Microbial and sensory quality changes in refrigerated minced goat meat stored under vacuum and in air

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Abstract

Goat mince was packed and stored at 4 ± 1°C. Mince was analysed physico-chemically and microbiologically at intervals 0, 3, 7, 10, 21 and 28 days for packs stored aerobically and 7, 14, 21, 28 and 40 days for vacuum packs. Although the initial pH of mince was 6.5, meat pH and extract release volume declined during vacuum storage. The microbial profile of aerobically stored mince was significantly higher than that in vacuum packs. The mean count of total aerobes of aerobic packages was higher than that of different groups of spoilage flora in vacuum packed mince. The air packed mince comprised the climax population (log\textsubscript{10} cfu g\textsuperscript{-1}) of aerobic plate counts (9.0), psychrotrophs (8.8), coliforms (6.0), enterobacteriaceae (6.0), \textit{Pseudomonas} (9.0), faecal streptococci (6.8), lactic acid bacteria (3.5), staphylococcal counts (5.5) and yeast and mould (4.0) counts, whereas bacterial (log\textsubscript{10} cfu g\textsuperscript{-1}) profile of vacuum packed mince included total aerobic plate counts (7.0), psychrotrophs (7.1), \textit{Pseudomonas} (7.6) faecal streptococci (7.3) and lactic acid bacteria counts (3.1). The shelf-life was 28 days for vacuum packed mince whereas similar overall acceptability scores were observed at 3 days for aerobic packages. During storage putrid odours in aerobically packed mince and sulphide odours in vacuum packs were observed. High pH of mince and the initial heavy carcass contamination promoted the rapid multiplication of facultative anaerobes leading to spoilage of the mince. © 2000 Published by Elsevier Science B.V. All rights reserved.

Keywords: Goat meat; Microbes; Vacuum packaging; Aerobic packaging; Spoilage; Shelf-life

1. Introduction

India possesses 1/5th of the global goat population producing more than 0.47 million tonnes of meat. Goat meat is the most widely consumed in this country and the extension of its shelf-life is important in marketing the product for internal consumption and export purposes. Vacuum packaging to extend the shelf-life of raw meat is well established. The principal objective of vacuum packaging is the partial or total inhibition of rapidly growing pseudomonads and allowance of dominance by flora of low spoilage potential lactic acid bacteria. The composition of the climax population that consequently develops on the packaged meat will be of mixed (Gill, 1996) type and dictates the course of spoilage which is largely affected by relative numbers of various spoilage types in the initial flora (Gill and Tan, 1979).
However, dominance of lactic acid bacteria in the climax population will depend on initial flora of lactics, pH of meat, level of initial contamination and prevalence or absence of facultative anaerobic biota (Grau, 1980, 1981). Initial microbial load, gas permeability of packaging film and temperature of meat during storage play a significant role in extending the shelf-life of packaged meat (Gardner et al., 1967; Adams and Huffman, 1972; McMullen and Stiles, 1991). High pH (>5.8) meat tissue at 0°C or below under O2 depleted CO2 atmospheres exhibited no growth of facultative anaerobic bacteria and dominance by lactic acid bacteria (Gill and Harrison, 1989). Few studies have been conducted on vacuum packed lamb (Shaw et al., 1980; Moore and Gill, 1987; Sheridan et al., 1997). Compared with beef, shelf-life of vacuum packed lamb has been reported to be short. Gill and Jones (1994) reported a minimum shelf-life of 4 weeks for vacuum packed ground beef. The present study described physico-chemical, microbial and sensory changes in high pH (6.5) minced goat meat stored under vacuum in poly-ethylene pteraphthalate (PETPE) film and the aerobic storage life in low density polyethylene (LDPE) film at 4 ± 1°C.

2. Materials and methods

2.1. PETPE laminate

The PETPE film was a two-layered laminate (Flex Industries, Noida, India) with a water vapour transmission rate (WVTR) of 1.6 g cm⁻² per 24 h at 80% relative humidity at 37°C. One layer of this laminate was composed of PETPE with a thickness of 10μ and the other layer was polyethylene. The gas transmission rate of the film is not known. The PETPE bags were vacuum sealed using a Roschermatic packaging machine (Model VM 19S, Roscherwerke GmbH, Germany) and refrigerated (4 ± 1°C).

