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Effect of Low Temperature Preservation on Quality and Shelf Life of Buffalo Meat

¹G. Kandeepan and ²S. Biswas

¹Division of Livestock Products Technology, Indian Veterinary Research Institute,
Izatnagar-243122 (U.P.), India

²Department of Animal Products Technology and Marketing,
West Bengal University of Animal and Fishery Sciences, Kolkata-700037, India

Abstract: Buffalo meat is the only future remedy for nutritional security in India. If the quality gets deteriorated, the meat preserved in refrigerator would impact greatly on the health of consumers. Hence meat samples from five year old sixteen buffalo bulls were analyzed in the fresh state (0 day) and after 4 and 7 days in chiller ($4\pm 1^\circ\text{C}$) and 4, 7, 14, 30, 60 and 75 days in freezer ($-10\pm 1^\circ\text{C}$) in a domestic refrigerator. The values of ERV, WHC and proximate composition decreased with increasing storage period. Whereas pH, TBA no., tyrosine value, chilling loss and drip loss showed an increasing trend. The chiller storage increased but freezer decreased the microbial counts (SPC, PC and Coliforms). The values of odour and flavour scores decreased with increasing storage period. Whereas, texture, tenderness and juiciness scores showed an increasing trend. Thus it was concluded that a storage period upto 4 days in chiller and 30 days in freezer could satisfactorily maintain the buffalo meat quality.

Key words: Buffalo meat, chiller, freezer, physicochemical, microbial, sensory quality, storage period

INTRODUCTION

India has the largest livestock population in the world. It has about 98.00 million numbers of buffaloes, which is 61.68% of total population in the world. They contribute to 1.49 million metric tones of meat, amounting 23.72% of the total meat produced in India (FAO, 2005). Buffalo meat is the chief foreign exchange earner in meat sector. It is the major item of Indian meat export comprising 153, 956 MT and 95% of the total meat exported (APEDA, 2005).

In India, consumers purchase meat in fresh or frozen form mostly. To adjust with the fast growing life style of urbanization, they hardly find time to purchase meat daily. Hence they purchase meat in bulk to meet their daily requirements. This meat is stored in refrigerator and consumed on definite intervals. Deterioration of meat quality in refrigerator storage may have great impact on the health of consumers. Considering the importance from consumer viewpoint, a program has been ascribed to study the effect of refrigerator storage on buffalo meat quality. The objective of this study was to determine the physicochemical, microbiological and sensory changes of buffalo meat in domestic refrigerator. Thereby the shelf life of buffalo meat in Chiller and Freezer was established. This study has immense importance to satisfy consumer's query relating to how long buffalo meat can be stored without any deterioration in domestic refrigerator.

Corresponding Author: G. Kandeepan, Division of Livestock Products Technology,
Indian Veterinary Research Institute, Izatnagar-243122 (U.P), India

MATERIALS AND METHODS

Sample Collection and Preservation

Meat samples each weighing 2 kg from shoulder were removed from 20 buffalo bulls of 5 years old slaughtered at Municipal slaughter house, Tangra, Kolkata, West Bengal, India. The muscles were then utilized for the study. Five trials were conducted in each experiment from meat samples of buffalo bulls of same age group. Age of the buffalo bull carcasses was estimated by observing dentition. The samples were wrapped in highly gas permeable low density polyethylene and transported to the laboratory within 1 h postmortem.

The samples were kept in chiller (24 h at $4\pm 1^\circ\text{C}$) for ageing (Ziauddin, 2003). The separable fat and connective tissue were removed. Then the samples were packaged in low-density polyethylene, each containing 250 g of meat sample and stored in chiller and freezer, respectively for further study. One portion was analyzed in the fresh state (0 day) and the remaining portion after chiller storage ($4\pm 1^\circ\text{C}$) for 4 and 7 days and freezer storage ($-10\pm 1^\circ\text{C}$) for 4, 7, 14, 30, 60 and 75 days in a domestic refrigerator (Godrej Cold Gold Model). The stored samples were then analyzed for physicochemical, microbiological and sensory attributes during refrigeration preservation.

