Central University of Technology, Free State

THE INFLUENCE OF SUSPENSION METHOD, ELECTRICAL STIMULATION AND AGEING ON THE INTRINSIC TENDERNESS OF BONSMARA BEEF AND THE MEAT TRADE'S PERCEPTION THEREOF

by

WALTER DERBYSHIRE

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Supervisor: Prof. JFR Lues (Technikon Free State)
Co-supervisor: Prof. Gina Joubert (University of the Free State)
Dr Phillip Strydom (Agricultural Research Council –
Animal Nutrition and Animal Products Institute)

DECLARATION OF INDEPENDENT WORK

I, WALTER DERBYSHIRE, hereby declare that this research project, submitted in fulfilment of the degree MAGISTER TECHNOLOGIAE: ENVIRONMENTAL HEALTH, is my own independent work and has not been submitted before to any institution by me or anyone else as part of any qualification.

....
SIGNATURE OF STUDENT

....27 January 2003....
DATE

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ABSTRACT

Very few if any South African abattoirs apply the tenderstretch method to increase meat tenderness. Furthermore, the majority of abattoirs do not electrically stimulate carcasses, nor do they age meat. Consumers, however, regard tenderness as the single most important component of meat quality, which justifies the application of methods at abattoirs to enhance tenderness.

In this study the effect of electrical stimulation, hip suspension and ageing on tenderness of the *M. Longissimus* of 32 Bonsmara steer carcasses was investigated, as well as the perception of the meat trade towards the acceptability of alternatively suspended carcasses by the Bloemfontein meat trade.

Half of the carcasses (16) were electrically stimulated. After dressing all 32 carcasses were split in halves (64). Thirty-two carcass halves (16 ES and 16 NES) were hip suspended while the remaining 64 carcass halves remained conventionally suspended. After 24 hours chilling the *M. Longissimus* of each half was dissected from the carcass and divided into two samples. One sample from each half was immediately frozen at –18°C, while the other was allowed to age for 7 days at between 1 – 3 °C before being frozen. Small pieces of muscle were removed from each sample, before freezing, for histological analysis. The frozen samples were each cut into three steaks, allowed to thaw and then grilled. The tenderness was measured by means of shear force (Instron Universal Testing Machine, fitted with a Warner Bratzler shear device) on steaks grilled to an internal temperature of 70°C. Sarcomere lengths were measured and cooking data (cooking loss, evaporation loss, drip loss and thawing loss) recorded. A questionnaire was used to test the acceptability of hip-suspended carcasses by the meat trade in the Bloemfontein area.

When applied individually, all the above-mentioned treatments significantly reduced the shear force (tenderness) of the meat. In combinations, the treatments had a cumulative effect, especially when carcasses were Achilles suspended. Neither extended ageing nor electrical stimulation (ES) had a significant effect on tenderness when carcasses were hip suspended. Sarcomere lengths were significantly increased by hip suspension, but not affected by ES and ageing. Thawing loss was significantly reduced by ES, as well as by ageing in combination with ES or hip suspension. The suspension method, ageing and electrical stimulation had no effect on cooking loss, drip loss and evaporation loss.

Electrical stimulation and hip suspension as individual treatments significantly improved the tenderness of meat, but in combination did not significantly complement each other. In combination with ageing, both treatments produced the most tender meat with the least thawing loss. Depending on the market sector, there definitely is a place for all three specified methods in the South African meat trade.

In general, the 40 respondents to the questionnaire did not approve of the appearance of hip suspended carcasses. They were also concerned that it would take up too much space in their chillers and that it would cause difficulty during dissecting. The majority of respondents, however did not envisage problems with transport and with effective chilling and were of the opinion that their clients would accept and purchase the dissected cuts. The majority (72.5%) of respondents indicated that they would accept hip-suspended carcasses if the study proved that it would be more tender than conventionally suspended carcasses. Fifty-two point five percent (52.5%) were of the opinion that the meat trade in Bloemfontein would accept hip-suspended carcasses. Through a comprehensive extension and marketing campaign hip-suspended carcasses should be accepted by the South African meat trade.

OPSOMMING

Die "tenderstretch" of heup-hangmetode vir die daarstelling van vleissagtheid word selde indien ooit in Suid-Afrikaanse abattoirs toegepas. Die meerderheid abattoirs maak ook nie van elektriese stimulering (ES) van karkasse gebruik nie, en karkasse word ook nie gewoonlik verouder nie. Nietemin word vleissagtheid deur verbruikers as die belangrikste komponent van vleiskwaliteit geag, wat die aanwending van verskillende metodes vir die verkryging van vleissagtheid regverdig.

In dié studie is die effek van elektriese stimulering, heuphang en veroudering van karkasse op die sagtheid van die *M. Longissimus* van 32 jong Bonsmara beeste, sowel as die persepsie van die vleishandel in Bloemfontein met betrekking tot die aanvaarbaarheid van heup-gehangde karkasse, ondersoek.

Die helfte van die karkasse (16) is elektries gestimuleer. Na dressering is al 32 karkasse gehalveer (64). Twee-en dertig halwe karkasse (16 ES en 16 NES) is daarna heup-gehang terwyl die ander steeds op die konvensionele manier bly hang het. Na 24 uur verkoeling is die *M. Longissimus* van die karkasse verwyder en elkeen is in twee verdeel. Die helfte hiervan is onmiddelik bevries teen -18°C, terwyl die ander helfte eers vir 7 dae teen 1 – 3 °C verouder is voordat dit bevries is. Voor bevriesing is klein deeltjies van elke monster verwyder vir histologiese analise. Elke bevrore monsters is hierna in 3 biefstukke opgesny, ontdooi en gebraai. Die sagtheid is gemeet deur die skeurkrag van gaar biefstukke, wat berei is tot 'n interne temperatuur van 70°C, te meet. Sarkomeer-lengtes van die rou monsters is gemeet en die gaarmaak-data (ontdooiings-, drup-, kook- en verdampingsverlies) van die

monsters is versamel. 'n Vraelys is gebruik om die aanvaarbaarheid van heup-gehangde karkasse in die Bloemfonteinse vleishandel te bepaal.

Die individuele behandelings het onderskeidelik die skeurkrag (sagtheid) van die vleis, sonder uitsondering, beduidend verbeter. Kombinasies van behandelings het 'n kumulatiewe effek, gehad veral met betrekking tot Achilles-gehangde karkasse. Die sagtheid van heup-gehangde karkasse is nie beduidend verbeter deur veroudering of deur ES nie. Sarkomeer-lengtes is nie beïnvloed deur ES of deur veroudering nie, maar in die geval van heup-gehangde karkasse was hulle beduidend langer. Ontdooiingsverlies is beduidend verminder deur ES asook deur veroudering in kombinasie met ES of heuphang. Geeneen van die behandelings, elektriese stimulering, heuphang of veroudering het 'n invloed op die hoeveelheid kook-, drup- en verdampingsverlies gehad nie.

Elektriese stimulering en heuphang as individuele behandelings het die sagtheid van vleis beduidend versag, maar in kombinasie het hulle mekaar nie juis gekomplementeer nie. In kombinasie met veroudering het albei behandelings die sagste vleis met die minste ontdooiingsverlies gelewer. Afhangend van die tipe mark wat bedien word, behoort daar 'n plek vir elkeen van die drie genoemde metodes in die Suid-Afrikaanse vleishandel te wees.

Die voorkoms van heup-gehangde karkasse was nie aanvaarbaar vir die 40 respondente van die vraelys nie. Die respondente was ook van mening dat te veel ruimte in die koelkamers in beslag geneem sal word en dat die versnitting van karkasse bemoeilik kan word. Die meeste respondente was egter van mening dat die vervoer en effektiewe verkoeling van die karkasse nie problematies behoort te wees nie en dat dit deur hulle kliënte aanvaar sal word. Die meerderheid (72.5%) van die respondente het aangedui dat heup-gehangde karkasse vir hulle sowel as hul kliënte aanvaarbaar sal wees, indien die studie sou bevind dat dit konstant sagter vleis kon lewer. Twee-en-vyftig punt vyf persent (52.5%) van respondente was van mening dat heup-gehangde vleis deur die vleishandel in Bloemfontein aanvaar sal word. Deur gebruik te maak van 'n uitgebreide voorligtings- en bemarkingsveldtog, behoort die voorkoms van heup-gehangde karkasse deur die Suid-Afrikaanse vleishandel aanvaar te word.

CHAPTER 1

INTRODUCTION

CHAPTER 1: INTRODUCTION

1.1 INTRODUCTORY REMARKS

As man developed and became more financially independent he aspired to a better standard of living. This caused his dietary habits to undergo a paradigm shift in that the focus changed from satisfying a basic need for protein to one more quality related. Thus, regarding meat, the modern consumer has become more quality conscious with a preference for tenderness (Lawrie, 1998).

Consumer perceptions have furthermore become an important factor in the purchasing of meat. For example, if an individual has been served a tough steak in a restaurant he or she is hesitant in returning and would rather try another restaurant. Similarly, when a housewife selects a tender piece of steak in a supermarket, she prefers it to be bright red in colour with little fat, while in reality a succulent, tender piece of meat that has been well aged (ripened) would rather be darker in colour and well marbled (Aberle, Forrest, Gerrard, & Mills, 2001). The consumer often associates darker coloured meat with either a lack of freshness or an indication that the meat has been derived from an old animal. Such impressions reduce the expectation of flavour when the meat is consumed (Lawrie, 1998).

According to Aberle *et al.* (2001) the perception of tenderness has been described in terms of a number of conditions of the meat during mastication. There are wide variations regarding the softness of meat, ranging from a mushy to a woody consistency felt on contact with the tongue and the cheek. The perception of tenderness can in addition be created by the resistance of the meat to tooth pressure, the ease of fragmentation when the teeth cut across the fibres, and the mealiness of the meat (Lawrie, 1998). This is experienced when small particles cling to the tongue, gums and cheeks to give the sensation of dryness. The perception of tenderness can also be created through the adhesion that denotes the degree to which the fibres of the meat are held together by connective tissue surrounding the fibres, as well as the residue after chewing. This is detected as connective tissue remaining after most of the sample has been masticated (Lawrie, 1998).

One of the objectives of the meat trade is to produce meat that will satisfy the consumers' craving for tenderness and to do so consistently; in other words, to deliver tender meat that is guaranteed. To achieve this there has been a shift in marketing towards trademark marketing where the brand name products are marketed at a premium rate reflecting exclusivity, because this guarantees quality. Branding is becoming increasingly important in the red meat industry, and according to SAMIC (2001) there are already nine registered brands available in South Africa. As the consumers learn to trust trademarks the tendency in South Africa is likely to change as in some parts of Australia where sealed cartons of quality meat are sold, similar to our cartons of wine, bearing the trademark that guarantees the quality of the product (SAMIC, 2001).

1.2 BACKGROUND AND RATIONALE

The political changes that have taken place in South Africa over recent years, have empowered previously disadvantaged people, especially in the rural areas, and placed them in a better financial position, thereby increasing the demand for quality foodstuffs. The chosen providers of meat to these communities are the smaller abattoirs that are mostly situated in close proximity to the rural and marginal urban settlements. These abattoirs are graded as grade D and E abattoirs and 368 of these exist in South Africa (National Department of Agriculture, 2001). The consumers, mostly rural, who make use of meat from these D and E grade abattoirs expect quality meat and also regard tenderness as an important component of meat quality; however, the treatment of carcasses with electrical stimulation and/or ageing may not be economically viable at the smaller abattoirs, as electrical stimulators have to be installed or sufficient cooling facilities to carry stock have to be provided to allow for the ageing of meat.

It is therefore necessary to investigate alternative methods of obtaining meat tenderness. The results of this study should, in this regard, be of prime importance to rural communities. Similarly, larger more advanced abattoirs should benefit from the implementation of more cost-effective and less energy-demanding treatments to provide a product of superior quality at a lower cost. The perception of the existing urban meat trade regarding tenderstretch carcasses has to be evaluated prior to making suggestions as to future standardised treatments.

In terms of previous research on the topic, the interrelationship between hanging method, electrical stimulation and ageing of beef carcasses with regard to their influence on the tenderness of meat has not yet been fully investigated. The main aim of this study is therefore to establish which of the specified methods of obtaining tenderness is the most effective and whether combinations of these methods could result in a cumulative tenderising effect.

The objectives of this study are:

- to establish the influence of suspension method, electrical stimulation and ageing on the intrinsic tenderness of Bonsmara beef (shear force, sarcomere lengths, thawing, cooking, drip and evaporation loss),

- to determine the acceptability of hip-suspended beef carcasses by the local meat trade.

1.3 THE IMPORTANCE OF MEAT TENDERNESS

Meat quality, and consumer perceptions and preferences regarding meat quality, predominantly depend on the market sector and the production system (Strydom, 1999). With today's consumer preference for quality, beef quality can be defined as comprising four aspects of importance, namely visual, nutritional, safety and eating quality (Strydom, 1999), with eating quality consisting of tenderness, juiciness and flavour intensity. According to Lawrie (1998) consumer surveys predominantly regard meat tenderness as the single most important component of meat quality to the average consumer and the manipulation of this aspect has been well documented (Joseph & Connolly, 1977; Aberle & Judge, 1979; Al-aswad & Al-nagmawi, 1989; Buchter,1992; Crosley, 1992). Various factors such as species, sex, age, feed, handling, processing and chilling have been shown to play a role in determining the tenderness of meat. For years, scientists around the world have been seeking the so-called "tender gene", but according to Harper (1998) they may have been wasting their time, since research has shown that the genetic effect in meat tenderness is quite small and that more than 75% of the "toughening" in meat occurs during processing or on the farm (Harper, 1998). The two main factors that influence toughness of meat are the state of the muscle fibre bundles and the collagen connective tissue between them (Harper, 1998). Ferguson (1998) suggested that toughness in muscle fibres could be controlled by reducing stress in animals prior to slaughter and by correctly applying the post-slaughter chilling process. The reduction of stress during the transport, handling and feeding of animals preserves the pH balance in the muscles and prevents the meat from becoming tough.

Improved control over chilling prevents muscle shrinkage, known as cold shortening, and reduces the need for tenderising methods such as electrical stimulation and the tenderstretch method (Ferguson, 1998; Lawrie, 1998; Aberle *et al.*, 2001).

1.4 THE EFFECT OF MUSCULAR PROTEIN STATUS ON MEAT TENDERNESS

1.4.1 The contribution of muscle protein fractions

A muscle consists of various kinds of proteins of which two protein fractions in particular play an important role in determining the toughness or tenderness of meat (Van Zyl, 1995). They are the stromal proteins (connective tissue) responsible for the strength of a muscle, and myofibrillar proteins responsible for a muscle's ability to contract and relax, thereby enabling limbs to move. Apart from several other internal and external factors that influence the tenderness of meat, the structure of the muscle and the condition of the muscle protein in its raw state determine tenderness. During the cooking process these components are changed with the result that the tenderness experienced by the consumer becomes a complex interaction of several components (Van Zyl, 1995).

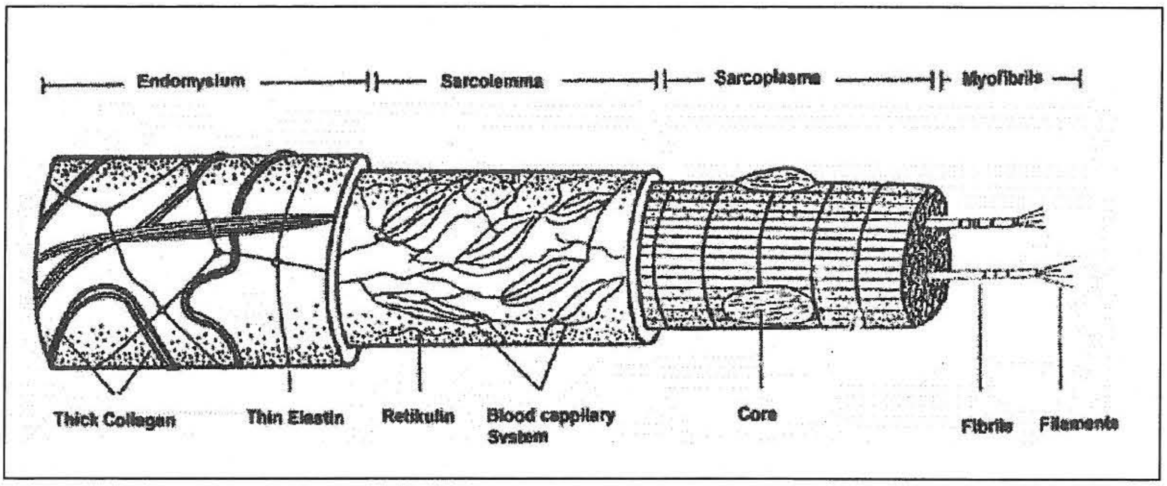


Fig. 1. The composition of a muscle fibre (Klingbiel, 1993).

1.4.1.1 The role of stromal proteins

Muscles fibers are surrounded by a layer of connective tissue, the endomysium (Figure 1), this encloses the double membrane of the sarcolemma. Between the endomysium and sarcolemma is the reticulin network. The sarcolemma encloses the myofibrils (Klingbiel, 1993). Connective tissue proteins influence the tenderness of the meat depending on the quantity occurring in muscles and the degree of cross-binding or solubility of the collagen in the connective tissue (Maree & Casey, 1993). The amount of connective tissue determines tenderness, for example strong shin muscles contain large amounts of connective tissue and weaker loin and fillet muscles contain less, explaining why meat differs in tenderness based on its origin in the carcass (Maree & Casey, 1993).

1.4.1.2 The role of solubility of connective tissue in determining tenderness

The younger the animal, the fewer the cross-connections (polymerisation) between the collagen fibres of the connective tissue (Lawrie, 1998). These collagen fibres are more soluble during cooking, are more easily transformed to soft gelatine and shrink less during heating than collagen from older animals, which is the reason why meat from younger animals is generally more tender than that from older ones (Maree & Casey, 1993).

1.4.1.3 The role of myofibrillar (contraction) proteins

The smallest structural unit of a muscle is the muscle fibre, which consists of the cell membrane (sarcolemma), cell fluid (sarcoplasma) and contraction proteins (fibrils) (Klingbiel, 1993). The two contraction proteins that cause contraction and relaxation in muscle proteins are actin and myosin, the thin and thick protein bundles respectively, which move over and pass each other during muscle movement (Van Zyl, 1995). Tenderisation occurs during post-mortem storage when disintegration of the myofibrillar structure occurs as a result of proteolytic action of the various enzyme systems in the muscles (Van Zyl, 1995). The contribution of the myofibrillar component of muscles to the tenderness of meat lies in the phenomenon that rapid chilling causes the muscle fibres to contract and causes toughness of meat (cold shortening) (Locker & Hagyard, 1963).

1.4.2 A description of the term rigor-mortis

Rigor mortis occurs when, after death, the muscles lose their extensibility when the supply of coenzyme, adenosine triphosphate (ATP) and glycogen is exhausted and a bond is formed between myosin and actin, forming actomyosin (Potter & Hotchkiss, 1995). In the meat trade the occurrence of an adequate degree of rigor mortis and a low ultimate pH of the meat are desirable characteristics (Van Zyl, 1995). The low pH inhibits bacterial growth while the lactic acid brings about the conversion of the connective tissue into gelatin, resulting in more tender meat after cooking. In physiologically normal animals, rigor in the skeletal muscles does not appear for 9-12 hours after slaughter, but this process can take up to 30 hours in beef (Pearson & Dutson, 1994). In cattle the pH of the meat directly after slaughter is about 7, eventually dropping to 5.5 in approximately 18 hours (ultimate pH), and then slightly rising due to the formation of alkaline substances associated with protein breakdown (Gracey & Collins, 1992; Potter & Hotchkiss, 1995).

