EFFECT OF ELECTRICAL STIMULATION ON BEEF QUALITY

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "**Effect of Electrical Stimulation on Beef Quality**" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled **"Effect of Electrical Stimulation on Beef Quality"** is a record of research work done independently by **Sri. M. Sunil** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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Introduction

INTRODUCTION

Meat is one of the important items in human diet. The consumer prefers to select meat on the basis of certain qualities. Flavour, juiciness and tenderness are generally considered as the important quality attributes of meat. Although ageing of meat improves its organoleptic qualities, the cost of holding carcasses for an extended period of time without deleterious changes can be very high. Therefore, the producer is looking for ways to reduce this holding time without forfeiting the qualities. Several practices that influence the cost and quality of meat and meat products from food animals have been introduced during the past few decades (Stern 1980).

Electrical stimulation of pre-rigor muscles of various kinds of animals, especially beef carcasses, has received considerable attention as a method for improving tenderness. It is considered as a relatively inexpensive method for reducing meat toughness by minimising post-mortem muscle shortening and thus improving the palatability of meat.

Increase in production costs of beef and rising beef prices have necessitated the utilization of meat from less preferred animals, such as aged animals. Electrical stimulation of carcasses of old cattle enhances the quality of meat and therefore, offer potential advantages for beef processors and consumers. This technology attracts meat processors because it requires little change in normal abattoir practice and also helps in hot deboning.

In electrical stimulation, pulses of electric current are passed through the carcass as immediately as possible after slaughter. Electrical stimulation in the early post-mortem period hastens the onset of rigor-mortis by accelerating the muscle metabolism (Carse, 1973, Bendall et al., 1976; Chrystal and Devine, 1978). Concomitantly, the post-mortem ageing process appears to be accelerated.

Several investigators have studied the different aspects of the influence of electrical stimulation on meat quality. The initial studies on electrical stimulation have been focussed on reducing the effect of cold-shortening (Bendall et al., 1976; Davey et al., 1976; Bouton et al., 1978). The other reported studies include different methods of electrical stimulation, its effect on organoleptic qualities (Carse, 1973; Savell et al., 1979, Dutson et al., 1981), processing properties (Ocerkman and Kwiatek, 1980; Ray et al., 1981), bacteriological quality (Mrigadat et al., 1980; Stern, 1980; Kotula, 1981) and structural and biochemical changes (Cross, 1979; Savell et al., 1979).

In India, except pigs, no animals are principally raised for meat production. Usually the unproductive and old animals are used for slaughter. Meat from these animals will be of inferior quality primarily because of its toughness. In India consumers prefer to purchase meat immediately after slaughter which prevents the post-mortem conditioning. This in turn affects the eating quality. Facilities for storage of meat under chilling condition are also limited. Therefore, electrical stimulation of carcass may be beneficial for improving the meat quality. Only a few attempts have been made in India to study the effect of electrical stimulation on meat quality (Vijayakumar James et al., 1990; Kannan et al., 1991; Mahajan and Panda, 1991 and Reddy et al., 1991). Above studies have been made on mutton and chicken only.

The present study was conducted to evaluate the effect of electrical stimulation on beef carcasses causing certain changes in physico-chemical qualities and surface bacterial load during storage at ambient and refrigeration temperatures.

Review of Literature

REVIEW OF LITERATURE

Factors affecting muscle tenderness have been extensively investigated over the past fifty years. The observation of muscle shortening as the major cause of meat toughness has led to the understanding that postmortem treatments are as important, like live animal factors such as breed, age and preslaughter state, in determining palatability.

Post-mortem electrical stimulation has recently received considerable attention as a method for improving muscle tenderness and other quality characteristics. Electrical stimulation was first discovered to increase tenderness in turkeys by Benjamin Franklin in 1749 (Lopez and Herbert, 1975). The present interest in electrical stimulation started from initial work by New Zealand researchers which was initiated primarily to avoid cold-shortening in lamb carcasses.

Electrical stimulation has been reported to have many beneficial effects on physical and bio-chemical qualities of meat.

Numerous investigators have reported the tenderizing potential of electrical stimulation (Carse, 1973; Chrystall and Hagyard, 1976; Bouton *et al*. 1980; Calkins *et al*., 1983; Takahashi *et al*., 1984; Stiffler *et al*., 1986; Marsh *et al*., 1987). Apart from improving tenderness favourable results were also reported on organoleptic qualities like flavour (Savell *et al*., 1979; Contreras *et al*., 1981; Dutson *et al*., 1981; Salm *et al*., 1981; Djordjevic *et al*., 1983), colour (Cross *et al*., 1979; Hall *et al*., 1980; Claus *et al*., 1984; Ledward *et al*., 1986; Unruh *et al*., 1986; Renerre and Bonhomme, 1991; Griffin *et al*., 1992; Hector *et al*., 1992; Jones *et al*., 1992), texture (Cross *et al*., 1979; Dutson *et al*., 1981; McKeith *et al*., 1982; Naewbanij *et al*., 1983) and overall palatability (Savell *et al*., 1978; McKeith *et al*., 1981; Riley *et al*., 1981; Riley *et al*., 1983; Koh *et al*., 1987).

Electrical stimulation has also certain economic advantages like faster chilling (Dutson *et al*., 1981; Elgasim *et al*., 1981) and reducing the cooler ageing period (Savell *et al*., 1978; Nilsson *et al*., 1979; Savell *et al*., 1981). It was reported to prevent cold-shortening (Davey *et al*., 1976; Bouton *et al*., 1978; ChristianRing and Taylor, 1988) and reduce heat-ring formation (Cross *et al*., 1984; Orcutt *et al*., 1984; Buyek *et al*., 1986).

Davey *et al*. (1976) reported that electrical stimulation may reconcile the conflicting requirements of fast chilling to avoid spoilage and slow chilling to avoid toughening.

Electrical stimulation of carcass was found to have certain technological advantages in the processing of meat and meat products (Ockerman and Kwiatek, 1980; Cross and Ivonne, T., 1981; Ray et al., 1981; Filipan et al., 1983; Kunihiko et al., 1986; Jones et al., 1986; Powell, 1991; Lawlis et al., 1992).

Research on the effect of electrical stimulation on organoleptic qualities, structural and biochemical changes and keeping quality on beef has been carried out extensively (Cross, 1979; Savell et al., 1979; Smith et al., 1979; McKeith et al., 1980; Hawrysh and Wolfe, 1983; Taylor and Cornell, 1985; Marsh et al., 1987; Koohmaraie et al., 1988; Wythes et al., 1988; Powell, 1991; Jones et al., 1992).

Studies on electrical stimulation in sheep and goat carcasses by Savell et al., 1977; Dutson et al., 1980; Hagyard et al., 1980; Riley et al., 1981; Moller et al., 1983; Bouton et al., 1984; Mathew, 1990; Vijayakumar James et al., 1990; Mahajan and Panda, 1991 and Reddy et al., 1991, in swine by Ockerman and Kwiatek, 1980; Swasdee et al., 1983; Grenwelge et al., 1984; Dransfield et al., 1991 and Taylor and Tantikov, 1992, in chicken by Froning and Uijttenboogaart, 1988; Janky et al., 1989 and Slavik et al., 1991, in rabbit by Mrigadat et al., 1980; Kang and Fukazawa, 1983; Horgan and Kuypers, 1985 and Kang et al., 1991, in deer by Aylard, 1982; Chrystall and Devine, 1983 obtained promising results in improving organoleptic qualities.

Ultrastructural and biochemical changes in electrically stimulated meat were studied by various research workers (Shaw and Walker, 1977; Savell et al., 1978; Will et al., 1980; Sorinmade and Cross, 1982; Salm et al., 1983; Swatland and Dutson, 1984; Fabiansson et al., 1985; Koh et al., 1987; Takahashi et al., 1987; Janky et al., 1989). Enzymatic changes as a result of electrical stimulation have also been reported (Dutson et al., 1980; Swatland, 1981; Wu et al., 1981; Newbold and Small, 1985; Dransfield et al., 1992; Pommier, 1992).

Effect of electrical stimulation and high temperature conditioning on meat qualities were studied (Marsh et al., 1981; Bouton et al., 1984; Babiker, 1985).

Combined effect of electrical stimulation and hot boning has been studied extensively (Ray et al., 1981; Taylor et al., 1981; Choi et al., 1984; Claus et al., 1984; Shivas et al., 1985; Ceechi et al., 1988).

Effect of electrical stimulation on storage and shelf life characteristics of meat has been carried out (Riley et al., 1980; Nortje et al., 1986; Seman et al., 1986; Moore and Young, 1991).

The effect due to different electrical parameters has been reported by various workers. Studies on high voltage stimulation have been done by Davey et al., 1976; Rosset and Roussel-Ciguard, 1980; Calkins, 1982 and Smulders et al., 1989 and on low voltage stimulation by Shaw and Walker, 1977; Nilsson et al., 1979; Taylor and Marshall, 1980; Murmann and Wenzel, 1981; Unruh et al., 1984; Fabiansson and Reutersward, 1985; Solomon, 1986; Carballo et al., 1989 and Hector et al., 1992.

Comparisons were also made between low and high voltage stimulation by Morton and Newbold, 1982; Rashid et al., 1983a; Powell et al., 1984; Stiffler et al., 1984; Horgan and Kuypers, 1985; Solomon, 1986; Koh et al., 1987; Zaglul and Cassens, 1987 and Smulders et al., 1989.

Various parameters like voltage, frequency, pulse and stimulation time have also been investigated (Shaw and Walker, 1977; Deatherage, 1980; Swatland, 1980; Takahashi et al., 1987).

2.1 pH

The muscle pH is an important physico-chemical quality as it is closely associated with the chemical and physical properties of meat. The muscle pH controls a number of factors like onset of rigor, tenderness and waterholding capacity which are extremely important to the meat-processing industry. The beneficial effect of electrical stimulation is mainly due to accelerated glycolysis and measurement of pH is an indicator.

Several research workers have demonstrated the effect of electrical stimulation post-mortem on pH decline.

Carse (1973) observed that increasing pulse voltage had a marked acceleration on the rate of pH decline in lamb carcasses.