Analytical Procedures

pH of the finely minced meat sample was determined by the method of Gillespie (1960) and was recorded using digital pH meter (Systronics Model 335). Extract Release Volume was determined as per the procedure outlined by Pearson (1968). The method used for determining the WHC was a modification of the high speed centrifugation method (Harris and Shorthose, 1988). Thiobarbituric acid number of meat samples was determined as per Strange *et al.* (1977) with slight modifications. The procedure of Strange *et al.* (1977) was followed with slight modification for estimation of tyrosine value and the calculation was by referring to the standard curve prepared as per the procedure of Pearson (1968). Weight of the meat packaged before keeping in chiller storage and after experimental period were noted and their difference in weights were expressed as chilling loss%. Drip loss was estimated by measuring the exuded meat juices after thawing and expressed as% of the initial weight.

The moisture, protein, ether extract and ash contents of buffalo meat were determined by the methods of AOAC (1995). Total plate count and psychrophilic count in the sample were determined by methods described by APHA (1984). Serial dilutions for inoculation were prepared according to ICMSF (1986). Coliforms were detected by the Touch plate method as described by Himedia Laboratories (FL 002, 2003). HiTouch *E. coli*/Coliform count Flexi plates were incubated at $35-37^\circ\text{C}$ for 18-20 h. As a result, blue coloured colonies of *E. coli* and red coloured colonies of other coliforms were observed due to the presence of indicator dye. Then the colonies were estimated per cm^2 of the plate.

Sensory Evaluation

The samples were cut into cubes of uniform size, cooked in a pressure cooker at 15 pounds pressure for 5 min and served warm with code numbers to a trained 10 member consumer panel. They were requested to score their individual preference in a nine point sensory scale. Individual ratings of panel members for the characteristic flavour, juiciness and tenderness etc., were subjected to statistical analysis.

Statistical Analysis

In the present investigation the data obtained from the experiment were statistically analyzed and interpreted for different types of estimation following the methodology as outlined by Snedecor and Cochran (1994).

RESULTS AND DISCUSSION

Physicochemical Parameters

pH

The pH of chilled and frozen buffalo meat after post slaughter showed an increasing trend with increase in storage period (Table 1). When compared with the zero (0) day a gradual increase in pH was observed in chiller and freezer stored meat. The results revealed that pH values increased with increasing storage period, which was also observed by Jayesh and Venkataramanujam (2000). On 4th day, the pH of chiller ($4\pm 1^\circ\text{C}$) stored buffalo meat was higher than the freezer ($-10\pm 1^\circ\text{C}$) stored meat. The autolysis and increase in microbial load raised the pH in 4 day chiller ($4\pm 1^\circ\text{C}$) stored meat. On the same day, pH in freezer ($-10\pm 1^\circ\text{C}$) storage was comparatively low. On 7 and 14th days of freezer storage the pH increased significantly ($p < 0.05$) from the value on 4th day. Seven day freezer stored buffalo meat showed a pH much lower than 7 day chiller stored meat. Kondaiah *et al.* (1986) observed a pH of 5.62 ± 0.14 on the same day. There was no significant rise in pH on 14 and 30th day of freezer storage. 60 and 75th days of freezer storage resulted in significantly higher pH. This significant increase in pH with prolonged freezer storage may be attributed to the fact that meat undergoes autolysis resulting in decrease in ERV and WHC with increase in pH (Strange *et al.*, 1977). But a final pH between 6.0 and 6.5 needs further investigation (Pearson, 1968).