Goat meat (obtained from non-descript animals of 2 years age) was purchased 3–4 h after slaughter from a local meat shop. Leg portion was cut into chunks after removing the loose fat, fascia and connective tissue. Meat chunks from two to three animals were pooled for each trial. Mince was prepared in the laboratory by passing the chunks through an 8 mm plate of the mincer (Electrolux, Sweden), and two trials were conducted.

The minced meat was divided into 200 g portions and placed in individual bags of LDPE for aerobic storage or in PETPE bags for vacuum storage. The LDPE bags were refrigerated (4 ± 1°C) without sealing the ends of pouches. The aerobically stored packs were analysed at 0, 3, 7, 10, 21 and 28 days. The vacuum packed samples were analysed at 0, 7, 14, 21, 28 and 40 days of storage.

2.2. Analyses of packed mince

pH of mince was determined by grinding 10 g of mince from each storage pack with 50 ml of distilled water with frequent blending. pH was recorded by dipping the combined glass electrode of a digital pH meter (Century, Model LP 901) in the mince slurry (Trout et al., 1992). Three readings were made on each sample and the mean recorded.

A 10 g mince from each storage pack was ground with 200 ml of distilled water in a Warring blender and the volume of the slurry was made up to 250 ml in a volumetric flask and filtered through Whatman No. 2 filter paper. 25 ml of filtrate was collected to which 75 ml of distilled water was added and titrated against 0.1 N NaOH with three drops of phenolphthalein. The amount of standardized 0.1 N NaOH required to neutralize the meat is expressed as total acidity (Konecko, 1979).

25 g mince was blended with 100 ml of distilled water in a Warring blender for 5 min. The resultant slurry was filtered through Whatman No. 2 filter paper and the amount of filtrate released in 15 min was expressed as extract release volume (Jay, 1964).

Minced meat was placed in sample holder of Lovibond tintometer (Model E, The Tintometer, Salisbury, UK) and secured against the viewing aperture. The colour of the mince was determined by adjusting the red and yellow units while blue units were kept constant (Froehlich et al., 1982).

2.3. Microbial analysis

Representative 10 g mince from each storage pack was transferred to a sterile mortar and blended with 90 ml of 0.1% peptone–water for 60 s. Individual serial decimal dilutions for mince from each storage pack were prepared in 9 ml volume of sterile 0.1% peptone–water up to 1 : 10⁶ dilution of the original
food sample. Duplicate 0.1–0.5 ml or 1 ml inoculum of appropriate dilutions were spread with a sterile glass spreader on pre-poured plates or pour plated, respectively, on the following media: for enumeration of aerobic plate counts on spread plates of plate count agar (PCA, Hi-Media Laboratories, M 091, Bombay) which were incubated at 30°C for 48 h; psychrotrophs on spread plates of plate count agar (PCA, Hi-Media, M 091) which were incubated at 4 ± 1°C for 10–14 days; *Pseudomonas* counts on spread plates of plate count agar (*Pseudomonas* fluorescein agar with 1 ppm crystal violet, Hi-Media, M 120) which were incubated at 30°C for 72 h; *Staphylococcus* counts on pour plates of plate count agar (PCA, Hi-Media, M 043) which were incubated at 37°C for 48 h; anaerobic plate counts on pour plates of plate count agar (PCA, Hi-Media, M 091) which were incubated at 35°C for 24 h; *Enterobacteriaceae* counts on pour plates of Violet Red Bile Glucose agar (VRBG, Hi-Media, M 581) which were incubated at 37°C for 24 h; faecal streptococci on pour plates of Slanetz and Bartley agar (SBM, Hi-Media, M 641) which were incubated at 37°C for 48 h; lactic acid bacteria counts on pour plates of MRS agar (MRS, Hi-Media, M 641) which were incubated at 30°C for 120 h; yeast and mould counts on pour plates of potato dextrose agar (PDA, Hi-Media, M 096) with 2% antibiotic (Chloramphenicol and chlortetracycline, 1 : 1) and the plates were incubated at 25°C for 120 h. Colonies were counted from each group of micro-flora and expressed as log per gram. The enumeration procedures as described by Speck (1975) were followed.