Bendall et al. (1976) reported that in undressed beef carcasses, stimulation induced a fall in pH to 6.0 within 1 h of slaughter and to 5.7 within 2.5 h in the major muscles of forelimb, back and thigh representing a gain of more than 8 h over the time required in nonstimulated carcasses hanging at 16°C.

The effect of electrical stimulation was found to induce a significantly lower muscle pH at 1, 4 and 24 h compared with nonstimulated beef carcasses or sides (Shaw and Walker, 1977).

Bouton et al. (1978) reported that muscles from stimulated beef sides had significantly lower pH values at 1, 4 and 24 h after slaughter than muscles from control sides.

The initial fall in pH (pH) was maximal between 9 to 16 pulses per second but the subsequent increased rate of pH fall following stimulation appeared to be independent of stimulation parameters (Chrystall and Devine, 1978).

Smith et al. (1979) observed that electrical stimulation lowered the pH of Longissimus dorsi muscles in beef carcasses at 2-11 h post-mortem.

Rozier et al. (1980) reported that low voltage electrical stimulation considerably reduced pH 1 h post-mortem.

The rate of fall of muscle pH was appreciably more rapid in the stimulated than the nonstimulated beef sides (Taylor and Marshall, 1980).

The most important effect of electrical stimulation is acceleration of glycolysis due to massive muscle contractions resulting in rapid accumulation of lactic acid and drop in pH (Dutson et al, 1981).

Post-mortem pH drop was accelerated by electrical stimulation of beef carcasses and rigor-mortis at pH 5.9 was advanced by 6 h compared with nonstimulated controls (Honikel and Woltersdorf, 1982).

Rashid et al. (1983b) found that electrically stimulated and slowly chilled (5 h at 14 $\pm$2°C) beef sides exhibited significantly rapid pH decline in Longissimas dorsi muscle.

Hawrysh and Wolfe (1983) observed that electrical stimulation caused a reduction in pH values at 1 h and 4 h post-mortem but at 24 h the pH of muscles from electrically stimulated and control mature cow carcasses were similar.

Significantly lower muscle pH values were achieved by the stimulated beef carcass side compared to the non-stimulated side at 0.5 and 4.0 h post stimulation (Toylor and Cornell, 1985).

High voltage stimulation increased the post-stimulation rate of pH fall than that with low voltage stimulation (Horgan and Kuypers, 1985).

Smulders et al. (1986) studied the effect of electrical stimulation in randomly assigned groups of bull carcasses derived from meat breeds of cattle and reported that stimulated carcasses in all groups showed a significantly more rapid pH fall upto 8 h post-mortem in _adductor_, _longissimus dorsi_ and _triceps brachii_ muscles.

Both low voltage and moderate voltage electrical stimulation system produced a rapid drop in muscle pH within the first 5 h post-mortem (Solomon, 1986).

Jones _et al_. (1992) reported that electrical stimulation lowered final muscle pH.

There was no effect on the ultimate pH of the meat by using electrical stimulation (Smith _et al_., 1977).

Significant differences were observed for pH values at 1 h and 6 h post-mortem for electrically stimulated vs nonstimulated sides while no significant differences were observed for 12 h and 24 h pH values (Savell _et al_., 1979).

Gariepy _et al_. (1992) in a study on electrical stimulation and 48 h ageing of bull and steer carcasses, observed that during cooling electrically stimulated sides had lower pH values when compared to their nonstimulated counterparts, but as the muscle temperature fell, differences in pH produced by stimulation were reduced and varied from 0.3 to 0 over the first 12 h post-mortem.

2.2 Microbiology

Microbial contamination of meat occurs during the process of slaughter and dressing. Such bacterial contamination has a bearing on the shelflife of meat and public health. Only a few studies have been reported on the effect of electrical stimulation on microbial quality of meat.

Investigations by Gilbert and Davey (1976) indicated that microbial differences between stimulated and nonstimulated beef sides were not significant. Differences in aerobic plate counts (APC) at 25°C between stimulated and nonstimulated samples prior to chilling, before boning and after boning (24 h post-mortem) and after ageing (96 h) were less than one log cycle.

In a study on storage stability and bacteriological profiles of refrigerated ground beef prepared from electrically stimulated and hot-boned carcasses, Raccah and Henrickson (1978) reported significant differences in APC between electrically stimulated and nonstimulated control carcasses on the third, fifth, sixth and seventh days of storage at 5°C. They also reported that shelflife of ground beef from electrically stimulated carcasses was prolonged by three days compared to the control.

Gill (1980) found that the growth of spoilage bacteria was unaffected by electrical stimulation.

No significant differences on bacterial counts between electrically stimulated and nonstimulated control samples were observed either initially or at termination of display for four days for either steak or ground beef sample (Hall et al., 1980).

Mrigadat et al. (1980) reported that electrical stimulation of beef sides did not cause any consitent marked changes in microbial types in ground beef, blade steaks, T bonesteaks or ribsteaks.

Stern (1980) reported that electrical stimulation excerted no significant effect on surface bacterial numbers in lamb cuts.

There were no significant differences in growth of various bacteria on ground beef made from electrically stimulated and nonstimulated muscles (Butler et al., 1981).

Contreras and Harrison (1981) reported lower microbial counts for electrically stimulated beef samples.

Research carried out to determine the influence of hot-boning and electrical stimulation on the microbial levels on beef carcasses showed that electrical stimulation had no significant effect on microbial counts (Kotula, 1981).

Kotula and Emswiler-Rose (1981) reported that electrical stimulation of beef carcasses had no apparent influence on the incidence or growth of aerobic bacteria.

Taylor et al. (1981) reported no difference in total viable counts between stimulated and control beef samples.

Berry and Kotula (1982) found that electrical stimulation caused no major microbial problems in vacuum packaged primals although coliform counts were higher for meat from electrically stimulated beef sides.

Oblinger (1983) has reviewed the microbiology of electrically stimulated beef and concluded that electrical stimulation did not alter the microbiological quality.

Ockerman and Szczawinski (1984) observed the effect of electrical stimulation of inoculated pork tissue on thermo-resistance of three bacteriae. They found electrical stimulation did not affect the thermo-resistance of *Streptococcus faecalis* but slightly decreased the thermoresistance of *Lactobacillus plantarum* and *Psuedomonas putrifaciens*.

Paleari *et al*. (1991) conducted microbiological analysis of electrically stimulated beef for total bacterial count, Lactobacillus, total enterobacteria and Pseudomonas and concluded that there were no significant variation due to electrical stimulation.

Slavic *et al*. (1991) investigated electrical stimulation as a method to eliminate or reduce the number of *Salmonella typhimurium* attached to chicken legs. Their results indicated that electrical stimulation was effective in killing bacteria in solution and in reducing the number of salmonellae attached to chicken legs.

2.3 Organoleptic qualities

Meat being a food its organoleptic qualities are important for consumers. They include tenderness, flavour, juiciness and colour. The most desirable effect of electrical stimulation on meat is tenderness. This is mainly evaluated subjectively by sensory panel evaluation and objectively by measuring the force required for shearing a uniform core of meat.

Savell *et al*. (1977) studied the effect of electrical stimulation of beef, lamb and goat carcasses on meat palatability and observed that in both taste panel evaluation and Warner-Bratzler shear values of longissimus muscle samples, from stimulated sides of all three species were significantly more tender than samples from non-stimulated sides.

Smith et al. (1977) observed that electrical stimulation of goat, lamb, beef and calf carcasses decreased shear force values and increased tenderness ratings by 12.55 per cent.

Savell et al. (1978) found that most consistent improvement elicited by electrical stimulation was in lowering the shear force and in increasing the sensory panel ratings (more tender, less organoleptically detectable connective tissue and more desirable overall palatability).

Electrical stimulation of beef carcasses soon after death had an accelerated tenderizing effect on the musculature under conditions of slow cooling. Electrical stimulation also reduced the shear force value on day one of storage from 11 to 6 kg/cm^2 (George et al., 1980).

McKeith et al. (1980) observed that electrical stimulation of mature cow carcasses increased tenderness similar to those achieved by electrical stimultion of young beef carcasses.

Electrically stimulated hot-boned products from beef had slightly higher cooking losses, more intense flavour and were slightly juicier than conventionally chilled products (Contreras _et al_., 1981).

Marsh _et al_. (1981) reported that electrical stimulation produced its desirable tenderizing effect mainly by fibre fracture.

Beef steaks from electrically stimulated carcasses were lower in shearforce values, more tender, lower in panel detectable connective tissue and higher in overall palatability ratings than steaks from non-stimulated carcasses (MeKeith _et al_., 1981).

Tenderness was improved by electrical stimulation of beef carcasses derived from cattle fed on a high energy diet upto 210 days, but juiciness and flavour were not affected (Salm _et al_., 1981).

Electrical stimulation of beef carcasses improved tenderness and flavour of fried, grilled and boiled samples (Djordjevic _et al_., 1983).

Fjelkner-Modig and Ruderus (1983) reported that electrically stimulated beef was more tender and juicy than nonstimulated beef.

Study on effect of electrical stimulation on quality of beef stored under varying conditions showed that electrical stimulation and rapid chilling caused significant improvement in tenderness (Foltys et al., 1983).

Takahashi et al. (1984) reported that low frequency high voltage stimulation excerted its beneficial tenderizing action by fracturing the muscle fibres.

Taylor and Cornell (1985) studied the effect of electrical stimulation and ageing either alone or in combination on beef tenderness. They found that electrical stimulation combined with ageing resulted in significantly more tender meat than by electrical stimulation alone.

The effect of electrical stimulation on beef was more pronounced depending on the rate of post-mortem muscle metabolism and initial shearforce value (Fabiansson and Reutersward, 1985).

Improved tenderness in electrically stimulated beef samples has been attributed to accelerated autolytic proteolysis by Fabiansson and Libelius (1985).

Electrical stimulation significantly improved most of the tenderness measurements on steaks from young bulls, but was effective only in decreasing shearforce values of steaks from steers (Stiffler et al., 1986).