Water Holding Capacity (WHC)

The Water Holding Capacity (WHC) of chilled and frozen buffalo meat after post slaughter showed a decreasing trend with increase in storage period (Table 1). Prolonged storage of buffalo meat showed a significantly lower WHC than its fresh state. Freezing produces some changes in the tissue, which reduces the WHC after thawing (Sanguinetti *et al.*, 1985). Chilling resulted in poor WHC than freezing (Kondaiah *et al.*, 1986). On 4 day storage, the WHC of frozen ($4\pm 1^\circ\text{C}$) buffalo meat was higher than the chilled ($-10\pm 1^\circ\text{C}$) buffalo meat. A high level of WHC in freezer was due to better water retention of meat caused by an immobilization of tissue water within the myofibrillar system (Hamm, 1975). The WHC of 7 day chilled meat differed significantly ($p < 0.05$) with the value of freezer stored meat on the same day. The results showed a significant reduction in WHC on 7 and 14th days of freezer storage, respectively. The loss of WHC observed was partly due to increased denaturation of protein and partly due to enhanced movement of water into extracellular spaces. Subsequent storage of 30, 60 and 75th days in freezer showed a quite significant decline in WHC. The loss of WHC in prolonged storage of meats may be due to the rate in post mortem pH falls, ice crystal formation, high ionic strength, protein denaturation, drip loss and above all, the bulk of meat stored and the capacity of the refrigeration facility (Lawrie, 1998).

Extract Release Volume (ERV)

In the present study, the Extract Release Volume (ERV) in buffalo meat after post slaughter decreased quite significantly ($p < 0.05$) with increase in storage period in the chiller and freezer (Table 1). The ERV of freshly slaughtered buffalo meat was significantly higher than the stored meat.

Table 1: Comparative appraisal between physicochemical parameters at different storage periods

Parameters	0	4C*	4F*	7C*	7F*	14F*	30F*	60F*	75F*
pH	5.64±0.03 ¹	5.74±0.03 ⁴	5.66±0.04 ⁴	6.18±0.01 ¹	5.71±0.03 ⁴	5.79±0.12 ^a	5.88±0.02 ²	6.01±0.03 ³	6.12±0.01 ^b
ERV (mL)	23.95±1.07 ^a	19.34±0.78 ^{b*}	22.09±0.76 ^b	14.53±0.03 ³	21.66±1.09 ^b	19.75±0.23 ^{b*}	18.81±1.19 ²	17.50±0.87 ^{2d}	15.53±0.03 ³
WHC (%)	75.98±0.57 ^a	71.83±0.47 ^{b*}	73.69±0.67 ^{b*}	67.68±0.02 ²	71.91±1.10 ²	67.92±1.10 ²	62.98±1.52 ⁴	57.84±1.08 ⁸	53.88±0.07 ⁷
TBA No	0.10±0.001 ¹	0.21±0.001 ¹	0.20±0.001 ¹	0.32±0.001 ¹	0.22±0.001 ¹	0.24±0.001 ¹	0.29±0.001 ¹	0.30±0.001 ¹	0.31±0.001 ¹
Tyrosine									
Value (mg %)	24.94±0.89 ²	29.60±0.69 ²	27.17±0.49 ⁴	35.63±0.02 ²	29.14±0.64 ⁴	30.13±0.64 ⁴	32.17±0.67 ³	34.16±0.73 ³	34.88±0.01 ¹
CLDL (%)		0.17±0.01 ^b	3.24±0.23 ¹	0.67±0.01 ¹	5.03±0.41 ¹	10.91±0.29 ⁴	12.08±0.54 ⁴	14.99±0.60 ³	17.11±0.06 ⁶

Means bearing different superscripts differ significantly ($p < 0.05$), C* represents Chiller ($4\pm 1^\circ\text{C}$) storage on respective days, F* represents Freezer ($-10\pm 1^\circ\text{C}$) storage on respective days

On 4 day storage, the results showed a higher ERV in freezer than in chiller stored meat. The significantly ($p < 0.05$) lower value in chiller may be due to a comparatively higher pH, total plate count (Strange *et al.*, 1977) and increased thiobarbituric acid value (Sushil Kumar *et al.*, 2000). Seven day chilled meat resulted in lower ERV. This differed significantly ($p < 0.05$) with the value of freezer stored meat on the same day. The results showed a quite significant ($p < 0.05$) reduction in ERV on 7, 14 and 30th days of freezer storage. A study by Jayesh and Venkataramanujam (2000) showed ERV values of 21.08 and 20.75 mL on 30 and 60th days of frozen stored mutton, respectively. In the present study, a significant ($p < 0.05$) decrease in ERV agreed with the fact that at the time of spoilage there was a decrease in ERV and an increase in pH and TBA values. Pearson (1968) reported that meat could be considered acceptable provided that the ERV is at least 17 mL.

