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Skin preservation and alternative fellmongering DAW.039

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CONTENTS

BACKGROUND AND INDUSTRY CONTEXT

(i) Preservation

Where possible, the best option is to process the skins fresh and as soon as possible after removal from the carcass. This eliminates the cost of preservation. It also reduces effluent costs and possible contamination of by-products by chemical preservatives.

Short term skin preservation (5-7 days), using a method compatible with acetate fellmongering, is believed to be necessary for the economic operation of the fellmongering industry. The reasons include economy of scale, since abattoirs within a district could supply a central processing plant, and short term fluctuations in supply could be reduced. In Australia, the main proponents for long term preservation (>3 months) argue that it is necessary to compensate for the cyclic nature of the sheep kill.

More recently, preservation has been perceived to be necessary where there may be a few hours delay between flaying and fellmongering. Skins which have been removed from the animal are at body temperature, and if stacked in a pile are liable to increase in temperature to a point where damage to the pelt occurs. The source of heat is post-mortem metabolic activity which can no longer be dissipated by regulated blood flow. If the skin is to be held for more than two hours then heat needs to be removed to avoid the effects of early putrefaction. The metabolic activity can be reduced by cooling the skin or by applying chemical treatment to stop metabolic activity.

If the skin is to be depilated with sodium sulphide it is necessary to reduce the skin temperature to around 20°C prior to painting, to minimise chemical damage to the skin. Conversely if the skin is to be acetate fellmongered immediately then there is no need to remove the heat as the skins are subsequently held overnight at approximately body temperature.

Current methods for short to long term preservation of sheep skins, (air-drying or salting) are incompatible with acetate fellmongering. Depilation can only be achieved by sweating, treatment with enzymes or the use of chemical depilants, such as lime/sulphide paint. Environmental and other considerations, such as wool quality, may severely restrict the use of these methods in the future. CSIRO (Money, 1985) has reported on the use of chemical preservatives such as sodium chlorite, calcium hypochlorite, zinc chloride, benzalkonium chloride and formaldehyde for short term preservation. Calcium hypochlorite can discolour wool, zinc chloride and formaldehyde inhibit enzyme activity and are unlikely to be compatible with acetate fellmongering. Formaldehyde cross links collagen and is only suitable as a preservative for subsequent wool on tanning. Chemicals can be sprayed on the flesh side or the skin may be soaked in an aqueous solution of the preservative. Many of the more recently described preservation procedures are for cattle hides and may not be appropriate for sheepskins. Whilst soaking of hides may be appropriate in some circumstances, soaking of sheepskins has many disadvantages. These include increased chemical, handling and transport costs, significantly increased effluent and a semi-scoured wool, which may be poorly accepted by the trade. For these reasons, this study has concentrated on procedures where the chemical preservative is applied to the flesh side of the skin only.

Salting was not considered to be suitable for short term preservation, mainly because of the effluent problems associated with the wetting back of the skin. Furthermore, this form of preservation is not compatible with subsequent acetate depilation.

Preservation may also be achieved by chilling and subsequent storage at reduced temperatures. Storage of skins at 4°C (short term) or -20°C (long term) has been proposed. Chilling would appear to be an attractive alternative to chemical preservation as the skins can be subsequently processed as fresh skins with their inherent advantages. However, a number of problems have to be overcome before chilling could be considered to be a practical proposition. For example, hanging individual skins in a conventional chiller, as practised with cattle hides, would be labour intensive and require a large amount of chiller space. Furthermore, it could result in drying of the flesh side of the skin which would interfere with subsequent acetate fellmongering. Chilling with cold water sprays may wet the wool increasing the transport and handling costs. The use of cryogenic liquids (nitrogen or carbon dioxide) would not lead to wet wool.

Chilling, of individual skins, prior to stacking and subsequent cold storage may be necessary. If fresh untreated skins were simply made into packs and put into a chiller or freezer the insulating properties of the wool may prevent skins in the centre of the pack from cooling rapidly enough to prevent putrefaction. If skins are stored frozen they will need to be defrosted before further processing. This would ideally be done in a chiller to allow skins on the outer part of the pack to remain at a suitable storage temperature while the inner skins come up to temperature. The time for this to occur is not known, nor are the optimal conditions for incubating skins which are initially at chiller temperatures.

Whatever the means of long term storage, skin drying may occur and this, per se, may prevent acetate fellmongering, despite adequate preservation. There is little in the literature on the effects of skin hydration on acetate depilation. Indeed the mechanism whereby drying leads to loss of ability to be acetate depilated is not known, nor is the degree of dehydration known at which this takes place.

(ii) Fellmongering

Fellmongering is the removal of wool from the flayed skin. The main methods are chemical wool dissolution or detachment of the wool from the follicle by the action of exogenous, endogenous or bacterial enzymes (sweating).

Strong alkali will dissolve wool, and the addition of reducing agents enhances this action. Lime is the most commonly used alkali and sodium sulphide the most commonly used reducing agent. This system has been used extensively for fellmongering coarser woolled skins. It can be used with green or wetted-back salted or dried skins. This method of depilation results in reduced return for the wool because sulphide damages the wool and the wool yield is at least 5% lower than those obtained by sweating or acetate depilation. Temperature control is necessary as temperatures in excess of 27°C lead to severe skin damage. Additionally, sodium sulphide is a hazardous chemical and when mixed with acid leads to the production of a deadly gas, hydrogen sulphide.

Sweating involves incubating the skins in a cool high humidity environment so that bacteria multiply and release enzymes which attack the follicle and loosen the wool. Sweating has been used in Australia in the past, however, it is a noxious and smelly procedure. It requires some

skill to judge just when the skins are ready to be dewoolled. If left too long then the skin rots and the pelt is useless, too short and the wool is difficult to remove and the grain layer may be damaged during removal. Wool loosening is often not uniform and the wool may be contaminated by flesh.

Exogenous enzymes are available which can be made into a paint and applied to the skin. They do result in wool loosening although it is somewhat erratic (Carrie and Woodroffe, 1960). Most enzyme preparations are applied by soaking skins in aqueous solutions, a procedure we have previously described as detrimental to the quality and value of the wool as well as producing the effluents associated with scouring. Exogenous enzyme dehairing is generally more costly than chemical dehairing. Commercial application has been largely restricted to the recovery of wool from trimmings or skin pieces in which the collagen has been denatured (eg. proteases), or as an aid to hair removal from cattle hides. In this latter application the enzymes generally attack the fibre, eg. keratinases from microbial sources, and so are of limited application when the fibre is valuable. Exogenous enzyme dehairing does have the advantage that it may be more specific, hence less skin damage, smaller quantities are needed, compared to chemical dehairing, and the effluent problem may be reduced.

Endogenous enzymes are found in lysosomes in the cells of the skin, and disruption of the lysosomes releases these enzymes. Lysosomal enzyme activation can be induced by reducing the skin pH, and the rate of their action increased, by raising the skin temperature. In the original patent (Graham, 1957) the relative humidity was not controlled, and increasing the temperature was said to only reduce the time taken to reach the point at which "the wool can be easily detached from the skin by pulling with the fingers". "The preferred temperature range is from 80 degrees to 95 degrees F" (27°C to 35°C), although the patent covers room temperature to 105°F (40.6°C). The current process to effect overnight depilation maintains the skins at around 35°C, in a high relative humidity atmosphere to prevent drying. Skin damage can occur if the pH is too low or if the temperature is too high. Loss of depilation can occur if the skin dries. The pH is regulated by using an appropriate buffer solution, generally based on an organic acid, such as acetic acid. The majority of lysosomal enzymes have optimal activity in the pH range 5.0 - 6.0, and to maintain this range the acid used needs to be able to buffer near these values. The buffering capacity over a given pH range depends upon the acid concentration and the pK_a of the acid. There has been a trend to economise on chemical costs by lowering the acid concentration, which reduces the buffering capacity of the paint, and to compensate for this the pH has also been lowered. The reduction in pH can lead to damage to the skin. At pH's below 4.0 there is a marked decrease in collagen strength and shrinkage temperature (Russell, 1974). Incubation temperatures have also been increased in the belief that this will improve depilation.

Once depilation has been achieved, the fellmonger is left with a pelt which, to maximise economic returns, needs further processing. Fellmongered skins, usually retain a small quantity of wool around the periphery of the pelt and this, together with gusset hair, is generally removed before further processing. This is usually done by exposing the pelt to alkali containing a reducing agent which, depending on the strength, can dissolve the entire hair or only the soft keratin at the hair root. Alkali also causes the pelt to swell and leads to protein hydrolysis and solubilization of some of the skin structural components which need to be removed prior to pickling. However, exposing the skin to alkali will eventually lead to modification and breakdown of collagen, giving poor quality leather. Prolonged exposure to alkali also increases collagen degradation. Skins which have not been exposed to alkaline dehairing may produce unacceptable leather, unless specially treated during tanning. Lime, a poorly soluble alkali, is

often used, and hence this process is commonly called "liming". Apart from being cheap, and readily available, a saturated solution has a pH of 12.5. Its low solubility is responsible for its buffering capacity, as HO^- are removed from solution they are replaced by more lime dissolving. However, additional HO^- can only be poorly buffered since the limited supply of soluble Ca^{2+} is precipitated from solution and no further buffering occurs. Lime does have some disadvantages. In fatty skins, the lime can react to form insoluble calcium soaps which are difficult to remove and may adversely effect subsequent tanning. "Lime blast" is the precipitation of insoluble calcium carbonate in the skin and can occur if the limed skin is exposed to atmospheric carbon dioxide. The lime quality is important as extraneous gritty contaminants, as well as gritty lime particles per se, may damage the grain layer during liming. Pre-exposure to lime or to an excess of alkali may induce alkali immunisation making subsequent hair removal more difficult.

Additives, sometimes called "sharpening agents", are disulphide bond breakers which can enhance hair removal and reduce the amount of alkali required to achieve satisfactory hair loss. Sodium sulphide (Na_2S) is commonly used because it is cheap, however it also has its disadvantages. It absorbs water from the air, and even the very weak carbonic acid which forms when water is exposed to air, will cause the breakdown of sodium sulphide into the lethal gas hydrogen sulphide. Another disadvantage is that when sodium sulphide is dissolved in water, it reacts as follows;

$$Na_2S + H_2O = NaOH + NaHS$$

The extra alkali may be harmful to the skin by causing increased swelling and hydrolysis. In addition there is the danger that, on acidification, the sodium hydrosulphide (NaHS) breaks down to hydrogen sulphide. Sodium hydrosulphide has been used as a sharpening agent to reduce the alkali produced but the potential problem of hydrogen sulphide production remains. Environmental concern may mean that sodium sulphide and sodium hydrosulphide will not be able to be used in the fellmongering industry without expensive and sophisticated safety precautions and effluent treatment. Other sharpening agents that have been used include calcium hydrosulphide, arsenic sulphide and sodium cyanide, all of which are toxic. A number of amines, some of them derived from old lime liquors have also been used.

The problems of alkaline immunisation, soap formation, swelling and environmental concerns about lime itself and the problem of the use and disposal of toxic sharpening agents have led to the need to develop more "environmentally friendly" liming and dehairing systems, such as BASF's Mollescal SF, in the tanning industry. The Mollescal system reduces or even eliminates the use of sulphide and is reported to produce a superior pelt but it is relatively expensive to use.

Once the wool and hair have been removed and the unwanted skin components dissolved then the pH must be lowered in preparation for tanning. This process is commonly called "deliming".

Deliming is often initiated by the addition of ammonium salts which both lower the pH and buffer the skins at around pH 9. The alkaline swelling is reduced and the skins can now be washed to remove wool and dissolved materials. Recently the use of ammonia salts in deliming has come under scrutiny from Environmental Authorities due to the ammonia in the effluent.

The fellmonger may at this stage add an enzyme or enzymes (bate) to assist in removal of the epidermis (scud).

The de-limed skin can then be graded and processed through to wet blue, blue crust or may be preserved for transport to the tanner. Preservation of pelts is generally by pickling which involves soaking the de-limed skins in a mixture of salt and acid, usually sulphuric but sometimes in combination with formic acid. Acid hydrolysis of the pelt may occur especially at high ambient temperatures, hence the need to carefully monitor acid levels. It is also necessary to include a fungicide for long term preservation.

(iii) Effluent

The fellmongering industry produces a number of unwanted by-products in its effluent including the chemicals used in the dehairing, liming and pickling operations. With growing awareness of hazards in the workplace, and the introduction of legislation to control them, the fellmonger may be obliged to replace toxic chemicals with less toxic ones. Chemical effluents can be minimised or even eliminated in a number of ways. These include replacement with a non-toxic alternative, better process control so that excess chemical is not released in the effluent and recovery of the chemical from the effluent. Recycling can also reduce the volume of chemical in the effluent eg. recycling lime liquors reuses the lime, and is claimed to be a better depilatory than fresh lime. The unavoidable components of the effluent from the fellmongery are wool, breakdown products of skin and wool, fat and dirt. These are unavoidable components of the raw effluent, and hence cannot be replaced by alternatives, however some can be minimised. Hair breakdown products, for example, can be reduced by using just enough sharpening agent to loosen the wool in the follicle, rather than dissolve the whole shaft. Wool fibres are easier to recovery than dissolved substances. Recycling liquors such as lime, as mentioned above, can produce a concentrated effluent, from which it may be easier to recover dissolved material.

It is desirable to replace noxious chemicals with more environmentally acceptable chemicals. A simple price comparison is not sufficient when assessing the cost of using a chemical. The total cost of using a chemical includes the purchase price, special precautions required for its use and the effluent treatment cost.

OBJECTIVES

(i) To develop procedures for the short term preservation (5-7 days) of sheep skins which are compatible with acetate fellmongering.

(ii) To evaluate procedures which are found to be technically feasible in terms of cost and environmental acceptability.

(iii) To investigate and develop procedures for fellmongering long term (3-4 months) preserved skins which are compatible with acetate fellmongering. (This is secondary to short term preservation since it would confer no particular advantage to the Australian sheep skin industry).

(iv) To evaluate procedures which are found to be technically feasible in terms of cost and environmental acceptability.

(v) To develop alternative fellmongering techniques, and to evaluate all depilation development work in terms of cost and environmental acceptability. The development of environmentally acceptable techniques for depilation of fresh, short and/or long term

preserved skins will seek to minimise water consumption and produce an effluent that is suitable for low cost land based treatment and disposal.