Marsh et al. (1987) reported that the effect of electrical stimulation on beef tenderness was highly dependent on the subsequent cooling rate. Tenderness was highest when glycolysis had proceeded at an intermediate rate (corresponding to the attainment of 3 h pH of about 6.1).

Combined electrical stunning and electrical stimulation of beef carcasses resulted in higher levels of tenderness in 19 per cent of the muscles examined and a decrease of 23 per cent in shearforce (Specht and Kunis, 1988).

Wythes et al. (1988) reported that electrical stimulation of beef carcasses had a much greater effect on tenderness than those of resting conditions before slaughter.

Gariepy et al. (1992) found same tenderizing effect on beef with electrical stimulation and 48 h ageing to that of nonstimulated but aged for 6 days.

Jones et al. (1992) reported that electrical stimulation reduced muscle shear value, brightened muscle colour at 24 h post-mortem but had no effect on marbling score.

2.4 Non-protein nitrogen

The non-protein nitrogenous water soluble substances primarily consisting of low molecular weight compounds such as aminoacids, peptides and nucleotides represent 1.5-2.0 per cent of the post-mortem muscle (Lawrie, 1979). Enhanced proteolysis will cause an increase in the content of non-protein nitrogen.

One of the mechanisms of tenderization of electrically stimulated meat is by autolytic proteolysis (Sorinmade and Cross, 1982).

Babiker and Lawrie (1983) reported that electrical stimulation and incubation at 30°C significantly increased the content of non-protein nitrogen in beef.

At the normal chilling rate, electrical stimulation enhanced degradation of myofibrillar protein viz. alpha actinins and troponin T (Salm et al., 1983).

Electrical stimulation accompanied by high temperature incubation of beef carcasses was found to increase the degradation of myofibrillar proteins (Babiker, 1985).

Improved tenderness of electrically stimulated beef samples could be easily explained by an accelerated autolytic proteolysis (Fabiansson and Libelius, 1985).

High post-mortem temperatures enhanced the degradation of proteins in beef muscle strips incubated at 25°C (Yu and Lee, 1986).

Dransfield (1991) reported that when the pH of muscle was lowered to about 6.1, Calpain I was activated resulting in proteolysis and tenderization in beef.

2.5 Electrical stimulation and chilling

Fresh meat is normally stored under chilled conditions, for its natural ageing without microbial spoilage. Various studies have been made to assess the effect of electrical stimulation on meat under chilled conditions.

Savell et al. (1978) found that electrical stimulation of beef carcasses could substantially reduce the time for cooler ageing.

Calkins et al. (1980) reported that optimum chilling time for maximising marbling score and USDA quality grade was 48 h for both electrically stimulated and non-stimulated beef sides.

Electrically stimulated meat had faster chilling rate and markedly reduced the time needed to reach constant temperature in chill coolers (Dutson et al., 1981).

Elgasim et al. (1981) in a study on the effect of electrical stimulation and delayed chilling of beef carcasses, found that stimulated carcasses cool faster at 1 h post-mortem. In delayed chilled carcasses, weight loss at 24 h post-mortem was lower in stimulated compared to nonstimulated carcasses.

Crouse et al. (1983) reported that sensory panel scores for beef from electrically stimulated carcasses chilled initially at 16°C were superior to the meat from stimulated carcasses chilled at 2°C.

Foltys et al. (1983) showed that electrical stimulation and rapid chilling of beef carcasses greatly reduced the risk of producing tough meat.

At the normal chilling rate, electrical stimulation enhanced degradation of myofibrillar proteins, but sarcomere length was not altered. When muscles were chilled rapidly, electrical stimulation did not improve tenderness or prevent cold shortening (Salm et al., 1983).

Grenwelge et al. (1984) reported that rapid chilling reduced the detrimental effect of electrical stimulation such as paler colour and muscle firmness in pork.

Electrical stimulation was found to be less effective when it was followed by moderate cooling (Buts _et al_., 1986).

Carballo _et al_. (1988) found that electrical stimulation prevented cold-shortening when it was followed by quick or slow chilling.

Pommier (1992) investigated methods of enhancing the rate of ageing of beef and found that acceleration of tenderness took place by electrical stimulation followed by slow chilling.

Materials and Methods

MATERIALS AND METHODS

In the present investigation ten beef carcasses of dairy cattle ranging between 8 to 12 years of age and 150 to 300 kg live weight were subjected to electrical stimulation to study its effect on various physico-chemical and bacteriological qualities.

Animals were stunned using captive bolt pistol. Dressing of animals was carried out manually by conventional method consisting of exsanguination, flaying and evisceration. Immediately after dressing fore-quarters were separated. Left fore-quarter was subjected to electrical stimulation (ES) and the other fore-quarter was used as control (C).

3.1 Electrical stimulation

The left fore-quarter was electrically stimulated within 30 min of exsanguination, using an electrical stimulator. Alternating current (pulsed 20 pules per second) at 110 volts, 50 Hz was used for stimulation. The current was applied for a period of 120 seconds in a cycle of two seconds 'on' and one second 'off'. Two copper electrodes were used for delivering the current.

Plate I. Carcass fore-quarter ready for electrical stimulation

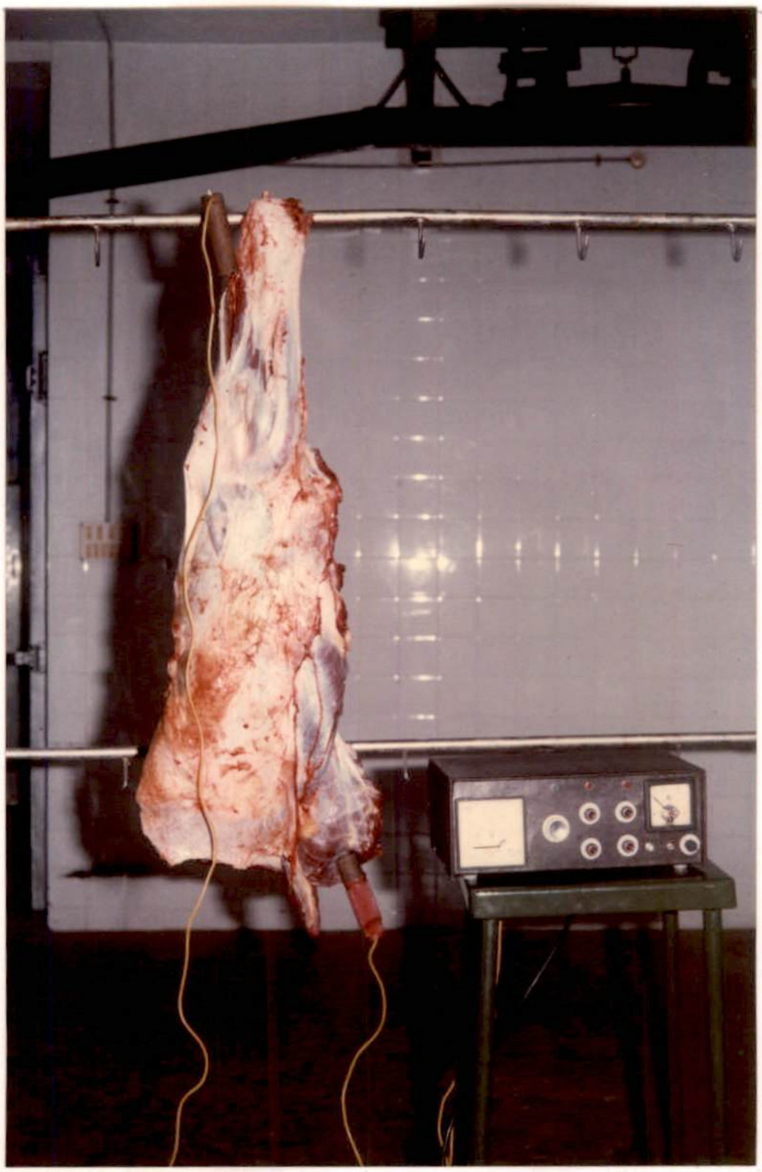


Plate 2. Carcass fore-quarter during electrical stimulation

Two meat samples each were taken from <u>triceps</u> <u>brachii</u> muscle of the electrically stimulated and control sides for analysis. One meat sample each from C and ES side was stored at ambient temperature and the other two meat samples were stored under refrigeration temperature (7 ± 1°C) for 24 h in polyethene covers. Representative samples were taken from C and ES meat stored at ambient and refrigeration temperatures at specific intervals and analysed for the following parameters:

1. pH
2. Non-protein nitrogen (NPN)
3. Total viable count (TVC) and
4. Sensory evaluation for:
    a. Flavour
    b. Juiciness
    c. Tenderness
    d. Connective tissue residue and
    e. Overall acceptability

3.2 Estimation of pH

The pH of the C and ES meat samples stored at ambient temperature were taken at 0, 1, 2, 4 and 8 h. The pH of the meat samples stored at refrigeration temperature were taken at 1, 2, 4, 8 and 24 h.

Procedure

The pH was estimated using the method described by Moeller et al., 1977. One gram meat was homogenised with 10 ml of 0.005 M sodium iodoacetate and the pH of the homogenate was taken using a Beckman's pH meter.

3.3 Estimation of non-protein nitrogen (NPN)

Meat samples stored at ambient temperature were taken for NPN analysis at 0 and 8 h. Meat samples stored under refrigeration were taken at 8 and 24 h.

Procedure

a. Preparation of trichloro acetic acid (TCA) filtrate

TCA filtrate of the meat samples was prepared following the method described by Bate Smith et al. (1944).

Ten gram of the meat sample was homogenised in a meat blender with water. The homogenous suspension was made upto 100 ml with water. To this 20 ml TCA (20 per cent) was added and mixed thoroughly. This solution was kept at room temperature for 10 min. Then it was filtered through a Whatman No.1 filter paper into a 100 ml volumetric flask. The precipitate on the filter paper was washed with TCA (20 per cent). Finally the volume of the filtrate was made upto 100 ml.

