3 (50%N₂+50%CO₂) and G4 (100%CO₂). The G4 paneer had the highest score for flavour, body and texture and total scores than rest of the paneer on every storage interval with gradual decrease in the sensory scores with increased storage period. The lower sensory scores in G2 paneer might be due to loss of inherent flavour and development acidic flavour and other FFA (Table -31) caused by different types of micro-organisms (Table-40). The retention of higher sensory characteristics in G3 and G4 paneer may be ascribed to the lower bacterial load (Table-40) and other associated changes such as glycolysis, proteolysis and lipolysis brought by them (Table-31). The Colour and appearance did not differ statistically on 21st and 28th day which might be due to more uniform light cream colour and appearance observed in paneer samples. The colour and appearance scores of all gas packed paneer decreased and differed from each other. The G2 paneer had the lowest and the G3 paneer had the highest scores at the end of 35th day storage. The lowest score in the 2 paneer was associated with slight mould growth on the surface. Between packages, P1 had lower flavour (40.5), body and texture (30.8) and total (83.7) scores than P2 after 21 days of storage. The above sensory scores continued decrease and reached 35.5, 28.1, and 74.8 respectively for flavour, body and texture and total scores. The decline in the sensory attributes are mainly associated end product formation such as acidity, FFA and soluble nitrogen, they not only bring about flavour changes but also weakening of protein matrix. Maniar et al. (1994) reported that cottage cheese packaged under different MAP showed decline in the sensory score after 28 days of storage, with 100% CO₂ packed sample producing best results. The interaction between gas and package was non-significant. The G2 paneer (100 % N₂) in P1 package became
 unacceptable due to deterioration in the flavour, body and texture and visible mold growth on 35th day and remained acceptable up to 28 days at 7±1°C.

The storage study was done for the rest of the paneer and the results of 42 day stored paneer are given in the Table -59. The G2P2 (100% N₂ in package two) had the lowest flavour, body and texture, colour and appearance and total scores which were 34.0, 23.0, 10.8 and 67.8 respectively than remaining paneer after 42 days of storage. The highest flavour, body and texture, colour and appearance and total scores were noticed in G4P2 (100% CO₂ in package two), which were 38.8, 31.0 12.0 and 81.8 respectively on 42nd day. The G2P2 paneer developed off-flavour, higher sourness and light rancidity, acquired very soft body with signs of mould growth on the surface. Furthermore the G2P2 secured less than 72 % score in each sensory attribute and became unacceptable on 42nd day and was considered best up to 35 days of storage at refrigerated temperature.

The storage study was continued for rest of the paneer and the results of 49 days stored paneer are presented in the Table- 60. The G3 paneer (50%N₂+50%CO₂) had lower flavour, body and texture, colour and appearance and total scores of 35.2, 26.3, 11.0 and 72.5 respectively after 49 days of storage than G4 paneer. Between packages, P1 paneer had 35.6, 26.2 and 73.2 for flavour, body and texture and total scores respectively than P2 paneer. The colour and appearance score was non-significant for the packages. The lower sensory scores are ascribed to higher bacterial as well as yeast and mould counts (Table-41 and 42) and their action on various substrate to form end products like lactic acid, FFA, soluble nitrogen (Table-32 and 33). Alves et al. (1996) studied the stability of Mozzarella cheese under Nitrogen and Carbon-dioxide and reported that the off-flavours developed after 31 days of storage of cheese under 50%N₂+50%CO₂, whereas, under 100% CO₂ atmosphere the off-flavour was noticed after 51 days. Further, they reported that the overall acceptability decreased gradually in and the decrease was more in cheese under 50%N₂+50%CO₂, than the cheese kept in 100% CO₂ atmosphere. The results of the present finding are also in line with Eliot et al., (1998). The G3 paneer in package P1 spoiled on 49th day and remained acceptable up to 42 day when stored at 7±1°C.

The remaining paneer were subjected to storage study and the results of 53 days stored paneer are recorded in the Table -61. Among paneer under different gas and
package combination, the G3P2 (50%N₂+50%CO₂ in package two) had the lowest flavour, body and texture and total scores of 33.7, 23.7 and 68.4 respectively than the G4P1 (100%CO₂ in package one) and G4P2 (100%CO₂ in package two). The colour and appearance did not show any statistical difference among paneer samples. The lower scores in G3P2 are associated with production acidic, slightly rancid flavours, softening of body, pastry texture and surface discolouration and thus rendering the paneer unacceptable on 53rd day. The G3P2 paneer remained well up to 49th day under refrigerated storage.