1.4.3 The influence of cold shortening of muscles

The contraction or shortening was initially reported by Locker (1959) upon developing the type I – IV division of sarcomere lengths, where the types ranged from type I (1,5 – 0,7 µm) representing extreme shortening to type IV (3,7 – 2,4 µm) representing relaxed muscle. In 1960, Locker concluded that muscle contraction or shortening prior to and during the onset of rigor mortis decreased meat tenderness and, according to Locker & Hagyard (1963), a fall in the meat temperature below 15°C pre-rigor induces contraction of the muscles, which can cause a severe increase in the eventual toughness of the meat after cooking. This process of cold shortening will occur in any part of the beef carcass that is cooled below approximately 10°C within 10 hours after slaughter (Bendall, 1972).

Cold shortening entails the contraction of muscles during the first few hours after slaughter because the carcass muscles still contain sufficient energy in the form of adenosine triphosphate (ATP) and glycogen (Gracey & Collins, 1992). The muscles attempt to retain their normal status, as in the live animal, by means of energy consumption. This means that the calcium pumps in the muscles still try to keep the calcium concentration in the muscle cells low, preventing contraction. When the muscle temperature drops to below 15 – 12°C, the calcium pumps are, however, slowed down by the cold. Their output falls, resulting in less calcium being pumped out of the barrier cells and causing the calcium concentration in the muscle cells to increase (Van Zyl, 1995). The result is that the increased calcium concentration removes the inhibiting effect that troponin and tropomyosin have on muscle contraction. The formation of Actomyosin causes the muscle to contract while ATP is still available as a source of energy. Therefore no muscular relaxation occurs and the muscle goes into rigor mortis while in a contracted state, resulting in extremely tough meat.

This problem is referred to as cold shrinking and can also be termed, abnormal toughness.

Herring, Cassens & Briskey (1965a) indicated that the sarcomere length reflected the extent of stretch or contraction induced by pre-rigor treatment. The choice of method for determining cold shortening is, therefore, the measuring of the sarcomere lengths of the myofibrils (Figure 2). The effects of cold shortening on the tenderness of meat were extensively investigated for 25 years until the 1980's when electrical stimulation as a technique to improve accelerated ageing was developed (Russel, 1999).

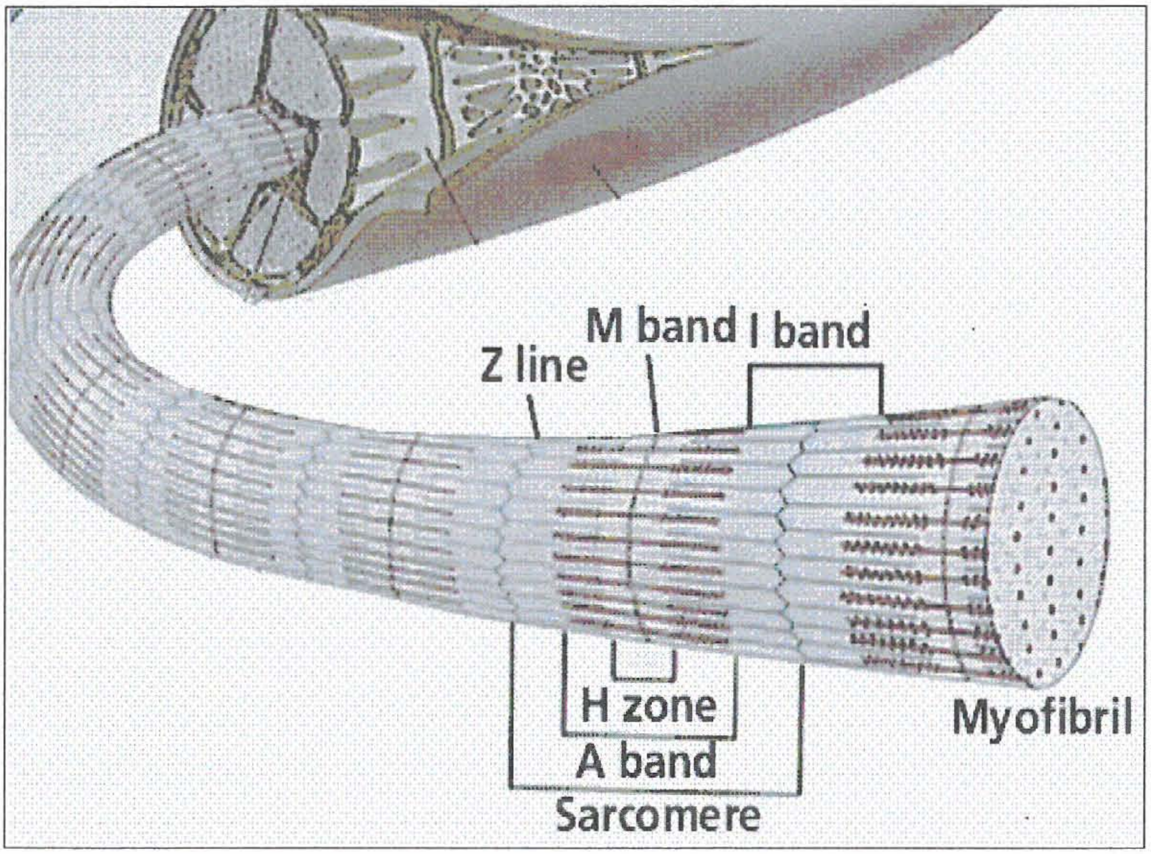


Fig. 2. Muscle fibre, illustrating sarcomere length (Purves *et al., 2001*)

1.4.4 Electrical stimulation

In 1749 the American statesman and scientist, Benjamin Franklin, discovered that an electric current passed through a carcass during the slaughtering process ensures exceptionally tender meat (Taylor, 1981). Although the use of electrical stimulation for the tenderising of meat was first suggested by Harsham and Deatherage in the United States as far back as 1951 (Lawrie, 1998), it was first used in New Zealand to prevent cold shortening as a result of too rapid cooling of lamb carcasses (Gracey & Collins, 1992). Electrical stimulation involves passing an electrical current through the carcass, which stimulates the muscles to contract and this uses up glycogen and ATP, thereby accelerating rigor (Taylor, 1981). When the electrical current is interrupted, there is still sufficient glycogen and ATP remaining in the muscles to enable them to relax, but because the energy reserves are low, rigor mortis begins earlier while the muscle temperature is still relatively high, with the result that rigor mortis takes place in relaxed muscles (Taylor, 1981). Consequently the sarcomere lengths are not affected, enabling the meat to retain its inherent tenderness (Kerth, Cain, Jackson, Ramsey & Miller, 1999).

Electrical stimulation prevents cold shortening and may also mechanically disrupt the muscle structure causing increased collagen solubility, which in turn results in more tender meat (Taylor & Tantikov, 1989). Taylor, Perry & Warkup, (1995) demonstrated that pork tenderness was significantly improved by applying high-voltage electrical stimulation at 20 minutes post-slaughter. The improvement in tenderness was attributed mainly to the alleviation of cold shortening toughness resulting from too rapid chilling, but an increase in tenderness also occurred at slower cooling rates where cold shortening was less likely (Taylor *et al.,* 1995).

Electrical stimulation, apart from preventing cold shortening, causes rigor mortis to set in much quicker and at higher carcass temperatures where it can promote the activity of endogenous proteolytic enzymes, including u-calpain, which are instrumental in promoting the ageing effect (Dransfield, Ledwith & Taylor, 1991). Dutson (1981) also found that ES in combination with ageing has a complementary effect on the tenderness of beef.

1.4.5 Ageing (conditioning) of meat

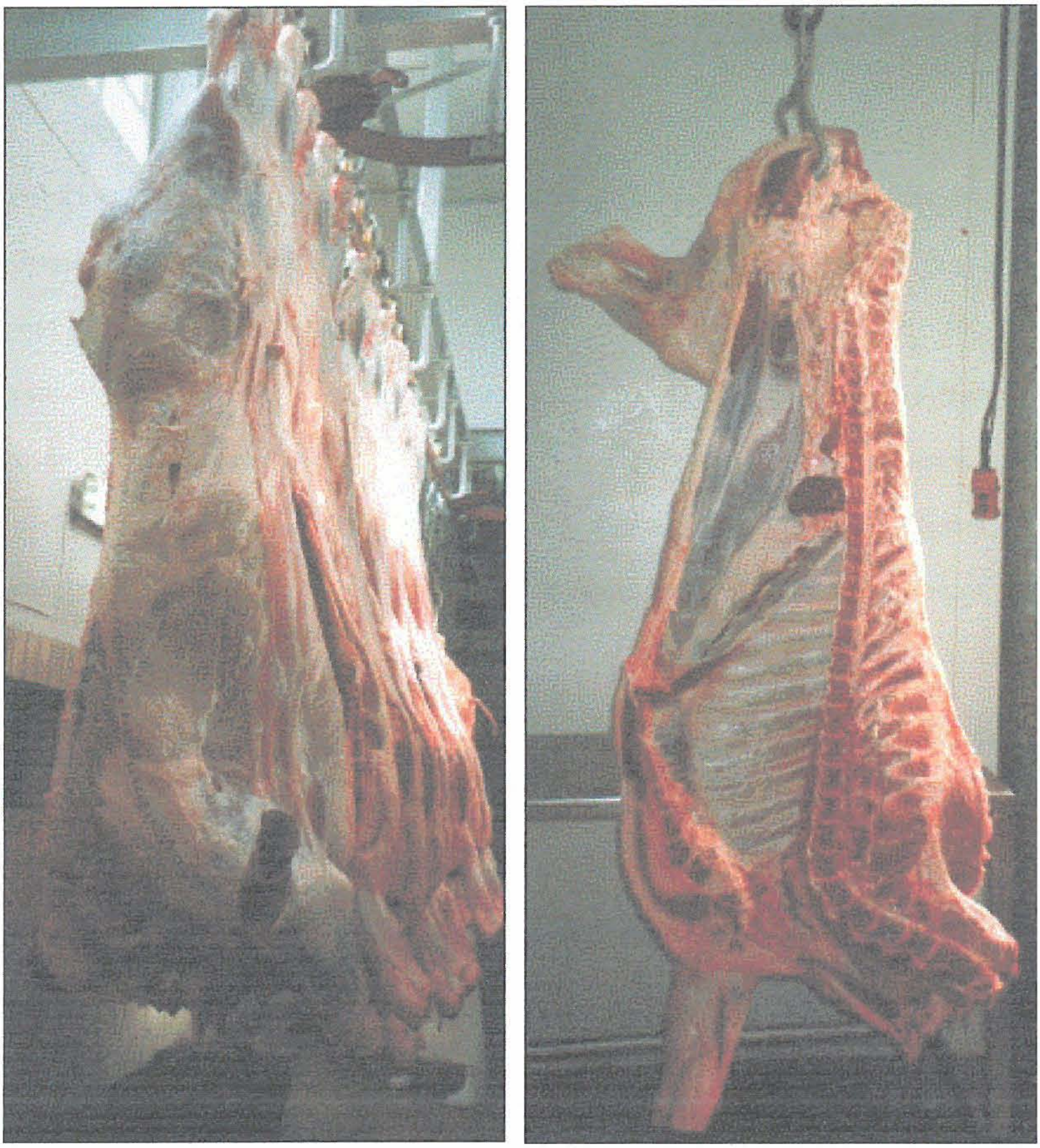
Over the years a number of authors have reported on the tenderising effects of ageing and have speculated on possible causes (Herring, Cassens & Briskey, 1966; MacBride & Parrish, 1977; Jeremiah & Martin, 1978; Jeremiah, Martin & Achtymichuk, 1984). Other workers have reported that the amount of tenderisation achieved through ageing was dependent upon various factors such as species, physiological maturity, sex, the anatomical location of the cut, the degree of muscle shortening during rigor, the duration of the ageing period, and the ageing temperature (Fapohunda and Okubanjo, 1987). Jeremiah & Martin (1978) concluded that 6 days of post- mortem ageing at 2°C produced acceptable tenderness in retail products of youthful bovine carcasses of all sexes, sizes and degrees of fatness. According to Gracey & Collins (1992) the increase in tenderness by ageing meat is the result of autolysis (also termed self-digestion) and is caused by the coagulation of muscle proteins and the softening and sealing of the collagen fibres. The toughness of meat, which occurs during rigor mortis, disappears as rigor mortis subsides and the coagulated proteins are again rendered soluble (Potter & Hotchkiss, 1995). Further tenderness is produced by the softening and sealing of the collagen fibres, which are converted into softer and more digestible gelatin by the action of lactic acid. Another, possibly predominant, factor is the effect of proteolysis by tissue proteinases, such as cathepsin, on the actual muscle fibres (Pearson & Dutson, 1994).

When meat is stored above freezing point at temperatures between 0 and 3°C the majority of changes that usually occur at higher temperatures still take place, only at a reduced rate. Atmospheric oxidation of fat leading to rancidity proceeds very slowly and enzyme action in the fat, which leads to the production of free fatty acids, is also very slow (Gracey, Collins & Huey, 1999). The action of bacteria is retarded but not arrested at these temperatures, while the proteolytic enzymes of the muscle fibres are active and bring about a desirable change known as conditioning or ripening. The latter is manifested by a marked increase in flavour, juiciness and tenderness of the meat (Aberle *et al.,* 2001).

1.4.6 The tenderstretch method of suspending beef sides (hip suspension)

Locker's findings regarding cold shortening (1960) prompted researchers to find methods of stretching sarcomeres. Herring *et al.* (1965a) demonstrated that the extent of shortening in a carcass depends on the physical restriction imposed by the attachment of the muscles to the skeleton of the animal. By varying the position of the carcass (Figure 3) it is possible to change the sarcomere length of various muscles by making use of the natural attachments of the muscle to prevent shortening during rigor mortis (Herring, Cassens & Briskey, 1965b).

The conventional method of carcass suspension (Achilles) distorts the arrangement of the skeleton and allows some muscles to shorten to the point where they are less tender. Placing a carcass side horizontally on a table with its legs perpendicular to the vertebrae improved the tenderness of several muscles (Herring *et al.,* 1965b). In addition, Eisenhut, Cassens, Bray & Briskey (1965) found that some muscles of an intact bovine carcass might shorten due to the anatomical position of the skeletal structure during the development of rigor mortis. Hostetler, Landmann, Link & Fitshugh (1970) postulated that if each individual skeletal



(A) (B)

Fig. 3. (A) Conventional suspension of beef carcasses with hook through the Achilles tendon (B) Hip-suspension (tenderstretch) of a beef carcass with hook through the obturator foramen (aitchbone)

muscle has a characteristic resting sarcomere length, shortening of sarcomeres below the resting lengths results in increasing toughness while the stretching of the sarcomeres beyond resting length causes little or no change in tenderness. This finally led to a search for a practical method of suspending the carcass that would result in the improvement in tenderness of several key muscles. Achilles suspension compacts the vertebrae of the lumber and sacral regions at the junction, allowing the muscles to contract (Hostetler *et al.,* 1970). Hip suspension, also known as the "tenderstretch method", entails the suspension of beef sides from the aitchbone (by means of a hook in the obturator foramen or "pope's eye"), allowing the hind limb to assume a relaxed position and largely preventing the muscles from shortening and becoming tough (Gracey *et al.,* 1999). It also allows the pelvic limb to be brought forward, straightening the vertebral column and allowing the carcass to be suspended in a manner that resembles the position of the animal's natural state in the veld. The vertebrae are pulled apart slightly to prevent the *M. Longissimus dorsi* in the lumbar area from shortening as much as in the case of Achilles suspension. This method constitutes a reversal of the former (Achilles suspension) by not permitting the *M Longissimus dorsi* to contract to the same degree due to a straightening of the spinal column (Hostetler, Link, Landmann & Fitshugh, 1970,1972,1973). Although the tenderstretch method promotes tenderness it alters the appearance of the carcass as well as the shape of the hindquarter and therefore alters the proportional yields of the respective retail cuts, which may not be acceptable to retailers.

The tenderstretch method of obtaining tenderness has been used for at least 80% of the beef slaughtered in the United Kingdom (Russel, 1999) and over the years many authors have praised the method as significantly reducing shear force values of the major muscles in the hindquarter of various species of farm animals (Herring *et al.,* 1965a, 1965b; Hostetler *et al.,* 1972; Jeremiah *et al.,* 1984). The tenderstretch method has also increased taste panel tenderness ratings (Jeremiah *et al.,* 1984).

1.4.7 The water-holding capacity of meat

At slaughter muscle consists of approximately 75% water. This amount, however, may be subject to considerable variation due to gains that occur during processing or losses through drip, evaporation or cooking. These gains or losses are important, firstly for economic reasons in that meat is sold by mass and losses which occur in the cooking process reduce the portion size of the meat, and secondly with respect to consumer satisfaction in that the juiciness, flavour, colour and tenderness of meat and meat products depend to a great extent on their water content, while excess drip produces an unattractive appearance and increases the risk of bacterial spoilage (Offer & Trinick, 1983; Lianje & Chen, 1989; Offer & Knight, 1989; Aberle *et al.,* 2001). The loss of fluid during storage and processing is of major concern to meat producers, processors and consumers and is directly related to the water-holding capacity of the meat (Mittal, Zhang & Barbut, 1992). Thus, meat with a high water-holding capacity will be higher yielding, more tender, firmer, and superior in forming emulsions than meat with a low water-holding capacity (Olsen, 1982).

1.5 TECHNICAL ASPECTS OF EXISTING METHODS APPLIED FOR THE TENDERISING OF MEAT

Meat tenderisation can be categorised into three groups, which include the stretching of sarcomeres, the disruption of the myofibrils and the disruption of the connective tissues. The following sections will discuss these methods that have been reported on by a number of authors since the 1950's (Locker, 1959, 1960; Herring *et al.,* 1965a, 1965b; Hostetler *et al.,* 1970, 1972, 1973; Hostetler, Carpenter, Smith & Dutson, 1975; Forrest, Aberle, Hendrick, Judge & Merkel, 1975; Jeremiah & Martin, 1977, 1978; Jeremiah *et al.,* 1984).

1.5.1 Stretching of the sarcomeres

As far back as 1960, Locker reported that muscle contraction or shortening before and during the onset of rigor mortis decreased meat tenderness. More tender meat could, therefore, be obtained by ensuring longer sarcomeres. This could be achieved by preventing the occurrence of cold shortening (Herring *et al.,* 1965a). Cold shortening could in turn be prevented by slowing down the drop in post-slaughter muscle temperature (Jeremiah *et al.,* 1984; Dreyer, Van Rensburg, Naudé, Gouws & Stiemie, 1979). In this regard the subcutaneous fat thickness plays a role in that it insulates the meat and prevents the heat from escaping (Dreyer *et al.,* 1979). Leaner carcasses therefore cool down more rapidly than those with more subcutaneous fat. High-temperature pre-rigor chilling can similarly reduce cold shortening (for example 16°C for 16 hours), as can the electrical stimulation of carcasses (Taylor, 1981). This should cause a rapid drop in muscle pH and a quicker onset of rigor mortis, thus preventing cold shortening caused by rapid pre-rigor reduction in temperature (Taylor, 1981). Sarcomeres can also be made longer by physically stretching them (Herring *et al.,* 1965a, 1965b; Hostetler *et al.,* 1970). Physical stretching of the sarcomeres can be brought about by hip suspension, which entails the suspension of carcasses by the obturator foramen (hip suspension). In this method the loose-hanging hind leg acts as a cantilever for stretching the sarcomeres. Another method of stretching sarcomeres entails the use of Stouffer's stretching devices, which employ the tenderstretch method in addition to the use of clamps and stretching rods (Forrest *et al.,* 1975). A third method that allows the stretching of sarcomeres is the TenderCut™ method during which the bones and connective tissues are cut around the muscles to allow stretching to take place (Forrest *et al.,* 1975).

1.5.2 Disruption of the myofibrils

The breakdown or disruption of the myofibrils results in improved meat tenderness. This can be achieved by the ageing of meat in a cooler at 0 - 3°C for one to six weeks. Tenderness is consequently brought about by an increased activity of the endogenous enzymes, such as calpains and cathepsins (Lawrie, 1998; Gracey *et al.,* 1999). Additional methods for the disruption of myofibrils include high-temperature post-rigor chilling whereby carcasses or meat are stored at 20°C for 24 hours, with the same effect on tenderness as the general ageing of meat at 2°C for 14 days (Pearson & Dutson, 1985). Furthermore, high-temperature pre-rigor chilling, which is achieved by keeping carcasses at 16°C for 16 hours directly after slaughter, allows rigor to set in at elevated temperatures and also disrupts the myofibrils (Forrest *et al.,* 1975). Electrical stimulation causes a rapid decline in pH, which releases cathepsins that, in turn, disrupt the myofibrils (Dransfield *et al.,* 1991). Calcium chloride infusion or injection, which entails the infusion of calcium chloride prior to rigor mortis or the post-rigor injection of a solution of calcium chloride into muscles (Forrest *et al.,* 1975), causes increased activity of calpains, which assists with the disruption of the myofibrils. The latter, however, is not being practised in South Africa.