METHODOLOGY

(i) Skins

Green skins were purchased from, or donated by the W.A. Meat Marketing Corporation Robb Jetty, Metro Meats Pty Ltd Katanning or Western Australian Pelt Processors Wongan Hills.

(ii) Skin Enzymes

Enzyme activities were measured using punched skin pieces or extracts of skin samples. Skin samples were hand shorn, cut into 20mm x 5mm strips and frozen at -20°C. These pieces were subsequently frozen in liquid nitrogen then ground in a Thomas-Wiley intermediate mill, fitted with a 40 mesh screen, which had also been cooled with liquid nitrogen. The ground tissues were stored at -20°C or vacuum dried in an FTS freeze drier then stored at -20°C. The ground material was mixed with an equal volume of chilled 0.9% saline and extracted at 4°C then centrifuged. The freeze dried material was reconstituted with chilled deionised water, or 1:10 diluted paint solution, to 10, 20, 40, 80, or 160 mg/mL, subsequently standardised to 20mg/mL, then extracted at 4°C and centrifuged. Enzyme activities were measured using the supernatants.

Polysaccharidase activity was measured using chondroitin 4 sulphate, chondroitin 6 sulphate, dermatan sulphate or hyaluronic acid as substrates. Proteolytic activity was measured using skim milk powder (casein), bovine serum albumin, azocasein or haemoglobin as substrates. The pH range examined was 3.5 to 5.0. Agarose gels were prepared by dissolving agarose (2% w/v) in deionised water in a boiling water bath. The substrate (2 mg/mL) was dissolved in a 1:10 dilution of the standard paint solution which had been adjusted to the required pH. Equal volumes of the gel and substrate were mixed, then 5 mL of the mixture dispensed into 55 x 14 mm petri dishes (Disposable products) and allowed to set on a level surface.

Punched (5 mm diameter) skin samples were washed with deionised water and placed on the gel. Four or five skin samples were placed on each dish, equidistant from each other and 10 mm from the edge. Alternatively 20 µL aliquots of the supernatant were dispensed into holes, 5 mm in diameter, punched equidistant from each other and 10 mm from the edge of the dish. The dishes were covered and placed in a sealed plastic container on several layers of tissue paper, saturated with deionised water, and incubated overnight at 37°C.

The polysaccharide gels were stained for 6 hours with 0.2% (w/v) toluidine blue in 0.1M acetic acid then destained overnight with 0.1M acetic acid (or deionised water for hyaluronic acid). The protein gels were stained with 0.01% (w/v) Coomassie brilliant blue (R250) in Coomassie destain (25% (v/v) ethyl alcohol plus 10% (v/v) acetic acid in deionised water) for 6 hours then destained overnight. The enzyme activity was measured from the unstained area surrounding the skin piece or punched hole.

(iii) Acetate Paints

Technical grade reagents were used throughout. Acetic acid was diluted to 40% (v/v) or 20% (v/v) with deionised water and the pH was adjusted by the addition of sodium hydroxide. A number of paints were prepared in increments of 0.25 pH units to cover the range 3.0 - 5.0. A control paint was made up of 38 parts acetic acid, 19 parts sodium acetate and 43 parts deionised water and the pH adjusted to 4.0. The paints were sprayed onto skins which were then incubated for 16 hours at 35°C and 90% relative humidity. The application rate was measured by weighing the spray bottle before and after spraying each skin.

Reduced strength (1:10) paint solutions were prepared by diluting the full strength material with deionised water and readjusting the pH with concentrated acetic acid or sodium hydroxide solutions.

(iv) Air drying

Skins were cut into 300 x 460 mm pieces, weighed and hung flesh side out in the shade under ambient conditions or in a chiller at 4°C. Daily, the pieces were weighed and one piece was painted with acetate depilatory and incubated for 16 hours at 37°C and 90% relative humidity. Depilation was assessed manually and in a limited number of studies the depilation index was determined, as described below. When depilation became difficult, pieces were wet back by soaking overnight in saline before being painted with acetate paint.

(v) Vacuum drying

Skin pieces (approx. 150 x 400 mm) were weighed and vacuum dried in an FTS Systems freeze drier. Water loss was measured by weighing the pieces every day and drying continued until a constant weight was achieved. Half the pieces were immediately wet back by soaking for 24 hours in 0.9% NaCl, whereas the other half were kept on the bench, under ambient conditions, for 7 days before being wet back. After wetting back the pieces were painted, incubated at 37°C and 90% relative humidity, then the ease of depilation was assessed manually after 16 or 40 hours incubation.

(vi) Freezing

Skin pieces were folded, in half down the midline, flesh to flesh, sealed in plastic bags and stored at -20°C. The pieces were removed at various times and the effectiveness of acetate depilation assessed.

Twenty five green skins were stacked on a standard pallet and the volume they occupied was measured. Quotes on the cost of refrigerated storage were obtained from a local cold store operator (P&O Cold Stores).

(vii) Incubator conditions

Green skins were obtained from the abattoir and half were folded down the backbone then stored overnight in a chiller to reduce skin temperature to around 4°C. The fresh or chilled green skins were painted or sprayed with acetate paint then incubated either folded, side to side,

or hung, on 25 x 25 mm poles, at 30°C or 35°C with a relative humidity setpoint in the range 35% to 95%. The ease of depilation was manually assessed after 16-20 hours incubation.

(viii) Plate freezer trials

A plate freezer was constructed from a standard (1143 x 1530 mm) aluminium freezer plate (Acme refrigeration) connected to a Kirby/Tecumseh condensing unit (AH2467JB1). An extra receiver was incorporated to accommodate the large volume of refrigerant held in the plate. The refrigeration plant was able to reduce the surface temperature of the unloaded plate to -40°C.

From a fresh skin a rectangle of 460 x 300 mm was cut. This was split across the backbone to give two samples of 300 x 230 mm. The samples were cooled on the plate freezer then folded. Eight samples were put into a 20 L polystyrene "lobster box". Temperature probes were placed into the centre of the skin pieces and beneath the bottom skin and the temperatures logged overnight. This was repeated for different times and positions on the plate.

Two trials were conducted at a country abattoir (295 km from Perth) in mid autumn. Skins were placed on the plate freezer for 20 to 30 seconds, then folded flesh to flesh and stacked or stacked flesh to flesh. As a control, untreated skins were similarly folded and stacked. A third stack was made of skins which had been sprayed with acetate paint. Temperature probes were placed at regular intervals within the three stacks. The skins were transported to Perth and temperatures logged. The next day skin "freshness" was assessed. Representative samples of the skins were fellmongered and pickled as described elsewhere. A similar trial in mid winter took skins from Perth to Wongan Hills (200 km) for same day fellmongering and subsequent pickling. Ease of depilation was assessed by the operator of the wool pulling machine. Representative samples were tanned.

(ix) Carbon dioxide (CO_2) chilling

Skins were chilled with CO_2 "snow" using a snow horn, which produces solid CO_2 from liquid CO_2. The use of the equipment and liquid CO_2 were donated by C.I.G. The volume of liquid to chill the skins was measured by weighing the gas bottle before and after spraying the skins. The skins were stacked flesh to flesh, put into a chiller at 4°C and the temperature in the middle of the stack monitored. The skins were left uncovered in the chiller for 26 days, removed, acetate painted and incubated overnight at 35°C and 75% relative humidity. Ease of depilation was assessed manually.

Skins were snowed for 5, 10, 20 or 30 seconds, an untreated control was included. The skins were then transported to Wongan Hills (mid winter) for fellmongering and pickling. The temperature was monitored during transport. The skins were left in a pile overnight before being fellmongered. Ease of depilation was assessed both manually and from the amount of wool left on the pelt after two passes through a wool pulling machine. The pelts were pickled and representative samples were tanned.

(x) Chemical preservation

Chemicals assessed were acetic acid, sodium metabisulphite and Vantoc CL (ICI). Skins were painted with the chemical preservative, folded and stacked then covered with hessian or placed into a plastic bag and left for up to 7 days. Depilation was assessed manually and the skins limed and pickled as described in section (xv).

(xi) Depilation index

To quantitate wool looseness, a modification of the depilation index described by Lennox (1945) was determined. The force needed to remove different sized staples, at a speed of 500 mm/min, was measured using an Instron 1122 Universal Testing Machine. The staple was trimmed, from the outer end, into 2 cm or 5 cm lengths and weighed. The depilation index used, was the calculated slope of the linear regression between depilation force and staple weight per cm.

(xii) Shrinkage temperature

Shrinkage temperatures (T_S) were generally measured on either dewooled or pickled pelts which had been equilibrated overnight in a solution of 0.2% sodium acetate as recommended by Massey University (Anon.). In some experiments the skins/pelts were not equilibrated, and T_S was measured in air. The temperature at which the collagen failed (T_F) was measured by continuing to heat the sample beyond T_S at approximately 2°C per minute until the peak tension had fallen by 10%. The shape of the upper portion of the tension versus temperature curve closely followed a second order polynomial which, after curve fitting, was differentiated to solve for T_F (Fig. 1).

(xiii) Model liming experiments

Pieces of knitting wool (5 ply Cleckheaton for preliminary testing then 8 ply Panda Domino for the main experiments) were prepared by tying 3 cm loops with approximately 18 cm between knots and, after folding in the middle, placed in 3DT tubes (Disposable Products). One mL of the liming solution was added and, after incubation, the breaking tension of the wool measured using an Instron 1122 Universal Testing Machine. Five or six replicates were measured for each solution. In a preliminary experiment the wool was exposed to 2 mL of 2% (w/v) lime or 2% (w/v) sodium sulphide for 4 hours before incubating for 16 hours in 1 mL of 2% (w/v) lime plus 2% (w/v) sodium sulphide.

(xiv) Incubator conditions

The incubator (internal volume of 12m^3) was constructed using 100 mm colorbond and styrene sandwich panel. It was heated using a 1.2 kW single phase fan heater, with humidity provided by two 1.5 kW humidifiers and the air continuously circulated using a 100 W centrifugal fan. The humidifiers were based on a simple system of two carbon electrodes in a small volume of water. This method has a built in safety feature in that the current stops when the water level drops below the bottom of the electrodes. Humidity and temperature control was achieved using a Hewlett Packard HP3497A Data Acquisition and Control Unit controlled by an IBM PC 'XT' compatible computer. This unit monitored the skin temperature, wet bulb temperature and dry bulb temperature and calculated the relative humidity.

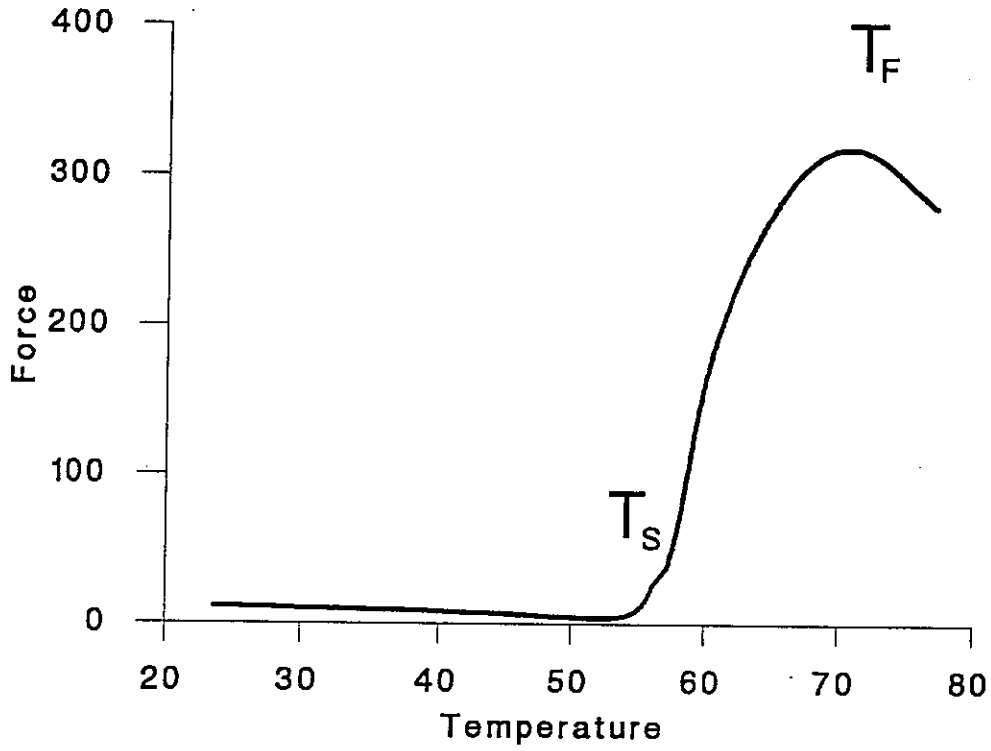

Fig. 1. Measurement of the shrinkage (T_S) and failure (T_F) temperatures.

The humidity and dry bulb temperature was used to control the humidifiers and air heater. Dry bulb temperature was regulated to setpoint ± 0.2°C and the humidity to setpoint ± 2%. Figure 2 shows a typical plot of conditions inside the incubator during an overnight incubation.

Skins were painted, folded flesh to flesh and placed on slotted racks or hung on 25 x 25 mm poles in the incubator. Some of the skins hung on poles were painted with the control paint which had been thickened with cornstarch. The temperature was set to 30°C or 35°C, and the relative humidity in the range 35% to 95%.

(xv) Liming and pickling

The mass or volume of chemical used was based on the dewooled pelt weight, 100% corresponds to the weight of the pelts.

(a) Pelts were drummed for 30 min in 125% water and 1.35% sodium carbonate, then running drained for 30 min. One hundred percent of 0.02% 2-mercaptoethanol in sodium hydroxide at pH 12 was added and drummed for 60 min. The float was increased to 250% with water, 2-mercaptoethanol added to 0.2%, the pH adjusted to 12.0 with sodium hydroxide and left overnight with occasional drumming for 1-2 min. In the morning the pelts were drummed for 30 min then given a running wash for 30 min. The float was adjusted to 200% with water and ammonium chloride added to 3%. The pelts were then drummed for 30 min, the skins drained and given a running wash for 30 min. The float was adjusted to 100% with water and 10% sodium chloride added. The skins were drummed for 30 min and the pH was then adjusted to 2.0 by the addition of sulphuric acid. The pelts were horsed for two days, trimmed then packed in plastic bags and stored.