Ten millilitre of the filtrate was digested with 8 ml of concentrated sulphuric acid (AR grade) and 2 g of digestion mixture consisting of copper sulphate and potassium sulphate in the ratio 1:4. The digestion was continued until the solution became colourless. After cooling the contents were made upto 100 ml. An aliquot of 10 ml was taken for Kjeldahl distillation to determine the nitrogen content.

b. Determination of nitrogen

The amount of nitrogen present in the sample was determined by MicroKjeldahl method described by Hawk et al. (1954).

Ten millilitre of made up digest was transferred into the distillation chamber of a MicroKjeldahl distillation assembly, followed by 20 ml of 40 per cent sodium hydroxide solution. A small flask containing 0.1 N sulphuric acid was kept below the condenser of the distillation apparatus so that the tip of the condenser outlet dipped below the level of acid solution. The sample was steam distilled until 8.10 ml of the distillate was collected in the receiving flask. The flask was taken out and the tip of the condenser outlet was washed with a jet of distilled water, collecting the washings also in the same flask. The nitrogen was estimated colorimetrically using Nesselerisation of the digest. The colorimetric nitrogen standard was prepared as follows. A stock solution containing 471.6 mg of ammonium sulphate (AR grade) per litre was prepared. Ten ml of the stock solution was diluted to 100 ml from which 20 ml was used as the working standard.

Four millilitre of the individual samples and 20 ml of the working standard were pipetted out into separate 50 ml volumetric flasks. They were diluted to 35 ml with ammonia free distilled water. To every flask 6 ml Nesseler's reagent was added and the volume was made upto 50 ml with ammonia free distilled water. Mixed the contents by inverting the flasks several times (The standard now contained 0.2 mg of nitrogen). A reagent blank was also prepared using the same procedure described above. The percentage transmittance of the samples as well as the standard were read in a spectrophotometer (Spectronic 20 Miller Roy) at 520 nm and set to 100 per cent transmittance against the blank.

Calculation

$$\text{mg of nitrogen in the unknown} = \frac{u}{s} \times \text{mg of nitrogen in standard} \times \text{D.F.}$$

u = reading of unknown

s = reading of standard

D.F. = Dilution Factor

3.4 Total viable count

Total viable count (TVC) of aerobic organisms was determined by the procedure recommended by American Public Health Association (1976).

Surface swabs were taken from meat samples stored at ambient temperature at 0, 8 and 12 h. From meat samples under refrigeration swabs were taken at 8, 12 and 24 h.

Procedure

An area of 25 cm^2 on external surface was demarkated with a sterile aluminium template. This area was swabbed with a sterile cotton swab moistened in 0.1 per cent peptone water. This swab was then transferred into a flask containing 25 ml of sterile 0.1 per cent peptone water (Diluent).

Preparation of sample

Swab was mixed thoroughly by shaking to disperse the bacteria from the swab into the diluent. From this 10 ml was transferred to a flask containing 90 ml diluent with the help of a sterile graduated pipette, so as to form 1 in 10 dilution. Further ten fold dilutions were made by transferring 1 ml inoculum to 9 ml of the diluent. TVC was evaluated by Pour plate method. Petriplates in duplicate were inoculated with 1 ml each of the inoculum from the selected decimal dilution of the samples. About 15.20 ml sterile, molten standard plate count agar (Appendix) (Hi-media) maintained at 45°C was poured in each petridish and mixed with the inoculum by gentle rotatory movement.

After solidification of the medium at room temperature these plates were incubated at 37°C for 24 hours. The plates having 30 to 300 colony forming units (CFU) were selected and counted. After applying the dilution factor of plate counted, the counts were expressed as $\log_{10}$ CFU per square centimetre of the sample.

3.5 Sensory evaluation

Sensory evaluation was done for flavour, juiciness, tenderness, connective tissue residue and overall acceptability. Representative samples from the meat stored at ambient temperature were taken at 0 and 8 h and from meat stored under refrigeration were taken at 8 and 24 h.

Samples of meat from refrigeration temperature were thawed to room temperature. Meat samples were cut into 1/2" cubes (10 g) and cooked in polypropylene bags by immersing it in boiling water bath for 40 min. Cooked meat samples were served to semitrained taste-panelists who were provided with a 9 point hedonic scale score card (Appendix).

3.6 Statistical analysis

Data were analysed using paired 'T' test as explained by Snedecor and Cochran (1967).

Results

RESULTS

4.1 pH

The mean pH values of control (C) and electrically stimulated (ES) samples at different intervals of storage at ambient and refrigeration temperatures are given in Table 1. The initial pH of the meat (6.90 ± 0.01) slowly reduced on storage both at ambient and refrigeration temperatures. This tendency was noticed both in C and ES meat. The pH of C stored at ambient temperature fell to 6.76 ± 0.01, 6.64 ± 0.02, 6.47 ± 0.04 and 6.25 ± 0.05 at 1, 2, 4 and 8 h respectively. Immediately after electrical stimulation, the pH dropped from initial 6.90 ± 0.01 to 6.43 ± 0.03. On storage at ambient temperature it dropped to 6.34 ± 0.02, 6.27 ± 0.03, 6.12 ± 0.04 and 5.95 ± 0.03 at 1, 2, 4 and 8 h respectively. When C samples were refrigerated, a gradual reduction in pH from an initial 6.90 ± 0.01 to 6.83 ± 0.02, 6.72 ± 0.02, 6.53 ± 0.05, 6.33 ± 0.05 and 5.68 ± 0.03 at intervals of 1, 2, 8 and 24 h respectively was noticed.

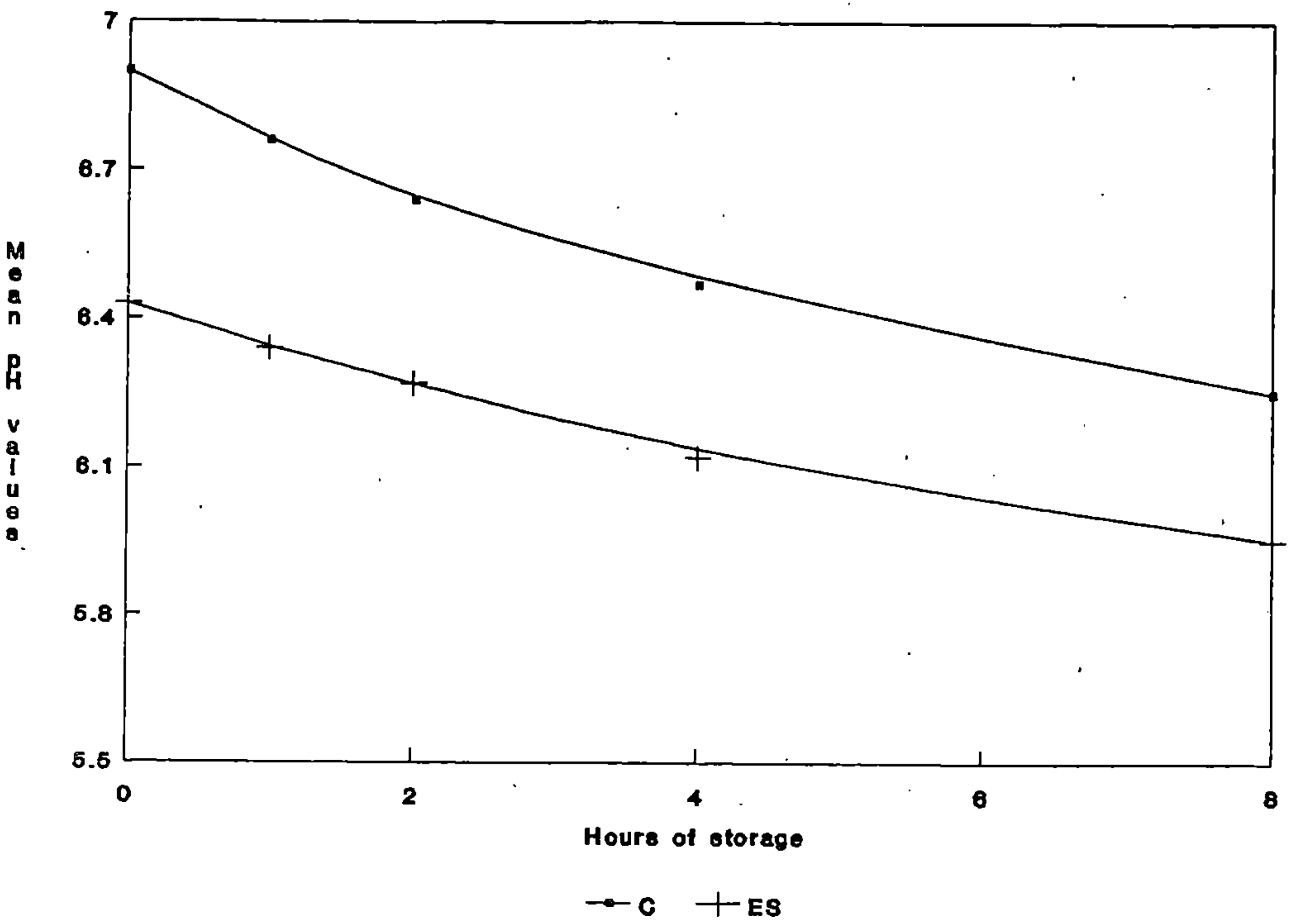
In the case of ES meat, the pH was reduced to 6.38 ± 0.02, 6.32 ± 0.02, 6.22 ± 0.02, 6.05 ± 0.04 and 5.69 ± 0.02 at intervals of 1, 2, 4, 8 and 24 h respectively during refrigerated storage. Electrical stimulation has resulted in able 1. pH values of beef stored at ambient and refrigeration temperatures at different intervals

urs of orage	Ambient temperature		Refrigeration temperature	
	Control (Mean ± SE)	Electrically stimulated (Mean ± SE)	Control (Mean ± SE)	Electrically stimulated (Mean ± SE)
0	6.90 ± 0.01	** 6.43 ± 0.03	6.90 ± 0.01	** 6.43 ± 0.03
1	6.76 ± 0.01	** 6.34 ± 0.02	6.83 ± 0.02	** 6.38 ± 0.02
2	6.64 ± 0.02	** 6.27 ± 0.03	6.72 ± 0.02	** 6.32 ± 0.02
4	6.47 ± 0.04	** 6.12 ± 0.04	6.53 ± 0.05	** 6.22 ± 0.02
8	6.25 ± 0.05	** 5.95 ± 0.03	6.33 ± 0.05	** 6.05 ± 0.04
24	--	--	5.68 ± 0.03	5.69 ± 0.02