The storage study was further continued for 63 days for the rest of the paneer and the data are presented in the Table –62. The G4P1 and G4P2 had lower flavour, body and texture, and total scores. The sensory scores of each attribute were less than 72% except colour and appearance made the product unacceptable on 63rd day. The G4P1 and G4P2 d remained acceptable up to 56 days of storage at 7±1°C.

5.3.5. Rheological characteristics of fried and cooked paneer

The raw paneer is deep fried before cooking along with various vegetables for increasing the acceptability of paneer. The acceptable experimental and control paneer samples at the end of storage period (30±1°C and 7±1°C) were subjected to frying and cooking in order to confirm whether the stored samples withstand the adverse conditions of frying and cooking. Further, the rheological characteristics of fried and cooked paneer made from stored paneer experimental and control paneer samples were also compared with the fried and cooked paneer made from fresh control (FC).

The Fig -5 shows the rheological characteristics of fried and cooked paneer made from 1 day stored control paneer G1P1 and G1P2 at 30±1°C. Even though, the hardness and chewiness decreased, the springiness and cohesiveness of G1P1 and G1P2 were similar to FC. The decrease in the hardness and chewiness may be due the higher degradation of protein in the raw paneer. However, during frying and cooking the rheological characteristics are regained to a greater extent. Pant et al. (1993) reported that the springiness remained more or less the same after frying and cooking of paneer.

The rheological characteristics of fried and cooked paneer made from 2 days MAP paneer at 30±1°C is depicted in the Fig- 6. All paneer in different MA showed lower hardness and chewiness as compared to FC fried and cooked paneer. Though the hardness and chewiness decreased, the springiness and cohesiveness were equal to FC. The decrease in the hardness in paneer under various MA is associated with the hydrolysis and liberation of soluble nitrogen that might have contributed to the protein network. Chawla et al. (1985) evaluated the rheological characteristics of fried and cooked paneer and reported that cooking had the tendency to narrow down the textural quality of paneer. Though, the hardness and chewiness of all MA fried and cooked paneer were not comparable to FC, they maintained good structural integrity during frying and cooking.
The rheological characteristics of fried and cooked paneer made from 7 days stored control paneer G1P1 and G1P2 at 7±1°C were also evaluated (Fig-7). The springiness and cohesiveness did not have any differences among FC and control G1P1 and G1P2 paneer, though the hardness and chewiness were lower in G1P1 and G1P2 paneer. The lower chewiness may be due to weakening of protein network caused by various proteolytic organisms during storage of raw paneer. The present study is in accordance with the findings of Kalab et al. (1988). Desai et al. (1991) studied the textural analysis for fried and cooked paneer and reported that variations in the textural characteristics among paneer samples.

The rheological characteristics of fried and cooked paneer made from 28, 35 and 42 days stored paneer under various MA (G2P1, G2P2 and G3P1) are shown in the Fig - 8, 9 and 10. The hardness and chewiness of G2P1, G2P2 and G3P1 fried and cooked paneer were lower, whereas, the springiness and cohesiveness were comparable to that of FC fried and cooked paneer. The hardness and chewiness of paneer are mainly governed by the protein integrity and their network. During storage considerable bacterial activity would have resulted in the degradation of protein and liberating more soluble nitrogen content that would have weakened the protein structure in these MAP samples. However, the frying and cooking conditions helped to regain the textural attributes of paneer stored under different MA and packaging materials.

The rheological quality fried and cooked paneer made from of 49 and 56 days stored paneer of G3P1, G4P1 and G4P2 are displayed in Fig-11 and 12. The hardness, springiness and cohesiveness of G3P1, G4P1 and G4P2 fried and cooked paneer were almost equal to the FC fried and cooked paneer. However, the chewiness was lower in above experimental paneer than FC fried and cooked paneer. The extent of protein hydrolysis is responsible for the decrease in the above rheological properties.

All the stored paneer samples maintained their structural integrity during frying and cooking.