According to Gracey *et al.* (1999) exogenous enzymes, such as tropical plant enzymes, may be used for the disruption of myofibrils. These enzymes, for example Pro-Ten (Swift Company, Chicago), developed in the late 1950's, can be injected into the live animal 10 – 15 minutes prior to slaughter (optimum time range for maximum tenderness). Other tropical plant enzymes that are used as marinades are Papain (papaya), Bromelin (pineapple) and Ficin (fig) (Forrest *et al.,* 1975; Potter & Hotchkiss, 1995; Lawrie, 1998; Gracey *et.al.,* 1999). Electrical stimulation of carcasses causes violent contraction of the muscles resulting in myofibril tearing (Kerth *et al.,* 1999). Blade or needle tenderisation breaks off the myofibrils by means of machines fitted with multiple blades and/or needles that penetrate the meat. Physical or mechanical severance entails the scoring, dicing, cubing, grinding or chopping of meat. Forrest *et al.* (1975) describe another method known as Hydodyne,™ which entails placing meat in a sealed water-filled chamber and setting off an explosion which consequently destroys most of the Z-lines in order to considerably improve the tenderness of the meat.

1.5.3 Disruption of the connective tissues

The disruption of connective tissue can be achieved by making use of exogenous enzymes, or the marination of meat in a 2% solution of NaCl and acetic acid in water (Forrest *et al.,* 1975), or by making use of fungal enzymes or tropical plant enzymes (Gracey & Collins, 1992). As in the case of myofibrillar disruption, connective tissue can also be disrupted by the severance of the stromal proteins, for example blade or needle tenderisation, as well as mechanical severance. It can also be achieved by the conversion of collagen to gelatine by moist-heat cooking for a long period with steam generation (braise, stew or simmer) (Forrest *et al.,* 1975).

1.6 THE PERCEPTION OF THE MEAT TRADE TOWARDS HIP-SUSPENDED CARCASSES

The tenderstretch method of suspension alters the shape of the carcass, because by suspending the carcass sides from the obturator foramen, the leg of the carcass side acts as a counter- lever for stretching the muscles (Herring *et al.,* 1965a, 1965b; Hostetler *et al.,* 1970, 1972, 1973, 1975). If rigor mortis sets in while the carcass sides are in this position the appearance of the carcass is altered. This happens notwithstanding re-suspension by the Achilles tendon after rigor mortis has set in. The perception of the meat trade regarding the acceptability of hip-suspended carcasses was tested by means of a questionnaire, conducted in the Bloemfontein area. This was done in order to establish whether problems could be envisaged that would hamper the successful introduction and/or implementation of the tenderstrech method, should the study show that the implementation would be advantageous to the meat trade in that consumers could be assured of more tender meat on a constant basis.

CHAPTER 2

MATERIALS AND METHODS

CHAPTER 2: MATERIALS AND METHODS

2.1 MOTIVATION FOR THE USE OF BONSMARA CATTLE

The Bonsmara cattle breed is a South African breed that was specifically bred for South African conditions from the Afrikaner, Hereford and Shorthorn breeds (Bonsmara Cattle Breeders Society of South Africa, 2001). It was decided to use this breed in the study, as Bonsmaras are found throughout South Africa under all possible grazing and climatical conditions. Also by focusing on Bonsmaras, the intrinsic variation in meat tenderness amongst various breeds was eliminated. According to statistics obtained from Beefcor, one of South Africa's largest feedlots, Bonsmaras constitute 11,9% of animals handled in their feedlots (Mr Peter Milton, 2001, Animal Scientist Consultant, Beefcor, personal communication). Taking into account the fact that during the research period at least 20 breeds were being handled at the feedlot, it was safe to conclude that meat from the Bonsmara breed comprised a major portion of meat consumed by South Africans.

The Bonsmara Beef Abattoir in Kroonstad, which slaughters and debones Bonsmaras on a daily basis for a retail outlet named Country Cuts, was selected as study site. Country Cuts guarantees quality by selling only choice Bonsmara beef cuts that are guaranteed tender and which are produced without using hormone implants (Country Cuts, 2001).

2.2 MOTIVATION FOR THE USE OF M. *LONGISSIMUS*

A telephonic survey of 25 restaurants in the Bloemfontein area was conducted, to determine the most popular steak served. It emerged that sirloin is by far the most popular cut and in fact several restaurants admitted to serving sirloin when clients ordered rump steak, because they felt the clients did not know the difference anyway. The *M. Longissumus* (loin) extends from the neck to the *Sacrum Ileum*. It is the longest muscle in the body and, with regard to tenderness, is rated as intermediate due to its broad distribution of sarcomere patterns (Locker, 1959).

2.3 SAMPLING PROTOCOL

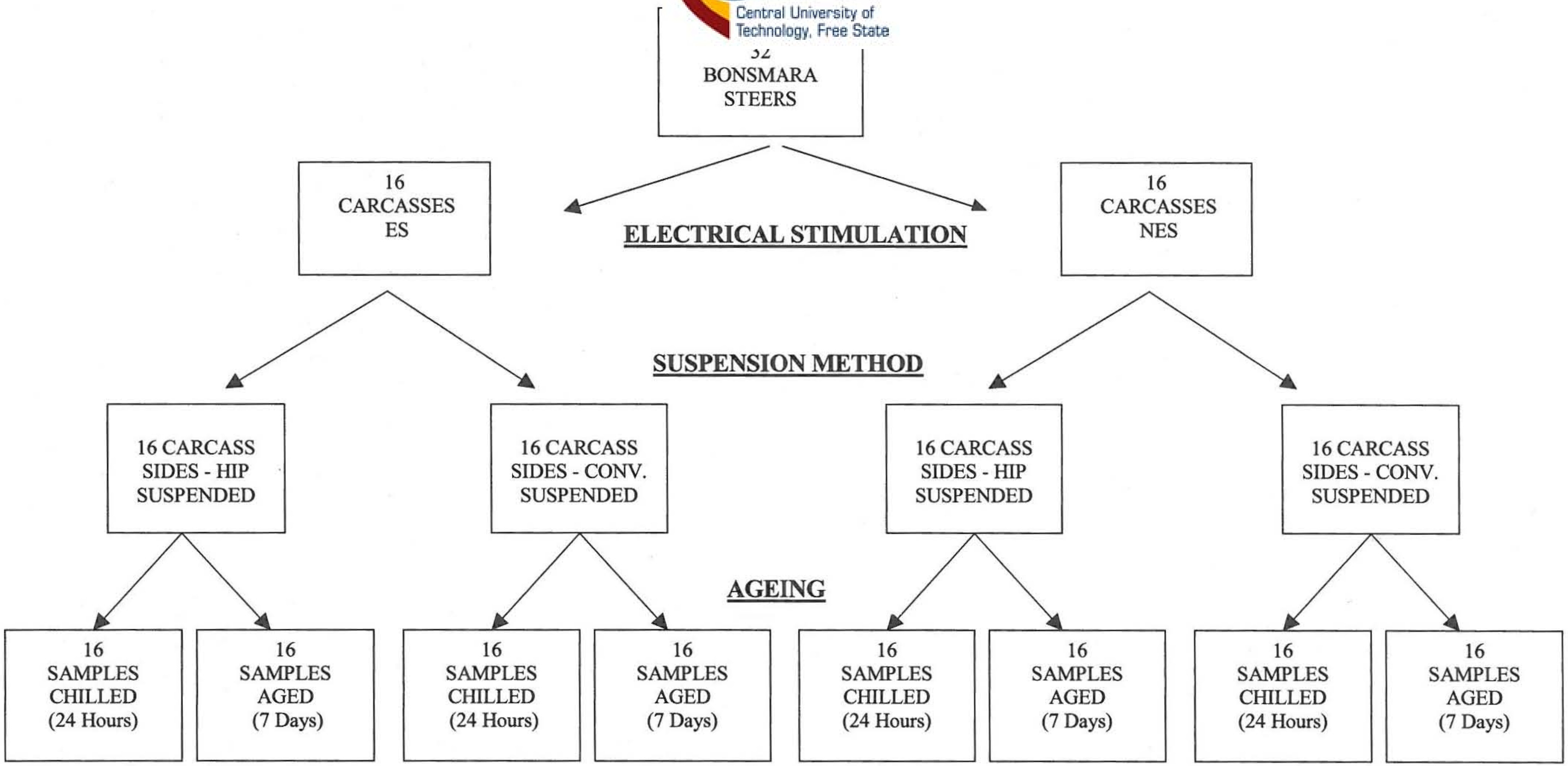
Figure 4 shows the treatment and sampling layout for the study. Thirty-two young Bonsmara steers from the Kroonstad area (Free State Province) that had been subjected to the same feeding programme, prior to slaughter, were used for the study. The sample size and scheme were determined in collaboration with the Department of Biostatistics, University of the Free State.

2.3.1 The selection and treatment of animals prior to slaughter

Calves remained with the cows up to the age of six to eight months, after which they were sent to feedlots for rounding off and marketing. At these feedlots all calves were fed the same feeding formula until they reached the desired weight for marketing. The animals used in the experiment were all steers of approximately 12 months of age and were selected to have the same meat classification (grading and fat distribution). This was important as the size of the animal, as well as the fat distribution, have been shown to affect the rate of chilling of carcasses as well as the amount of cold shortening that takes place during the initial cooling (Dreyer *et al.*, 1979).

2.3.2 Performing electrical stimulation

Electrical stimulation was performed with a low-voltage electrical stimulator that was connected to the carcass directly after the throat was cut. A current of 160 volts was passed



LEGEND:

ES	Electrical stimulation
NES	No electrical stimulation
HIP	Suspended through abturator foramen (aitch bone)
CONV.	Conventionally suspended (achilles tendon)

- Variables are listed in terms of their sequence of application after slaughter

Fig. 4. The sampling protocol followed in the study

through the carcass at intervals of 4 seconds on and 3 seconds off, for a duration of 90 seconds. During the "on"cycle the current pulsated at 5 milliseconds on and 70 milliseconds off.

2.3.3 Sampling procedure

The selected cattle were slaughtered at Bonsmara Beef Abattoir in Kroonstad under the personal supervision of the student. Sixteen of the thirty-two selected carcasses were not electrically stimulated after slaughter, while the remaining sixteen were electrically stimulated directly after slaughter using the aforementioned method. The carcasses were clearly marked to allow for easy identification after dressing. After the carcasses had been split, one side of each carcass was suspended from the obturator foramen (aitchbone) with the hind leg acting as a cantilever (hip suspension), while the other side remained suspended from its Achilles tendon. The carcasses were subsequently left at room temperature for about two hours before being chilled for 24 hours.

2.3.4 Collection of samples for histological and texture analysis

After 24 hours' chilling at 1 – 3°C the *M. Longissimus dorsi* was dissected from each carcass half, totaling 32 hip-suspended and 32 conventionally suspended sides (sixty-four samples in total). Each sample was divided into two cuts, of which one was coded, vacuum packed and frozen at -20°C, in order to terminate ageing. Sub-samples were also collected for the determining of sarcomere lengths. The remaining sixty-four samples were coded, vacuum packed and kept at 1 - 3°C for 7 days to allow ageing. After 7 days of ageing these samples were also opened, sub-samples collected for the determining of sarcomere lengths and also frozen at minus 20°C. Finally, all the frozen samples (128 in total) were taken to the Agricultural Research Institute at Irene for the performance of texture analysis (Figure 4).

2.4 TEXTURE ANALYSIS

2.4.1 Determining shear force

Shear force represents the amount of force required to shear through a cylindrical core (13.5mm diameter) of cooked muscle, perpendicular to the grain, at a crosshead speed of 400mm per second (Ms Ina van Heerden, 2001; Technical Adviser, Irene Research Council, personal communication). The frozen loin samples were cut into three 25mm steaks and re-vacuumed to prevent thawing loss. The steaks were allowed to thaw (24 hours at 0°C) and weighed to determine the mass of the steaks and calculate thawing loss. Steaks were then grilled in calibrated ovens ("fan-grilled", 200°C) with the door closed until an internal temperature of 70°C, measured with a hand-probe thermometer (Comark, model 9003), was reached in the geometrical centre of the meat sample. During grilling the steaks were turned every 8–10 minutes. After removal from the oven the steaks were again weighed to determine evaporation, cooking and drip loss, then cooled down to room temperature. They were then wrapped in aluminium foil and re-cooled for 24 hours, after which a physical texture analysis was performed on three cylindrical core samples (13.5mm diameter) taken from each steak, using an Instron Universal Testing Machine (Model 4301, Series IX), fitted with a Warner Bratzler shear device. Three steaks were cut from each of the original 128 samples. Out of each steak, in turn, three cylindrical core samples were cut for texture analysis, totalling 1152 repetitions.

2.4.2 Determining thawing, cooking, evaporation and drip loss

Thawing loss is the amount of fluid lost during thawing, while cooking loss is the difference in mass between the raw and the cooked steaks (total loss). Drip loss represents the amount of fluid lost through dripping during the cooking process, and evaporation loss is the cooking loss minus the drip loss (Ms Ina van Heerden, 2001, Technical Adviser, Irene Research Council, personal communication).

2.5 HISTOLOGICAL ANALYSIS

2.5.1 Determining sarcomere lengths

The method described by Herring *et al.* (1965a) was used for the histological measurements. The same sampling protocol used for the collection of samples for texture analysis was used for the determining of sarcomere lengths. The samples, packed in a hepcooler, were taken to the histological laboratory of the Technikon Free State for further processing. Measurement of sarcomere lengths was performed immediately on arrival to determine the effect of the various treatments on the myofibril network of the muscle.

2.6 DETERMINING THE ACCEPTABLILITY OF HIP SUSPENSION TO THE MEAT TRADE IN BLOEMFONTEIN

Questionnaires (Appendix A) completed by means of interviews were used for the gathering of information regarding the acceptability of meat derived from carcasses that have been hip suspended. A simple random sample of 40 out of a total of eighty butchers in the Bloemfontein area was selected in collaboration with the Department of Biostatistics, University of the Free State, which also assisted in the compilation of the questionnaire. The questionnaires evaluated the perceptions of the purchasers at the selected butcheries as to the appearance of hip-suspended beef carcasses, whether problems with regard to the appearance of these carcasses amongst members of the public were envisaged, as well as possible implications regarding transport, handling and chilling. Although some of the respondents bore knowledge of the tenderstretch method (hip suspension), photographs were used during the interviews to add to the respondents' understanding of the differences between conventionally suspended and hip-suspended carcasses (Figure 3). A student enrolled in the B. Tech.: Environmental Health at the Technikon Free State conducted the interviews. Upon completion of the interviews the questionnaires were coded and statistically evaluated.

2.7 STATISTICAL ANALYSIS OF ACCUMULATED DATA

Differences in means between various sample groups were determined by using an analysis of variance (ANOVA) procedure. The Tukey-Kramer multiple-comparison test (alpha = 0.05) was used to identify differences between treatment means. This procedure was performed in collaboration with the Department of Food Science (University of the Free State). With regard to the descriptive data collected through the interviews, frequencies and percentages of responses were calculated in collaboration with the Department of Biostatistics, University of the Free State.

CHAPTER 3

RESULTS AND DISCUSSION

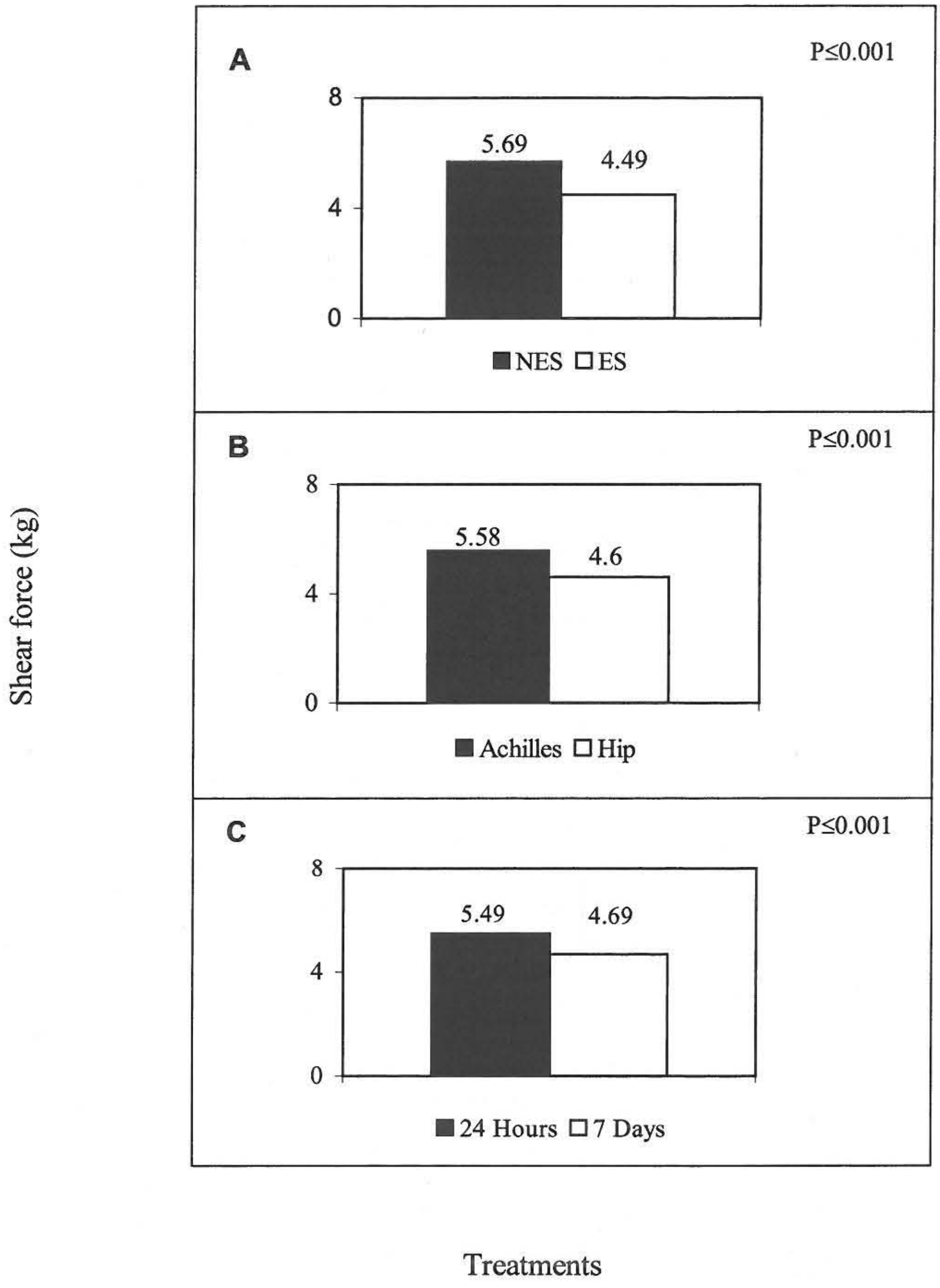
CHAPTER 3: RESULTS AND DISCUSSION

3.1 TEXTURE ANALYSIS

3.1.1 Shear force

The shear force results obtained from each of the three main effects, namely electrical stimulation, suspension method and ageing, obtained from samples of the *M. Longissimus,* are shown in Figure 5. With regard to electrical stimulation, carcasses that were electrically stimulated (ES) resulted in significantly ($P \leq 0.001$) lower shear force values (improved tenderness) than non-electrically stimulated (NES) carcasses as indicated by the superscripts in the figures. The shear force values of hip-suspended carcasses were also significantly ($P \leq 0.001$) lower than those of conventionally suspended carcasses, and in the case of ageing, the carcasses that were aged for 7 days resulted in significantly ($P \leq 0.001$) lower shear force values compared to samples that had been chilled for 24 hours (Figure 5).