= $P<0.05$

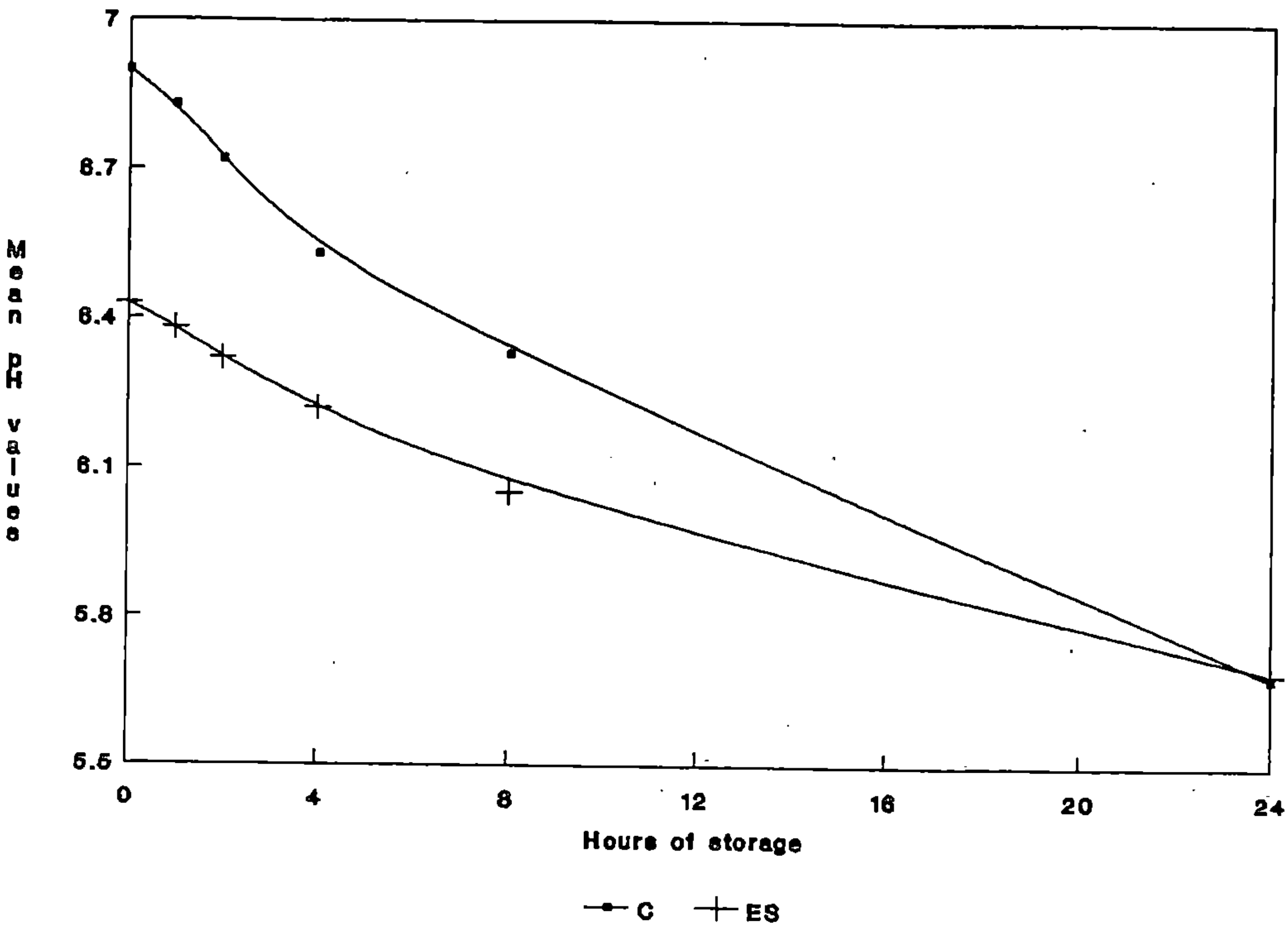
= $P<0.01$

Fig. 1



Rate of fall in pH of control and electrically stimulated beef during storage at ambient temperature

Fig. 2



Rate of fall in pH of control and electrically stimulated beef during storage at refrigeration temperature a highly significant ($P < 0.01$) reduction in the pH immediately after stimulation. The pH values of E meat were significantly lower ($P < 0.01$) than C meat at 1, 2, 4 and 8 h of storage both at refrigeration and ambient temperatures. There was no significant difference between C and ES meat at 24 h of storage at refrigeration temperature. Progressive reduction in pH was noticed in ES and C meat stored at ambient temperature. This reduction was high for the first 2 h of storage and thereafter it slowed down upto 8 h (Fig.1). The fall in pH during refrigerated storage was slower compared to that of ambient temperature, but the pH became almost equal at 24 h in both C and ES meat (Fig.2).

4.2 Non protein nitrogen (NPN)

The NPN values of control (C) and electrically stimulated (ES) beef at all intervals of storage at ambient and refrigeration temperatures are shown in Table 2. In both conditions of storage increase in NPN content was observed. At ambient temperature, the NPN value increased from 1346.93 $\pm$ 11.17 to 1374.37 $\pm$ 12.39 mg/100 g at 8 h of storage for C meat. Corresponding values for ES meat were 1380.00 $\pm$ 11.33 and 1411.69 $\pm$ 7.56. In the case of refrigerated meat, the NPN values of C samples were 1357.47 $\pm$ 12.51 and 1408.16 $\pm$ 11.52 per mg/100 g at 8 and 24 h whereas in ES sample corresponding values were 1397.64 $\pm$ 11.73 and 1444.80 $\pm$ 11.09 per mg/100 g.

Table 2. NPN values of beef stored at ambient and refrigeration temperatures at different intervals

Hours of storage	Ambient temperature		Refrigeration temperature	
	Control (Mean $\pm$ SE)	Electrically stimulated (Mean $\pm$ SE)	Control (Mean $\pm$ SE)	Electrically stimulated (Mean $\pm$ SE)
0	1346.93 $\pm$ 11.17	** 1380.31 $\pm$ 11.33	1346.93 $\pm$ 11.17	** 1380.31 $\pm$ 11.33
8	1374.37 $\pm$ 12.39	** 1411.69 $\pm$ 7.56	1357.47 $\pm$ 12.51	** 1397.64 $\pm$ 11.73
24	--	--	1408.16 $\pm$ 11.52	** 1444.80 $\pm$ 11.09

= $P<0.05$

* = $P<0.01$

NPN in mg/100 g of beef

NPN values were found to increase at every point of observation in ES meat compared to that of C meat. At 8 h of storage both at ambient and at refrigeration temperatures the difference in NPN values between C and ES meat was highly significant ($P < 0.01$). At 24 h also the NPN content of ES meat was significantly ($P < 0.01$) higher than the C meat.

4.3 Total viable count (TVC)

The mean TVC/cm^2 of C and ES meat at various intervals of storage at ambient and refrigeration temperatures are given in Table 3. The mean initial TVC in C meat was 5.65 $\pm$ 0.03 log_{10} CFU/cm^2. The corresponding values of ES sample was 5.61 $\pm$ 0.02 log_{10} CFU/cm^2. There was no significant difference between the two. On storage at ambient temperature, the TVC of C sample at 8 h was 5.85 $\pm$ 0.02 log_{10} CFU/cm^2 whereas in ES sample it was 5.69 $\pm$ 0.04. The difference was highly significant ($P < 0.01$). At 12 h, the TVC in C and ES samples were 7.03 $\pm$ 0.02 log_{10} CFU/cm^2 and 6.84 $\pm$ 0.03 log_{10} CFU/cm^2 respectively. The difference in TVC was highly significant ($P < 0.01$). In the case of refrigerated storage the mean TVC of C sample at 8 h was 5.66 $\pm$ 0.03 and for ES sample it was 5.64 $\pm$ 0.03. There was no significant difference between the two. At 12 h the corresponding TVC were 6.89 $\pm$ 0.02 log_{10} CFU/cm^2 and 6.70 $\pm$ 0.03 log_{10} CFU/cm^2 respectively. The counts were significantly ($P < 0.05$)

Table 3. Total viable count of beef stored at ambient and refrigeration temperatures at different intervals