5.3.6. Cost of manufacturing of MAP paneer

The cost of manufacturing for 18 kg paneer (out put of 100 kg milk) was calculated separately for control paneer (G1) and paneer under various MA, G2 (100% N₂), G3 (50%N₂+50%CO₂) and G4 (100% CO₂). The total production cost was slightly higher for paneer in different MA, G2, G3 and G4 at Rs. 88.74, Rs. 88.87 and Rs.88.99 per kg of paneer respectively, whereas the corresponding for control paneer G1 was Rs.85.99 (Table -63). The difference in the cost was accounted primarily by the fixed cost as capital investments on equipment for MAP was higher than control paneer. There was also a difference in the operating cost specifically with regard to the cost of power and gas used for MAP. The power cost was worked out to Rs. 4.5 and Rs.9.0 for control and MAP respectively. The cost of gas for filling of 180 pouches G2, G3 and G4 was estimated at Rs.29.34, Rs.31.50 and Rs.33.66 respectively. The difference in the cost of production of MAP paneer of G2 (100% N₂), G3 (50%N₂+50%CO₂) and G4 (100% CO₂) was 3.2 %, 3.3% and 3.5 % higher than the control paneer (G1). The MAP incurred additional capital investment cost of Rs.3, 26,010 which has a life period of 10 years. Though the capital investment was higher, the corresponding benefit was very substantial in terms of shelf-life improvement. The shelf-life of MAP paneer under 100% N₂, 50%N₂+50%CO₂ and 100% CO₂ was 35-
42, 42-49, 56 days, respectively and control paneer was only 7 days at 7±1°C. Further, MAP had 2 days, while control paneer had 1 day shelf-life at 30±1°C.

5.4. Effect of modified atmosphere packaging and packaging materials on microwave exposed paneer

5.4.1. Chemical quality of paneer

5.4.1.1. Fresh paneer

The effect of modified atmosphere packaging (MAP) and packaging materials on the chemical quality of microwave exposed paneer was investigated and the results are presented in the Table - 64. There was a little variation in the moisture, fat, protein, acidity, pH, SN and FFA contents of R1, R2 and R3 paneer as well as in P1 and P2 paneer samples. The minor changes may be due to microwave exposure of paneer. Though variation was recorded, neither the treatment nor the package had influence on the chemical quality of fresh paneer. The compositions of paneer confirm earlier reports Sachdeva et al. (1991) and Nayak and Bector (2001).

5.4.1.2. Stored paneer

5.4.1.2.1. Changes in paneer at ambient temperature

The chemical changes in moisture, fat, and protein contents of paneer during storage at 30±1°C are presented in the Table-65. The moisture content of all R1, R2 and R3 as well as P1 and P2 paneer samples decreased while protein and fat contents increased as the storage period increased from 1 to 3 days. However, appreciable change among paneer samples was not recorded which was evident from non-statistical differences observed in the above chemical constituents.

The effect of microwaved followed by MAP of paneer in P1 and P2 packages on acidity, pH, SN and FFA for a period of 1 to 3 days is shown in the Table-66. The acidity, SN and FFA content of all the treated paneer increased over a period of 3 days. The higher increases in the above soluble constituents were recorded in R1 paneer (Microwaved+100% N₂) than R3 paneer. The higher levels of acidity, SN and FFA in R1 might be due to higher microbial load (Table- 72) than R3 paneer, which would have brought more lactose, protein and fat hydrolysis in stored paneer. Between packages P1 had higher values for the above chemical constituents than P2 paneer. This might be associated with the difference in the microbial quality as well as the differences in the thickness and barrier properties of packaging material. The present
study is in agreement with Thakral \textit{et al.} (1990) who recorded increase in acidity, soluble nitrogen and FFA during storage of paneer at ambient temperature.

5.4.1.2.2. Changes in paneer at refrigeration temperature

Paneer stability during storage at 7±1º C was evaluated and the data on moisture, fat, and protein contents are given for a period of 7 to 42 days (Table 67 and 68). The moisture content of all paneer samples gradually decreased in each storage interval. The moisture content on 7\textsuperscript{th} day ranged from 52.42\% (R2) to 52.49\% (R3) which decreased in R1, R2 and R3 as well as P1 and P2 paneer gradually over the period of 42 days of storage and ranged from 49.16\%(R1) to 49.28\%(R3). Higher reduction in the moisture content may be due to little evaporation of water from paneer samples during microwave heating. However, all the paneer samples were similar in their moisture content. The fat and protein contents subsequently increased over the storage period due to evaporation of moisture. However, the increase in fat and protein contents did not show any statistical difference among R1, R2 and R3 paneer as well as paneer in P1 and P2. All paneer samples (R1, R2 and R3 and P1 and P2) showed drastic reduction in the moisture content at the end of 42 days of storage and remained well up to 35 days at 7±1º C.