(b) Pelts were drummed for 30 min in 125% water and 1.35% sodium carbonate, then running drained for 30 min and refloated to 50%. Sodium sulphide was added as a slurry to 1% and then drummed for 30 min. Lime was added to 5%, again as a slurry, drummed for 30 min and then left overnight. Next morning the pelts were drummed for 30 min, running washed for 30 min, then refloated to 100% with water, 2.5% hydrogen peroxide added and run for a further 30 min. Ammonium chloride was added to 2.5% and run for 30 min, then running drained for 30 min. Sodium chloride was added to 15%, the pH adjusted to 2.0 by the addition of sulphuric acid then 0.25% Busan 30 was added. The skins were dumped into a container, left overnight then horsed for two days, trimmed, packed in plastic bags and stored.

(c) Skins were washed and running drained for 30 min, floated to 100% and 2% of the sharpening agent being tested was added, followed by 1-2 hours drumming. Sodium hydroxide was added slowly until the pH was 12.5 and the skins drummed (4 rpm) for 5 minutes in each hour overnight. The skins were drained and washed for 10 minutes, then ammonium chloride was added until the pH had fallen to around 8 and the phenolphthalein indicator remained clear when applied to the pelts. The skins were washed with a running drain for 15 min. The float was adjusted to 100% with water and salt added to a Beaume of 10 (about 11%). The pH was adjusted to 2.0 by the addition of 10% sulphuric acid and 0.25% of Busan 30 added. The skins were dumped into a container with the pickle liquor and left overnight. Horsed for 2 days and stored in plastic bags.

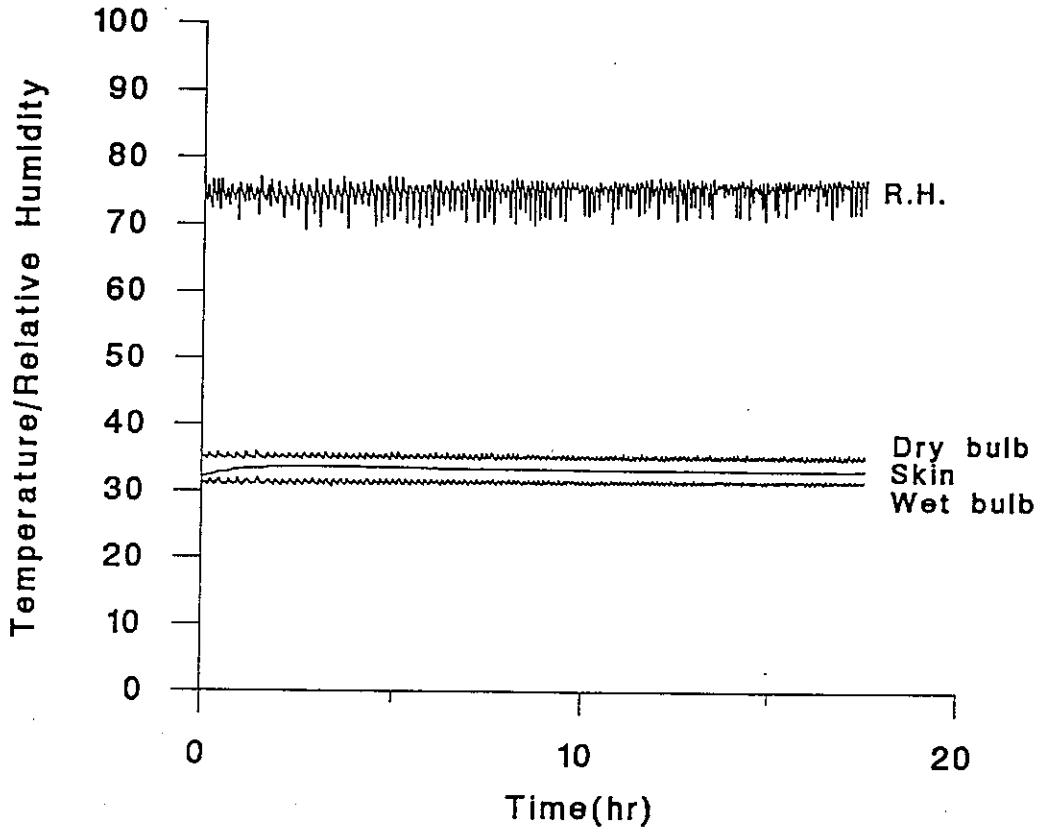

Fig. 2. A typical recording of dry bulb temperature, wet bulb temperature, skin temperature and calculated relative humidity during an overnight incubation.

(d) Skins were floated to 125%, neutralised with 1.35% sodium carbonate and drummed for 30 minutes, drained then running drained for 30 minutes. The float was adjusted to 100% and 1% Mollescal SF added, drummed for 1 hour then 2% sodium sulphide added. After drumming for 30 minutes, 2% lime was added, drummed for 15 minutes then left overnight to drum for 5 minutes in every hour. The skins were drained and running washed for 10 minutes, float adjusted to 100% and 2.5% ammonium chloride added and drummed for 30 minutes. After draining the float was adjusted to 100% and 10% sodium chloride added. The pH was adjusted to 2.0 ,with 10% sulphuric acid, then 0.25% Busan 30 added. The pickled pelts were dumped into a container with the pickle liquor, left overnight, horsed and then stored in plastic bags.

The quality of the pickled pelts was assessed by feel, visual inspection and in some cases by measuring shrinkage temperature. In the latter part of the study, pelt quality was also assessed after liming or on neutralised pickled pelts by the application of Sortassist (Hodgson Chemicals). At the request of a local tanner, Sortassist was used to assess the quality of commercially produced pickled pelts.

(xvi) Histological evaluation of acetate depilation

Skin samples were taken (a) prior to and after incubation overnight at 37°C, (b) prior to and after incubation at room temperature (with or without acetate preservation) and again after incubating at 37°C or (c) prior to and after drying for 1, 2, 5 and 23 days. The pieces were placed into 10% buffered formalin which was replaced with fresh buffer after 24 hours. The specimens were blocked in paraffin, sectioned into 5 μm slices, mounted on glass slides and stained with haematoxylin and eosin for structural evaluation or with Gram's stain for gram positive bacteria.

FINDINGS AND CONCLUSIONS

RESULTS

(i) Characterisation of skin enzymic activities

Glycosaminoglycanase activities

The size of the clear area of the gel, around where the skin piece had been placed, is a measure of the enzymic activity. The relationship between concentration of ground skin and clear area (after correction for the size of the well) is shown in Fig. 3. The measured coefficient of variation (C.V.) was not influenced by substrate or by pH and ranged from 2.6 to 15.1 (Mean = 5.41, S.D. = 3.38) (Fig. 4). Maximum enzymic activity of skin pieces on substrates of hyaluronic acid, chondroitin 4 sulphate or chondroitin 6 sulphate was pH 4.5 (Fig. 5). Maximum activity of extracts from ground skin against dermatan sulphate, chondroitin 4 sulphate or chondroitin 6 sulphate was also at pH 4.5 (Fig. 6).

The pH dependence of the enzymic activity present in deionised water extracts of freeze dried ground skin is shown in Fig. 6, and for the 1:10 buffer extracts in Fig. 7.

Overall the optimal pH to determine glycosaminoglycanase activities was in the pH range 4.0 to 4.5.

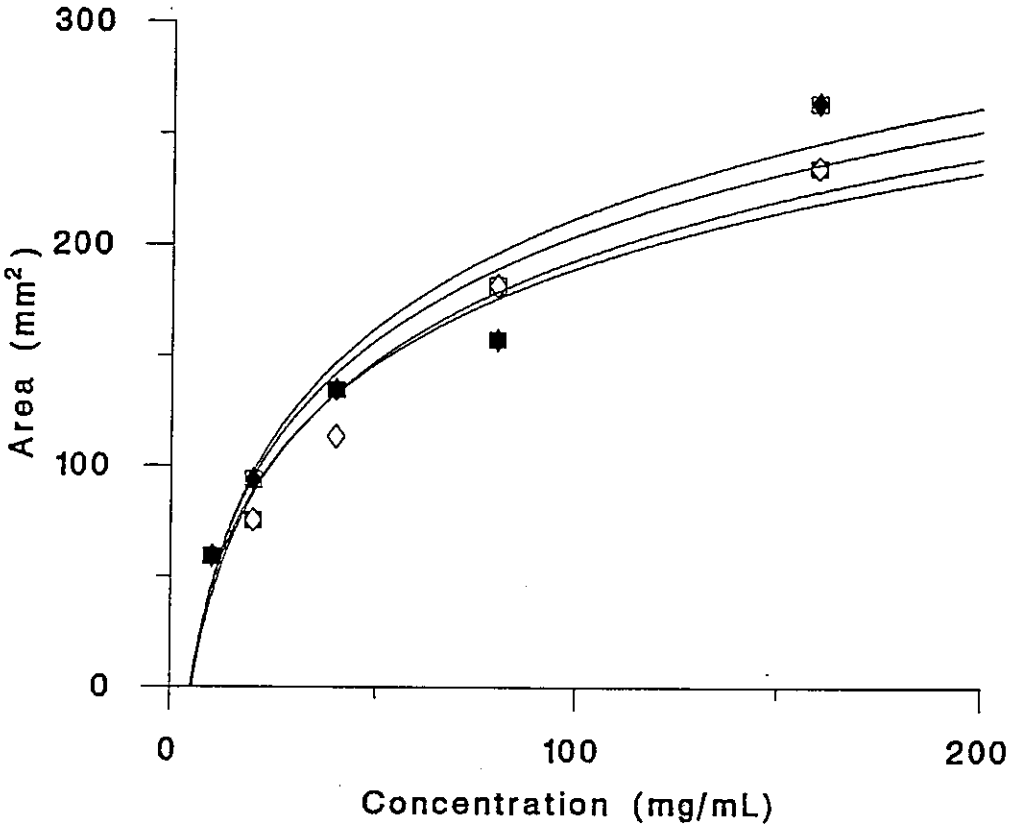

Fig. 3. Plots of cleared area versus concentration of ground skin at various pH's. The substrate was chondroitin 6 sulphate. The pH's were (□) 3.5, (■) 4.0, (◊) 4.5 and (♦) 5.0.

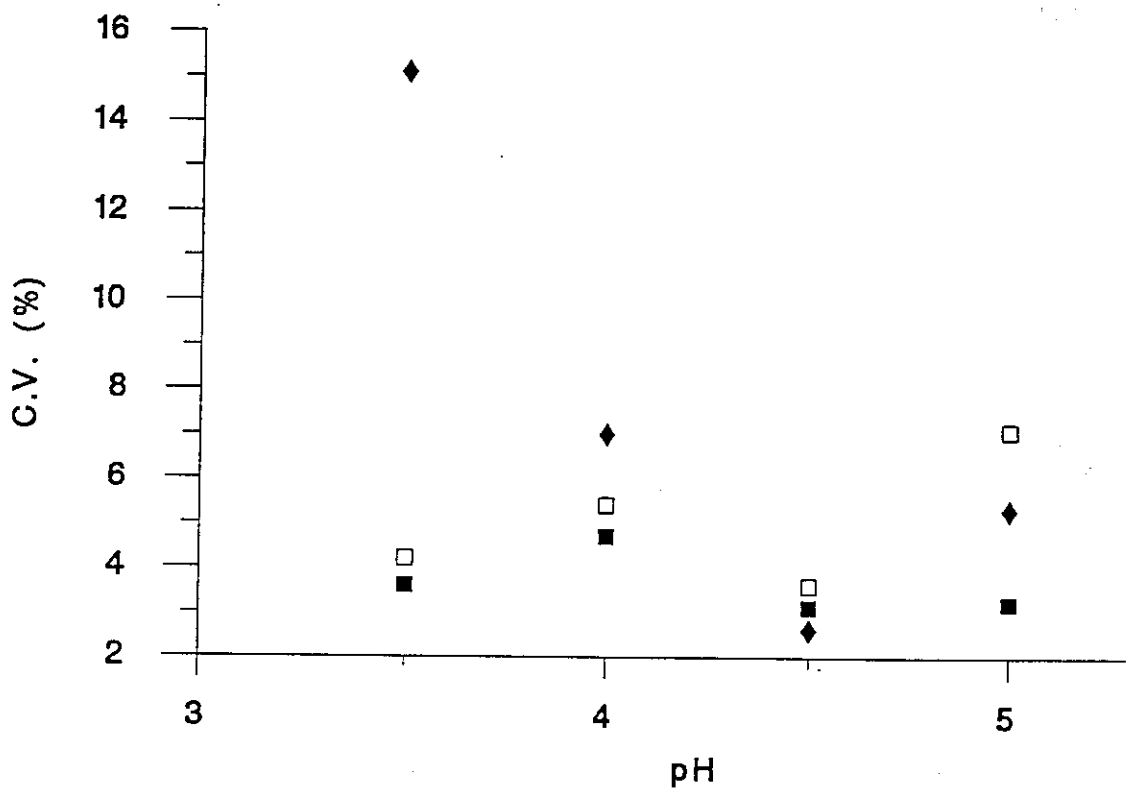

Fig. 4. Effect of pH on the coefficient of variation (C.V.). The substrates were (□) hyaluronic acid, (■) chondriotin 4 sulphate and (♦) chondroitin 6 sulphate.