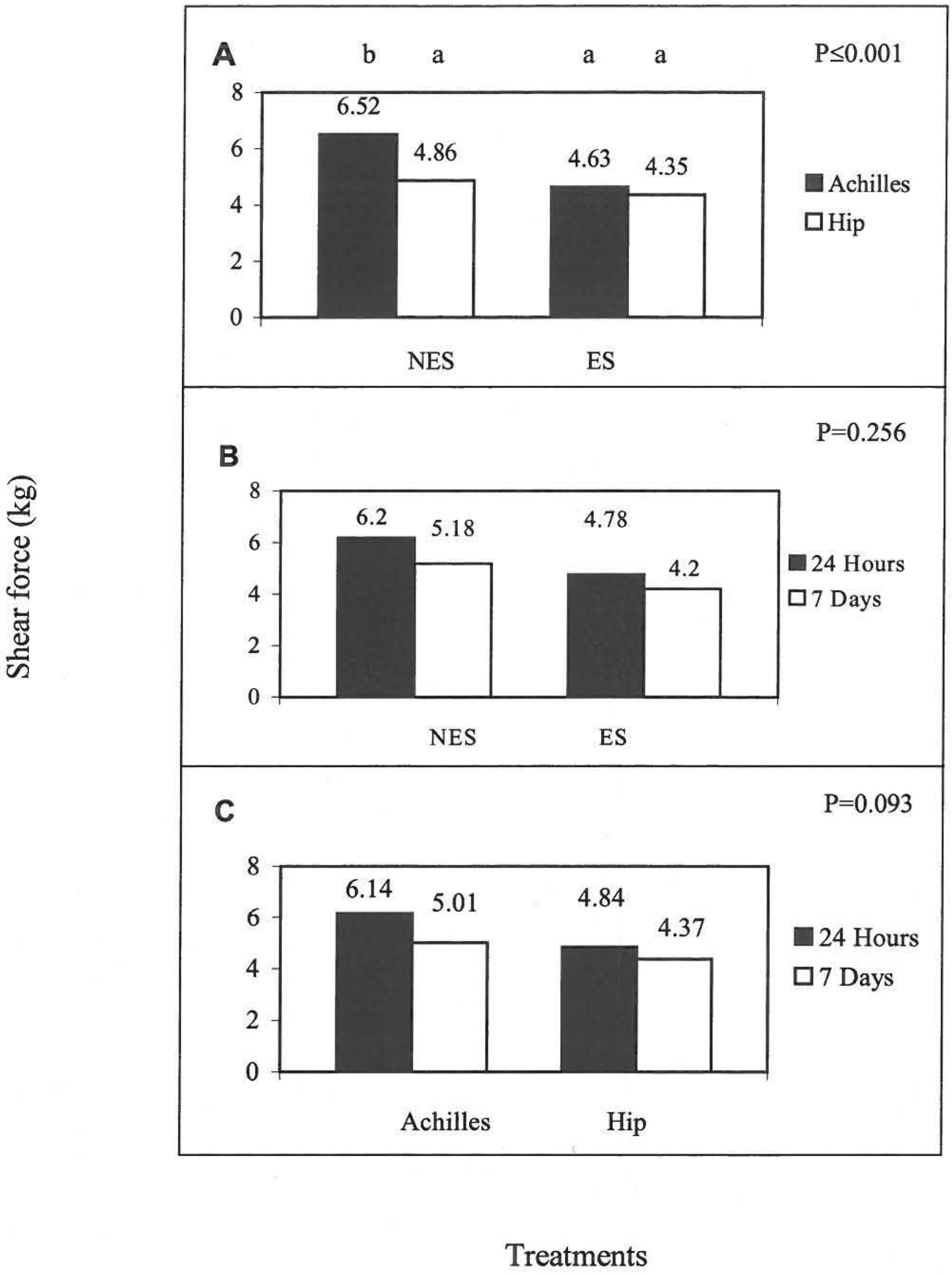
The two-way interactions between combinations of treatments is shown in Figure 6. Figure 6A shows the interaction between electrical stimulation and suspension method and indicates that the interaction between these two variables was statistically significant ($P \leq 0.001$).



ES = Electrical stimulation, NES = No electrical stimulation, Achilles = Conventionally suspended, Hip = Suspended through obturator foramen, 24 Hours = Ageing for 24 hours, 7 Days = Ageing for 7 days

* Means with different superscripts differ significantly.

Fig. 5. Mean shear force values in relation to: (A) Electrical stimulation, (B) Suspension method and (C) Ageing.



ES = Electrical stimulation, NES = No electrical stimulation, Achilles = Conventionally suspended, Hip = Suspended through obturator foramen, 24 Hours = Ageing for 24 hours, 7 Days = Ageing for 7 days

* Means with different superscripts differ significantly.

Fig. 6. Shear force values in relation to the interactions: (A) ES and Suspension method (B) ES and Ageing and (C) Suspension method and Ageing.

The effect of hip suspension was significant ($P \leq 0.05$) in the case of NES carcasses but not in ES carcasses (Figure 6A). The improvement in tenderness was 1.66 kilograms (kg) in NES carcasses compared to 0.28 kg gained in ES carcasses. Electrically stimulated Achilles-suspended carcasses produced significantly ($P \leq 0.05$) lower shear force values than NES Achilles-suspended carcasses (1.88 kg), while the effect of electrical stimulation was not significant in the case of hip-suspended carcasses (0.51 kg).

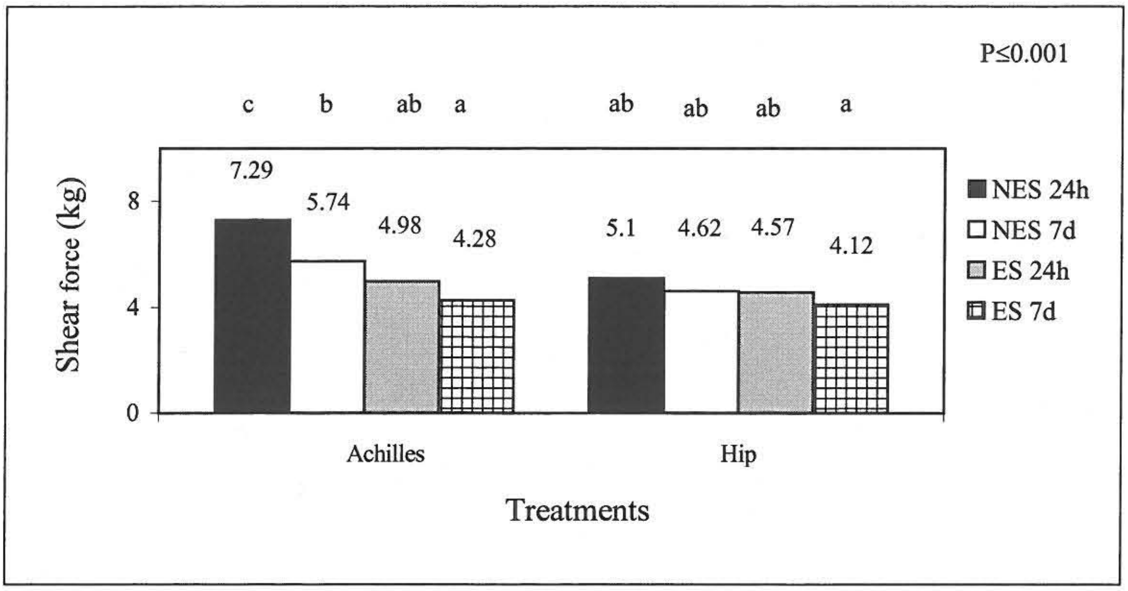
In Figure 6B the interaction between ageing and electrical stimulation is shown. Although the interactions between these two variables were not statistically significant ($P=0.256$), the effect of ageing was more pronounced when carcasses were not electrically stimulated compared to carcasses that were electrically stimulated. The improvement in tenderness was 1.02 kg for NES carcasses, compared to 0.58 kg that was gained in ES carcasses. In carcasses chilled for 24 hours the tenderness was improved by 1.42 kg with ES and, in the case of carcasses aged for 7 days, by 0.98 kg.

Figure 6C reflects the interaction between ageing and suspension method. The interaction between these two variables approached significance at $P \leq 0.1$. The effect of ageing for 7 days was more in Achilles-suspended carcasses than in hip-suspended carcasses. The improvement in tenderness for those aged for 7 days was 1.13 kg in Achilles-suspended carcasses compared to 0.47 kg in hip-suspended carcasses. The influence of hip suspension on carcasses chilled for 24 hours was more than in carcasses aged for 7 days. The improvement in tenderness was 1.2 kg for 24 hour-chilled carcasses compared to 0.64 kg for those aged for 7 days.

The three-way interaction of ageing, suspension method and electrical stimulation was highly significant (P≤0.001) and the following interesting observations were made: As shown in Figure 7, each treatment effect on its own (ES, ageing and suspension method) or combinations thereof resulted in significantly lower (P≤0.05) shear values if compared to NES, Achilles-suspension carcasses aged for 24 hours, which was used as the control.

The conclusion drawn from Figure 7 was that whilst hip suspension significantly (P≤0.05) reduced the tenderness when compared to the control, neither ageing for 7 days nor ES, or even the combination of ES and 7 days of ageing, had a significant effect on the tenderness when carcasses were hip suspended. In contrast to this, with Achilles suspension the carcasses responded significantly (P≤0.05) to 7 days of ageing as well as to electrical stimulation. The combination of ES and 7 days of ageing had significantly (P≤0.05) better tenderness than both NES carcasses aged for 7 days, as well as those aged for 24 hours.

All three main effects (ES, suspension method and ageing) produced significantly (P≤0.05) lower shear force values than the control. However, not one of these effects on its own produced significantly lower shear force values than any other, except in combination, where ES together with ageing in both Achilles- and hip-suspended carcasses produced significantly lower shear force values than both NES Achilles-suspended carcasses and those aged for 7 days.



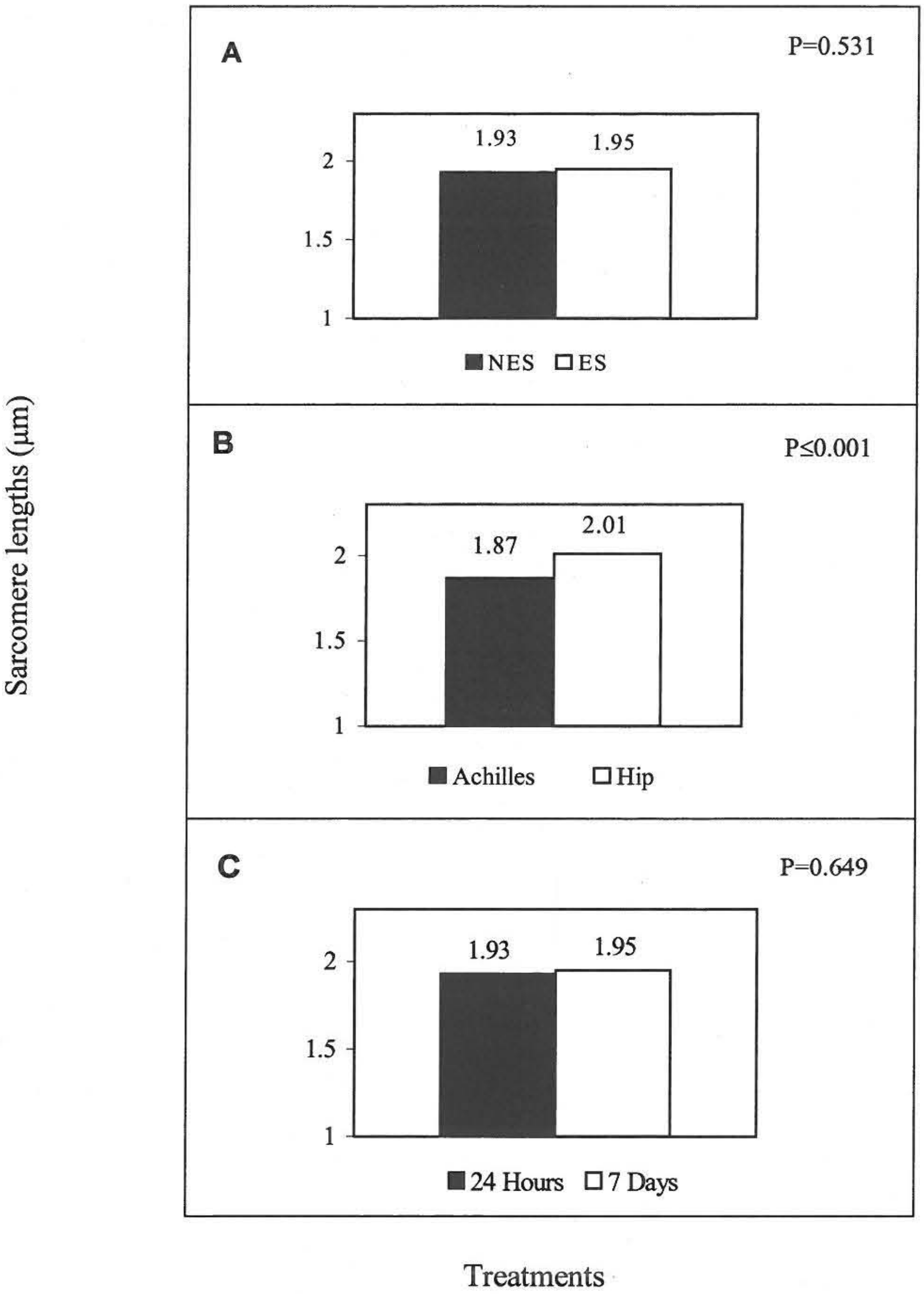
ES = Electrical stimulation, NES = No electrical stimulation, Achilles = Conventionally suspended, Hip = Suspended through obturator foramen, 24 Hours = Ageing for 24 hours, 7 Days = Ageing for 7 days

* Means with different superscripts differ significantly.

Fig. 7. Shear force values in relation to the interactions between: Electrical Stimulation, Suspension method and Ageing.

3.1.2 Sarcomere lengths

The results obtained from the measuring of sarcomere lengths for each of the three main effects, namely electrical stimulation, suspension method and ageing, obtained from samples of the *M. Longissimus,* are shown in Figure 8. With regard to electrical stimulation the effect on sarcomere length was not significant (P=0.531 - Fig. 8A). The sarcomere lengths of hip-suspended carcasses were significantly (P≤0.001) longer than those of conventionally suspended (Achilles) carcasses (Fig. 8B), but ageing for 7 days had no significant effect on sarcomere lengths (P=0.649 - Fig. 8C).



ES = Electrical stimulation, NES = No electrical stimulation, Achilles = Conventionally suspended, Hip = Suspended through obturator foramen, 24 Hours = Ageing for 24 hours, 7 Days = Ageing for 7 days

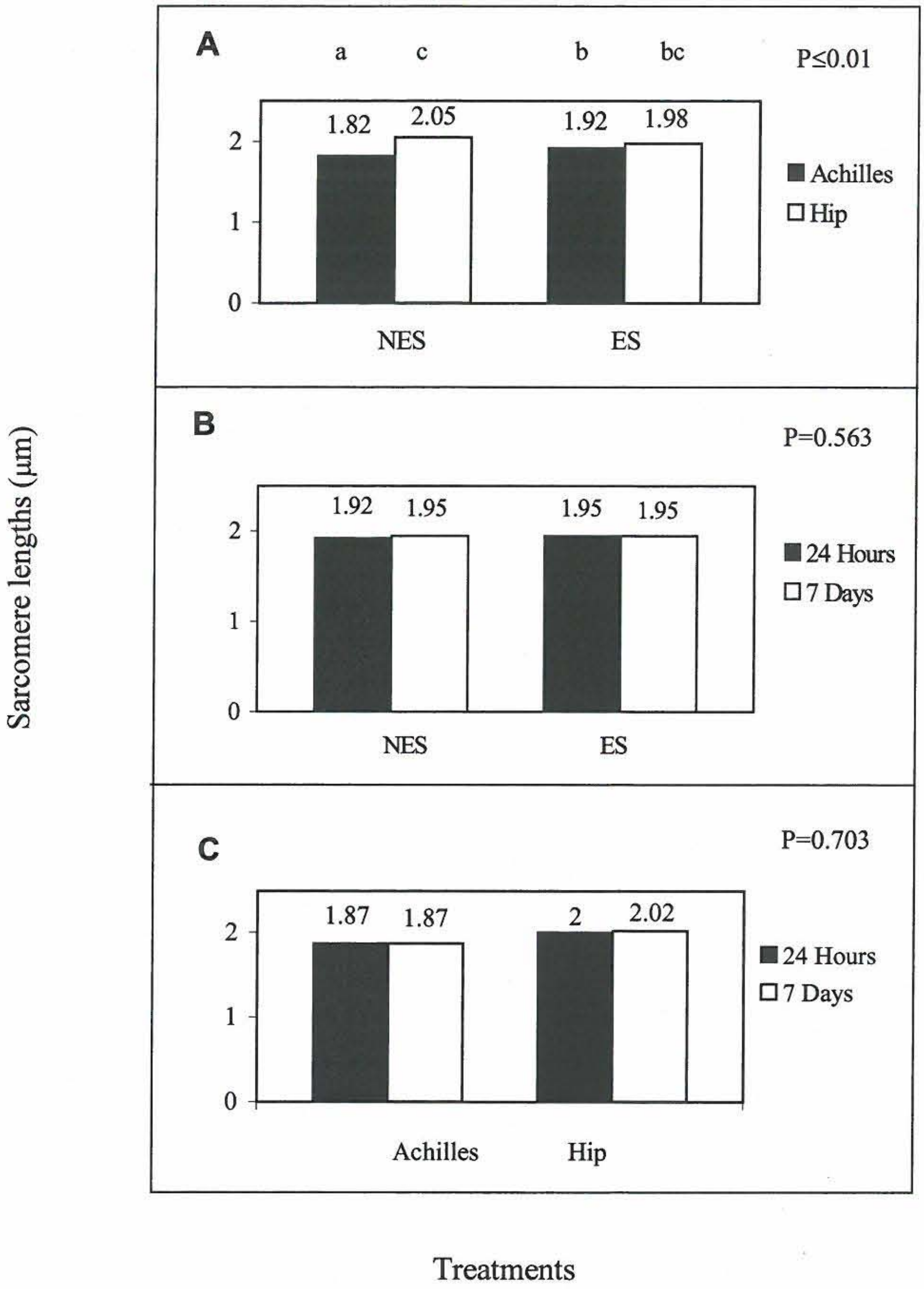
* Means with different superscripts differ significantly.

Fig. 8. Mean sarcomere lengths in relation to: (A) Electrical Stimulation; (B) Suspension method and (C) Ageing.

In Figure 9 the results of the two-way interactions between the main effects are shown. Figure 9A illustrates the interaction between suspension method and electrical stimulation, which was found to be significant ($P \leq 0.01$). The sarcomere lengths of hip-suspended carcasses were significantly ($P \leq 0.05$) longer than those of carcasses that were Achilles-suspended with NES. However, when electrically stimulated, the sarcomere lengths of hip-suspended carcasses were slightly (not significantly) longer. Electrically stimulated Achilles-suspended carcasses resulted in significantly ($P \leq 0.05$) longer sarcomere lengths than their NES counterparts. Therefore, although the main effect ES on its own did not have a significant influence on sarcomere lengths (Figure 8), when in interaction with suspension method, Achilles-suspended carcasses resulted in significantly ($P \leq 0.05$) longer sarcomere lengths than the Achilles-suspended NES carcasses.

According to Figure 9B the interaction between electrical stimulation and ageing was not statistically significant. As the means of the sarcomere lengths are similar it can be accepted that ageing does not interact with electrical stimulation.

Figure 9C shows the interaction between ageing and suspension method. The interaction was statistically not significant, however, the sarcomere lengths of carcasses that were aged for 24 hours as well as those aged for 7 days were longer when carcasses were hip-suspended than those that were Achilles-suspended.