The effect of MAP and packaging materials of microwave treated paneer on acidity, pH, SN and FFA are shown for a period of 7 to 42 days (Table 69 and 70). The acidity, SN and FFA contents of all paneer samples increased while pH decreased during storage period of 42 days. The increase was not appreciable up to 14 day in any of the paneer samples. However, after 21 days of storage, the R1 (Microwaved+100\%N\textsubscript{2}) paneer had higher acidity, SN, FFA and SN and lower pH than R2 and R3 paneer. The paneer in P1 package had higher values than P2 for the above soluble chemical constituents. The R1 paneer continued to show higher increase in acidity, SN, and FFA over the period of 42 day than R2 (Microwaved+50\%N\textsubscript{2}+50\%CO\textsubscript{2}) and R3 (Microwaved+100\%CO\textsubscript{2}) paneer, whereas R2 and R3 were similar in the chemical constituents. The P1 paneer had higher values in the above chemical constituents throughout the storage. From 35\textsuperscript{th} day onwards all paneer differed from each other in acidity, SN and FFA contents and the R3 paneer had the lowest values for the afore said chemical constituents. The higher increase in the soluble constituents in R1 and P1 paneer may be attributed to the higher bacterial load.
in this sample (Table-74) as well as differences in the barrier properties of these packaging materials. Arora and Gupta (1980) recorded increase in soluble nitrogen, acidity and decrease in pH when paneer was stored at 10°C. The interaction effect between the gas and package was recorded non-significant as the gas and package did not have any reaction between them.

5.4.2. Microbiological quality of paneer
5.4.2.1. Fresh paneer

The standard plate counts (SPC), coliform counts (CFC) and yeast and mould counts (YMC) were evaluated immediately for microwaved followed by MAP packed paneer in package P1 and P2 as well as during storage.

The results on microbiological quality of fresh paneer presented in the Table -71. The SPC ranged from 2.26 (R3) to 2.32 (R1) and YMC from 1.37(R3) to 1.41(R1) log 10 cfu/g. However, there was no apparent difference in the above microbial counts of R1, R2 and R3 paneer as well as in paneer in P1 and P2 package. This indicated that neither the microwaved followed by MAP paneer nor the package influenced the initial micro flora of fresh paneer. No coliform was detected in any of the fresh paneer samples. This could be due to heat generated by microwave that might have inactivated the coliforms. Knutson et al. (1987) reported that heating of milk to 72.2°C for 10 sec in a 1200 W, 2450 MHz continuous microwave reduced the coliforms to less than 1 cfu/ml of milk.

5.4.2.2. Stored paneer
5.4.2.2.1. Changes in paneer at ambient temperature

The microbial quality of paneer during storage at 30±1°C is given in the Table -72. As compared to fresh paneer, there was a slight reduction in the SPC and YMC in R2 and R3 paneer on day 1. This could be due to the inhibitory caused by microwave as well as by carbon-dioxide in these paneer samples. The SPC and YMC counts increased during 3 days storage and all paneer samples differed from each other in the microbiological counts. The R1 paneer had higher, while the R3 paneer had lower SPC and YMC in all storage intervals. Similarly the P1 paneer had higher counts
of above microbes than P2 paneer in all successive storage period. Coliforms were absent in all paneer samples. The differences in the microbial counts in the paneer samples may be associated with the reduction in the headspace gas composition which showed gradual reduction during storage period (Fig –G and H, Appendix-II). The results of this investigation are in accordance with Singh et al. (1989 and 1988).