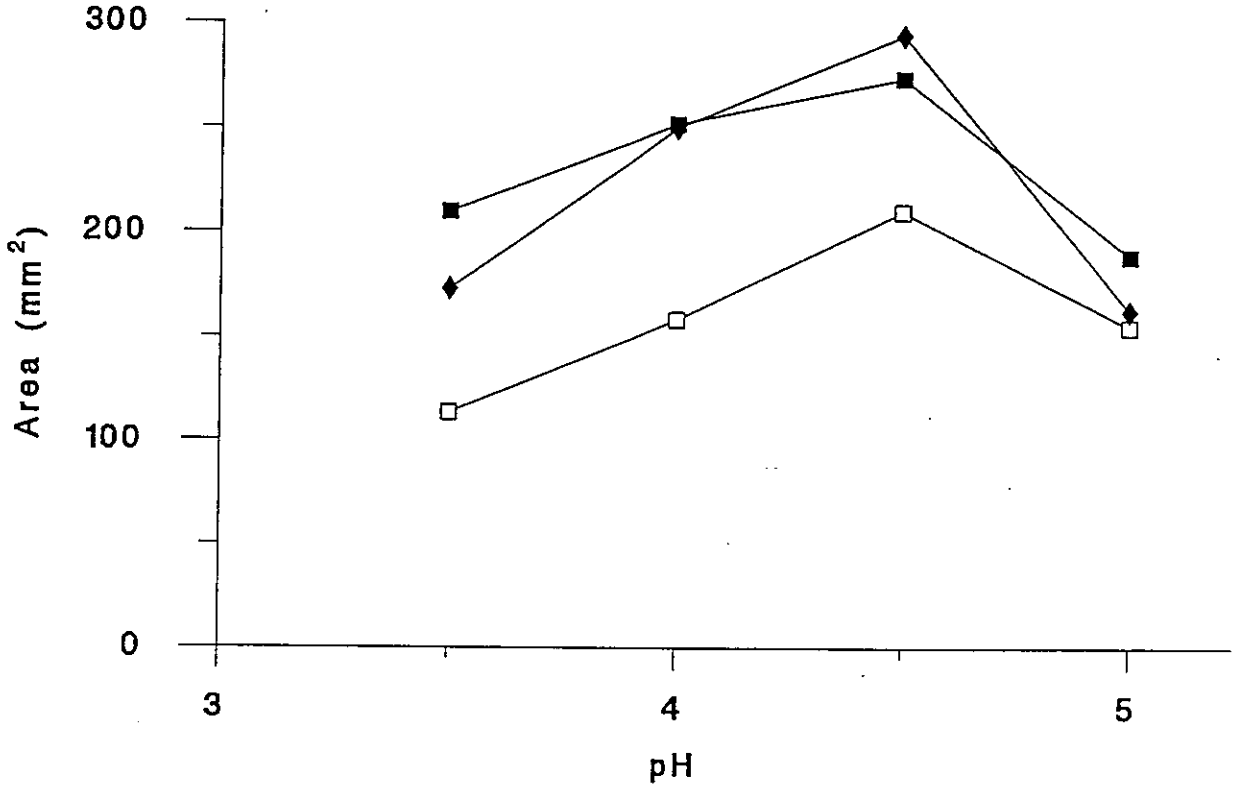

Fig. 5. The effects of pH on the enzymic activities of skin punches. The substrates were (■) chondroitin 4 sulphate, (□) hyaluronic acid and (♦) chondroitin 6 sulphate.

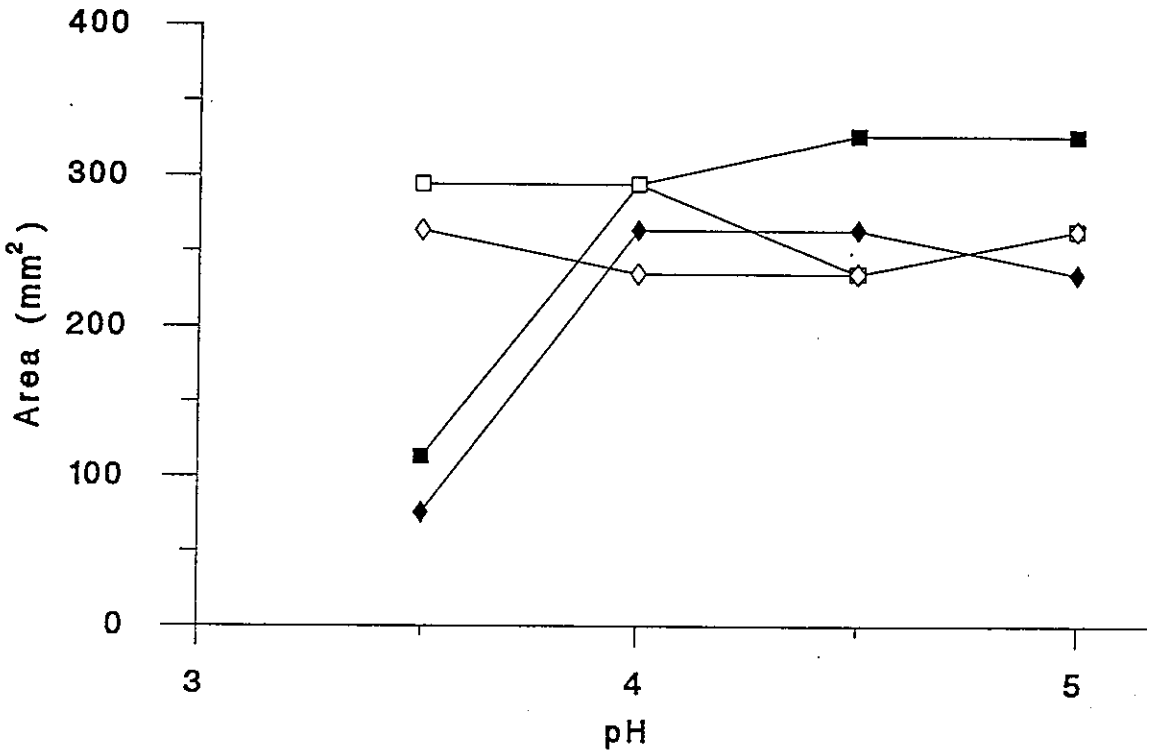

Fig. 6. The effects of pH on the enzymic activities present in deionised water extracts of powdered skin. The substrates were (■) dermatan sulphate, (□) chondroitin B sulphate, (♦) chondroitin 6 sulphate and (◊) chondroitin 4 sulphate.

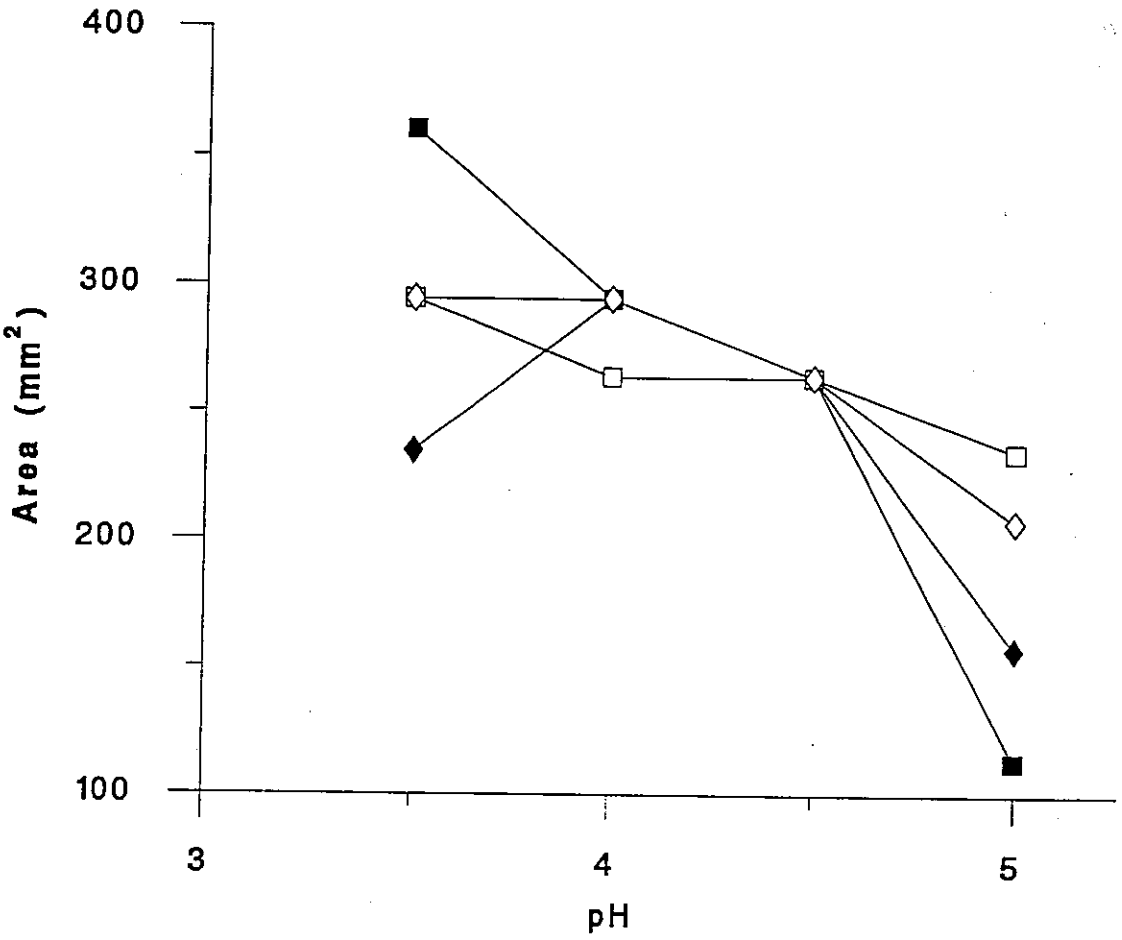

Fig. 7. The effects of pH on the enzymic activities present in acetate buffer extracts of powdered skin. The substrates were (■) dermatan sulphate, (□) chondroitin B sulphate, (♦) chondroitin 6 sulphate and (◊) chondroitin 4 sulphate.

Protease activity

In general leaching of protein from ground reconstituted skins made estimation of proteolytic activity extremely difficult. These proteins were stained in the gels and masked any clearance of the substrate from the gel. With the coloured substrates, azocasein or haemoglobin, no clearing of colour around the wells was observed. In addition the limited solubility of haemoglobin at low pH made it unsuitable as a substrate.

Skin punches showed proteolytic activity against casein but not against serum albumin. Proteolytic activity was detected by clearing of the gel prior to staining and also during the initial destain. However, in some experiments, the casein diffused from the gel during destaining so the final ring diameter could not be determined.

(ii) Air drying

As skins dried in air the ease of wool removal remained relatively constant and then abruptly became more difficult as the water loss approached 70% (Fig. 8). In summer this took less than a day, whereas in winter it took up to 5-6 days. Drying the skins in a chiller at 4°C did not prevent loss of acetate depilation. Soaking the partially dried skins in water prior to painting with acetate paint did not improve depilation. Prior painting of the skins with acetate paint did not prevent loss of depilation with drying.

No consistent effects of drying on enzymic activities, at the different pH's, were observed during drying over 5 - 7 days, whether measured using skin punches (Fig. 9) or extracts of ground skin (Fig. 10). With the exception of the activity against hyaluronic acid, freezing, grinding and then freeze drying did not affect enzymic activity. Activity against hyaluronic acid was virtually destroyed during processing.

No significant decrease in proteolytic activity against casein was observed, although the skin could not be acetate depilated on the fifth day of drying.

(iii) Vacuum drying

Vacuum dried skins were successfully depilated after wetting back. However when stored, unsealed, at room temperature they absorbed water from the air and could not then be acetate depilated, even though they regained as little as 20% of the original water lost.

(iv) Chilling and freezing

Skins which had been stored at 0°C, 5°C or 10°C for up to 7 days were successfully depilated following painting with acetate buffer and incubation at 37°C for 16 hours. No significant decline in the enzymic activities during storage of these skins occurred.

Skin pieces stored frozen for 2 weeks could be acetate depilated and there was no decrease in glycosaminoglycanase activities.

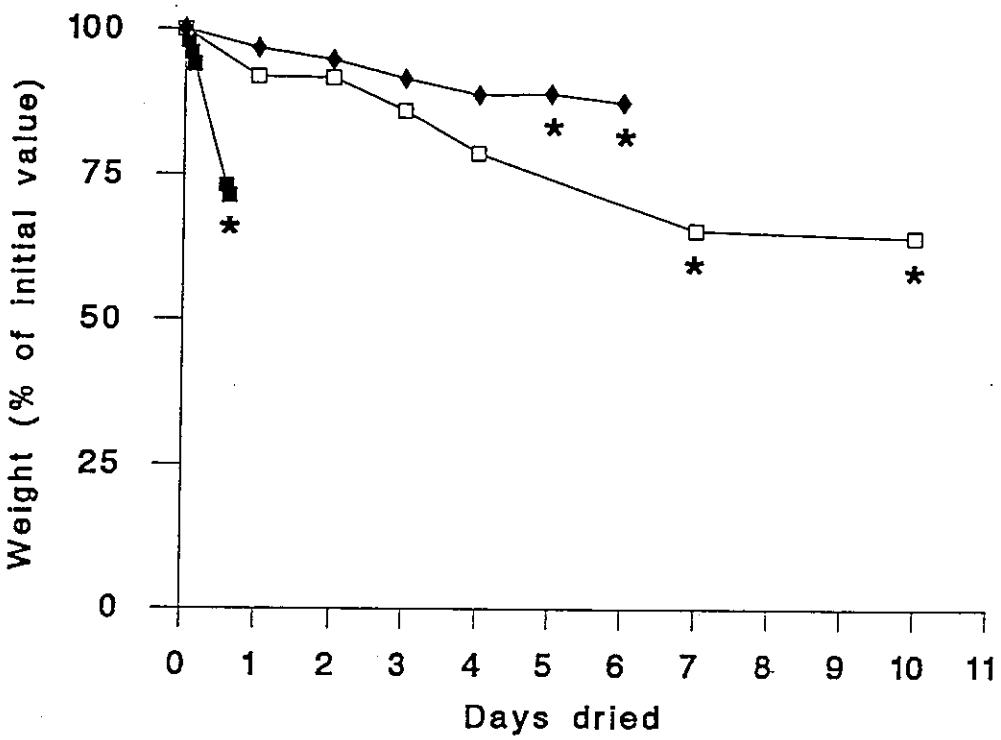

Fig. 8. Time course of weight loss and ease of depilation for skins dried in air during (■) summer, (□) winter or in a (♦) 4°C chiller. (✶) indicates difficult depilation.