2.4. Sensory (objective) evaluation of packed mince

Goat meat mince in aerobic packages and under vacuum was assessed 2 h after opening the packs at each storage interval by a three member semi-trained panel for colour, odour, discoloration and over all acceptability traits (Gill and Jones, 1994; Gill and McGinnis, 1995). The colour acceptability of mince was scored on a 7-point scale with slight modification in the procedure where 7 represents bright red and 1 indicates extremely dull red. The degree of discoloration of the mince in the package was expressed in percent on a 5 point scale (1: no discoloration, 2: 1–10%, 3: 11–25%, 4: 25–50%, 5: 50–100%). The odour acceptability of the mince was assessed on a 4 point scale where 1 indicates no off-odour, 4 represents strong off-odour. The type of odours developed during storage was recorded. The overall acceptability of the mince was assessed on a 7 point scale where 7 represents extremely acceptable and 1 indicates extremely unacceptable.

2.5. Statistical analysis

Data were analysed statistically for all the parameters according to procedures described by Snedecor and Cochran (1967). Analysis of variance were used to assess pH, total acidity, ERV and microbial counts based on a linear model that included aerobic and vacuum storage conditions and storage time within storage condition. The difference between the means were tested by critical difference. The sensory evaluation scores (colour, discoloration, odour and overall acceptability) and Lovibond colour units (red, yellow and green) of minced goat meat were tested using chi-square analysis. The hypothesis that the initial values are not affected due to aerobic or vacuum storage was tested for each parameter.

3. Results

The mean pH, total acidity and extract release volume of minced goat meat under aerobic and/or vacuum storage at 4 ± 1°C is shown in Table 1. The initial pH of minced goat meat used in this study was high (6.5). The extract release volume decreased and total acidity increased during storage in both aerobic and vacuum packages. There was no significant effect of storage period on pH of meat under both the storage conditions (Table 1).

The microbial growth in the mince stored aerobically or under vacuum is shown in Figs. 1–9. Analysis of variance of the data indicated a significant effect of the storage condition on the counts of all the microbial groups except for lactic acid bacteria and yeasts and moulds. The lactic acid bacteria and *Pseudomonas* counts increased while those of enterobacteriaceae decreased by day 7 under both the storage conditions. There was a significant drop in the lactic counts during further storage of aerobic or vacuum stored samples up to 28 days. The growth of *Pseudomonas* was restrained while that of enterobacteriaceae increased.
from day 7 to 28 in the vacuum stored mince. There was no significant difference between the initial and the day 28 counts of the vacuum stored samples for all the microbial groups except for total aerobes, psychrotrophs and _Pseudomonas_.

Yeast and mould counts did not form a major part of the prevalent micro-flora during storage both in aerobic (log 4.0) and vacuum (log 2.0) at day 28. Overall, aerobically stored samples had higher microbial counts than that of vacuum packed samples.

The vacuum packed goat meat was bright red at 7 days and moderately bright red at 14, 21 and 28 days of storage whereas aerobically stored samples were slightly bright red at 0, 3, 7 days and slightly dull red at 10, 21 days and dull red at 28 days (Table 2). Vacuum packed goat meat had no discoloration up to 14 days