Thio Barbituric Acid (TBA) value

The buffalo meat showed an increasing Thiobarbituric Acid (TBA) value with increase in storage period (Table 1). The TBA value of fresh buffalo meat was significantly lower than the chiller and freezer stored meat. Das *et al.* (1988) observed the TBA value of fresh buffalo meat as 0.07 ± 0.07 . This increase in TBA value was mainly attributed to the oxygen permeability of the packaged meat (Sen, 1996) leading to lipid oxidation (Strange *et al.*, 1977). A significantly ($p < 0.05$) high TBA values were observed in buffalo meat stored for 4 days in chiller ($4 \pm 1^\circ\text{C}$) and freezer ($-10 \pm 1^\circ\text{C}$) than the fresh state. A gradual and significant ($p < 0.05$) rise in TBA No. was observed on 7 and 14th days of freezer storage. Anand *et al.* (1999) noticed a consistent rise in TBA with lipid peroxidation. As the preservation reached 30, 60 and 75th days, the observations showed highly significant ($p < 0.05$) values on the respective days. Strange *et al.* (1977) observed that the changes observed in TBA numbers were not specifically due to bacterial action.

Tyrosine Value

In the present study, the tyrosine value of buffalo meat increased significantly ($p < 0.05$) with increase in storage period (Table 1). The increase in tyrosine value may be attributed mainly to intrinsic (autolysis) changes in meat and partly to bacterial action (Agnihotri, 1988; Dainty *et al.*, 1975; Strange *et al.*, 1977). 4th day chiller ($4 \pm 1^\circ\text{C}$) stored buffalo meat showed a significantly ($p < 0.05$) higher tyrosine value higher than the freezer ($-10 \pm 1^\circ\text{C}$) stored meat. Dainty *et al.* (1975) attributed the increased concentration of tyrosine to the proteolytic enzymes produced at the late logarithmic phase of the bacterial growth. This supports the observations of chilled meat. Subsequently the tyrosine value increased, respectively on 7, 14, 30, 60 and 75th days of freezer storage. Ziauddin *et al.* (1993) concluded that the spoiled buffalo meat had a tyrosine value of 63-79 mg%.

Chilling Loss and Drip Loss

On the 4th day in the present study, the observations showed a significant chilling loss in the stored buffalo meat (Table 1). On the same day, the frozen ($-10 \pm 1^\circ\text{C}$) buffalo meat showed a significant drip loss. Van der wal *et al.* (1995) observed a drip loss in buffalo longissimus lumborum as 3.9% in conventional chilling when meat was nearer to the ultimate pH. As the storage period in the freezer increased, the amount of drip got increased (Ambrosiades *et al.*, 1994; Steven *et al.*, 1998; Strange, 1987; Ziauddin *et al.*, 1993), as recorded in the present study. This marked increase in drip on later days of storage were due to shortening of the sarcomere (Honikel *et al.*, 1968), increased enzyme activity (Strange, 1987), the degree of fibre distribution and translocation of water (Ramsbottom and Koonz, 1939). Curie and Wolfe (1983) showed that the amount of juice squeezed from beef muscles increased from 1-30% as the extracellular space increased with storage time.