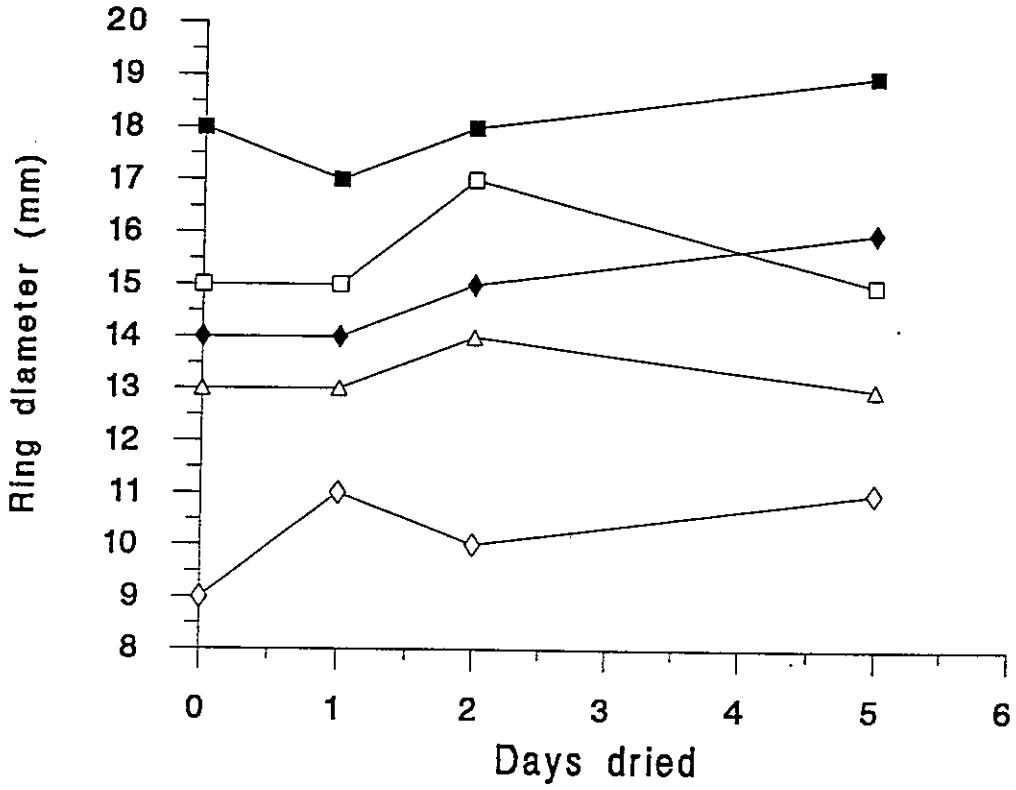

Fig. 9. Effect of drying on enzymic activities present in skin punches. The substrates were (■) casein, (□) hyaluronic acid, (♦) dermatan sulphate, (◊) chondroitin B sulphate and (△) chondroitin 6 sulphate.

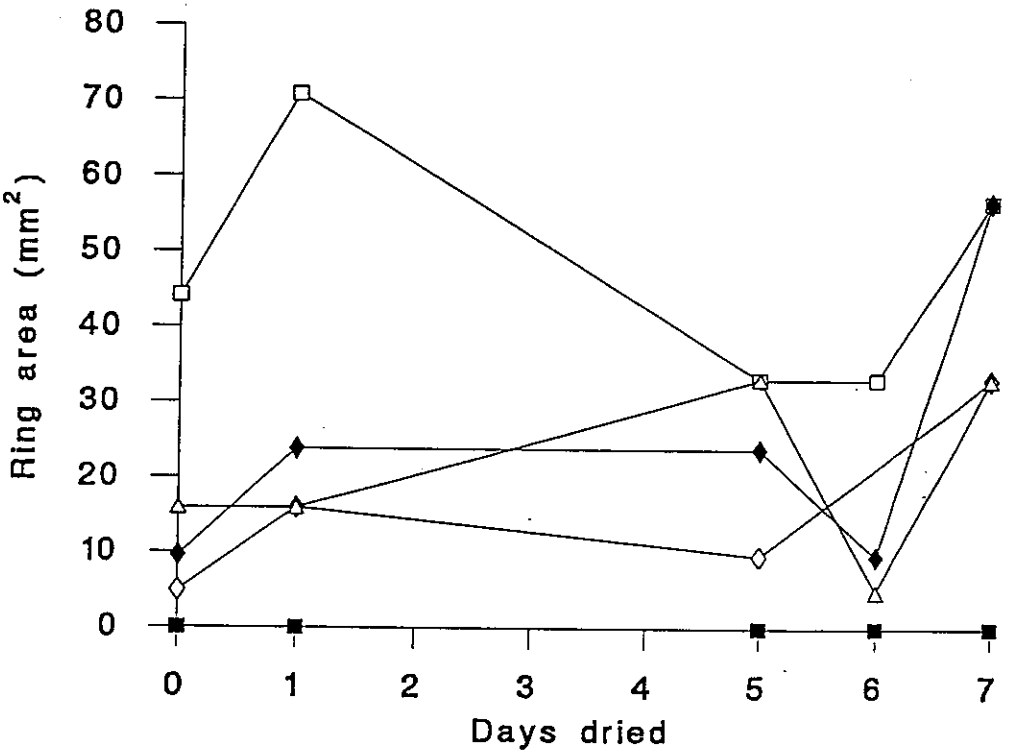

Fig. 10. Effect of drying on the enzymic activities of ground skin. The substrates were (■) hyaluronic acid, (□) dermatan sulphate, (◊) chondroitin B sulphate, (♦) chondroitin 6 sulphate and (Δ) chondroitin 4 sulphate.

It was found that approximately 200 skins with "1 inch" wool could be stacked on a pallet to a total height of "4 foot 6 inches" (current terminology). The present cost of storing such a pallet at 4°C or -20°C is $6.50 per week plus a one off handling charge of $12.00. Storage for a month would cost $0.19/skin or $0.45/skin for 3 months, exclusive of pallet packing and transport costs.

(v) Plate freezing

Green skin pieces were successfully cooled, without sticking to the surface of the plate freezer. There was some variation from skin to skin and position on the plate, however the skin temperature could be reduced to 4°C or less within 30 seconds (Fig. 11). Some patches of frozen skin were always found when the average skin temperature was reduced to 4°C. However when the skins subsequently were folded, or placed skin to skin, the temperature rapidly equilibrated. Longer times on the plate led to skin freezing and increased the time that the skin stayed frozen after its removal from the plate (Fig. 12). The larger the area of frozen skin the more difficult it was to fold the skin, although face to face stacking was possible. When whole skins were chilled, face to face stacking led to larger areas of the skin drying out compared to skins folded in half.

In the abattoir trials, the temperatures of untreated skins were found to increase initially, then fall but were still above ambient after 24 hours (Fig. 13). In general, the temperature of skins at the centre of the pack were higher and remained elevated for a longer time than those at the top and bottom of the stack. The maximum temperature occurred within 5 to 10 hours after stacking and was in the range 28.5°C - 32.5°C. The chilled skins gained heat during storage and by 15 hours the temperatures had stabilised to near ambient 21.8°C ± 1.0°C (mean ± S.D.) whereas the average temperature of the untreated skins was 5.8°C higher (27.6°C ± 1.8°C).

After 24 hours the untreated skins were putrid, and in the process of becoming flyblown. In contrast, the chilled skins were acceptable even after 48 hours. Depilation of the untreated skins, although possible, was unpleasant and more difficult than depilation of the previously chilled skins. However, the quality of the pickled pelts appeared to be unaffected.

The running costs involved in plate freezing/chilling are low. With two plates, one labourer would be able to process 4-6 skins per minute, assuming a labour cost of $10.00 per hour then the cost per skin is about 3 to 5 cents.

(vi) Carbon dioxide chilling

It was found that 1 kg of liquid CO_2 produced approximately 0.5 kg of snow and this was sufficient to surface freeze most of the surface of the skin. The skins rapidly equilibrated to 4°C. After 26 days in the chiller, the smell was acceptable, however the flesh side was mottled and coloured. Drying was quite marked at the periphery of the skins, especially where flesh had been exposed. Acetate depilation was found to be very difficult even on parts of the skin that did not appear to have dried. Skins chilled with CO_2 and fellmongered within 24 hours were readily depilated. It was found that a 5 to 10 second burst of CO_2 consumed 0.4 to 0.8 kg of liquid CO_2 and was sufficient to cool lamb skins to around 0°C to 15°C respectively (Fig. 14).

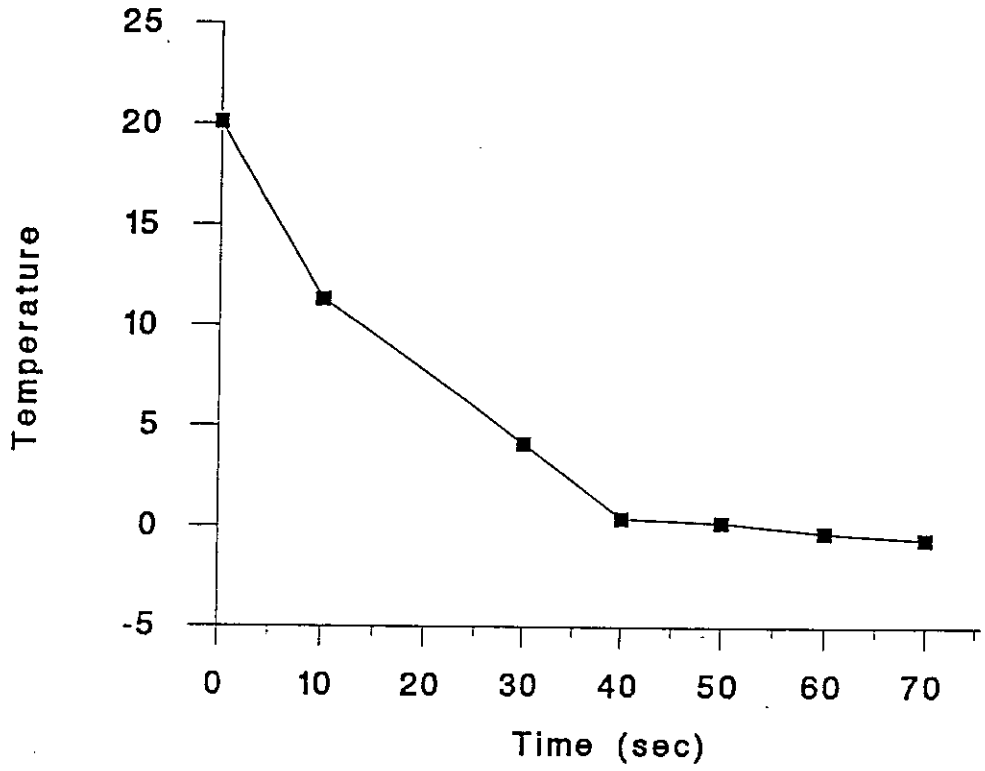

Fig. 11. Dependence of chilled skin temperature on the time on the plate freezer.

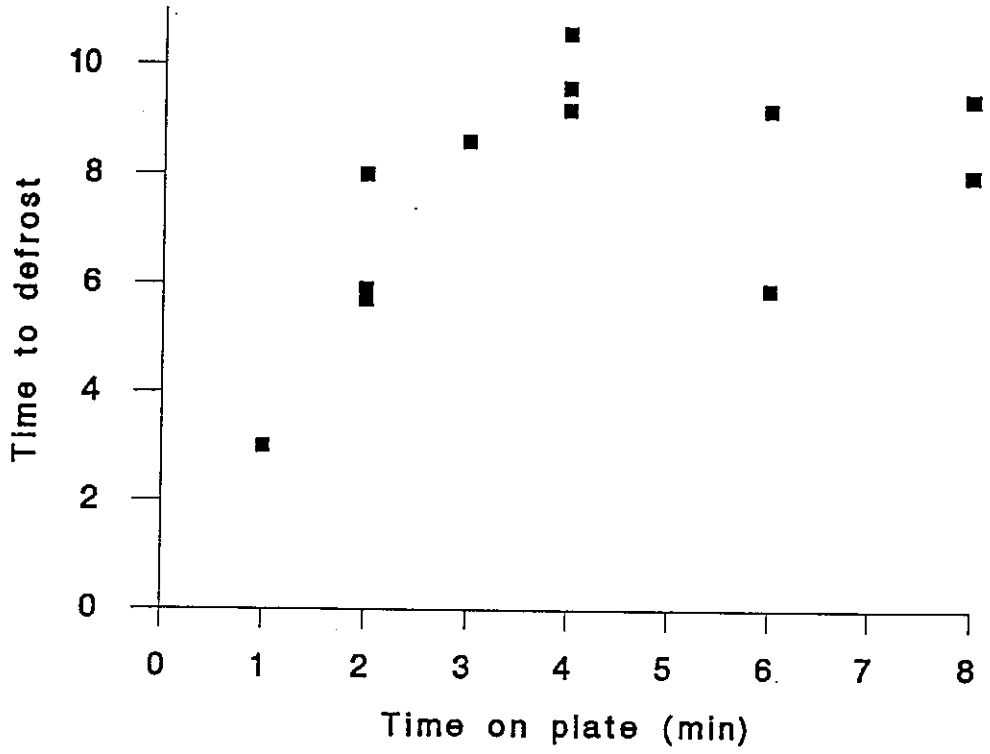

Fig. 12. Plot of time on the plate freezer versus the time required for the skin to defrost.