### Table 1

<table>
<thead>
<tr>
<th>Storage condition</th>
<th>Storage time (days)</th>
<th>pH</th>
<th>Total acidity</th>
<th>ERV (ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial</td>
<td>6.53 ± 0.18&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.70 ± 0.10&lt;sup&gt;a&lt;/sup&gt;</td>
<td>41.00 ± 0.35&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Aerobic</td>
<td>3</td>
<td>6.38 ± 0.01&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.00 ± 0.00&lt;sup&gt;b&lt;/sup&gt;</td>
<td>38.50 ± 0.35&lt;sup&gt;ab&lt;/sup&gt;</td>
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<tr>
<td></td>
<td>7</td>
<td>6.11 ± 0.005&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.00 ± 0.00&lt;sup&gt;b&lt;/sup&gt;</td>
<td>36.00 ± 1.00&lt;sup&gt;b&lt;/sup&gt;</td>
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<td></td>
<td>10</td>
<td>6.13 ± 0.17&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.30 ± 0.00&lt;sup&gt;c&lt;/sup&gt;</td>
<td>24.50 ± 0.50&lt;sup&gt;c&lt;/sup&gt;</td>
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<td></td>
<td>21</td>
<td>6.25 ± 0.01&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.30 ± 0.00&lt;sup&gt;c&lt;/sup&gt;</td>
<td>30.25 ± 0.25&lt;sup&gt;d&lt;/sup&gt;</td>
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<tr>
<td></td>
<td>28&lt;sup&gt;b&lt;/sup&gt;</td>
<td>ND&lt;sup&gt;d&lt;/sup&gt;</td>
<td>ND&lt;sup&gt;d&lt;/sup&gt;</td>
<td>ND&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>Vacuum</td>
<td>7</td>
<td>6.00 ± 0.01&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.30 ± 0.00&lt;sup&gt;b&lt;/sup&gt;</td>
<td>24.00 ± 0.50&lt;sup&gt;b&lt;/sup&gt;</td>
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<tr>
<td></td>
<td>14</td>
<td>6.10 ± 0.00&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.20 ± 0.00&lt;sup&gt;b&lt;/sup&gt;</td>
<td>25.50 ± 0.50&lt;sup&gt;c&lt;/sup&gt;</td>
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<tr>
<td></td>
<td>21</td>
<td>6.07 ± 0.01&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.40 ± 0.00&lt;sup&gt;b&lt;/sup&gt;</td>
<td>32.50 ± 0.50&lt;sup&gt;d&lt;/sup&gt;</td>
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<tr>
<td></td>
<td>28</td>
<td>6.10 ± 0.01&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.20 ± 0.00&lt;sup&gt;b&lt;/sup&gt;</td>
<td>24.50 ± 0.50&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
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<td></td>
<td>40&lt;sup&gt;c&lt;/sup&gt;</td>
<td>6.03 ± 0.00&lt;sup&gt;a&lt;/sup&gt;</td>
<td>ND&lt;sup&gt;d&lt;/sup&gt;</td>
<td>ND&lt;sup&gt;d&lt;/sup&gt;</td>
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</tbody>
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<sup>a</sup> Means followed by the same alphabets do not differ significantly (\(P < 0.05\)).

<sup>b</sup> Spoiled due to putrefactive odours.

<sup>c</sup> Spoiled due to sulphide odours.

<sup>d</sup> ND: Not done.

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*Fig. 1. Lactic acid bacteria counts of minced goat meat under aerobic or vacuum storage at refrigeration temperature.*
storage and at 21 and 28 days there was a slight discolouration 1–10% in the pack. The aerobically stored samples showed 25–50% discolouration at 7 days and 50–100% discolouration at 21 days. The vacuum packed samples were spoiled by sulphide odours at 40 days while the aerobically stored packs spoiled by putrefactive odours at 28 days. Thus, on 28th day, the vacuum packed samples were extremely acceptable while the aerobically stored samples were unacceptable.

Chi-square analysis of the data also indicated significantly higher discolouration scores in aerobically stored mince (Table 2), significantly higher yellow colour units for vacuum packs (Table 3) and lower overall acceptability scores (Table 2) for aerobically stored samples when compared with the initial values.
4. Discussion

Data on microbial and sensory evaluation of minced goat meat stored at 4 ± 1°C indicated a shelf-life of 28 days under vacuum compared with similar overall acceptability scores at 3 days observed in aerobically stored samples. The low storage life of aerobically stored samples was due to loss of colour. Shaw et al. (1980) also reported that the colour scores of refrigerated lamb loins in aerobic storage were lower than that under vacuum for 6 weeks. Vacuum packed goat meat mince maintained bright red colour up to 40 days even when the meat was spoiled. Gill and Jones (1994) observed that the master packed ground beef in anoxic state continued to maintain its bloom up to 32 days although its shelf-life was only 21 days. The spoilage of vacuum packed mince by sulphide odours has also been reported by earlier workers (Hanna et al., 1979, 1983). Greenish discolouration of the drip might be due to oxidation of heme to greenish myoglobin or by
formation of sulphmyoglobin between myoglobin and hydrogen sulphide (Nicol et al., 1970; Taylor and Shaw, 1977).

There were decreases in pH and ERV during storage under vacuum. In normal pH meats, decrease in pH and increase in ERV (Sutherland et al., 1975) or no significant changes in pH or ERV (Turner, 1960; Pearson, 1968) have been reported. Total acidity increased during storage under vacuum. Sutherland et al. (1975) observed decrease in total alkalinity in vacuum stored beef.