Moisture

The moisture content of buffalo meat decreased quite significantly ($p < 0.05$) with prolonged storage period in chiller and freezer (Table 2). Four day stored buffalo meat in chiller ($4 \pm 1^\circ\text{C}$) showed

Table 2: A comparative appraisal between proximate composition at different storage periods

Contents	0	4C*	4F*	7C*	7F*	14F*	30F*	60F*	75F*
Moisture (%)	76.87±0.41 ¹	76.31±0.36 ²	76.18±0.29 ³	72.94±0.04 ⁴	75.66±0.63 ^{5a}	74.21±0.64 ⁶	70.73±0.43 ⁷	68.25±0.54 ⁸	65.17±0.13 ⁹
Protein (%)	20.41±0.16 ¹	18.95±0.24 ²	19.80±0.46 ^{3a}	15.70±0.02 ⁴	19.69±0.39 ^{5a}	19.23±0.39 ^{6a}	18.10±0.36 ^{7a}	16.57±0.37 ^{8a}	16.19±0.01 ⁹
Ether Extract (%)	1.46±0.07 ¹	1.09±0.04 ^{2a}	1.30±0.13 ^{3a}	0.76±0.01 ⁴	1.20±0.13 ^{5a}	1.15±0.07 ^{6a}	1.11±0.06 ^{7a}	0.80±0.001 ⁸	0.77±0.002 ⁹
Ash (%)	1.21±0.08	1.10±0.15	1.00±0.15	1.03±0.01	0.96±0.11	1.08±0.01	1.090.13	1.02±0.03	1.03±0.01

Means bearing different superscripts differ significantly ($p < 0.05$), C* represents Chiller (4±1°C) storage on respective days, F* represents Freezer (-10±1°C) storage on respective days

lower moisture content than the freezer (-10±1°C). A slight difference in moisture content was observed between the 4th day chiller and freezer stored meat. This loss in moisture was due to evaporation of moisture from meat in chiller (Arief *et al.*, 1989). Whereas, it was due to sublimation of surface water of the meat to colder surfaces in the vicinity of the freezer (Taylor *et al.*, 1990). Gradually the moisture content of the meat decreased on 7 and 14th days of freezer storage. Kondaiah *et al.* (1986) studied the moisture content of frozen buffalo meat at -10°C for 7 days as 76.4%. Subsequently, on 30, 60 and 75th days of freezer storage a significant ($p < 0.05$) decrease in moisture content was recorded. The marked moisture losses encountered in later storage periods may be accounted for the myofibrillar distortion undergone by the meat in the freezer that led to the poor water retention ability of the meat.

Protein

The present study showed a decrease in protein content of buffalo meat with increase in storage period (Table 2). In fact, Krishnan and Sharma (1991) reported buffalo skeletal meat containing 20.32% total protein. The main reason behind decline in protein on prolonged storage was due to protein denaturation exhibited in drip loss and proteolysis induced by enzymatic activities of psychrotrophic microbial growth (Peterson and Gunderson, 1960). Buffalo meat stored for 4 days in chiller (4± 1°C) showed a significantly lower protein content than the freezer (-10±1°C) stored meat. The lower protein content of chilled meat might be due to increased microbial growth resulted from higher water activity (a_w) and enzymatic autolysis (Rao *et al.*, 1998). In 7 day chilled meat the protein content was observed to be lower than 7 and 14th days of freezer stored meat. In fact, on 30, 60 and 75th days of frozen storage the meat has lost a significant ($p < 0.05$) amount of protein. This significant loss in later days of freezer storage might be a result of ice formation raising the solute concentration in the tissue.

Ether Extract

The fat content of buffalo meat decreased with increase in storage period (Table 2). Joksimovic (1971) stated a fat content of 1.08% in buffalo bulls. The fat content of 4th day chiller stored meat was markedly lower than the freezer stored buffalo meat. A marked difference in chiller might be attributed to the exposure of strong light, as in display cabinets, which accelerated oxidation of fats causing discolouration (Lea, 1938). The fat content of the 7th day chilled meat differed significantly ($p < 0.05$) with the value of frozen stored meat on the same day. There was a gradual decrease in fat content on 7 and 14th day stored buffalo meat. Subsequently 30, 60 and 75th day freezer stored buffalo meat showed a decreased fat content. This lipid oxidation occurred during freezer storage of meat was mainly due to losses in triglyceride fraction. Agnihotri (1988) reported deterioration in meat lipids took place due to intermediary activities of endogenous meat enzymes leading to hydrolysis of fat.