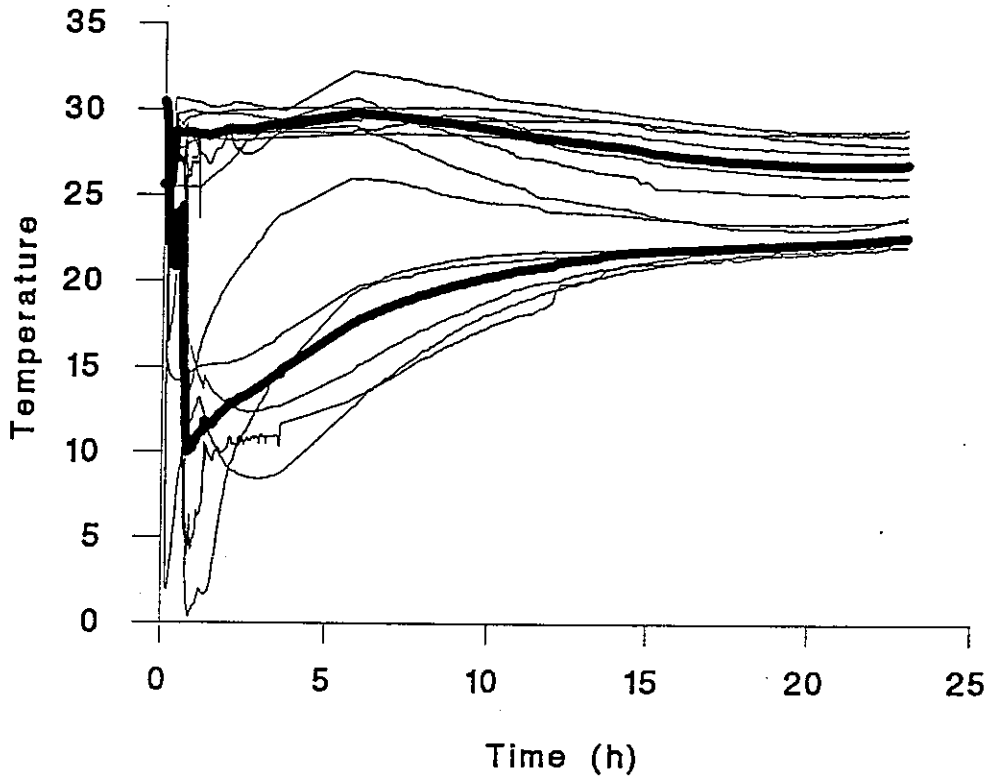

Fig. 13. Typical skin temperatures versus time plots obtained during the abattoir plate freezer trials. The lower six traces were for chilled skins and the top eight traces for untreated skins. The heavy lines are the averages.

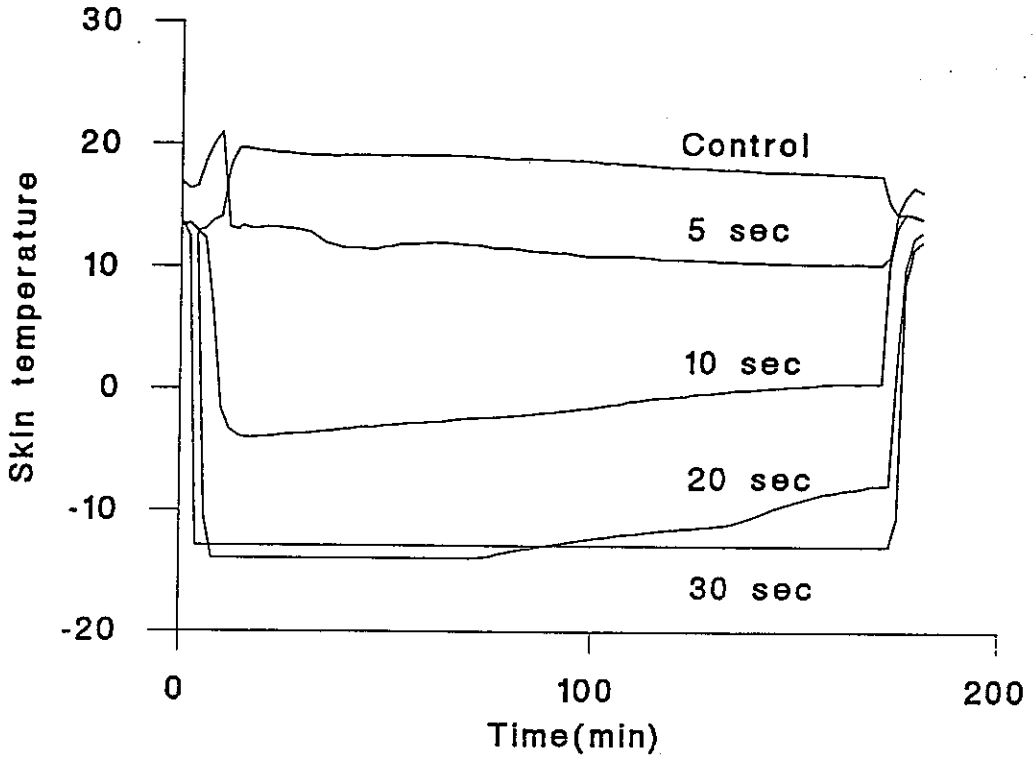

Fig. 14. Skin temperature profiles obtained after spraying with carbon dioxide for varying lengths of time.

The cost of CO_2 depends on the number of skins chilled per day and the desired skin temperature. A one off run of 460 skins would cost approximately $0.40 per skin to cool to 15°C, whereas a daily throughput of 2000 skins would cost approximately $0.08 per skin. To cool to 0°C would be twice as expensive. The labour costs associated with CO_2 chilling could be expected to be equivalent to or higher than those incurred in plate chilling.

The conversion rate of liquid to snow (1 kg liquid produced 0.48 kg of snow) was later confirmed by CIG in a large scale trial.

(vii) Chemical preservation

Skins sprayed with water, Vantoc CL (10%) or dilute acetic acid (2% v/v), with or without sodium metabisulphite and stored at room temperature for 7 days were maggoty and, with the exception of Vantoc CL, showed considerable fungal growth. After painting and incubation at 35°C for 16 hours, most of the wool could be removed from the skins but there were areas where removal was difficult. Skin enzymic activity was not affected by the preservative nor was there any significant decline during storage.

Skins sprayed with sodium metabisulphite (2% to 16%) were preserved for only one day, and after seven days were putrid. Skins sprayed with sodium metabisulphite (2% to 16%) then sprayed with acetate paint the following day were well preserved after seven days, however they could not be acetate depilated.

Skins which had been sprayed with acetate paint and placed into a stack were well preserved after 7 days storage at ambient temperature. They could be fellmongered without subsequent incubation at 35°C. Preservation did not appear to be affected by ambient temperature as trials in summer and winter gave the same result. The appearance and feel of the skins and the subsequent pickled pelts were unchanged during preservation. Storage had little, if any affect on the shrinkage temperatures (Fig. 15).

In the abattoir trials, skins sprayed with acetate paint did not show the rise in temperature seen with the untreated skins (Fig. 16). The temperatures of skins in the middle of the pack were higher than outside skins, although all skins cooled at approximately the same rate.

In autumn covering the skins with hessian did not prevent flystrike nor did enclosing the skins in plastic bags, although it appeared to delay it by a few days. Apart from the maggot damage, the skins were adequately preserved and fellmongered readily after 7 days without incubation at 35°C. The maggot damage was to the grain layer and confined to the periphery of the pelt. Pelt quality was good as assessed by feel, visual inspection and lack of uptake of the dye in Sortassist.

The cost of acetate preservation is effectively zero if the skin is to be subsequently acetate fellmongered.

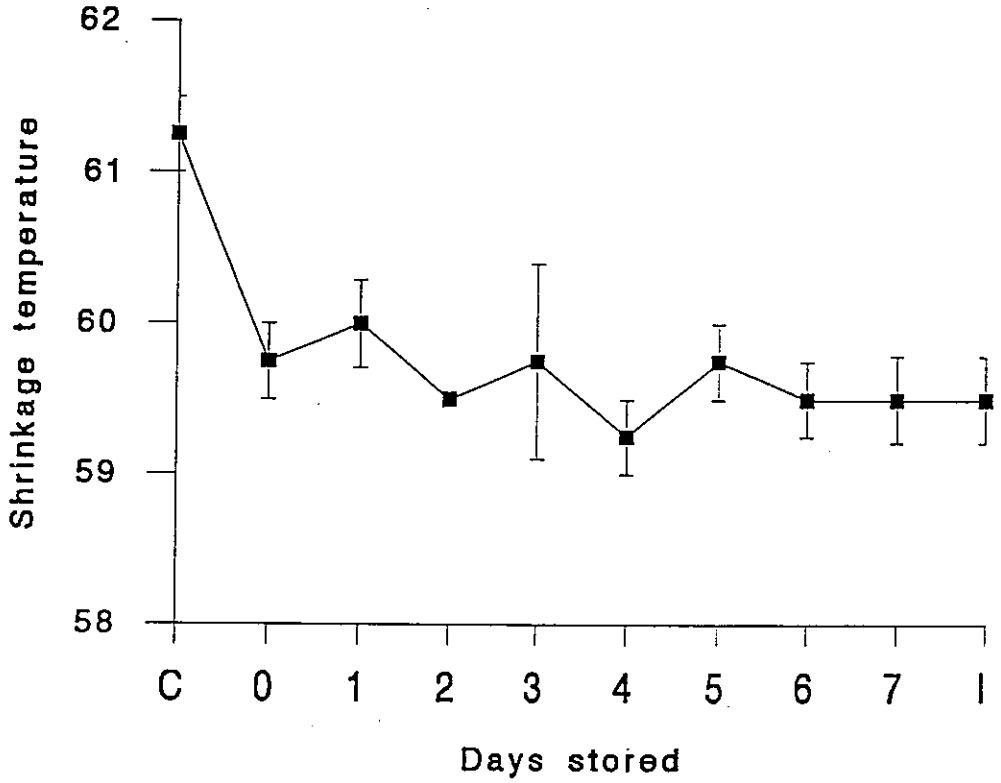

Fig. 15. The average shrinkage temperature (n = 4) obtained with samples of acetate preserved skins after various storage times. For comparison the values obtained with pre-painted (C) and post-incubated skin (I) are included.

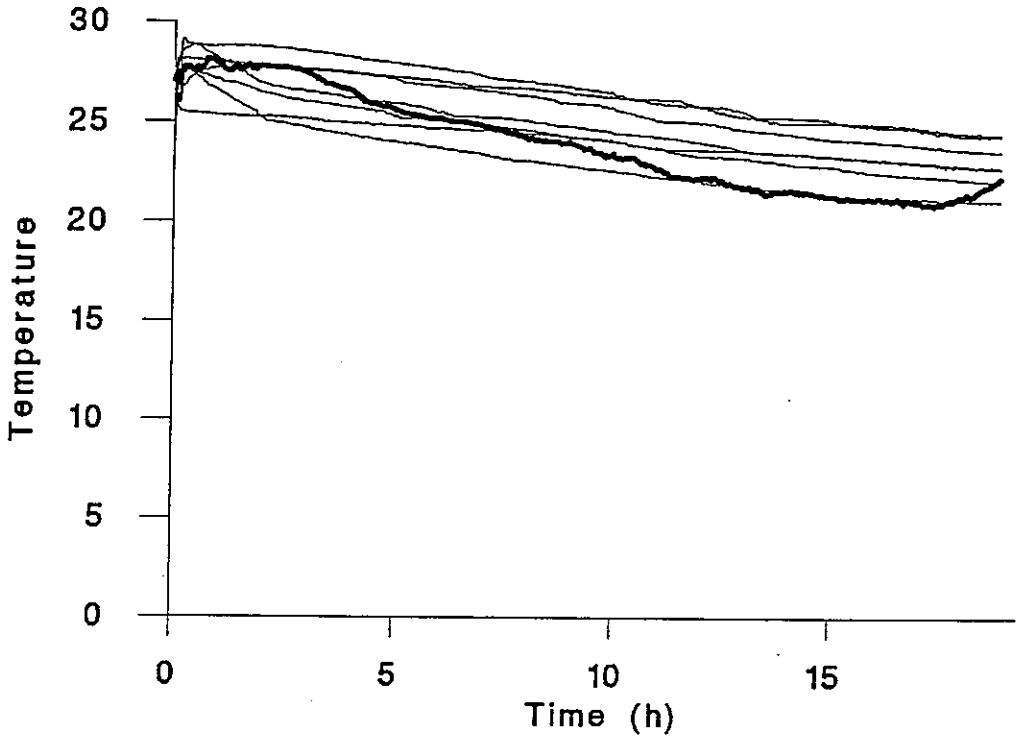

Fig. 16. Time/skin temperature profiles obtained with acetate buffer preserved skins during the abattoir trials. The heavy line is the ambient temperature.

(viii) Depilation index

Only reasonable linear correlations between the force required to pull the staple from the skin and staple size were obtained. However, few of the lines passed through zero (Fig. 17).

The intercept did not appear to be related to the ease of depilation, and the slope of the lines only approximated the manually assessed ease of depilation. By limiting the range of the data fitted by the regression line, there was an improvement in the correlation between the calculated and manually assessed ease of depilation, and some of the day to day variation reduced. The day to day and skin to skin variation of the measured depilation index together with its variance from manually assessed ease of depilation made it a poor quantitative objective estimate of the ease of depilation. Changing the rate of pull, angle of pull or position of the sample did not improve the depilation index.

(ix) Acetate Depilation

With young lamb skins the control paint did not cause visible damage to the pelt and they were easily depilated. The 40% paint at pH 3.0, 3.25 and 3.5 destroyed most of the skin and caused visible damage at pH 3.75 and 4.0. At pH 4.25, 4.5, 4.75 and 5.0 pelts were easily depilated and appeared undamaged. Measured using the procedure recommended by Massey University (Anon) the T_S of the 40% strength paint depilated skins at pH 3.75 and 4.0 was marginally reduced compared to pH 4.25, 4.5 and 5.0 and also to the control skins. However, the T_S and T_F values of the pickled pelts were not reduced by the lower pH paints (Fig. 18). Skin pieces which had been soaked in 1:10 strength paint solutions or painted with full strength paint and kept overnight showed markedly reduced T_S when it was measured at the pH of the paint (Fig. 19). At pH's below 4.0 the soaked skin pieces were partly gelatinised and in parts the wool came away with the grain layer.

For older lamb skins sprayed with 40% or 20% paint, there was no significant difference between the volume of paint applied, 67.7 ± 8.7 mL versus 65.5 ± 9.6 mL (mean $\pm$ S.D.) respectively. The control skins were easily depilated and the pelt, both before and after pickling, did not appear damaged.

Between pH 3.5 - 4.5, paint strength did not effect depilation or pelt quality. Below pH 3.5 depilation was more difficult with the 40% paint. Above pH 4.5 depilation was considerably harder on those skins treated with the low strength paint, whereas below pH 3.5, the low strength paint caused more damage to the skin. Neither T_S nor T_F were affected by pH of the paint, although they appeared to be lower in those pelts treated with 40% acetate paint (Fig. 20). There is also a suggestion of reduced T_S and possibly T_F at lower pH, however the reduction, if any, is small and variable.