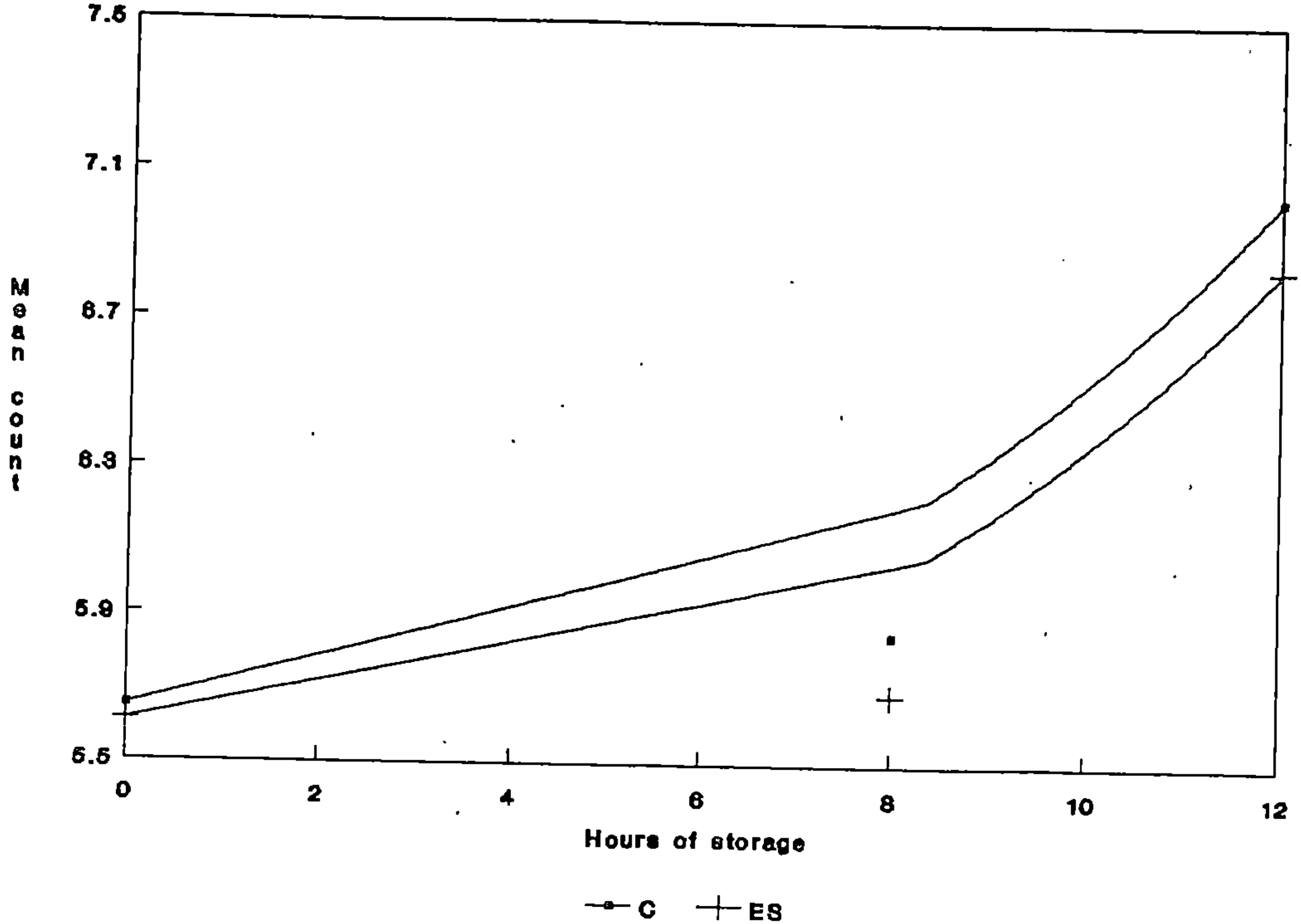
Hours of storage	Ambient temperature		Refrigeration temperature	
	Control (Mean $\pm$ SE)	Electrically stimulated (Mean $\pm$ SE)	Control (Mean $\pm$ SE)	Electrically stimulated (Mean $\pm$ SE)
0	5.65 $\pm$ 0.03	5.61 $\pm$ 0.02	5.65 $\pm$ 0.02	5.61 $\pm$ 0.02
8	5.85 $\pm$ 0.02	** 5.69 $\pm$ 0.04	5.66 $\pm$ 0.03	5.64 $\pm$ 0.03
12	7.03 $\pm$ 0.02	** 6.84 $\pm$ 0.03	6.89 $\pm$ 0.02	* 6.70 $\pm$ 0.03
24	--	--	6.96 $\pm$ 0.01	6.94 $\pm$ 0.01

* = $P<0.05$

** = $P<0.01$

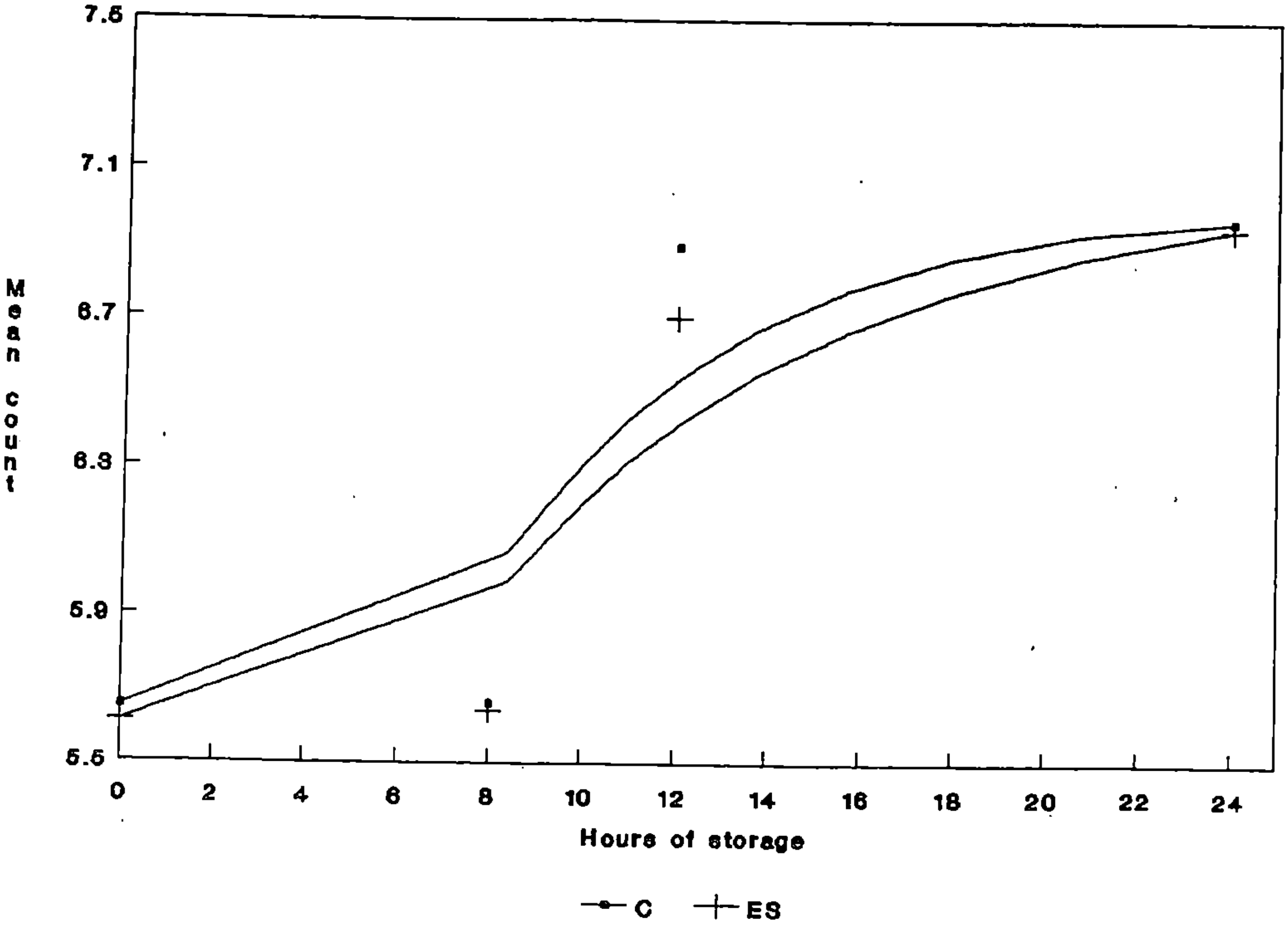
TVC in $\log_{10}$ CFU/cm^2

Fig.3



Total viable count (log 10) of control and electrically stimulated beef during storage at ambient temperature

Fig. 4



Total viable count (log 10) of control and electrically stimulated beef during storage at refrigeration temperature different. At 24 h of storage, the TVC in C and ES meat were 6.96 ± 0.01 and 6.94 ± 0.01 respectively. These two counts were not significantly different. The trend of bacterial multiplication/survivability in C and ES meat stored at ambient and refrigeration temperatures is shown in Fig.3 and 4 respectively.

4.4 Sensory evaluation

The results of sensory evaluation of C and ES meat stored at ambient and refrigeration temperatures at different intervals are given in Tables 4 to 8.

4.4.1 Flavour

The flavour score of meat at 0 h in respect of C and ES were 4.39 ± 0.08 and 4.41 ± 0.08 respectively (Table 4) showing no significant difference. At 8 h of storage at ambient temperature the flavour scores for C and ES samples were 4.85 ± 0.05 and 4.90 ± 0.4, respectively. The difference in flavour score was significant ($P < 0.05$). At 8 h of refrigerated storage the scores were 4.90 ± 0.05 and 4.89 ± 0.05. This difference was not significant. At 24 h the scores for C and ES samples were 5.19 ± 0.04 and 5.23 ± 0.04 respectively. These values were also not significantly different.

Table 4. Flavour scores of beef stored at ambient and refrigeration temperatures at different intervals

Hours of storage	Ambient temperature		Refrigeration temperature	
	Control (Mean ± SE)	Electrically stimulated (Mean ± SE)	Control (Mean ± SE)	Electrically stimulated (Mean ± SE)
0	4.39 ± 0.08	4.41 ± 0.08	4.39 ± 0.08	4.41 ± 0.08
8	4.85 ± 0.05	* 4.90 ± 0.04	4.90 ± 0.05	4.89 ± 0.05
24	--	--	5.19 ± 0.04	5.23 ± 0.04

* = $P<0.05$

** = $P<0.01$

4.4.2 Juiciness

Juiciness scores for C and ES meat samples at ambient and refrigeration temperatures at different intervals are given in Table 5. The scores for C and ES samples at 0 h of storage were 5.57 ± 0.06 and 5.64 ± 0.04 respectively. These scores were found to have significant (P <0.05) difference. At 8 h of storage at ambient temperature, significant increase (P <0.05) in juiciness was noticed for ES meat than for C, the scores being 5.39 ± 0.03 for C and 5.50 ± 0.05 for ES samples. The scores at 8 h of storage under refrigeration for C was 5.28 ± 0.04 and that for ES was 5.30 ± 0.04. There was no significant difference between the two. At 24 h the juiciness score for C meat was 5.41 ± 0.05 and that for ES meat was 5.63 ± 0.05. They were significantly different (P <0.05).