Ash

The ash content of buffalo meat decreased non significantly ($p < 0.05$) with increase in storage period (Table 2). The content of the fresh buffalo meat was higher than the chiller and freezer stored meat. Borone *et al.* (1983) reported higher ash content (1.3%) for buffalo meat than in cattle (1.1%). The results showed a higher value for 4 days of chilled meat than the frozen meat. Infact, a non-significant decrease in ash percentage was reported by Ziauddin *et al.* (1994) which coincided with this study.

Microbiological study

Standard Plate Count (SPC)

The SPC of chilled buffalo meat after post slaughter showed an increasing trend with increase in storage period. But the frozen meat showed a decreasing trend with increasing storage period (Table 3). On 4th day, the SPC of chiller (4±1°C) stored buffalo meat was higher than the freezer (-10±1°C) stored meat. It was clear from the above result that chilling increased but freezing decreased bacterial load which was also observed by Bhadekar *et al.* (1987). Lawrie (1998) attributed the microbial growth to the growth promoting effect of moisture on microbes in meat stored in chiller. On 7 and 14th days of freezer storage the SPC decreased significantly (p<0.05) from the count on 4th day. Das *et al.* (1988) indicated decline in microbial load from 5.45 in fresh to 4.73 log cfu/g in 15 days frozen buffalo meat at -10 °C. With progress in frozen storage, a significant (p<0.05) difference in SPC was observed between 30, 60 and 75th days. Bacchil and Jaiswal (1987) concluded that the bacterial count declined from the initial 1.1×10^6 to 6.7×10^5 g⁻¹ in one month frozen buffalo meat at -10°C. The differences in values were due to the load of bacteria initially present on the meat. Consequently freezing generally produced about a 2 log g⁻¹ reduction in mesophiles and psychrotrophs numbers (Kraft *et al.*, 1979). Though pH increased in frozen meat, bacterial numbers did not reach millions.

Psychrophilic count (PC)

The PC of frozen buffalo meat after post slaughter showed a decreasing trend with increase in storage period (Table 3). Whereas, chilled buffalo meat showed an increase in psychrophilic count. Sen and Sharma (2003) observed a PC of 4.34 log cfu cm⁻² in fresh buffalo meat. In fact, Kotula (1975) stated that outside of the neck was the site that contained the greatest number of psychrotrophic bacteria, whereas the outside flank contained the lowest. Interestingly, the shoulder muscles utilized in the present study confirmed this finding. On 4 day storage, the PC of chilled (4±1°C) buffalo meat was higher than the frozen (-10±1°C) buffalo meat. The PC of 7 day chilled meat differed significantly (p<0.05) with the value of freezer stored meat on the same day. The results showed a significant reduction in PC on 7 and 14th days of freezer storage, respectively. Subsequent storage of 30, 60 and 75th days in freezer showed a quite significant decline in psychrophilic count. Kulkarni *et al.* (1987) reported a decline in PC from an initial count (6.36 log cfu g⁻¹) to a 30 days frozen meat PC of 5.70 log cfu g⁻¹. The increased enzyme activity of psychrotrophs at low temperature hugely contributed to deterioration of meat quality.

Total Coliform Count (TCC)

In the present study, the total coliforms in buffalo meat after post slaughter decreased quite significantly (p<0.05) with increase in storage period in the freezer (Table 3). Contrastingly, on 4 day storage, the results showed a higher coliform count in chiller than in freezer stored meat. Seven day chilled meat resulted in higher TCC. This differed significantly (p<0.05) with the value of freezer stored meat on the same day. The results showed a quite significant (p<0.05) reduction in TCC on 7, 14 and 30 th days of freezer storage. Kulkarni *et al.* (1987) reported that the TCC decreased from an initial count of 5.56 log to 5.49 log cfu cm⁻² on 30 th day. On 60 and 75th days of freezer storage the coliforms showed the least count, following significant (p<0.05) reduction in the count from 30th day of freezer storage. Govt. of India (Thulasi, 1997) indicated microbiological standards for raw meats (chilled/frozen) which states that buffalo meat, veal, mutton and minced meat must contain upto 10 g⁻¹ *E. coli* in 3 out of 5 samples and the remaining 2 may contain 100 g⁻¹.