5.4.2.2.2. Changes in paneer at refrigeration temperature

The microbiological changes for a period of 7 to 42 days were also recorded at 7±1º C and the counts are given in the Table – 73 to 74. As compared to fresh paneer, there was a considerable reduction in the SPC and YMC in all paneer including P1 and P2 after 7 days of storage. This reduction might be ascribed to inhibitory effect caused by both microwave and the gases especially carbon-dioxide. The above microbial counts gradually increased in all paneer during storage. The R1 paneer had higher SPC (2.92 log 10 cfu/g) and YMC (1.83 log 10 cfu/g), while the R3 had lower counts throughout the storage period up to 42 days. The paneer in P1 had higher counts of SPC (2.81 log 10 cfu/g) and YMC (1.63 log 10 cfu/g) than P2 paneer on 42nd day. The higher and lower counts may be due to reduction in the headspace gas composition (Fig – I and J) as well as the differences in the thickness of packaging material which could have influenced the various barrier properties. The increase in microbial counts are comparable with earlier reports (Sachdeva et al., 1990a ; Singh et al.,1991).The interaction effect was non significant as the packaging materials selected had showed inertness to gases.

5.4.3. Rheological quality of paneer

5.4.3.1. Fresh paneer

The effect of microwaved followed by MAP paneer samples in different packaging materials on the rheological characteristics of fresh paneer was studied and the results are presented in the Table -75. The fresh R1, R2 and R3 as well as paneer packed in P1 and P2 had no appreciable difference in their hardness, springiness, cohesiveness and chewiness as evident from non-significant difference observed among them. This indicated that neither the microwave exposed followed by MAP paneer nor
the packaging material had no influence on the rheological properties of paneer samples. The results of the present study are in agreement with the reports of Pant et al. (1993) and Kalab et al. (1988) for the fresh paneer.

5.4.3.2. Stored paneer

5.4.3.2.1. Changes in paneer at ambient temperature

The effect of microwave exposed followed by MAP on the rheological changes of paneer during storage at 30±1°C is presented in the Table-76. The hardness of all paneer samples gradually increased whereas, the springiness, cohesiveness and chewiness decreased as the storage period progressed. The R1 paneer had lowest hardness, springiness, cohesiveness and springiness than R2 and R3 paneer while the P1 paneer showed lower rheological characteristics than P2 up to 2 days of storage. On 3rd day, the hardness excessively increased in all paneer samples, while springiness, cohesiveness and chewiness decreased. However, these changes were not much significant as all the paneer were similar in above rheological attributes. The P1 and P2 paneer were also similar in above rheological attributes. The increase in the hardness in all microwave exposed followed by MAP of paneer may be associated with more loss of moisture when exposed to microwave as well as subsequent reduction during storage. Generally microwave exposed samples show lower moisture content due to evaporation of moisture. The difference in the rheological properties of P1 and P2 paneer may be associated with the difference in the thickness as well as the composite layer of packaging material that would have improved the barrier properties especially in the P2 package. The rheological characteristics of all paneer samples were poor after 3 days of storage at 30±1°C. The paneer samples were good up to 2 day of storage at 30±1°C. w.r.t. rheological characteristics

5.4.3.2.2. Changes in paneer at refrigerated temperature

The storage changed of microwave exposed paneer packed under different MA in P1 and P2 packages are shown in the Table-77 and 78. The rheological characteristics (hardness, springiness, cohesiveness and chewiness) of 7 days stored paneer showed no appreciable changes among R1, R2 and R3 paneer as well as paneer in P1 and P2 packages. The hardness was continued to increase in all paneer samples, while the springiness, cohesiveness and chewiness decreased as the storage period increased from 14 to 42 days. The R1 paneer had lower hardness, springiness,
cohesiveness and chewiness and remained similar to R2 paneer, whereas, the R3 paneer had higher aforesaid rheological characteristics up to 28 days of storage. On 35\textsuperscript{th} day, the R1 paneer had lower hardness, springiness, cohesiveness and chewiness than R2 and R3 paneer, whereas, the R2 and R3 were similar to each other for the above rheological quality. On 42\textsuperscript{nd} day, the hardness increased excessively, while the springiness, cohesiveness and chewiness decreased in all paneer samples including paneer in P1 and P2 package. However, these changes were statistically non-significant. Between packages, on 14\textsuperscript{th} and 21\textsuperscript{st} day, hardness and chewiness of P1 paneer were lower than P2, whereas, the springiness and cohesiveness were similar in both paneer. After 28 days of storage, the P1 and P2 had similar hardness and springiness, whereas, the cohesiveness and chewiness were lower in P1 than P2. All the rheological characteristics continued to increase and the P1 had lower values than P2 paneer. The increase in the hardness in all paneer samples may be attributed to the loss of moisture in these samples due to evaporation during microwave treatment (Table - 68). Further, the differences in the barrier properties of packaging together with the extent of protein hydrolysis would have contributed to the above rheological changes in stored paneer. The rheological characteristics of all paneer were poor on 42\textsuperscript{nd} day. However, all paneer stored up to 35 days were found to be satisfactory w.r.t. rheological characteristics.