4.4.3 Tenderness

Tenderness score for meat samples at 0 h in case of C was 3.89 ± 0.08 and for ES 4.08 ± 0.04 (Table 6). The difference in scores was not significant. At 8 h of storage at ambient temperature, the tenderness scores for C and ES samples were 4.38 ± 0.04 and 4.61 ± 0.09 respectively. This difference was significant (P <0.05). In the case of meat stored under refrigeration for 8 h highly significant increase (P≤0.01) in tenderness for ES meat was noticed in comparison

Table 5. Juiciness scores of beef stored at ambient and refrigeration temperatures at different intervals

Hours of storage	Ambient temperature		Refrigeration temperature	
	Control (Mean ± SE)	Electrically stimulated (Mean ± SE)	Control (Mean ± SE)	Electrically stimulated (Mean ± SE)
0	5.57 ± 0.06	5.64 ± 0.04 *	5.57 ± 0.06	5.69 ± 0.04
8	5.39 ± 0.03	5.50 ± 0.05 *	5.28 ± 0.04	5.30 ± 0.04
24	--	--	5.41 ± 0.05	5.63 ± 0.05 *

* = P<0.05

** = P<0.01

Table 6. Tenderness scores of beef stored at ambient and refrigeration temperatures at different intervals

Hours of storage	Ambient temperature		Refrigeration temperature	
	Control (Mean ± SE)	Electrically stimulated (Mean ± SE)	Control (Mean ± SE)	Electrically stimulated (Mean ± SE)
0	3.89 ± 0.08	4.08 ± 0.04	3.89 ± 0.08	4.08 ± 0.04
8	4.38 ± 0.03	4.61 ± 0.09*	4.38 ± 0.04	4.71 ± 0.04**
24	--	--	5.02 ± 0.07	6.24 ± 0.05**

* = P<0.05

** = P<0.01

to C, the scores being 4.71 ± 0.04 and 4.38 ± 0.04. At 24 h tenderness score for C meat was 5.02 ± 0.07 and that for ES was 6.24 ± 0.05. This increase in tenderness for ES meat sample was highly significant ($P<0.01$).

4.4.4 Connective tissue residue (CTR)

Connective tissue residue scores for C and ES meat are given in Table 7. At 0 h the scores of C and ES samples were 4.72 ± 0.05 and 4.66 ± 0.03 respectively. There was no significant difference between the two values. The scores obtained at 8 h of storage at ambient temperature were 4.80 ± 0.03 and 4.77 ± 0.03 for C and ES samples respectively. These scores were also not significantly different. Under refrigerated storage at 8 h the score for C meat was 4.84 ± 0.04 and for ES it was 4.78 ± 0.06. The difference between the scores was not significant. At 24 h the scores obtained for C and ES samples were 4.80 ± 0.12 and 4.83 ± 0.08, respectively showing no significant difference between the two.

4.4.5 Overall acceptability

Overall acceptability scores of both C and ES samples are given in Table 8. At 0 h the score for C was 3.76 ± 0.05 and for ES 3.80 ± 0.07. There was no significant difference between the two. At 8 h of storage at ambient temperature the

Table 7. Connective-tissue residue scores of beef stored at ambient and refrigeration temperatures at different intervals

Hours of storage	Ambient temperature		Refrigeration temperature	
	Control (Mean ± SE)	Electrically stimulated (Mean ± SE)	Control (Mean ± SE)	Electrically stimulated (Mean ± SE)
0	4.72 ± 0.05	4.66 ± 0.03	4.72 ± 0.05	4.66 ± 0.03
8	4.80 ± 0.03	4.77 ± 0.03	4.84 ± 0.04	4.78 ± 0.06
24	--	--	4.80 ± 0.12	4.83 ± 0.08

scores were 4.35 ± 0.06 for C meat and 4.50 ± 0.07 for ES. The difference was highly significant ($P<0.01$). Under refrigeration scores at 8 h were 4.51 ± 0.07 for C and 4.66 ± 0.09 for ES. There was no significant difference between the two. At 24 h the overall acceptability scores for C and ES meat were 5.42 ± 0.06 and 6.17 ± 0.11 respectively, the difference being highly significant ($P <0.01$).

able 8. Overall acceptability scores of beef stored at ambient and refrigeration temperatures of different intervals

ours of torage	Ambient temperature		Refrigeration temperature	
	Control (Mean ± SE)	Electrically stimulated (Mean ± SE)	Control (Mean ± SE)	Electrically stimulated (Mean ± SE)
0	3.76 ± 0.05	3.80 ± 0.05	3.76 ± 0.05	3.80 ± 0.05
8	4.35 ± 0.06	** 4.50 ± 0.07	4.51 ± 0.07	4.66 ± 0.09
24	--	--	5.42 ± 0.06	** 6.17 ± 0.11

= P<0.05

= P<0.01

Discussion

DISCUSSION

5.1 pH

Post-mortem drop in pH is a well known phenomenon. The rate of fall in pH is influenced by different factors. The effect of electrical stimulation on changes in pH on storage at different temperature and time were evaluated in the present study. It was observed that pH of ES samples was significantly lower than that for the C samples at 0, 1, 2, 4 and 8 h of storage, both at ambient and refrigerated temperatures. Very similar pattern in reduction of pH due to electrical stimulation has been reported by Savell et al., 1979; Smith et al., 1979; Taylor and Marshal, 1980 and Hawrysh and Wolfe, 1983. The pH values of C and ES samples at 24 h of storage was not significantly different. Similar finding has been reported by Savell et al. (1979) and Hawrysh and Wolfe (1983) indicating that electrical stimulation accelerates post-mortem glycolysis and thereby lowers pH initially but that it does not change the ultimate pH. The most important effect of electrical stimulation is acceleration of glycolysis due to massive muscle contractions, resulting in rapid accumulation of lactic acid and drop in pH (Dutson et al., 1981). In this study the pH drop during stimulation for 120 was 0.47 units. But Chrystal and Devine (1978) reported approximately 0.7 unit pH drop in 120 seconds. Newbold and Small (1985) suggested that the magnitude of pH fall during stimulation was dependent on the pH of muscle at the time of stimulation. The fall in pH of ES sample was pronounced upto 8 h of storage. This agrees with the report of Smulders et al. (1986) who observed rapid fall in pH during first 8 h post-mortem in adductor, Longissimus dorsi and Triceps brachii muscle. The rate of fall in pH of meat at refrigeration temperature was slower compared to meat stored at ambient temperature upto 8 h during storage. This may be due to the influence of temperature. Rashid et al. (1983) reported that electrically stimulated and slowly chilled beef sides exhibited significantly rapid pH decline and Pommier (1991) reported that the pH decline was significantly affected by the chilling rate. By electrical stimulation, the drop in pH to a value below 6 was attained in a faster rate than that in control. Similar observations were made by Bendall et al. (1976). Electrical stimulation followed by storage at ambient temperature has brought about a fall in pH to a value below 6 at a shorter time compared to storage under refrigeration temperature.

5.2 Non-protein nitrogen (NPN)

In this study higher NPN values were obtained at every point of observation in ES samples compared to the corresponding C samples. Similar results of increased content of NPN in electrically stimulated samples incubated at 30°C were reported by Babiker and Lawric (1983). They postulated that this increase was due to enhanced protcolysis. At 8 h of storage the NPN content was more in samples stored at ambient temperature compared to samples stored at refrigeration temperature. This confirms the findings by Babiker (1985) who observed that high temperature incubation of beef carcasses was found to increase the degradation of myofibrillar proteins. Yu and Lee (1986) reported that high post-mortem temperature enhanced the degradation of muscle protein. The NPN content was increased with the storage both at ambient and refrigeration temperatures in all samples in the present study. The progressive increase in NPN in C samples stored both at ambient and refrigeration temperatures indicates post-slaughter biochemical changes taking place in the muscle. Electrical stimulation accelerates this phenomenon and hence results in higher NPN value.

5.3 Total viable count (TVC)

Reports indicate that the effect of electrical stimulation on microbial count was inconsistent. In the present study also difference in TVC between C and ES samples varied at different intervals of storage both at ambient and refrigeration temperatures. The TVC of ES samples were numerically slightly lower than that for the corresponding C samples at every point of observation. But statistically significant lower count for ES samples were obtained only at 8 and 12 h of storage at ambient temperature and 12 h of storage under refrigeration. Similar results of lower counts for electrically stimulated samples were reported by Raccah and Henrickson (1978), Mrigadat et al. (1980) and Contreras and Harrison (1981). This reduction in count for ES samples could involve changes initiated by electrical stimulation affecting the viability of microbial cells such as decrease in pH, proteolytic activity and increase in temperature (Mrigadat et al. (loc. cit). Riley et al. (1980) is of opinion that electrical stimulation may have a possible delterious effect on either bacteria or on meat as a growth medium. There was no significant difference in TVC between C and ES samples at 0, 8 and 24 h of storage under refrigeration. Several investigators have reported insignificant effect on microbial count of meat due to electrical stimulation (Gill, 1980; Hall et al., 1980; Stern, 1980; Kotula, 1981; Kotula and Emswiler-Rose, 1981; Taylor et al., 1981; Berry and Kotula, 1982 and Paleari et al., 1991). Kotula and Emswiler-Rose (1981) suggested that the rapid decline in pH in beef muscle from 6.9 to 5.7 as a result of electrical stimulation evidently had no noticeable influence on the surface bacteria. The TVC was found to be significantly lower in ES samples than in C samples stored at ambient temperature for 8 and 12 h and at refrigeration temperature for 12 h.

5.4 Sensory evaluation

The sensory evaluation was carried out using a (semi-trained) 5 member taste-panel. The taste-panel scores differed for different organoleptic qualities at different intervals of storage both at ambient and refrigeration temperatures.

5.4.1 Flavour

Flavour is a complex sensation which involves odour, taste, texture, temperature and pH. Flavour scores for ES samples were not significantly different from that of C sample except at 8 h of storage at ambient temperature. Seideman and Cross (1982) concluded that the changes in flavour of beef by electrical stimulation was not always observed. Similar reports of insignificant difference in flavour scores were made by Smith et al., 1979; Salm et al., 1981 and Crouse et al. 1983. But at 8 h of storage at ambient temperature ES sample had a significantly higher flavour rating than the corresponding C sample. Improvement in flavour due to electrical stimulation was reported by Savell et al., 1979; Contreras et al., 1981 and Djordjevic et al., 1983. Savell (1979) is of opinion that electrical stimulation may produce chemical compounds like hypoxanthine from complete breakdown of ATP which may be responsible for 'aged' meat flavour. All the above reports are based on study of meat stored under chilled condition after electrical stimulation. The present observation of higher flavour score at 8 h was for the meat stored at ambient temperature after stimulation. This storage temperature might have influenced the enzymatic activity resulting in early development of flavour.