Table 3: A comparative appraisal between microbiological parameters at different storage periods

Parameters	0	4C*	4F*	7C*	7F*	14F*	30F*	60F*	75F*
SPC (log ₁₀ cfu g ⁻¹)	5.51±0.07 ^a	5.70±0.05 ^b	5.32±0.07 ^{bc}	6.82±0.01 ^c	5.25±0.08 ^d	5.14±0.15 ^e	4.79±0.07 ^f	4.47±0.08 ^g	4.32±0.01 ^h
PC (log ₁₀ cfu g ⁻¹)	4.60±0.12 ^a	4.85±0.14 ^b	4.35±0.14 ^{bc}	5.76±0.01 ^c	4.26±0.07 ^d	4.07±0.03 ^e	3.65±0.10 ^f	3.27±0.07 ^g	3.14±0.20 ^h
Coliforms (cfu cm ⁻²)	18.00±0.82 ^a	40.00±1.80 ^b	15.00±1.23 ^c	102.00±0.01 ^d	12.00±2.56 ^e	9.00±1.55 ^f	7.00±0.80 ^g	2.00±0.18 ^h	1.00±0.06 ⁱ

Means bearing different superscripts differ significantly (p<0.05); C*represents Chiller (4±1°C) storage on respective days, F* represents Freezer (-10±1°C) storage on respective days

Sensory scores

Odour

The buffalo meat showed decreasing odour scores with increase in storage period (Table 4). On 4th day of storage, the odour scores were quite lower in chiller ($4\pm 1^\circ\text{C}$) than in freezer ($-10\pm 1^\circ\text{C}$). The scores in these two storage conditions showed that the freezer maintained the odour better than the chiller. Sharma and Sen (2000) and Sen and Sharma (2003) also recorded similar observation. The odour scores decreased significantly ($p < 0.05$) on prolonged days of freezer storage.

Flavour

In the present study, the flavour scores of buffalo meat decreased significantly ($p < 0.05$) with increase in storage period (Table 4). Four day chilled buffalo meat had a significantly ($p < 0.05$) lower flavour score than the frozen meat. A high flavour score in freezer may be attributed to a low pH compared to a high pH in chiller. In 7 day chilled meat the flavour score was not recorded since the meat was spoiled. Prolonged storage in freezer resulted decline in flavour scores. Flavour scores decreased quite significantly ($p < 0.05$) on 7, 14, 30, 60 and 75th days of frozen storage. This decline in flavour scores in frozen storage was also reported by Ristic and Schon (1980).

Texture

The texture scores of buffalo meat improved quite significantly ($p < 0.05$) with prolonged storage period in chiller and freezer (Table 4). 4 day stored buffalo meat in chiller ($4\pm 1^\circ\text{C}$) showed a lower texture score than the freezer ($-10\pm 1^\circ\text{C}$). The scores increased gradually with increase in freezer storage. This increased score in freezer storage was also studied by Arief *et al.* (1989). Freezing tenderized meat by splitting fibre and breaking or stretching connective tissue surrounding muscle fibers and fibre bundles (Hiner and Hankins, 1951). Texture scores of 30 and 60 th days of frozen meat showed a significant ($p < 0.05$) variation.

Tenderness

The present study showed an increase in tenderness scores of buffalo meat with increase in storage period (Table 4). 4 day freezer stored buffalo meat showed an increase in tenderness score than the chilled meat. An increased tenderness score in chilled meat was reported by Dushyanthan *et al.* (1994). Spoilage was observed in 7th day chilled meat. Since that meat couldn't be used for consumption, the scores were not recorded on that day. The results showed a gradual increase in tenderness scores in 7, 14, 30, 60 and 75 days of frozen buffalo meat. The results showed a significant ($p < 0.05$) improvement in tenderness scores at 30 and 60 days of storage. Guenther *et al.* (1960) indicated that the formation of intercellular and intracellular ice crystals during frozen condition indirectly contributed to tenderization of meat.