The highly variable shelf-life of vacuum packed fresh meat has been attributed to differences in pH (Rousset and Renerre, 1991), film permeability (Hodges et al., 1974) and initial contamination and storage temperature (Bell and Garout, 1994). In the present study, the initial pH of meat was very high (pH 6.5) with high enterobacteriaceae counts

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Fig. 6. Staphylococcal counts of minced goat meat under aerobic or vacuum storage at refrigeration temperature.

Fig. 7. Yeast and mould counts of minced goat meat under aerobic or vacuum storage at refrigeration temperature.
Meat with very high pH (>6.0) had a very short shelf-life even in vacuum packaging (Bem et al., 1976) as enterobacteriaceae and Brochothrix compete better with rapid bacterial breakdown of amino-acids producing unpleasant smelling products such as H₂S or ammonia (Newton and Gill, 1981). In our study, the growth of lactic acid bacteria on the vacuum packed meat in the beginning of spoilage was very slow (log 3.1 g⁻¹ at 28 days) unlike previous studies (Egan, 1983; Dainty and Mackey, 1992). The slow growth of lactic acid bacteria may be due to high initial pH of meat and growth dominance by facultative anaerobic biota (enterobacteriaceae). These results are in accordance with Grau (1980, 1981) on high pH vacuum packed meat.

The increases in Pseudomonas counts in the first week of vacuum storage were in agreement with Sutherland et al. (1975). There were increases in total aerobic and psychrotrophic populations as the conditions were not completely anoxic in vacuum packa-
ging due to oxygen ingress through the plastic film (Nottingham, 1982). The low coliform and faecal streptococcal counts in vacuum compared with the aerobic storage were in accordance with Sutherland et al. (1975) on vacuum packed beef. The staphylococcal counts at 28 days of vacuum storage were lower than in aerobic storage. However, Venugopal et al. (1993) reported unusually high staphylococcal counts in vacuum packed beef possibly due to high initial contamination.

5. Conclusion

Vacuum packaging improves the colour and micro-biological shelf-life of high pH minced goat meat

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Colour, discolouration, odour and overall acceptability scores of minced goat meat under aerobic or vacuum packed (PETPE laminate) storage at refrigeration temperaturea</th>
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<tbody>
<tr>
<td>Storage Condition</td>
<td>Storage time (days)</td>
</tr>
<tr>
<td>Initial</td>
<td>5.00a</td>
</tr>
<tr>
<td>Aerobic</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>7</td>
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<td></td>
<td>10</td>
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<tr>
<td>Vacuum</td>
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<td>40</td>
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a Numbers followed by the same alphabets, placed on the basis of chi-square values, do not differ significantly (P < 0.05).
b 7: Bright red; 4: Slightly dull; 1: Extremely dull.
c 1: No discolouration; 5: 50–100% discolouration.
d 1: No off odour; 4: Strong off odour.
e 7: Extremely acceptable; 4: Neither acceptable nor unacceptable; 1: Extremely unacceptable.

ging due to oxygen ingress through the plastic film (Nottingham, 1982). The low coliform and faecal streptococcal counts in vacuum compared with the aerobic storage were in accordance with Sutherland et al. (1975) on vacuum packed beef. The staphylococcal counts at 28 days of vacuum storage were lower than in aerobic storage. However, Venugopal et al. (1993) reported unusually high staphylococcal counts in vacuum packed beef possibly due to high initial contamination.

5. Conclusion

Vacuum packaging improves the colour and micro-biological shelf-life of high pH minced goat meat

<table>
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<tr>
<th>Table 3</th>
<th>Lovibond colour units of minced goat meat under aerobic or vacuum packed (PETPE laminate) storage at refrigeration temperaturea</th>
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<tr>
<td>Storage condition</td>
<td>Storage time (days)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Initial</td>
<td>5.4a</td>
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<td>Aerobic</td>
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<td>40</td>
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</tbody>
</table>

a Numbers followed by the same alphabets, placed on the basis of chi-square values, do not differ significantly (P < 0.05).
b ND: Not done due to greenish discoloration in the drip.
when compared with aerobic storage by maintaining colour and restraining microbial growth with increased acceptability scores.

References