5.4.2 Juiciness

Difference in taste panel scores for juiciness between C and ES samples varied at different intervals of storage at ambient and refrigerated temperatures. Significant improvement in juiciness for ES sample was obtained immediately after electrical stimulation and also at 8 h at ambient temperature storage and 24 h of refrigerated storage. Improvement in juiciness in electrically stimulated meat was reported by Contreras et al. (1981) and Fielkner-Modig and Ruderus (1983). The juiciness of meat was increased by electrical stimulation. Storage at ambient temperature favoured early beneficial effect than at refrigeration temperature.

5.4.3 Tenderness

Tenderness is the most important organoleptic quality of meat and electrical stimulation is advocated as one of the methods for its improvement. In the present study significant improvement in tenderness was observed in samples following electrical stimulation. Tenderness was found to be higher in ES samples than in C samples at 8 h of storage at ambient temperature as well as at 8 h and 24 h at refrigeration temperature. Savell et al., 1977; Smith et al., 1977; Cross et al., 1979 and Mckeith et al., 1980 reported improvement in tenderness of mature beef subjected to electrical stimulation. They made studies on electrically stimulated meat under chilled conditions. Keeping carcasses at higher temperature (hot tenderisation) is one of the methods of tenderisation of meat (Lawrie (1979); Marsh et al., 1981). In the present study, storage of meat at ambient temperature might have brought in early attainment of tenderness and electrical stimulation has exercised an added effect. The rapid attainment of low muscle pH and the resultant prevention of cold shortening is regarded as a highly beneficial influence on beef tenderness (Carse, 1973; Bouton et al., 1978 and Christian Ring and Taylor, 1988). Samples taken immediately after stimulation showed no significant difference in tenderness ratings between C and ES. This indicates that the effect of electrical stimulation on tenderness may be due to the action of proteolytic enzymes rather than that of breakage of muscle fibre structure.

5.4.4 Connective tissue residue

Connective tissue residue or sensory connective tissue indicates residue after chewing. In this study there was no significant difference in connective tissue residue between C and ES samples. Solomon (1986) reported no significant difference in connective tissue residue due to electrical stimulation. But Savell _et al_., 1978, Mckeith _et al_., 1981 and Ray _et al_., 1983 reported higher sensory panel ratings for connective tissue in electrically stimulated meat. In the present study no conclusion could be arrived at for the effect of electrical stimulation on meat in respect of connective tissue residue.

5.4.5 Overall acceptability

Improvement in overall acceptability in stimulated muscles, has been reported by many workers (Savell _et al_., 1978; Mckeith _et al_., 1981 and Riley _et al_., 1981).

In this study significant increase in overall acceptability for ES sample was obtained at 8 h of storage at ambient temperature and at 24 h of storage under refrigeration. The scores obtained in sensory evaluation of C and ES samples indicate that in respect of flavour, juiciness and tenderness electrically stimulated meat was rated high. This benefit can be attributed to both electrical stimulation and storage at ambient temperature which hastens the sensory attributes. This is reflected in the higher overall acceptability score also.

Summary

SUMMARY

Organoleptic quality of the meat is the most important parameter as far as the consumer is concerved. Among this tenderness rates first. To improve tenderness of meat without affecting the other qualities different methods have been tried. Among these methods electrical stimulation has its own beneficial effect. The present study was undertaken to evaluate the effect of electrical stimulation on carcass with regard to certain qualities of beef on storage at ambient and refrigeration temperatures. Assessment of the effect of electrical stimulation was made on changes in pH, total viable count organoleptic characters like flavour, juiciness, tenderness, connective-tissue residue and overall acceptability.

Ten beef carcasses of dairy cattle between 8 and 12 years of age and 250 and 300 kg of live weight obtained from the Kerala Agricultural University slaughter house were subjected to the study. At the end of the slaughter-line the fore-quarter was split longitudinally. The left fore-quarter was subjected to electrical stimulation using a stimulator which delivered an alternating current at 110 V and 50 Hz and 20 pulses per second for 120 seconds. This is the

experimental group (ES). The right fore-quarter was kept as control (C). From *triceps brachii* muscle two samples each were collected from ES immediately after stimulation and from C simultaneously. Samples were tested at 0 h for pH, total viable count (TVC) and Non-protein nitrogen (NPN). The organoleptic characters of meat were judged by a team of semi-trained personnel. The samples collected at 0 h were tested for organoleptic characters. Both ES and C were stored a sample each at ambient temperature for 12 h and at refrigeration (7 ± 1°C) for 24 h. They were analysed periodically at intervals of 8 and 24 h in case of refrigerated sample and 8 h in samples kept at ambient temperature for NPN and organoleptic qualities. In addition to these intervals TVC was monitored at 12 h also both at ambient and refrigeration temperatures. pH was monitored at intervals of 1, 2, 4, 8 at ambient temperature and 1, 2, 4, 8 and 24 h at refrigeration temperature.

The initial pH (6.90 ± 0.01) was found to fall gradually on storage to 6.25 ± 0.05 at ambient temperature and 6.33 ± 0.05 in the case of refrigeration temperature in C at 8 h of storage. ES has shown higher rate of fall than C and the difference was highly significant. At 24 h there was no significant difference between C and ES in pH value.

Highly significant increase in NPN was noticed in ES than in C at 0 h. At 8 h increase in NPN was noticed in ES compared to C stored at ambient and refrigeration temperatures and the increase was highly significant. At 24 h the same phenomenon was noticed in ES sample.

There was slight reduction in TVC at 0 h due to electrical stimulation. But it was not significant. The TVC was increased on storage at ambient and refrigeration temperatures. It was significantly lower in ES at 8 and 12 h than in C at ambient temperature. Under refrigeration the difference was not significant at 8 h and at 12 h in ES the TVC was lower than that for C and the difference was significant ($P<0.05$).

In the results of evaluation of organoleptic characters, the flavour score difference was noticed at 8 h of storage at ambient temperature, and in ES it was significantly higher than that in C ($P<0.05$). The juiciness score was significantly higher in ES than in C at 0 and 8 h of storage at ambient temperature and at 24 h in refrigeration temperature ($P<0.05$). There was no difference is tenderness between C and ES at oh. At 8 h of storage ES tenderness score was significantly higher than that of C at ambient temperature. There was highly significant increase in tenderness in ES than in C for meat stored under refrigeration for 8 and 24 h. No significant difference was noticed in connective-tissue residue between C and ES. The ES sample was found to have higher overall acceptability than C and the difference was highly significant ($P<0.01$) at 8 h of storage at ambient temperature and 24 h at refrigeration temperature.

The study indicates that electrical stimulation of carcass immediately after slaughter enhances meat quality with respect to pH changes, NPN value, TVC and organoleptic characters and therefore can be adopted as one of the methods to improve the tenderness and keeping qualities at ambient temperature at least for 8 h.

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* Originals not seen

Appendices

APPENDIX 1

Plate Count Agar

Tryptone	-	5.0 g
Yeast extract	-	2.5 g
Dextrose	-	1.0 g
Agar	-	15.0 g
Aq. Dist	-	1000 ml

Dissolved the ingredients in distilled water and adjusted the pH to 7.0 ± 0.02 with 0.1 N sodium hydroxide solution. Sterilized by autoclaving at 121°C for 15 minutes.

APPENDIX 2

Score Card (Scale 1-9 Scores)

Name: Date: Exp. No.

Sample No.	Tenderness	Flavour	Juiciness	Connective tissue residue	Overall acceptability
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					

High - 7-9 Medium - 4-6 Low - 1-3

Tenderness	1 = extremely tough 9 = extremely tender
Flavour	1 = extremely bland 9 = extremely intense
Juiciness	1 = extremely dry 9 = extremely juicy
Connective tissue residue	1 = abundant 9 = absent
Overall acceptability	1 = not acceptable 9 = highly acceptable

EFFECT OF ELECTRICAL STIMULATION
ON
BEEF QUALITY

By

M. SUNIL

ABSTRACT OF A THESIS

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requirement for the degree

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ABSTRACT

Application of electrical stimulation to pre-rigor muscle is considered as a method to prevent cold-shortening and to improve tenderness and consumer acceptability. The present study was conducted to evaluate the effect of electrical stimulation on changes in pH, Non-protein nitrogen (NPN) content, Total viable count (TVC) and organoleptic characters of beef stored at ambient and refrigeration temperatures, at specified intervals of time. Ten carcasses of adult cattle were subjected to the study. Electrical stimulation (ES) (alternating current at 110 V, 50 Hz and 20 pulses per second) was applied on left fore-quarter for 120 seconds. The right fore-quarter was kept as control (C). Triceps brachii muscles were collected from ES and C sides immediately after stimulation and stored at ambient temperature for 12 h and at refrigeration temperature for 24 h. The rate of fall in pH in ES was highly significant than in C at all intervals except at 24 h. The fall in pH in C was faster at ambient temperature compared to that under refrigeration temperature upto 8 h. Highly significant increase in NPN was observed during storage in ES compared to C. TVC was found to increase on storage at both temperatures. But the increase was significantly lower in ES than in C at

ambient temperature at 8 h. In refrigerated samples, at 12 h TVC in ES was lower than in C and the difference was significant ($P<0.05$). The organoleptic characters of samples were evaluated by a 5 member semi-trained taste panel. The flavour score for ES at ambient temperature was significantly higher than for C at 8 h. The juiciness score was significantly higher in ES than in C at 0 and 8 h at ambient temperature and at 24 h at refrigeration temperature. Tenderness score at 8 h was significantly higher in ES than in C at ambient temperature. Under refrigeration temperature difference in tenderness score between C and ES samples was highly significant at 8 and 24 h. No significant difference was noticed in connective tissue score between C and ES samples. There was highly significant increase in overall acceptability for ES than for C at 8 h at ambient temperature and 24 h at refrigeration temperature.