Juiciness

The juiciness scores of buffalo meat improved with increase in storage period (Table 4). Four days of chiller stored meat showed a lesser score than the freezer stored meat. It was evident that

Table 4: A comparative appraisal between Sensory scores at different storage periods

Treatments	0	4C*	4F*	7C*	7F*	14F*	30F*	60F*	75F*
Odour	7.50±0.22 ^a	6.75±0.30 ^{ab}	7.03±0.26 ^{ab}	4.06±0.06 ^c	7.06±0.17 ^{ab}	6.75±0.19 ^b	6.00±0.20 ^c	5.19±0.10 ^d	4.94±0.06 ^e
Flavour	7.50±0.16 ^a	5.50±0.26 ^{cd}	6.81±0.20 ^b	NR	6.56±0.26 ^b	6.38±0.18 ^{bc}	5.81±0.39 ^c	5.00±0.20 ^d	4.06±0.06 ^e
Texture	5.00±0.16 ^{de}	5.03±0.20 ^c	5.34±0.13 ^c	NR	5.44±0.18 ^c	5.56±0.18 ^c	6.38±0.29 ^b	7.13±0.18 ^a	7.09±0.10 ^a
Tenderness	5.13±0.47 ^a	5.25±0.19 ^a	5.44±0.24 ^{ab}	NR	5.56±0.16 ^{ab}	5.94±0.27 ^b	6.38±0.24 ^b	7.44±0.16 ^a	7.52±0.03 ^a
Juiciness	5.06±0.38 ^{ab}	5.13±0.22 ^a	5.25±0.31 ^a	NR	5.58±0.26 ^{ab}	5.69±0.22 ^a	6.44±0.13 ^b	7.19±0.10 ^a	5.13±0.09 ^a
Overall acceptance	7.31±0.22 ^a	5.94±0.25 ^b	6.94±0.21 ^a	4.94±0.06 ^c	6.81±0.29 ^a	6.75±0.30 ^a	6.00±0.18 ^b	5.13±0.27 ^c	5.00±0.01 ^d

Means bearing different superscripts differ significantly ($p < 0.05$), C*represents Chiller ($4\pm 1^\circ\text{C}$) storage on respective days, F* represents Freezer ($-10\pm 1^\circ\text{C}$) storage on respective days, NR: Value was not recorded since the meat was spoiled

though chilling and freezing improved the juiciness scores, freezing bettered chilling in the effort. The scores improved quite significantly ($p < 0.05$) with increase in freezer storage. Arief *et al.* (1989) recorded an increased juiciness scores on 30 and 60th days of freezer storage. Though there were marked drip losses in later days of freezer storage, it was not significant enough to reflect on the juiciness characteristic of the meat during sensory evaluation.

Overall Acceptability

The overall acceptance scores of buffalo meat decreased significantly ($p < 0.05$) with increase in storage period (Table 4). The results showed a higher acceptability score for 4 days of frozen meat than the chilled meat. 7th day chilled meat showed the lowest overall acceptance score. This differed significantly ($p < 0.05$) with the score of frozen meat on the same day. A gradual decline in score was recorded on prolonged days of freezer storage. Marriot *et al.* (1980) and Selvaraj *et al.* (1988) also observed this decreasing trend in acceptability of frozen meat.

CONCLUSIONS

Although 60 days of frozen meat increased some of the sensory parameters, owing to the fact that meat is praised for its richness in protein, domestic frozen meat would be best if consumed before 30 days of storage. The loss of protein as drip with increased frozen storage was mainly attributed to the large extracellular ice crystal formation in the muscle fibers. Taking into account of all the above considerations, it may be concluded that a storage period upto 4 days in chiller ($4 \pm 1^\circ\text{C}$) and 30 days in freezer ($-10 \pm 1^\circ\text{C}$) would satisfactorily maintain the buffalo meat quality.

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