5.4.4. Sensory quality of paneer

5.4.4.1. Fresh paneer

The effect of microwave exposed followed by MAP of paneer in different packaging materials on the sensory quality of fresh paneer is given in the Table- 79. The flavour, body and texture, colour and appearance and total scores of fresh R1, R2 and R3 as well as the paneer in P1 and P2 have varied slightly. However, the variation was not appreciable as all the paneer retained the characteristics sensory attributes as far as fresh paneer is concerned.

5.4.4.2. Stored paneer

5.4.4.2.1. Changes in paneer at ambient temperature

The sensory changes in microwave exposed followed by MAP of paneer during storage at 30\pm1\textdegree C are presented in the Table-80. The data revealed that after 1 day storage, the R1 paneer had the lowest flavour, body and texture and total scores than R2
and R3, while the R2 paneer was similar to R3 in the above textural attributes. Between packages, P1 paneer had lower flavour and total scores than P2. The sensory scores of each attribute continued to decrease as the storage period increased. After 2 days, similar trend was seen as noticed on day 1 among paneer samples as well as between packages. The reduction in the sensory scores is associated with loss of clean acidic sweet nutty flavour in paneer. Further, the body and texture become little hard and dry. The colour and appearance also became little dull. After 3 days of storage, except R3 paneer the R1 and R2 paneer secured lower flavour and total scores, whereas, the body and texture and colour and appearance of all paneer have drastically reduced. This may be due to production of little stale flavour, more hard body and texture and very dry surface and dull appearance. Singh et al. (1991) recorded decline in the sensory scores of paneer treated with sorbic acid when stored at ambient temperature. Though the flavour and total scores were more than 72 % in R3 paneer, it failed to score minimum of 72% in the body and texture and colour and appearance score. Patil and Gupta (1986) proposed that for acceptance of paneer it must secure at least 72% of its maximum score in each attribute. On day 3rd all paneer became unacceptable for consumption and remained well up to 2 days when stored at 30±1°C.

5.4.4.2.2. Changes in paneer at refrigeration temperature

The effect of microwave exposure followed by MAP of paneer on the sensory changes in paneer during storage at 7±1°C is given in the Table 81 and 82. The sensory scores decreased on 7th day as compared to fresh samples. The R1 paneer had lower score than R3 paneer, however it was similar to R2 paneer in flavour score. The body and text, colour and appearance and total scores were similar among R1, R2 and R3 paneer after 7 days of storage. The paneer in P1 and P2 package also similar w.r.t above sensory attributes including flavour. The R1 paneer had lower sensory, body and texture, and total scores than R2 and R3 paneer, whereas, the R2 and R3 paneer were similar in the sensory attributes. The P1 paneer had lower flavour and total scores than P2 paneer. The sensory attributes of all paneer samples decreased with increased storage period. The R1 paneer was continued to secure lower sensory score while the R3 paneer secured higher scores over the storage period up to 35 days. Similarly the paneer in P1 package had lower sensory scores than the P2 paneer. The decrease in the sensory scores might be attributed to gradual reduction in the inherent acidic, rich nutty flavour and loss of freshness and development of little staleness. The body and texture
became harder and development of dry surface. After 35th day, all the paneer scored lower than 72% of the maximum in each attribute except flavour. The decrease in the body and texture and colour and appearance scores is associated with development of very hard body, surface dehydration. This may be due to loss of moisture and dull appearance of the product. Vishwehwaraiah (1987) reported surface drying and hardening of paneer stored at low temperature. According to Patil and Gupta (1986) for the acceptance of paneer, it must secure a minimum of 72% in each attribute. All the paneer samples were unacceptable on 42nd day and remained well up to 35 days when stored under refrigeration.