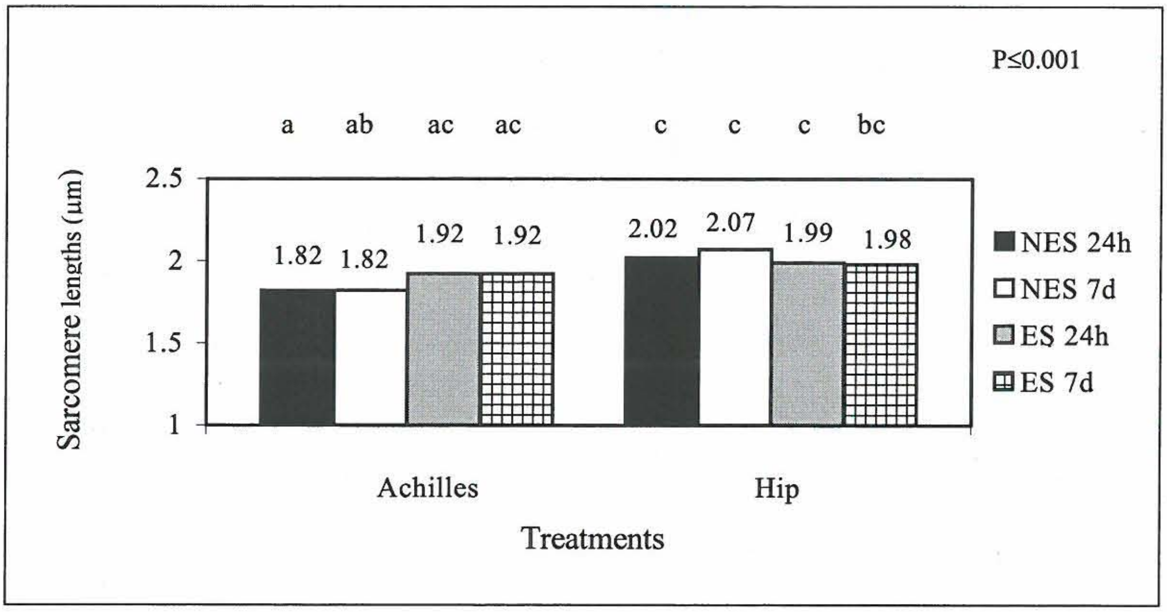


ES = Electrical stimulation, NES = No electrical stimulation, Achilles = Conventionally suspended, Hip = Suspended through obturator foramen, 24 Hours = Ageing for 24 hours, 7 Days = Ageing for 7 days

* Means with different superscripts differ significantly.

Fig. 9. Sarcomere length interactions in relation to (A) ES and Suspension method; (B) ES and Ageing; (C) Suspension method and Ageing.

The three-way interaction of the main effects namely ageing, suspension method and electrical stimulation are shown in Figure 10. The interaction was highly significant (P≤0.001), and the following results were obtained. NES, Achilles-suspended, 24-hour-aged carcasses were regarded as the control. In Achilles-suspended carcasses all the treatments except ageing or combinations of these treatments tended to produce slightly longer sarcomere lengths, although none of them were significantly longer. The sarcomere lengths of hip-suspended carcasses did not increase significantly with additional treatments (ageing and ES) or combinations thereof. Hip-suspended carcasses and carcasses that were hip-suspended in combination with the other main effects had significantly longer (P≤0.05) sarcomere lengths when compared to the control.



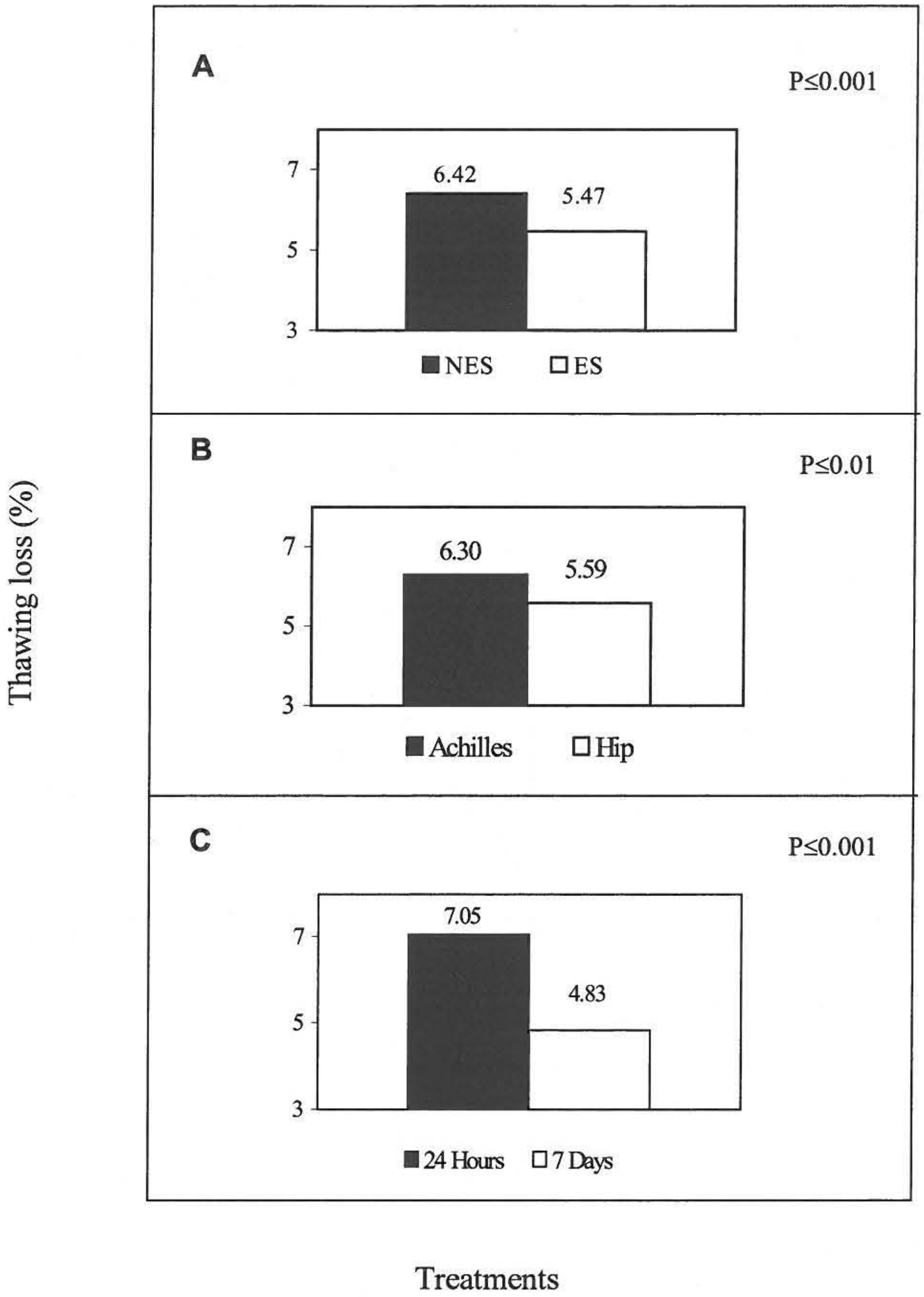
ES = Electrical stimulation, NES = No electrical stimulation, Achilles = Conventionally suspended, Hip = Suspended through obturator foramen, 24 Hours = Ageing for 24 hours, 7 Days = Ageing for 7 days

* Means with different superscripts differ significantly.

Fig. 10. Interaction of sarcomere lengths in relation to: Electrical stimulation, Suspension method and Ageing.

3.1.3 Thawing loss

The thawing loss results obtained for each of the three main effects, namely electrical stimulation, suspension method and ageing, obtained from samples of the *M. Longissimus,* are shown in Figure 11. Electrical stimulation resulted in significantly ($P \leq 0.001$) less thawing loss compared to NES carcasses. It can, therefore, be accepted that ES had a definite influence on the amount of thawing loss (Fig. 11A). With regard to suspension method, the amount of thawing loss in hip-suspended carcasses was significantly less ($P \leq 0.01$) than that in conventionally suspended (Achilles) carcasses (Fig. 11B), and when the carcasses were subjected to ageing (Fig. 11C) those aged for 7 days had significantly less ($P \leq 0.001$) thawing loss compared to those subjected to 24 hours of ageing.



ES = Electrical stimulation, NES = No electrical stimulation, Achilles = Conventionally suspended, Hip = Suspended through obturator foramen, 24 Hours = Ageing for 24 hours,7 Days = Ageing for 7 days

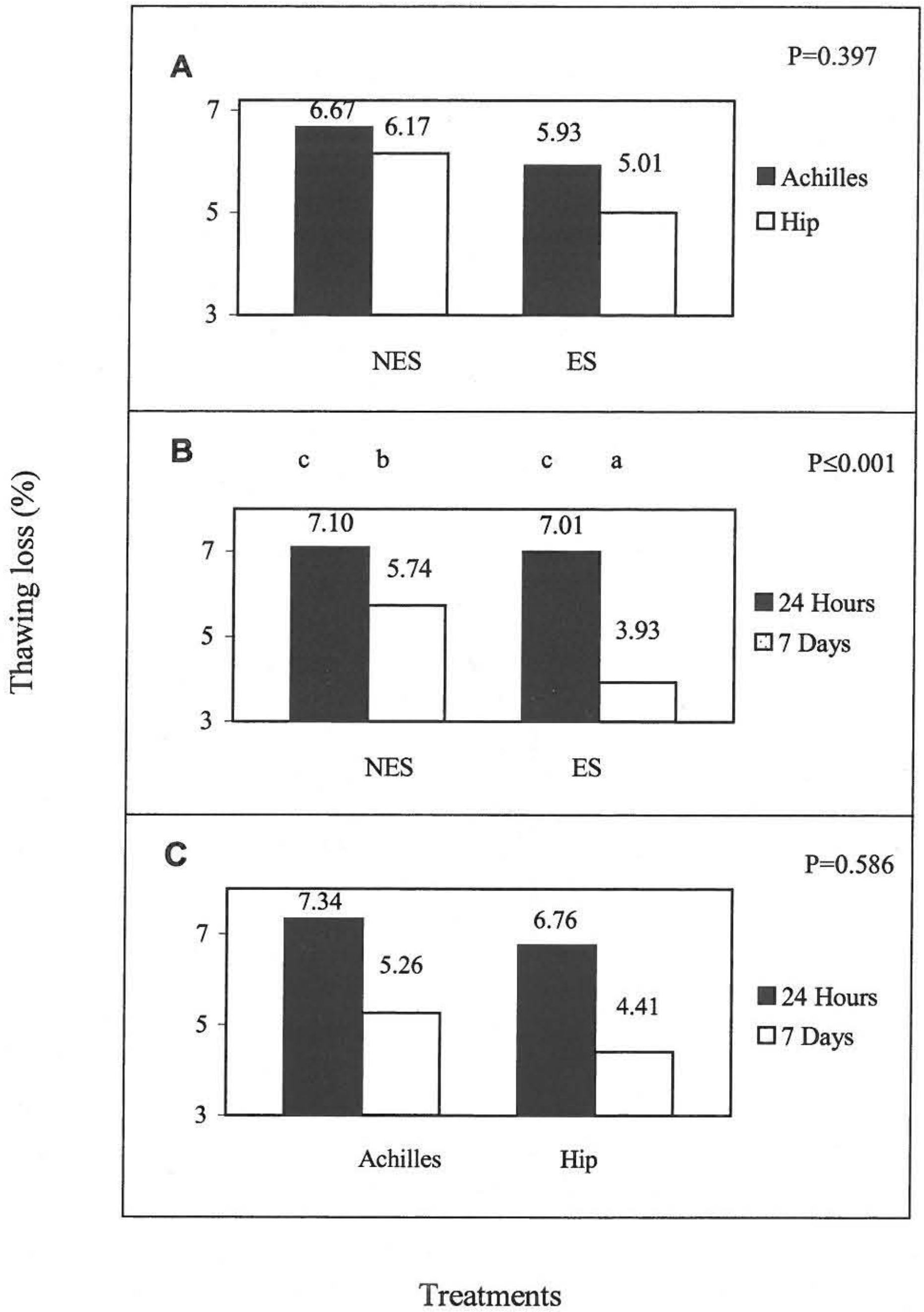
* Means with different superscripts differ significantly.

Fig. 11. Thawing loss in relation to: (A) Electrical stimulation, (B) Suspension method and (C) Ageing.

In Figure 12 the two-way interactions between combinations of treatments pertaining to thawing loss are shown. The interaction between ES and suspension method was not significant ($P=0.397$) (Fig. 12A); however it showed that ES reduced the amount of thawing loss in both Achilles- and hip-suspended carcasses. In the case of hip-suspended carcasses the reduction was significant ($P \leq 0.05$).

The interaction between ES and ageing (Fig. 12B) was significant ($P<0.001$). Electrical stimulation resulted in significantly less ($P \leq 0.05$) thawing loss in carcasses aged for 7 days, whereas it had virtually no influence on carcasses aged for 24 hours. Ageing for 7 days significantly ($P \leq 0.05$) reduced thawing loss in both ES and NES carcasses.

Although the interaction between suspension method and ageing was not significant ($P=0.586$) the following could be derived: Carcasses aged for 7 days reduced thawing loss in both Achilles and hip-suspended carcasses (Fig. 12C).

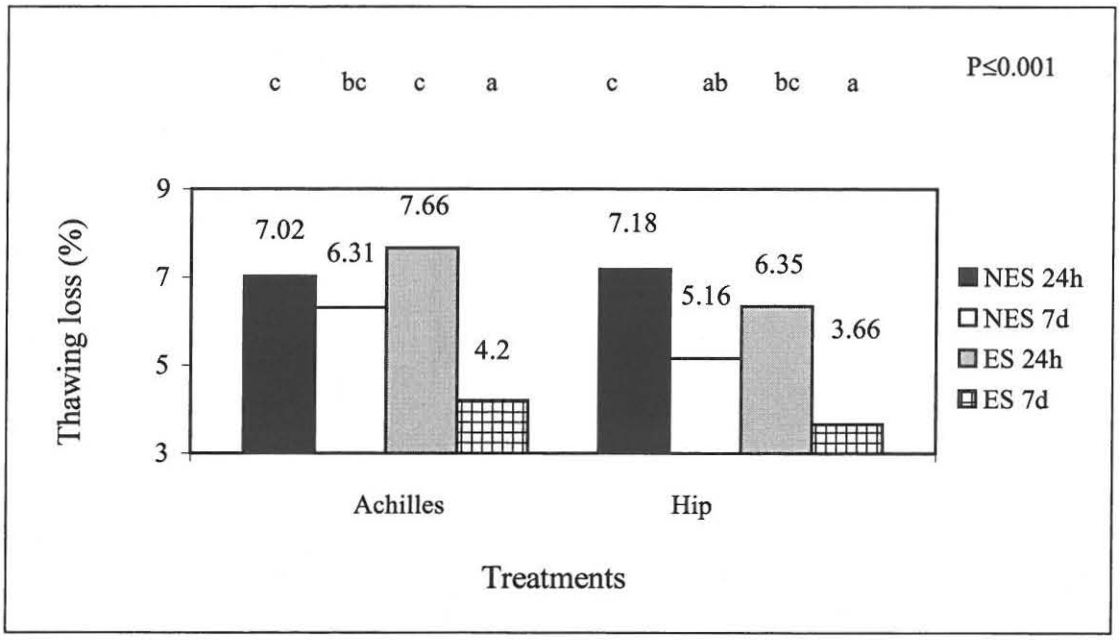


ES = Electrical stimulation, NES = No electrical stimulation, Achilles = Conventionally suspended, Hip = Suspended through obturator foramen, 24 Hours = Ageing for 24 hours,7 Days = Ageing for 7 days

* Means with different superscripts differ significantly.

Fig. 12. Interaction of Thawing loss in relation to: (A) ES and Suspension Method, (B) ES and Ageing and (C) Suspension method and Ageing.

Figure 13 shows the highly significant ($P<0.001$) interactions between the three main effects, electrical stimulation, suspension method and ageing, with regard to thawing loss. Using Achilles-suspended carcasses that had been chilled for 24 hours as control, the following conclusions were drawn: With Achilles-suspension only, ES carcasses that had been aged for 7 days had significantly ($P\leq0.05$) less thawing loss than the control. In hip-suspended carcasses, 7 days of ageing as well as the combination of ES and 7 days of ageing, significantly ($P\leq0.05$) reduced the amount of thawing loss. The combination of hip suspension and ageing resulted in significantly ($P\leq0.05$) less thawing loss if compared to Achilles-suspended, ES carcasses, as well as the control. Hip suspension, ES and ageing for 7 days also produced significantly less thawing loss ($P\leq0.05$) compared to the control, as well as NES, Achilles-suspended carcasses aged for 7 days and ES, Achilles-suspended carcasses aged for 24 hours.



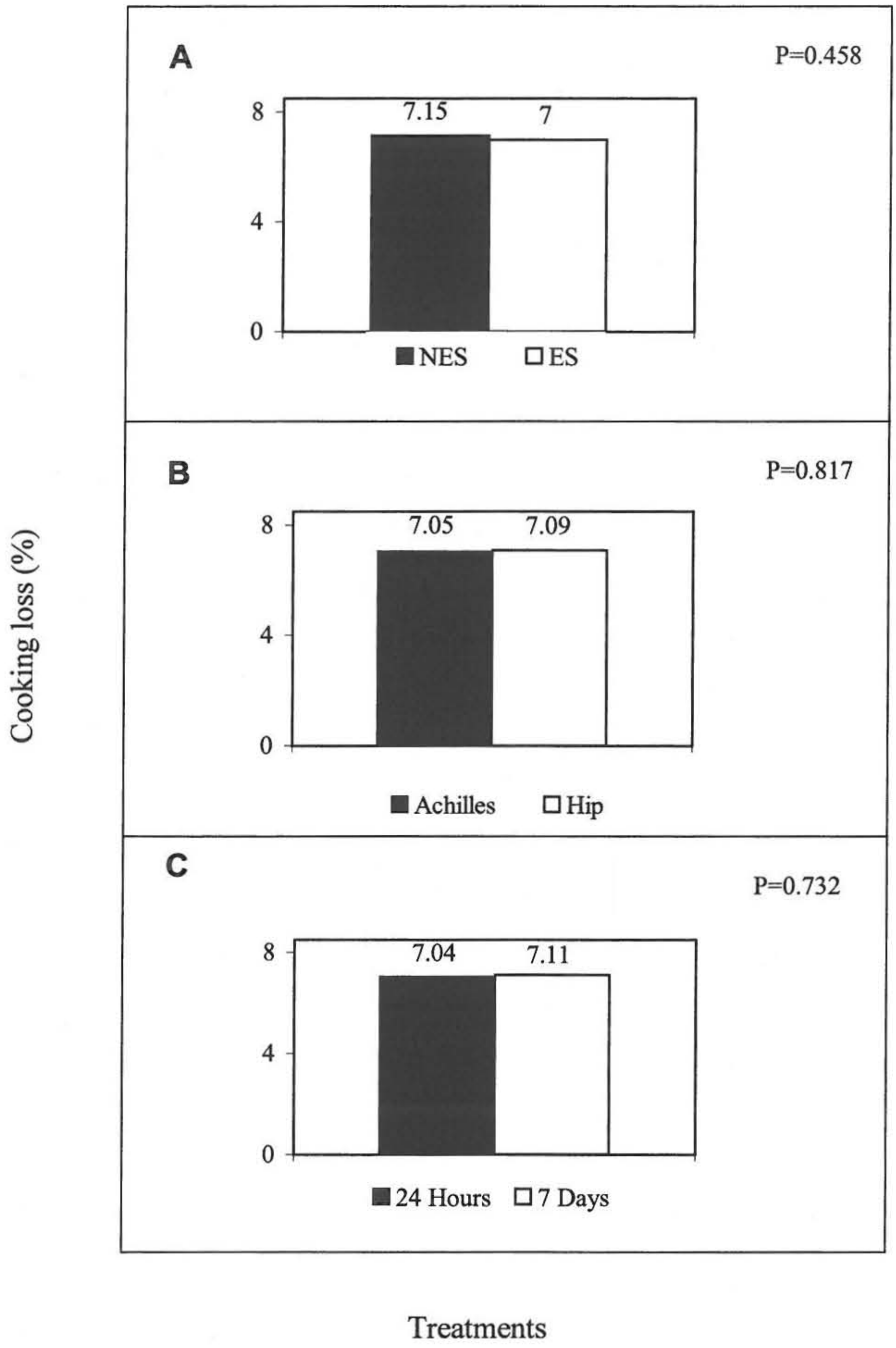
ES = Electrical stimulation, NES = No electrical stimulation, Achilles = Conventionally suspended, Hip = Suspended through obturator foramen, 24 Hours = Ageing for 24 hours, 7 Days = Ageing for 7 days

* Means with different superscripts differ significantly.