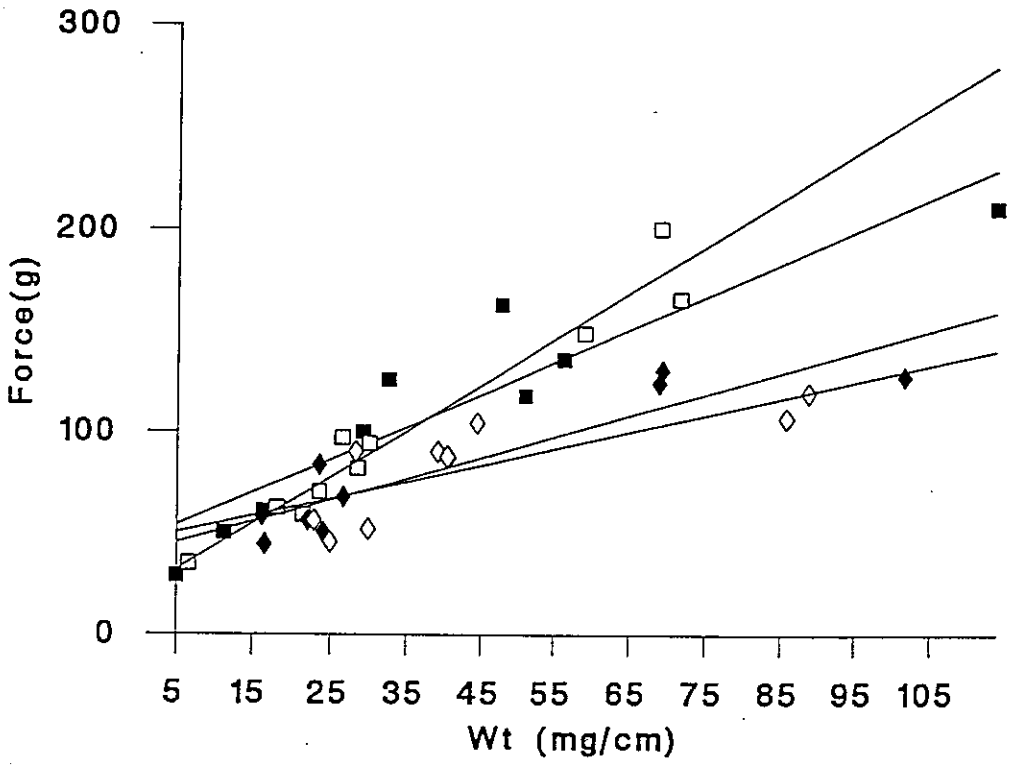

Fig. 17. Plots of depilation force versus staple size with each side of two skins. (■) skin one, (♦) skin two (Open left and closed right).

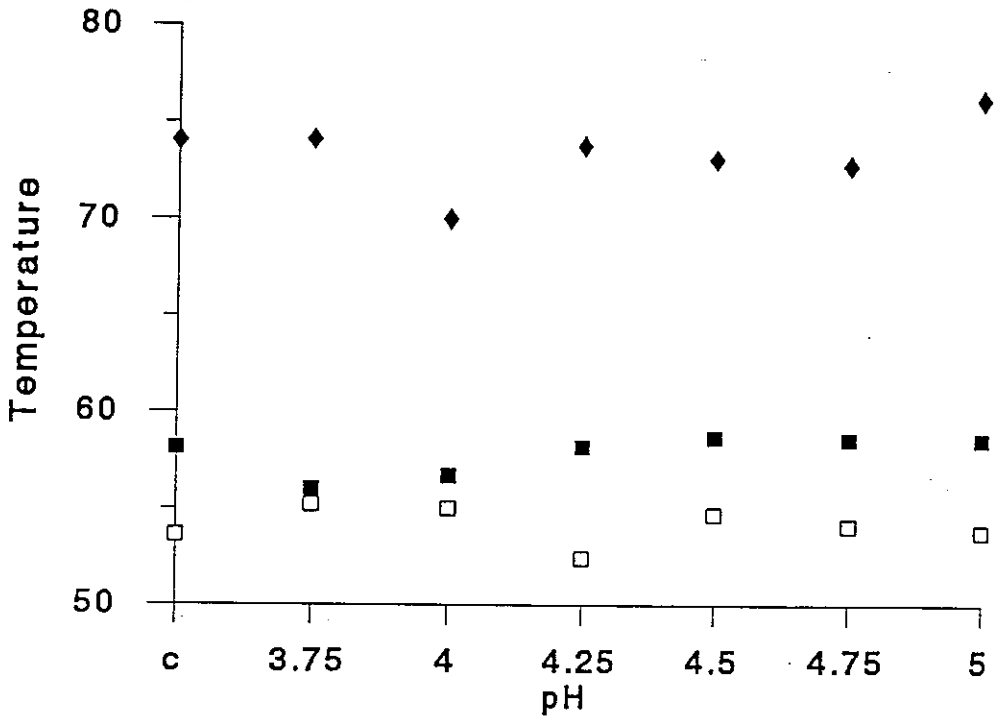

Fig. 18. Effect of depilant pH on the thermal stability of fellmongered and pickled skins. (■) T_S of skins, (□) T_S of pelts and (♦) T_F of pelts (c) control.

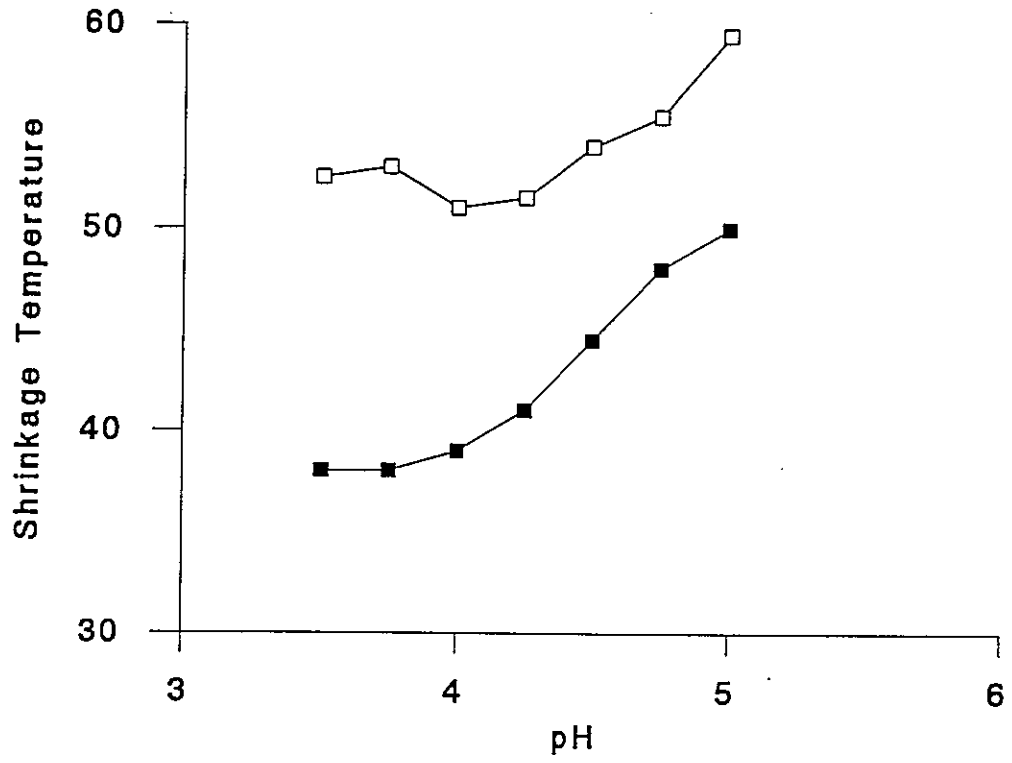

Fig. 19. Shrinkage temperatures of (■) soaked and (□) painted skins measured at the paint pH.

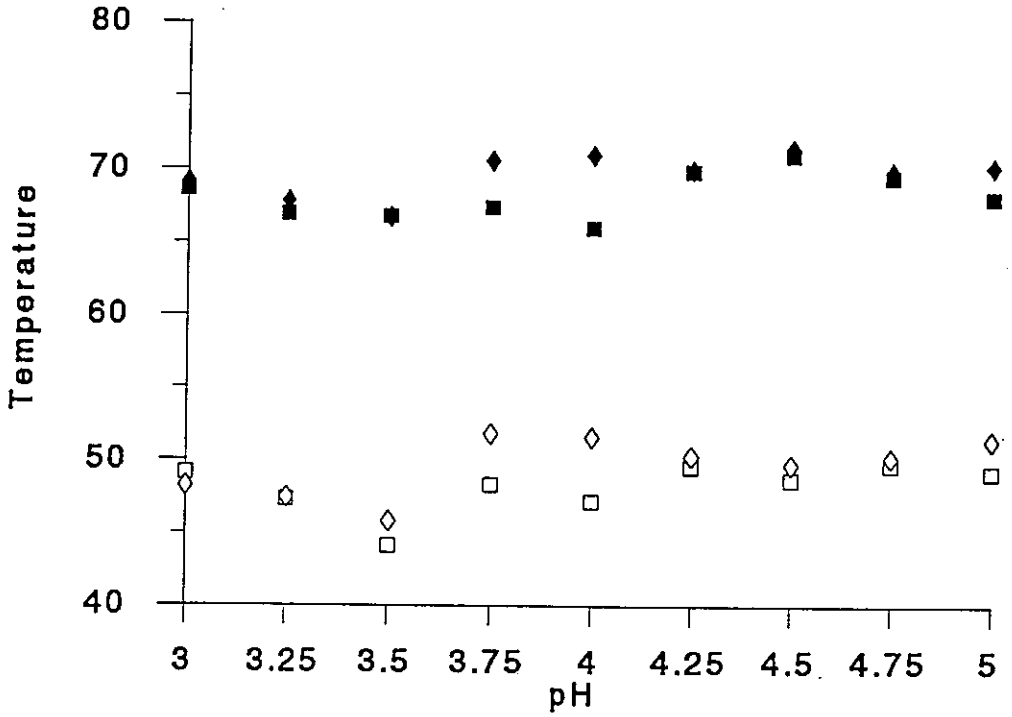

Fig. 20. The effects of acetic acid concentration and pH of the depilant paint on the T_s (open symbols) and T_F (closed symbols) of pickled pelts. The acetic acid concentration was (■) 40% or (♦) 20%.

(x) Model liming experiments

Sodium hydroxide alone will hydrolyse wool and the addition of 2-mercaptoethanol enhances its action (Fig. 21). Thioglycolic acid and the amino acid cysteine have been shown to have a similar action to mercaptoethanol, although the optimum conditions for their use have yet to be determined. A partial comparison between lime and sodium hydroxide in the presence of sharpeners suggests that sodium hydroxide may be a better hydrolytic agent. It has been possible to demonstrate alkali immunisation, whereby pre-exposure to lime reduces the effect of the sharpening agent on wool removal (Fig. 22).

(xi) Incubator conditions

Folded skins incubated at 30°C or 35°C with relative humidities ranging from 35% to 95% showed little drying, even at the edges, however there was a trend for drying to be less at the lower temperature and higher humidities. The skin temperature stabilised, within approximately 5 hours, at a value between the wet and dry bulb temperatures (Fig. 23). For a given dry bulb temperature, as the humidity increased so did the skin temperature (Fig. 24). Skins hung on poles at relative humidities in the range 35%-55% showed marked, but patchy, drying and depilation was difficult over these areas. At higher relative humidities drying was less of a problem although depilation was still significantly more difficult on skins painted with unthickened paint.

(xii) Liming and pickling

The quality of the pickled pelts produced by all of the liming, deliming and pickling procedures was good as assessed by feel, T_s, visual inspection and non-uptake of the dye in Sortassist. Processing faults, eg flay marks and the natural pinhole of merino pelts, were highlighted by the Sortassist dye. Application of Sortassist to commercially produced pickled pelts revealed a number of faults which were not easily seen by normal visual inspection of the pelt. These included wool puller scratches and fine strain damage through the body of the pelt and grain damage highlighted by excessive dye uptake.

(xiii) Histological evaluation

Acetate paint preservation did not prevent the widespread tissue disruption seen in untreated skins, however it did prevent bacterial proliferation and migration into the skin. In both, the wool was readily removed from the skin. In contrast, wool loosening after overnight incubation at 35°C with acetate paint was accompanied by considerably less tissue disruption. Dried skin showed some thinning of the collagen layer but the greatest shrinkage was in the grain layer. Rehydration restored the thickness of the collagen layer but the grain layer thickness was less than in the fresh state.

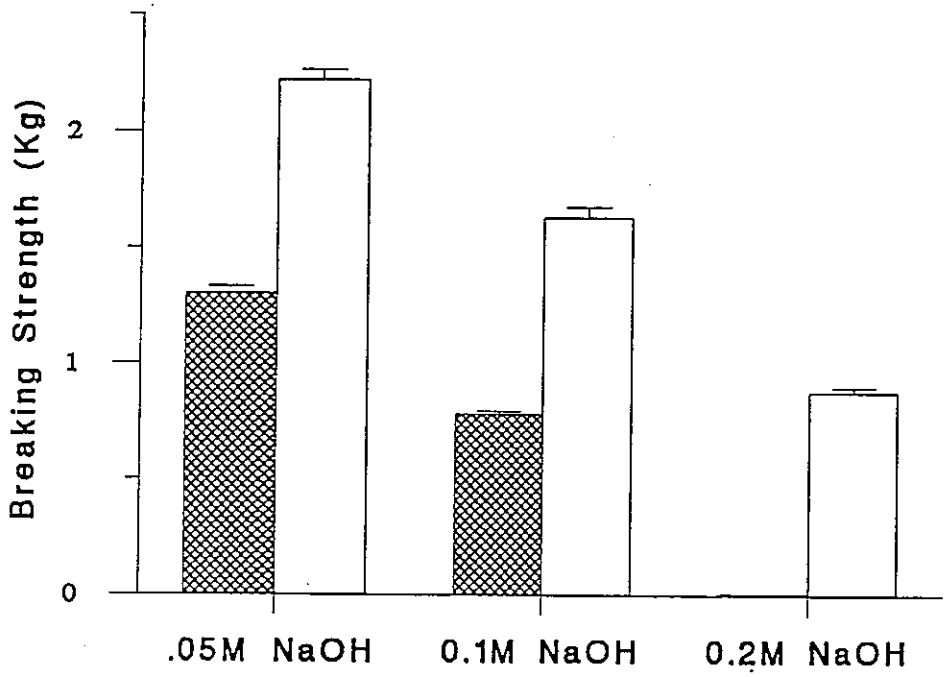

Fig. 21. Effect of 1% (v/v) (hatched) or 0% (plain) mercaptoethanol on the breaking strength of wool in the presence of differing concentrations of NaOH.