Fig. 13. Interaction of thawing loss in relation to: (A) Electrical Stimulation, (B) Suspension method and (C) Ageing.

3.1.4 Cooking loss

The cooking loss results obtained for each of the three main effects, namely electrical stimulation, suspension method and ageing, obtained from samples of the *M. Longissimus,* are shown in Figure 14. Figure 14 A, B and C shows the mean cooking loss values of electrical stimulation, suspension method and ageing. None of the main effects were statistically significant.

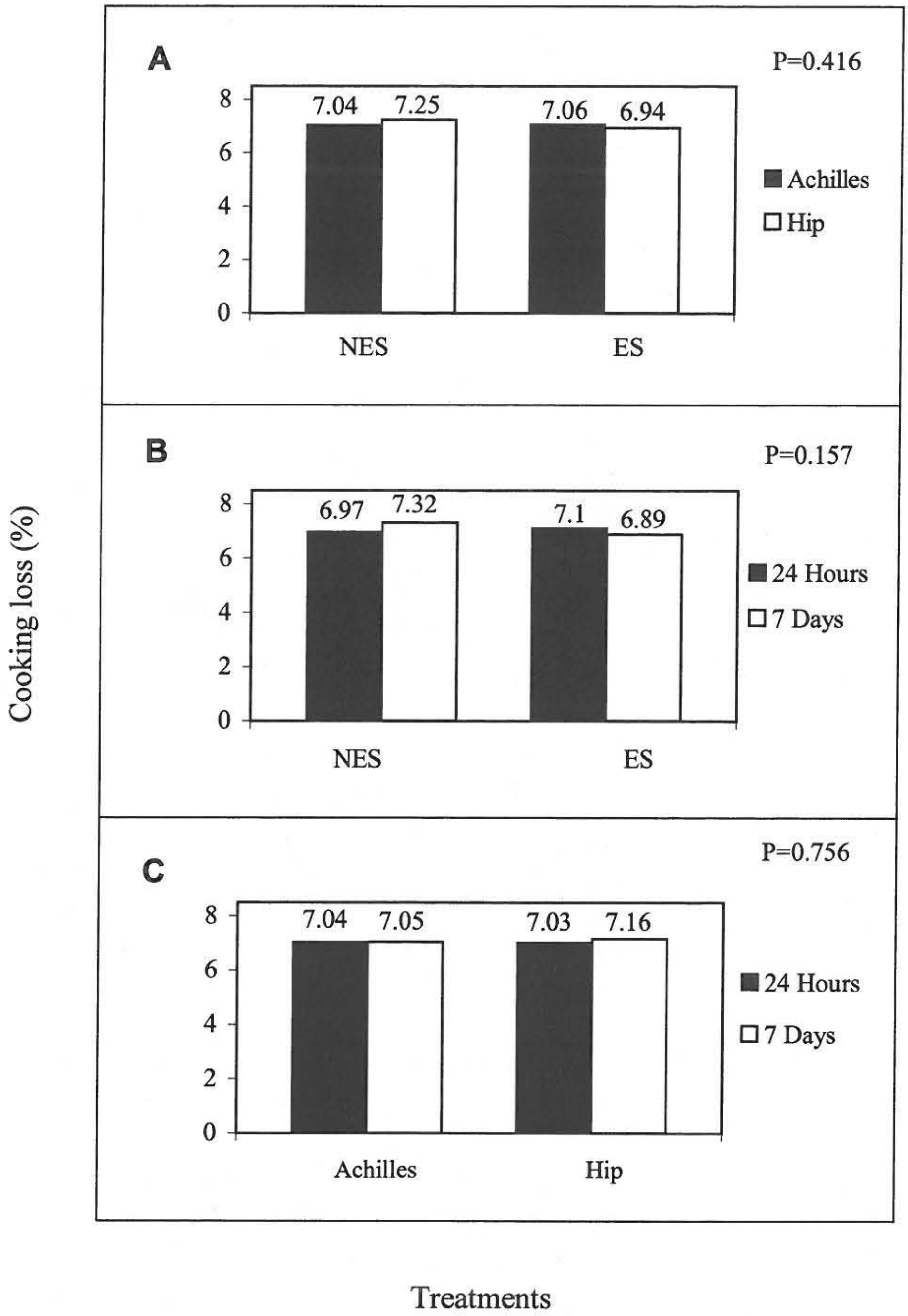


ES = Electrical stimulation, NES = No electrical stimulation, Achilles = Conventionally suspended, Hip = Suspended through obturator foramen, 24 Hours = Ageing for 24 hours,7 Days = Ageing for 7 days

* Means with different superscripts differ significantly.

Fig. 14. Mean cooking loss values in relation to: (A) Electrical Stimulation, (B) Suspension method and (C) Ageing.

Figure 15 A, B and C shows the two-way interactions between the main effects, namely electrical stimulation, suspension method and ageing, in relation to cooking loss. None of the interactions were statistically significant, and virtually no differences in means were found.

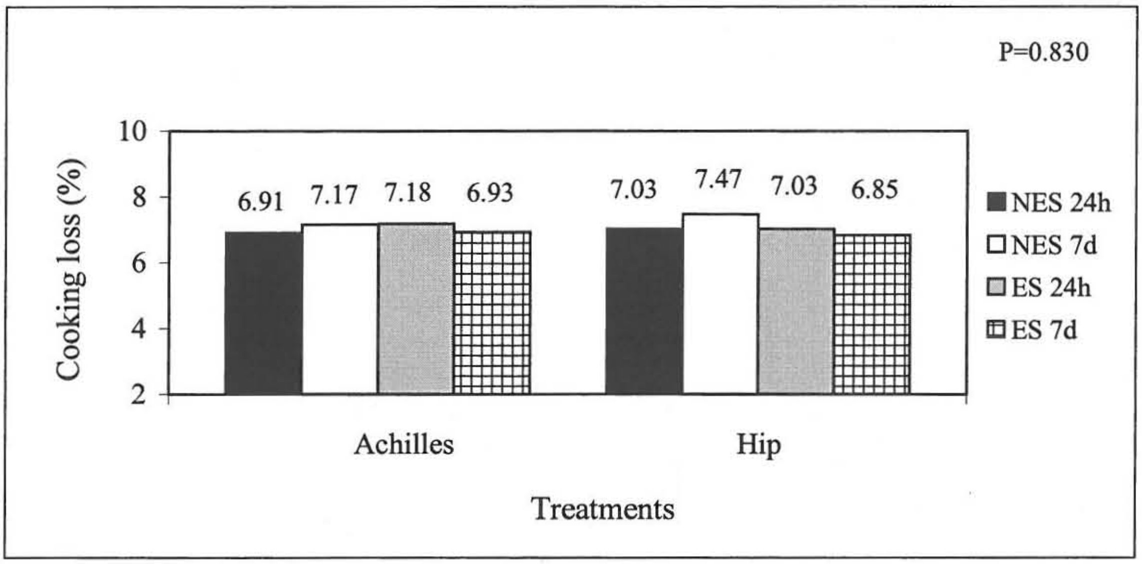


ES = Electrical stimulation, NES = No electrical stimulation, Achilles = Conventionally suspended, Hip = Suspended through obturator foramen, 24 Hours = Ageing for 24 hours,7 Days = Ageing for 7 days

* Means with different superscripts differ significantly.

Fig. 15. Interaction of cooking loss in relation to: (A) ES and Suspension method, (B) ES and Ageing and (C) Suspension method and Ageing.

Figure 16 shows the three-way interactions between the main effects, namely electrical stimulation, suspension method and ageing, in relation to cooking loss. The interactions were not statistically significant and virtually no differences in means were found.



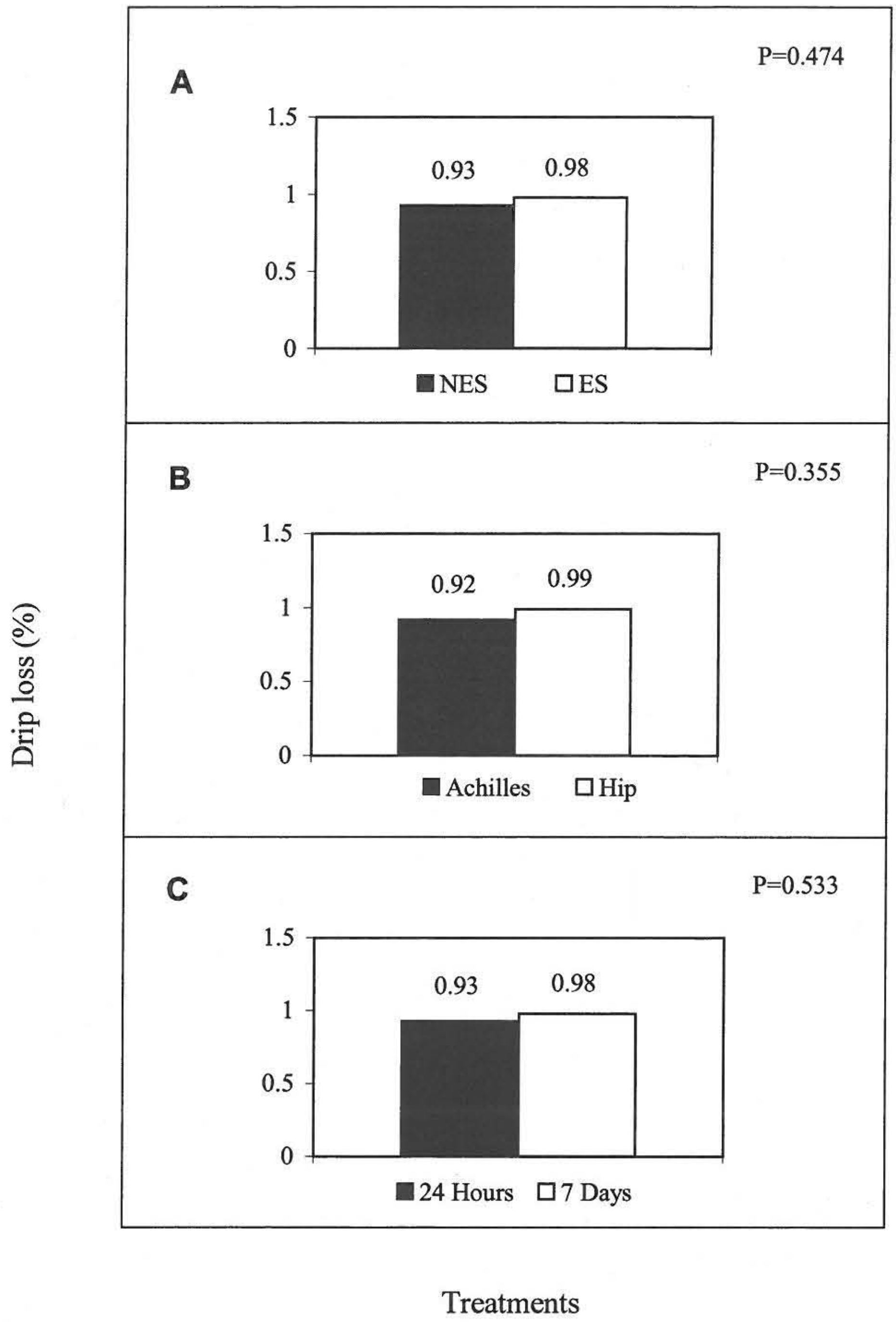
ES = Electrical stimulation, NES = No electrical stimulation, Achilles = Conventionally suspended, Hip = Suspended through obturator foramen, 24 Hours = Ageing for 24 hours,7 Days = Ageing for 7 days

* Means with different superscripts differ significantly.

Fig. 16. Cooking loss interactions in relation to: (A) Electrical Stimulation, (B) Suspension method and (C) Ageing.

3.1.5 Drip loss

The drip loss force results obtained for each of the three main effects, electrical stimulation, suspension method and ageing, obtained from samples of the *M. Longissimus,* are shown in Figure 17. Figure 17 A, B and C shows the mean drip loss values of electrical stimulation, suspension method and ageing. None of the effects were statistically significant, and virtually no differences in means were found.

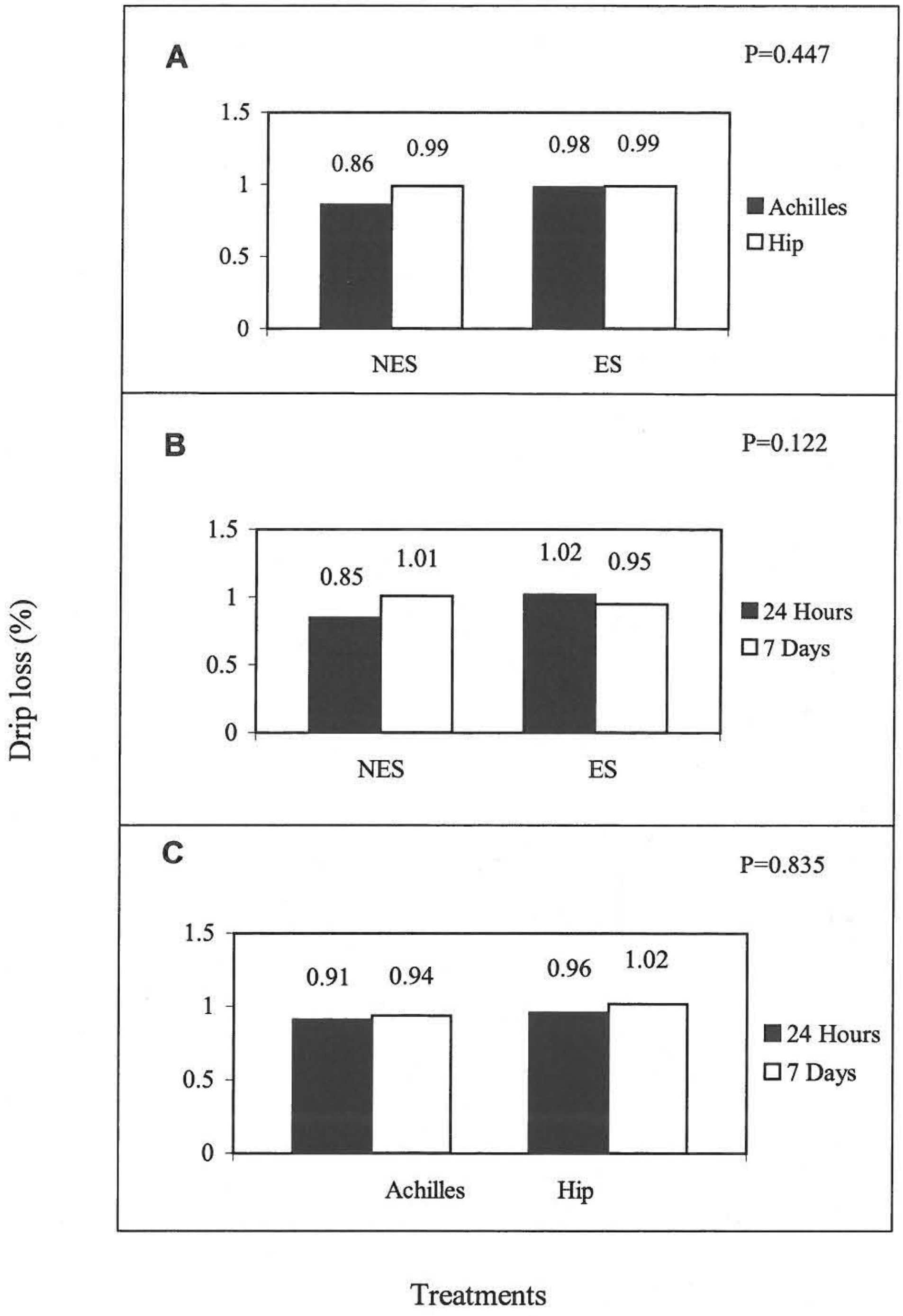


ES = Electrical stimulation, NES = No electrical stimulation, Achilles = Conventionally suspended, Hip = Suspended through obturator foramen, 24 Hours = Ageing for 24 hours,7 Days = Ageing for 7 days

* Means with different superscripts differ significantly.

Fig. 17. Drip loss in relation to: (A) Electrical Stimulation, (B) Suspension method and (C) Ageing.

Figure 18 A, B and C shows the two-way interactions between the main effects, namely electrical stimulation, suspension method and ageing, in relation to drip loss. None of the interactions were statistically significant, and virtually no differences in means were observed.

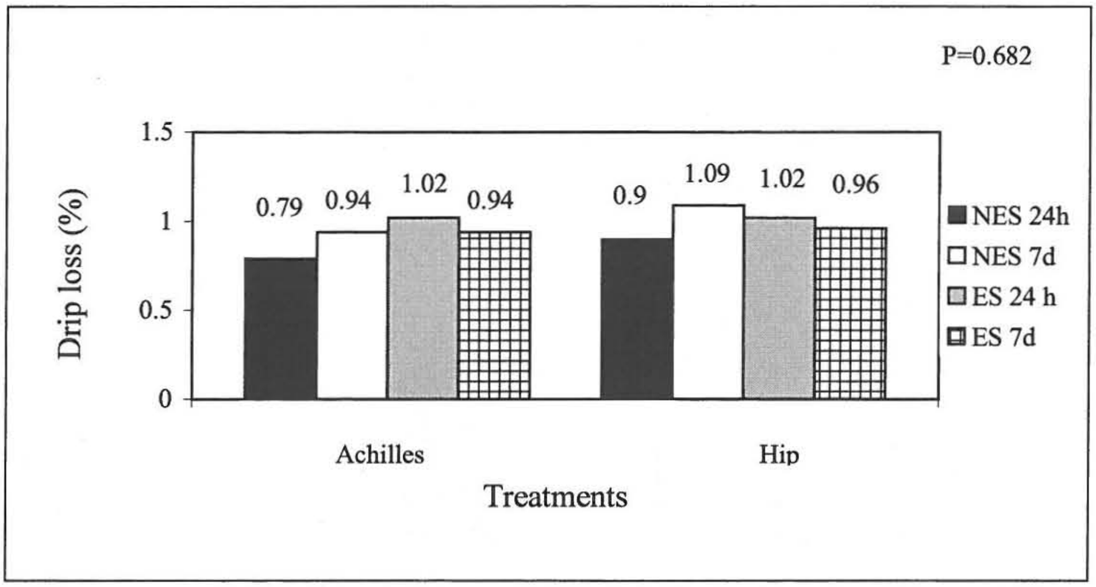


ES = Electrical stimulation, NES = No electrical stimulation, Achilles = Conventionally suspended, Hip = Suspended through obturator foramen, 24 Hours = Ageing for 24 hours,7 Days = Ageing for 7 days

* Means with different superscripts differ significantly.

Fig. 18. Drip loss in relation to the interactions between: (A) ES and Suspension method, (B) ES and Ageing and (C) Suspension and Ageing.

Figure 19 shows the three-way interactions between the main effects, namely electrical stimulation, suspension method and ageing, in relation to drip loss. The interactions were not statistically significant, and virtually no differences in means were observed.



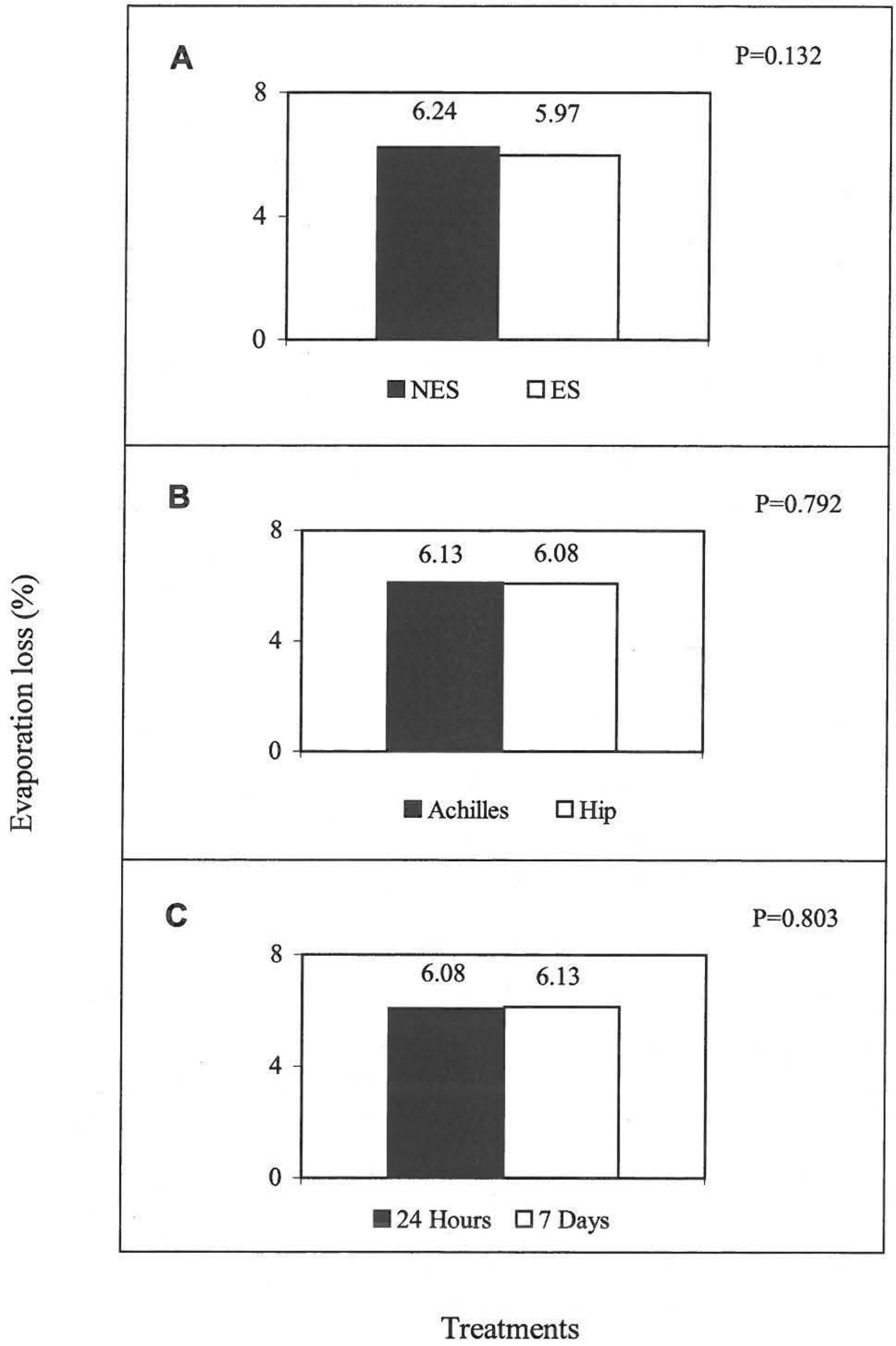
ES = Electrical stimulation, NES = No electrical stimulation, Achilles = Conventionally suspended, Hip = Suspended through obturator foramen, 24 Hours = Ageing for 24 hours,7 Days = Ageing for 7 days

* Means with different superscripts differ significantly.

Fig. 19. Drip loss in relation to the interactions between: (A) Electrical Stimulation, (B) Suspension method and (C) Ageing.

3.1.6 Evaporation loss

The evaporation loss results obtained for each of the three main effects, namely electrical stimulation, suspension method and ageing, obtained from samples of the *M. Longissimus,* are shown in Figure 20. Figure 20 A, B and C shows the mean evaporation loss values of Electrical stimulation, suspension method and ageing. None of the effects were statistically significant, and virtually no differences in means were observed.

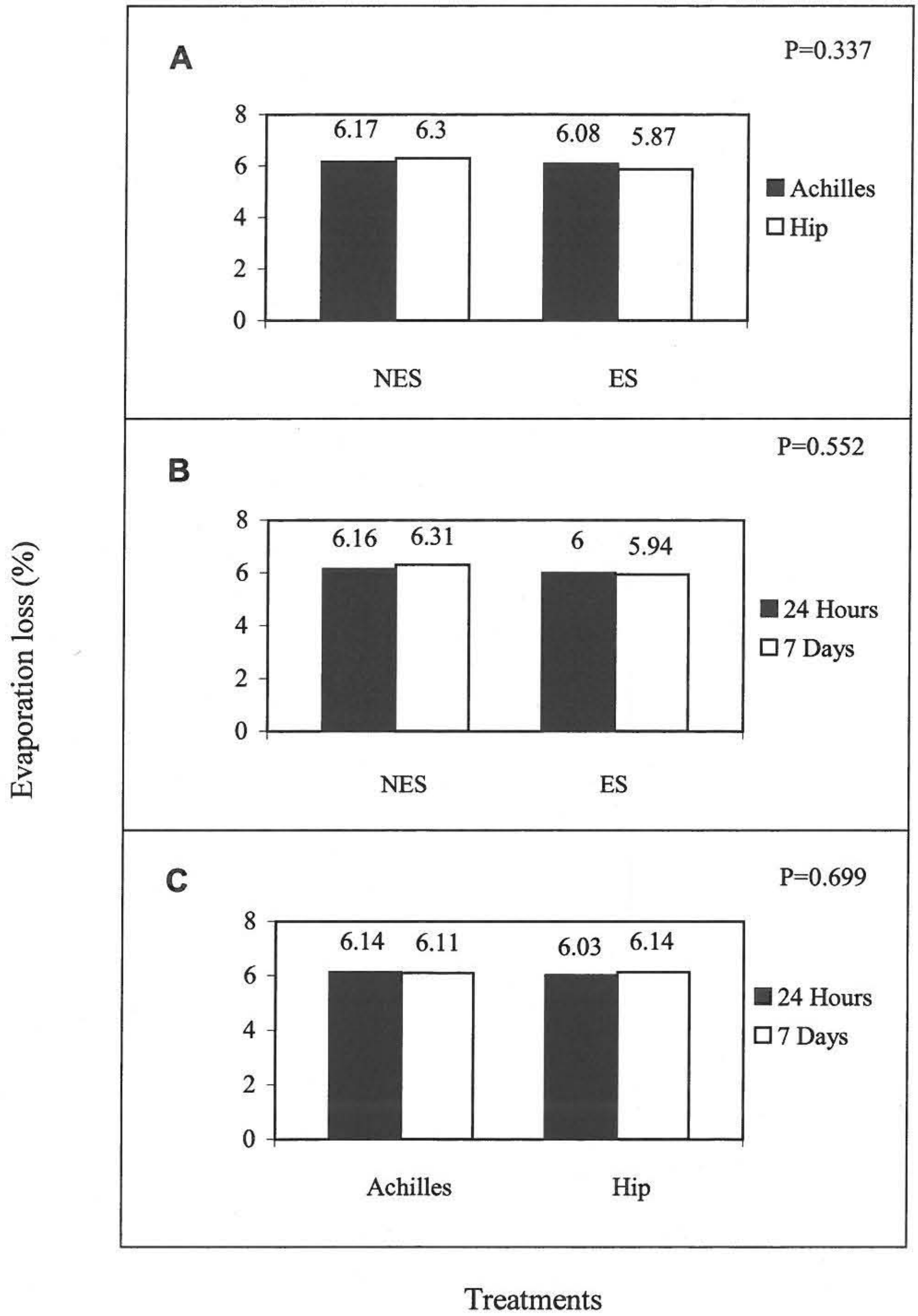


ES = Electrical stimulation, NES = No electrical stimulation, Achilles = Conventionally suspended, Hip = Suspended through obturator foramen, 24 Hours = Ageing for 24 hours,7 Days = Ageing for 7 days

* Means with different superscripts differ significantly.

Fig. 20. Evaporation loss in relation to: (A) Electrical stimulation, (B) Suspension method and (C) Ageing.

Figure 21 A, B and C shows the two-way interactions between the main effects, namely electrical stimulation, suspension method and ageing, in relation to evaporation loss. None of the interactions were statistically significant, and virtually no differences in means were observed.

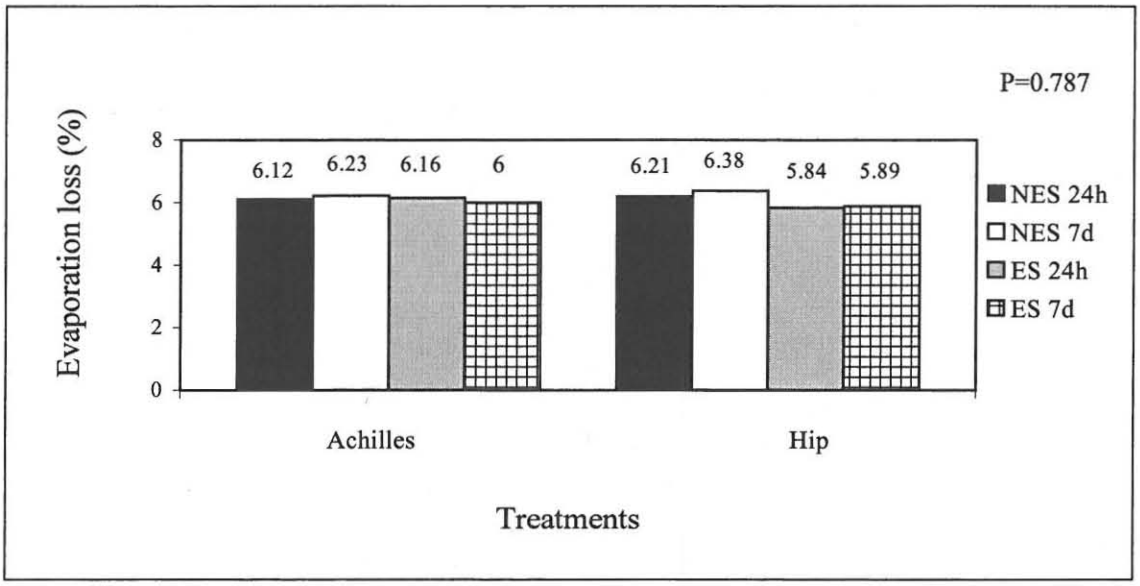


ES = Electrical stimulation, NES = No electrical stimulation, Achilles = Conventionally suspended, Hip = Suspended through obturator foramen, 24 Hours = Ageing for 24 hours,7 Days = Ageing for 7 days

* Means with different superscripts differ significantly.

Fig. 21. Evaporation loss in relation to the interaction between: (A) ES and Suspension method, (B) ES and Ageing and (C) Suspension method and Ageing.

Figure 22 shows the three-way interaction between the main effects, namely electrical stimulation, suspension method and ageing, in relation to evaporation loss. The interactions were not statistically significant, and virtually no differences in means were observed.



ES = Electrical stimulation, NES = No electrical stimulation, Achilles = Conventionally suspended, Hip = Suspended through obturator foramen, 24 Hours = Ageing for 24 hours, 7 Days = Ageing for 7 days

* Means with different superscripts differ significantly.

Fig. 22. Evaporation loss in relation to the interactions between: (A) Electrical Stimulation, (B) Suspension method and (C) Ageing.

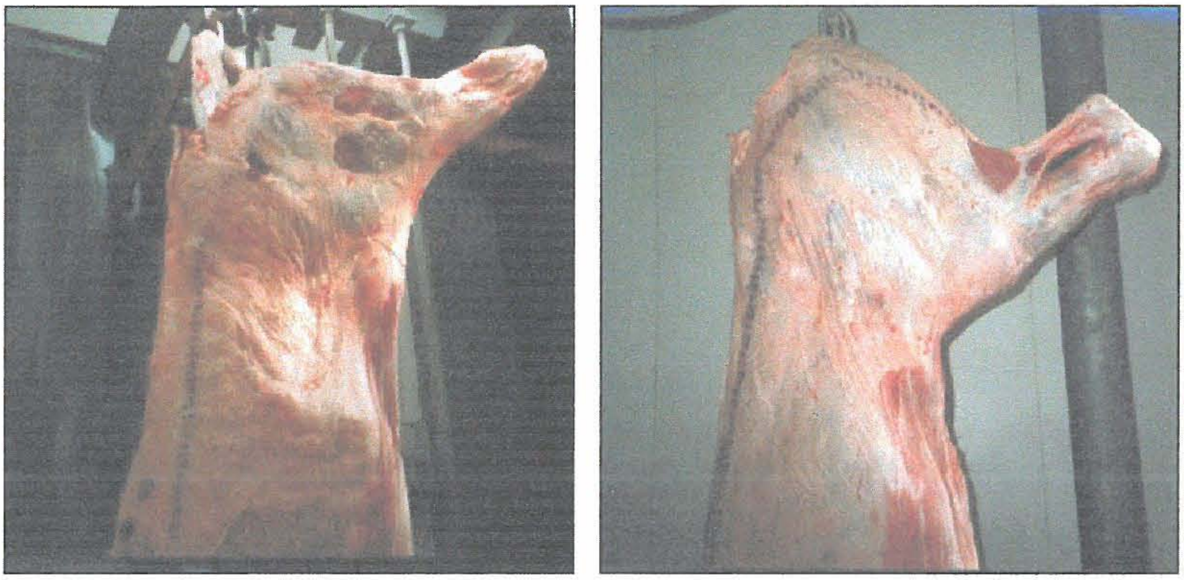
3.1.7 General discussion

3.1.7.1 Electrical stimulation

Electrical stimulation significantly (P≤0.001) reduced the shear force values of samples of *M. Longissimus*. This observation corresponds with reports by Dransfield *et al.,* 1991. Electrical stimulation in interaction with the suspension method significantly (P≤0.05) reduced the shear force values of Achilles-suspended carcasses and, in interaction with ageing, it also significantly (P≤0.05) reduced the shear force values of carcasses aged for 24 hours and those aged for 7 days. Furthermore, in the three-way interaction of electrical stimulation, hip suspension and ageing, ES on its own and in combination with 7 days of ageing also significantly reduced the shear force values of Achilles-suspended carcasses compared to the control (NES carcasses aged for 24 hours).

Electrical stimulation had no effect on sarcomere lengths. Kerth *et al.* (1999) also found that the sarcomere lengths of sheep were not affected by electrical stimulation. With ES in interaction with the suspension method the sarcomere lengths of Achilles-suspended carcasses were significantly (P≤0.05) longer than in the case of ES only, but in interaction with ageing, ES had no effect. In a three-way interaction between all three main effects, ES also had no effect on sarcomere lengths. ES causes rigor mortis to set in much quicker and at a higher temperature (Taylor, 1991). This phenomenon could be visibly observed while performing the experiment (Fig. 15). The hip suspension took place after carcass dressing and the splitting of the carcasses, which took approximately 2 hours. By this time rigor mortis was already at an advanced stage and possibly explains why sarcomere lengths were not longer in electrically stimulated carcasses.

Electrical stimulation significantly ($P \leq 0.05$) reduced the thawing loss (in the literature thawing loss is also referred to as drip loss). In interaction with suspension method, ES significantly ($P \leq 0.05$) reduced thawing loss of hip-suspended carcasses and in interaction with ageing, ES significantly ($P \leq 0.05$) reduced thawing loss of carcasses aged for 7 days. In the three-way interaction of the main effects, ES in combination with 7 days of ageing, thawing loss was significantly ($P \leq 0.05$) less than in the control in both Achilles- and hip-suspended carcasses. The findings regarding thawing loss are contrary to literature, which suggests that the rapid drop in pH after ES normally results in increased drip (thawing loss) (Lawrie, 1998). In this study electrical stimulation had no effect on cooking loss, drip loss and evaporation loss.



(A) (B)

Fig. 15. (A) Electrically stimulated hip-suspended beef carcass side (B) Non-electrically stimulated hip-suspended beef carcass side.

3.1.7.2 Ageing

Ageing significantly reduced the shear force values of the *M. Longissimus*. In interaction with ES, ageing significantly ($P \leq 0.01$) reduced shear force values compared to NES carcasses and, in interaction with the suspension method, ageing significantly ($P \leq 0.01$) reduced shear force values of Achilles-suspended carcasses (Fig. 6B and C). Ageing in combination with hip suspension significantly improved the tenderness in comparison with Achilles-suspended unaged carcasses. These results agree with those of Dransfield, Brown & Rhodes (1976), who reported that ageing and hip suspension in combination is better than ageing and conventional suspension. In a study on pigs Taylor *et al.* (1995) reported improved tenderness in both ES and hip-suspended carcasses after 10 days of ageing (Fig. 7).

Ageing did not affect sarcomere lengths. This finding corresponds with findings by Jeremiah & Martin (1978) who disagree with previous research that suggested that the tenderisation produced by ageing results from an increase in the length of sarcomeres, and with findings by MacBride & Parrish (1977) who reported that myofibril fragmentation plays a more significant role in the tenderness of aged meat than does sarcomere lengths. Ageing had the most positive results when it came to thawing loss in that Achilles suspended, ES carcasses aged for 7 days produced significantly less thawing loss than the control, and in hip-suspended carcasses both NES and ES carcasses aged for 7 days produced significantly less thawing loss. In this study it was found that ageing had no significant effect on cooking loss, drip loss or evaporation loss.

3.1.7.3 *Hip suspension*

Locker (1960) reported that the final state of muscle contraction and ultimate tenderness was largely dependent upon the amount of strain on the muscles before and during rigor mortis. A number of authors have also demonstrated that muscle stretching before or during rigor mortis increases the length of sarcomeres (Herring *et al.,* 1965a and b,1966; Arango, Smith, Carpenter & Cross, 1970; Hostetler *et al.,* 1970, 1972, 1973, 1975; Jeremiah *et al.,* 1984; Dransfield *et al.,* 1991). This study indicated that the tenderstretch (hip suspension) method significantly (P≤0.001) reduced not only the shear force value of *M. Longissimus* but also significantly (P≤0.001) increased the sarcomere lengths. These results are consistent with previous reports that the tenderstretch method of suspension lowered shear force values and increased the length of *M. Longissimus* sarcomeres (Herring *et al.,* 1965a, 1966; Arango *et al.,* 1970; Hostetler *et al.,* 1970, 1972, 1973, 1975; Jeremiah *et al.,* 1984; Dransfield *et al.,* 1991).

This study showed that neither extended ageing nor ES had a significant effect on tenderness when carcasses were hip suspended (Fig. 6A & B and Fig.7). This agrees with the findings of Dransfield *et al.* (1991) who in a similar study performed on pigs, noted that the combined use of ES and hip suspension appeared to have no added benefit. Hip suspension in combination with ageing had significantly better tenderness than Achilles-suspended carcasses, both aged and unaged – an observation also confirmed by Dransfield *et al.* (1991).

Researchers differ to various extents regarding the practicality of the tenderstrech method. Some have suggested that the method was practical and worthwhile for improving beef tenderness (Hostetler *et al.,* 1970, 1972, 1973) and of considerable commercial value, whereas others such as Jeremiah & Martin (1978) were of the opinion that such an improvement in tenderness may not be enough to justify industrial adoption of the technique, particularly in view of the additional requirements for labour and chiller space, and the necessity for new cutting methods. This is in agreement with the findings of Dreyer *et al.* (1979) who acknowledged the advantages of the method but recommended the implementation thereof only in fully integrated meat plants where all the processes, from slaughtering to deboning, take place under one roof.

Hip suspension reduced thawing loss significantly ($P \leq 0.01$). In interaction with ES the thawing loss was also significantly ($P \leq 0.05$) reduced. The combination of hip suspension and ageing produced significantly less thawing loss, which is an added advantage for the implementation of the method in South African abattoirs. Hip suspension, however, had no significant influence on cooking loss, drip loss and evaporation loss.

3.2 PERCEPTIONS OF THE BLOEMFONTEIN MEAT TRADE REGARDING HIP-SUSPENDED CARCASSES

In Table 1, general demographic information regarding the respondents is shown. The ages of the respondents ranged from 22 to 59 years of age, with experience ranging between 2 and 36 years in the meat trade. The median age of the respondents was 41.5 years and the median years of experience in the meat trade was 15 years (Table1).

Table 1. General demographic information regarding respondents

Number of respondents	40
Period of time in which interviews were conducted	7 days during Aug. and Sept. 2000
Age range of respondents	Between 22 – 59 years
Median age	41.5 years
Range of experience of respondents	Between 2 – 36 years
Median years of experience	15 years

Although the majority of the respondents had been involved in the meat trade for a relatively long period of time, it is expected that they were mostly concerned with the retail trade, which involves the purchasing of carcasses from the wholesalers or abattoirs, the dissecting of these carcasses into meat cuts, and the reselling thereof to the consumers. The respondents probably had very little or no abattoir experience and were most likely not involved with the transport of carcasses from abattoirs or wholesalers to retail premises.

3.2.1 Acceptability of appearance of hip-suspended carcasses

All the respondents (n=60) commented that they found the appearance of conventionally (Achilles) suspended carcasses to be acceptable. Table 2 shows the perception of the respondents regarding the appearance of hip-suspended carcasses.

Table 2. Comments regarding hip-suspended whole carcasses

	%Yes	No	Unsure	Reason, if negative	%
Acceptability (n=40)	25	**72.5**	2.5	Appearance Used to old shape	78.6 21.4
Difficulties with handling envisaged (n=40)	**47.5**	52.5		Hoist will be needed Hangs too high	93.8 6.2
Problems with deboning (n=40)	**60**	40		Dissecting difficult Damage Altered shape	82.6 4.4 13
Whether consumers would purchase the meat (n=40)	12.5	**65**	22.5	Used to conventional shape	100

The majority of respondents (72.5%) were of the opinion that hip-suspended carcasses were not acceptable mainly due to their appearance (Table 2). Although 52.5% of respondents did not envisage difficulties with the handling of these carcasses, 60% of the respondents expected problems with the deboning of hip-suspended carcasses, mainly because of difficulties with the dissecting. Sixty-five percent of respondents were of the opinion that consumers would not purchase the meat as a result of its unconventional shape.

3.2.2 Transport of hip-suspended carcasses

Comments regarding the transport of hip-suspended carcasses are summarized in Table 3. Contrary to obvious difficulties that could result from the shape of hip-suspended carcasses, the majority of respondents did not foresee problems regarding the transport of these carcasses. Fifty-five percent (55%) of them were, however, concerned about the space that the carcasses would take up in the vehicle due to the width of the carcasses. A number of respondents were concerned that the hooks would tear out from the carcasses.

Table 3. Comments regarding the transport of hip-suspended carcasses

	%Yes	No	Unsure	Reason, if negative	%
Problems from abattoir to wholesaler (n=40)	**25**	70	5	Tear out (Hooks)	70
				Too much space	20
				Difficult to suspend	10
Problems regarding space (n=40)	**55**	42.5	2.5	Hangs too wide	100
Difficulty with loading (n=40)	**25**	75		Will need hoist	88.9
				Too wide	11.1
Other problems envisaged (n=11)				Will tear out	90.9
				Hangs too wide	9.1

3.2.3 Chilling of hip-suspended carcasses

Sixty-seven point five percent (67.5%) of the respondents were of the opinion that the hip-suspended carcasses would take up more space in the chillers, because the altered shape would cause the carcasses to hang too wide (Table 4). Although 85% of the respondents did not think hip-suspended carcasses would have an influence on the air flow in the chillers, 15% of respondents were of the opinion that such carcasses might impair the air flow in the chiller, as they would hang too wide at the top. The majority (95%) of respondents did not envisage that hip suspension would have an influence on the effective chilling of these carcasses.

Table 4. Comments regarding the chilling of hip-suspended carcasses

	% Yes	No	Unsure	Reason, if negative	%
Whether it would take up more space in chillers (n=40)	**67.5**	32.5		Hangs too wide	100
Whether it would impair air flow (n=40)	**15**	85		Too wide at top, will impair air flow	100
Whether it would influence effective chilling (n=40)	**5**	95		Will impair air flow	100

3.2.4 Dissecting of hip-suspended carcasses

Eighty-two point five percent (82.5%) of the respondents envisaged problems regarding the dissecting of hip-suspended carcasses (Table 5). Of these, 53.1% were of the opinion that the altered shape of the carcasses would have an effect of the position of the various cuts within the carcass and would thus cause difficulty removing them. Thirty-one point three percent (31.3%) mentioned possible difficulties with dissecting specific cuts such as the topside, rump and silverside. Twelve point five percent (12.5%) of the respondents who envisaged problems were of the opinion that steaks might be wasted because the altered shape might require that they be trimmed, and 3.1% were concerned about the appearance of the altered shape of the dissected cuts (Table 5). The respondents were divided as to whether the altered shape of the carcasses would cause wastage of meat during dissection: 52.5% of respondents were of the opinion that meat would not be wasted, while 45% disagreed and 2.5% were unsure. The respondents who were of the opinion that meat might be wasted predominantly attributed the possible wastage to extra trimming required due to the peculiar shape of the carcasses. Twenty-five percent (25%) of respondents envisaged problems regarding the loading of hip-suspended carcasses. Of these 88.9% were of the opinion that a hoist would be needed to load and offload carcasses and 11.1% envisaged loading problems because the carcasses appear too wide to be loaded. Despite the mentioned problems 80% of the respondents were of the opinion that consumers would purchase the meat from hip-suspended carcasses. The general perception of the respondents regarding the meat cuts derived from hip-suspended carcasses was positive, with 54% of the respondents being of the opinion that the changes in the appearance of the retail cuts would be negligible.

Table 5. Comments regarding the dissecting of hip-suspended carcasses

	% Yes	No	Unsure	Reason, if negative	%
Problems regarding dissecting (n=40)	**82.5**	12.5	5	Position of cuts will change	53.1
				topside, rump, silverside difficult to dissect	31.3
				Steaks will be wasted	12.5
				Shape of cuts will change	3.1
Whether meat would be wasted (n=40)	**45**	52.5	2.5	Cuts will need extra trimming	60
				Damage by untrained personnel	26.7
				Hooks damage steaks	13.3
Difficulty with loading (n=40)	**25**	75		Will need hoist	88.9
				Carcasses too wide	11.1
Whether appearance of cuts would be acceptable to consumers (n=40)	80	**20**			
Trade's perception of cuts (n=37)				Change will be very small, if at all	54
				The shape of cuts will change	40.6
				Advantage too small for change	2.7
				Meat will be wasted	2.7

3.2.5 General comments regarding hip-suspended carcasses

The general comments and perceptions regarding the acceptability of hip-suspended carcasses are summarised in Table 6. Sixty-two point five percent (62.5%) of respondents stated that they would not purchase hip-suspended carcasses for the following reasons: (a) handling would be time consuming; (b) the appearance of the carcasses was unacceptable to them; (c) there might be losses due to meat being wasted, and (d) because of the additional training of personnel that would be required. If, however, the altered shape ensured more tender meat on a constant basis, 72% of all respondents indicated that they would purchase such meat. Seventy percent (70%) of respondents felt that consumers would purchase the meat, although

52% were of the opinion that the meat trade in Bloemfontein would not accept the altered shape of hip-suspended carcasses, because their colleagues in the meat trade were too conservative and that clients' habits did not change easily.

Table 6. General comments regarding the acceptability of hip-suspended carcasses and cuts

	% Yes	No	Unsure	Reason, if negative	%
Whether respondent would purchase the meat (n=40)	27.5	**62.5**	10	Time consuming	42.9
				Appearance	23.8
				Wastage of meat	19
				Personnel training	14.3
Whether respondents would purchase the meat if it were consistently more tender (n=40)	72.5	**27.5**		Losses too significant	44.5
				Appearance not acceptable	33.3
				Personnel would need training	11.1
				Do not believe meat can be more tender	11.1
Whether consumers would purchase the meat (n=40)	70	**22.5**	7.5	Appearance	57.1
				Used to old shape; do not adapt easily	42.9
Whether this meat would be accepted by the meat trade in Bloemfontein (n=40)	15	**52.5**	32.5	Too conservative	57.1
				Clients do not change easily (Force of habit)	42.9

3.2.6 General discussion of the perception of the meat trade regarding hip-suspended carcasses

Some of the comments made during the interviews left the impression that although the majority of respondents had been involved in the meat trade for a relatively long time, they were mostly involved in the retail trade. Meat was mostly ordered from wholesalers or purchased from the abattoirs per catalogue before being delivered at the butcheries. This could also be derived from some responses highlighting concerns that the hooks might tear out during suspension or transport. Experience should have proved that these concerns were unfounded, because the carcasses were hooked through the obturator foreman (aitchbone), a bone that cannot easily be torn out. Hip-suspended carcasses are usually re-suspended through the Achilles tendon prior to transport, since the treatment has already been completed (rigor mortis had set in while it was hip-suspended).

In general, the appearance of hip-suspended carcasses was not acceptable to the respondents as they were used to the appearance of the conventionally suspended carcasses. They were also of the opinion that it would take up more space in their chillers and they envisaged problems with the dissecting of hip-suspended carcasses, as the altered shape of the carcasses would presumably cause the meat cuts to alter their position within the carcass. Respondents also stated that they would prefer not to purchase the carcasses for resale in their butcheries. In contrast the general opinion of respondents was that they did not envisage any problems with the transport or with the effective chilling of carcasses. They also thought that the appearance of the various meat cuts would be acceptable to the public and that the public would purchase the meat cuts derived from hip-suspended carcasses. Most of the respondents were of the opinion that if it were proved that meat from hip-suspended carcasses was more tender than that from conventionally suspended carcasses, they would purchase the meat for resale in their butcheries.

In the light of the fact that this study proved that hip-suspended carcasses resulted in more tender meat, and based on the information obtained from the questionnaire, hip-suspended carcasses have a reasonable chance of being accepted by the meat trade in the Bloemfontein area. Should the implementation be attempted it would, however, have to be preceded by an extensive marketing and awareness campaign.

CHAPTER 4

CONCLUSION

CHAPTER 4: CONCLUSION

4.1 CONCLUDING REMARKS

The primary objective of this study was to establish the influence of different treatments on the tenderness of the meat of a specific breed. It was assumed that the primary objective of the meat trade was to produce guaranteed tender meat that would satisfy the consumers' demand for tenderness on a consistent basis, and that discerning consumers would be willing to pay more for guaranteed tender meat. However, in a telephonic survey conducted among 25 restaurateurs in the Bloemfontein area, the contrary was established. Price was the main criterion set by restaurateurs when it came to the purchasing of meat. The reasoning by some of the major chain restaurant groups was that people visit the restaurant primarily to socialise and enjoy the festive atmosphere and not the food. It does not matter whether they serve a top-quality (prime) steak or merely a reasonably medium tender steak, their patrons would not notice the difference. In addition to this the serving of a top-quality steak could have an adverse effect on their profit margin, as they could not increase their prices accordingly. This scenario might count for the majority of role players in the meat trade - however, there are discerning consumers and restaurateurs that insist on high-quality and branded products and are willing to pay for them.

Meat quality and consumer perceptions depend on the market sector being catered for. In order to address previously disadvantaged consumers' increasing need for quality, as well as the needs of existing discerning consumers, the answer would be to produce quality meat without increasing processing cost. This study proved that this can be achieved by combining existing methods used for the tenderisation of meat in processing plants, for example, electrical stimulation, hip suspension and ageing.

4.1.1 Electrical stimulation

Electrical stimulation is a very effective method and, as has been shown, significantly improves the tenderness of beef. Electrical stimulation is a standard procedure at most of the high-throughput (slaughtering more than twenty cattle units per day) abattoirs in South Africa. Although the equipment necessary for ES is expensive it does not have a significant influence on the processing costs of carcasses in these abattoirs, because of the volumes handled. It is therefore recommended that, if ES is at all economically viable, it should be performed at all abattoirs. It is imperative, however, that processing plants ensure the efficient application and maintenance of their equipment. Positive results cannot be obtained if equipment does not function properly or if the method used is not correct.

4.1.2 Ageing

It was demonstrated in this study that ageing significantly improves the tenderness of meat and can therefore be applied in combination with other methods or as an alternative to ES in areas where the latter cannot be applied. The advantages of ageing are that it can be done either while carcasses are still intact or after dissection and it can be executed by the processor, the wholesaler or the end user (abattoirs, wholesalers, restaurateurs, butchers or consumers). It is, however, a costly process as it takes up chiller space for a period of time. Another disadvantage is that spoilage can occur, as the end user does not necessarily know whether previous role players have aged the meat. Its intrinsic toughness (for example in the case of old animals) can also not be rectified through ageing and the amount of improvement in tenderness would then be relative to the tenderness at the onset of ageing.

4.1.2 Hip suspension

Hip suspension has been shown to significantly increase the tenderness of meat. Hip suspension may be a suitable substitute where ES cannot be executed, especially in low-throughput abattoirs where ageing and the execution of ES might not be economically viable. The privatisation that took place in the meat trade in 1993, as well as the political changes of 1994, resulted in numerous small abattoirs being established on farms and on smallholdings around cities. Very few of these abattoirs electrically stimulate, hip suspend or age their carcasses for various reasons (economics, small daily throughput, etc.), thus producing significantly tougher meat. This situation can be reversed by the use of the hip suspension method and although hip suspension only affects the five major muscles in the hindquarter of carcasses, it is recommended that it be implemented in all low-throughput abattoirs. The implementation thereof would have no added economic burden but would address the problem of catering to both market sectors without additional cost. Dreyer *et al.* (1979) recognised the fact that hip suspension significantly improves meat tenderness and recommended that consideration be given to its use in integrated processing plants where all the stages, from slaughtering to final processing are carried out under one roof. As a result of major technological advances over the past 10 years it would, in terms of economics and quality, now be viable to revert to the hip suspension of carcasses. For example, nowadays most low-throughput abattoirs make use of cooling facilities and, due to their low daily throughput, can accommodate hip-suspended carcasses irrespective of their unusual post rigor shape. An alternative might be to cut the carcasses into buttocks and loins and suspend them from hooks in the cooling facilities and transport vehicles.

Discerning consumers from rural areas presently buy their meat supplies in the cities, as they do not get the desired quality (regarding tenderness) at their butcheries in the rural areas. Money generated in rural areas that is being spent in urban areas is one of the reasons why rural communities are struggling financially. By making use of hip suspension in areas where ES is not economically viable, abattoirs in these communities can ensure that they produce the same quality meat without added cost, thereby preventing outflow of capital to the cities. Apart from these obvious benefits to the rural and informal meat trade in South Africa other technologically advanced, high-throughput abattoirs are increasingly looking for export opportunities. Similarly, by applying the treatments discussed in this study, these abattoirs can become internationally competitive, thereby contributing to the well being of the regional and national economy.

4.2 FUTURE RESEARCH

Whilst a holistic approach to meat quality is recommended, one must realise that the efficiency of the whole depends on the quality of its units. It is, therefore, imperative that research on improving meat quality be expanded. In order to make use of opportunities for export of meat and meat products, continued research in the following fields should be undertaken:

- Investigations into the advantages and disadvantages of the implementation of electrical stimulation, hip suspension and ageing, as well as combinations thereof at selected abattoirs;

- Investigations into the financial implications of electrical stimulation, hip suspension and ageing, individually or in combination, at selected abattoirs;

- Development of awareness and extension programmes regarding the implementation of hip suspension at abattoirs;

- Research into the effectiveness of electrical stimulation, hip suspension and ageing, as well as combinations thereof, on other species, for example ostriches, poultry, etc.

- Risk analysis regarding bacteriological, chemical, toxin and residue contaminants in meat that have been ES, hip suspended and aged and the development of models for the prediction of specific risks.

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APPENDIX A

TECHNIKON FREE STATE
SCHOOL OF ENVIRONMENTAL DEVELOPMENT AND AGRICULTURE

The influence of suspension method on the appearance of beef carcasses and the acceptability thereof by the meat trade.

Please complete the question(s) by marking with an **X** in the relevant space.

Questionnaire Number: -------------------------------------- [|] 1-2

Date: -- [| | |] 3-6

Name of Respondent: ---

Age of Respondent: -- [|] 7-8

Position in Business: ------------------------------------

Experience in Years: --- [|] 9-1

Business Name: --

Business Address:---

Tel No.: --

A. FULL CARCASS

Present respondent with colour photographs of carcasses suspended as follows:
(Photo 1: **Conventional suspension**, Photo 2: **Hip suspension**)

1. Regarding the appearance of conventionally suspended carcasses: Do you find it acceptable? | Yes | No | Unsure | ☐

2. If no, specify. --

WITH REGARD TO HIP-SUSPENDED CARCASSES

3. Regarding the appearance of the carcasses suspended in this way: Do you find it acceptable? | Yes | No | Unsure | ☐

4. If no, specify.--

----

5. Do you envisage difficulties that will impair the handling of carcasses by your personnel? | Yes | No | Unsure | ☐

6. If yes, specify.--

----

7. Do you envisage any problems with the de-boning of carcasses? | Yes | No | Unsure | ☐

8. If yes, specify.--

----

9. In your opinion would your customers purchase these carcasses?

Yes	No	Unsure

10. If no, specify.---

B. TRANSPORT

11. Do you envisage any problems in transporting these carcasses from the abattoir to the wholesaler? 31

Yes	No	Unsure

12. If yes, specify.---

----

13. Are you of the opinion that these carcasses would take up more space in the transport vehicle?

Yes	No	Unsure

14. If yes, specify.---

----

15. In your opinion, do you think your workers would find it difficult to load and unload these carcasses?

Yes	No	Unsure

16. If yes, specify. ---

----

17. Please state any other problems that you envisage regarding the transportation of these carcasses.
-- ☐ 43
-- ☐ 44
-- ☐ 45

C. CHILLING

18. Are you of the opinion these carcasses would take up more space in your chiller unit? | Yes | No | Unsure | ☐ 46

19. If yes, specify.--- ☐ 47
-- ☐ 48
-- ☐ 49
----

20. Do you think that these carcasses would impair the air flow in the chiller? | Yes | No | Unsure | ☐ 50

21. If yes, specify.--- ☐ 5
-- ☐ 5
-- ☐ 5

D. DISSECTING OF MEAT

WITH REGARD TO HIP-SUSPENDED DISSECTED CUTS

22. Do you envisage any difficulty in the dissecting of these carcasses? | Yes | No | Unsure | ☐ 54

23. If yes, specify.--- ☐ 55
-- ☐ 56
-- ☐ 57
----

24. Do you think any meat would be wasted? | Yes | No | Unsure | ☐ 58

25. If yes, specify.-- 59
-- 60
-- 61
----

26. Do you think that the difference in shape would influence the effective chilling of the meat? | Yes | No | Unsure | 62

27. If yes, specify.-- 63
-- 64
-- 65
----

28. In your opinion, would the appearance of meat from dissected cuts be acceptable to consumers? 66

	Acceptable	
	Not Acceptable	
	Uncertain	

29. What is your opinion of the dissected cuts derived from these carcasses?------------------------------- 67
-- 68
-- 69

E. GENERAL

30. Would you buy carcasses that had been hip suspended? | Yes | No | Unsure | 70

31. If no, specify.

Time consuming 71
Waste of meat 72
Other 73

32. If other, specify.-- 74
-- 75
-- 76
----

33. If hip-suspended beef ensures more tender meat on a constant basis, would you buy these carcasses?

Yes	No	Unsure

77

34. If no, specify.-- 78
-- 79
-- 80
----

35. In your opinion, would the consumer buy this meat?

Yes	No	Unsure

81

36. If no, specify.-- 82
-- 83
-- 84

37. In your opinion, would hip-suspended meat be accepted by the meat trade in Bloemfontein?

Yes	No	Unsure

85

38. If no, specify -- 86
-- 87
-- 88

END OF QUESTIONNAIRE