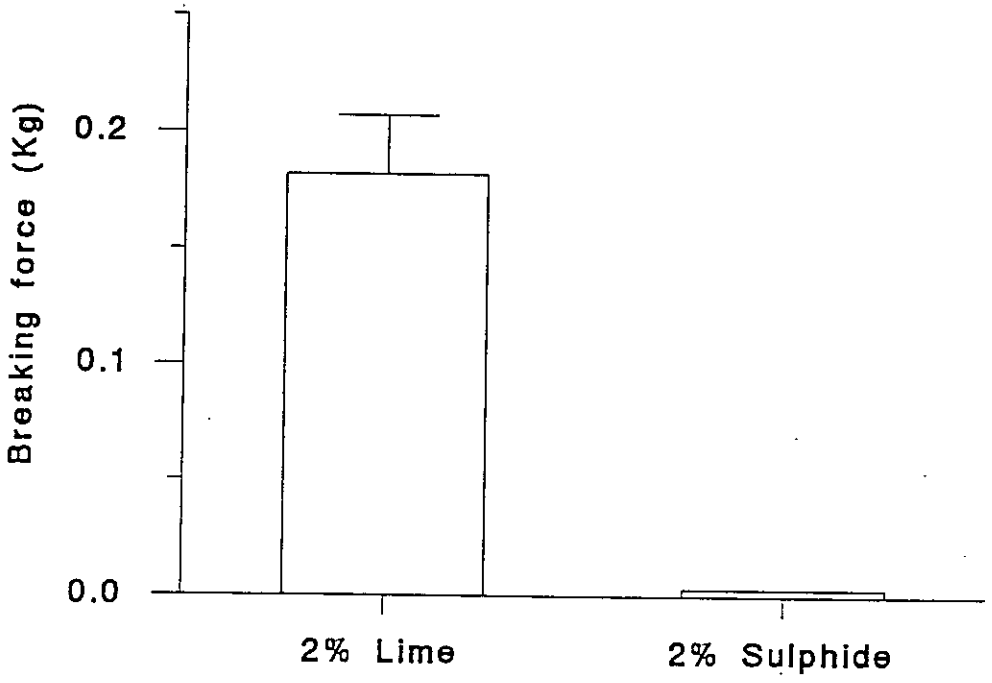

Fig. 22. The effects of exposure of wool to lime or sulphide prior to lime/sulphide treatment.

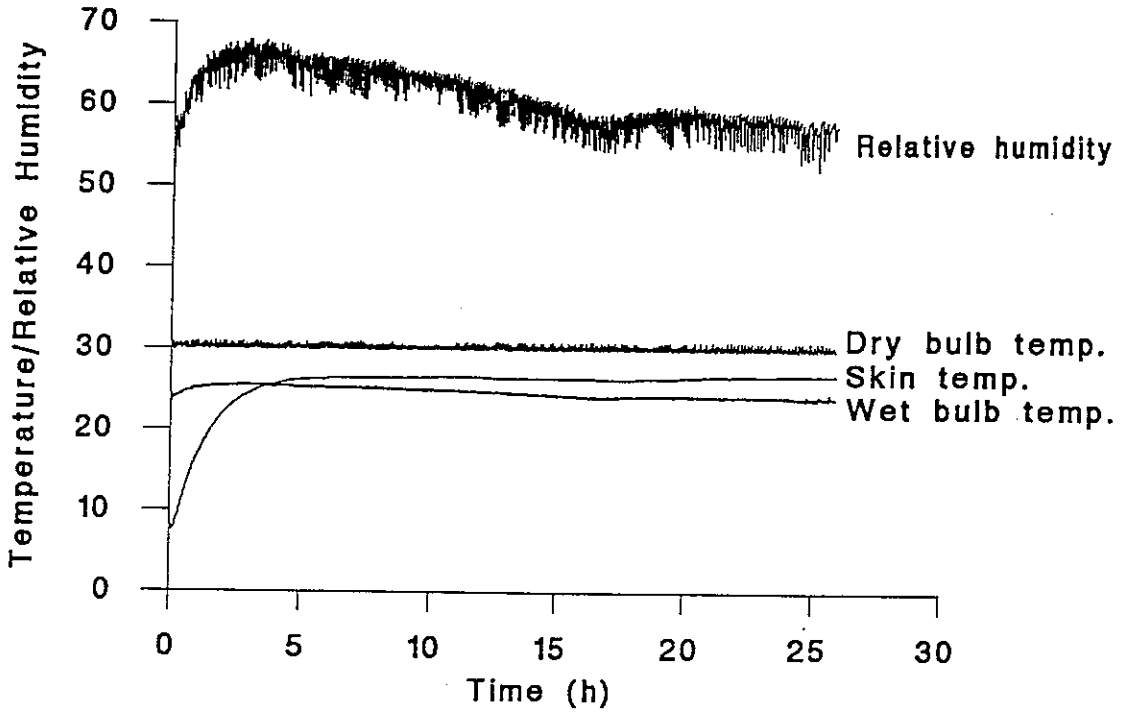

Fig. 23. Conditions during a typical incubation of chilled skins.

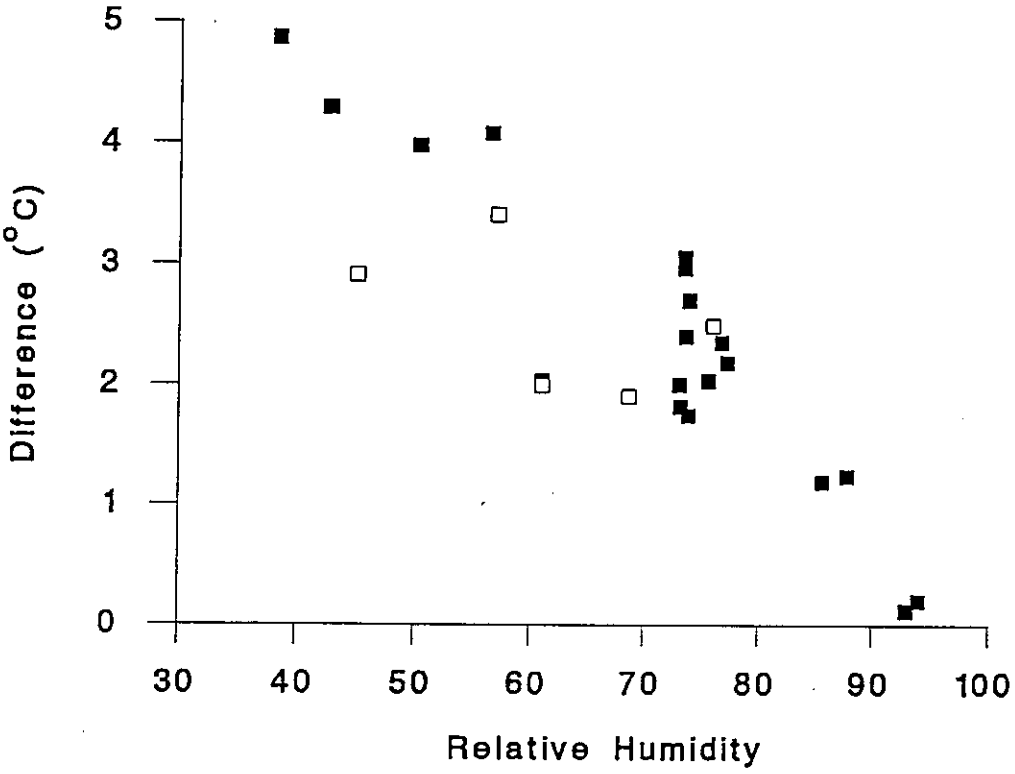

Fig. 24. The effect of humidity on the difference between dry bulb and skin temperatures. Dry bulb temperatures were (■) 35°C or (□) 30°C.

DISCUSSION

(i) Short-term preservation

The development of suitable procedures for short-term preservation (five to seven days), preferably compatible with acetate fellmongering, would allow the shipment of skins from small processors to a centralised fellmongery. Short-term preservation would also allow fellmongers to even out fluctuations in supply and could therefore be particularly advantageous to the Australian sheep industry.

Chemical preservation has some disadvantages including:

(i) All chemicals must be handled with care.
(ii) Soaking of sheepskins is particularly wasteful because of moisture retained by the wool.
(iii) Increased transport costs of wet wool.
(iv) Effluent restrictions and/or contamination of by-products restricts the types of chemicals that can be used.
(v) Chemical treatments are not recommended by CSIRO (Money, 1981) when temperatures are continuously above 30°C.
(vi) The chemicals used may interfere with subsequent processing.

The chemical preservatives examined by CSIRO mostly fall into one of the above. Formaldehyde is incompatible with fellmongering and zinc chloride inhibits acetate fellmongering. Hypochlorite discolours wool and benzalkonium chloride is only suitable for woolskin preservation for up to three days.

Dilute acetic acid, with or without sodium metabisulphite, and benzalkonium chloride are unsuitable for short-term preservation. Sodium metabisulphite alone was not suitable for preservation for more than one day.

The most promising form of short-term chemical preservation, found in the present study, is to spray the flesh side of skins with the acetate depilation paint. The use of acetate paint is attractive both in terms of cost and environmental acceptability. The cost of the spray is 7 to 10 cents per skin but, since its application is part of the acetate fellmongering process, the only costs incurred are associated with setting up a spraying operation at abattoirs (The cost may be partly offset by the energy saving of not having to incubate the skins at 35°C to 37°C). An additional benefit of fleshing and spraying at the abattoir is that the fleshings could go straight into the rendering operation.

Short-term preservation of skins by spraying with acetate paint gave good preservation against microbial attack. Furthermore it appears to inhibit metabolic activity as the temperature rise observed when untreated skins were stacked did not occur with acetate treated skins. However, it was found that acetate paint provided only limited protection against blow fly strike. In cool weather maggots were not evident even after 7 days but in warm weather maggots were evident after 3 days, compared with 16 hours for the untreated skins.

Acetate preservation is suitable for subsequent acetate fellmongering as it initiates the process. It is not suitable for preservation for subsequent wool on tanning due to its depilatory action.

Neither is it suitable for lime/sulphide depilation as it could react with the sulphide to release H_2S, unless the acid is neutralised prior to application of the sulphide paint.

Cold storage of chilled skins, with regard to cost and environmental acceptability, is an attractive proposition for the short-term preservation of sheepskins. Furthermore, unlike most forms of chemical preservation, chilled skins allow the fellmonger to select their subsequent treatment and are compatible with wool on tanning and acetate or lime/sulphide fellmongering.

This study found that satisfactory storage for 5 to 7 days could be achieved at 10°C and was compatible with acetate fellmongering. Preservation for 1 to 2 days, at ambient conditions, was possible if the skins were chilled to approximately 5°C after removal from the animal. This storage period could be extended if the skins were held in insulated containers or were frozen before storage.

Chilling skins, prior to low temperature storage, was easily achieved with a plate freezer using a refrigerant at temperatures readily available at most abattoirs and appears to be the most promising method of rapidly chilling skins. In this study chilling to approximately 5°C required less than 30 seconds on the plate however in practice this could be reduced. Using the present prototype, only trials involving a limited number of skins (approximately 6 consecutively) have been possible. Sticking of skins to the plate has not been a problem provided that the plate temperature was maintained below -20°C, but wet skins eg. after fleshing may present some problems. It is estimated that a plate could be purchased and installed in an abattoir using existing refrigeration facilities for less than $5,000. Subsequent running and maintenance costs would be low. Other potential applications for the plate freezer include cooling skins prior to lime/sulphide depilation and for chilling skins prior to long term storage.

Currently in New Zealand there is considerable interest in the use of CO_2 for rapidly chilling lambskins and the technique may have applications in this country. The system used in this study comprised a "snow" horn connected to a 200L Pressurised Liquid Container (PLC) and was simple to use and readily transportable. The PLC costs approximately $200 to hire from C.I.G. and contains sufficient CO_2 to chill approximately 500 skins. On a larger scale, C.I.G. estimate that for a works chilling 2,000 skins per day the cost of CO_2 would be approximately $0.08 per skin. Where only small numbers of skins need to be processed, or processing is intermittent, the storage and supply charges of liquid CO_2 are seen as a major hindrance to the commercial application of CO_2 chilling. In addition CO_2 is a "greenhouse" gas and Australia is committed to reduce emission. However, in the opinion of the Western Australian Environmental Protection Authority, a plant discharging 1 tonne per day would not be of concern. Care must be exercised with CO_2 as it is heavier than air and concentrations greater than 10% can cause unconsciousness and death.

Liquid nitrogen could also be used for the rapid chilling of skins. It is not as toxic as CO_2 but can lead to asphyxiation due to displacement of air, it is not a greenhouse gas but otherwise the disadvantages of its use are as for CO_2. Its potential was not examined in this project because of inadequate equipment and facilities for the handling of such cryogenic liquids.

(ii) Long-term preservation

Some fellmongers believe that the ability to process preserved skins is important to the economic viability of the operation as it would provide feedstock for plants during times of low

kill. Others, however, have argued that the development of long-term (3 to 4 months) preservation techniques which are compatible with environmentally acceptable forms of fellmongering, for example acetate depilation, would confer no particular advantage to the Australian sheep skin industry. Also the necessity to process skins a few days after removal would confer a strategic advantage on local processors over their overseas competitors.

Traditionally, in Australia, long-term preservation has been achieved by air drying or salting, neither of which is compatible with subsequent acetate depilation.

Freeze (vacuum) drying of skins was found to be compatible with acetate depilation provided rehydration during storage was prevented. This could probably be achieved by sealing skin packs in plastic. However, vacuum drying is unlikely to be a practical procedure for preservation due to the high energy costs of the process and the problems associated with subsequent processing eg. the cost and effluent associated with wetting back the skins.

No method of long-term chemical preservation, compatible with acetate fellmongering, was identified in this study.

The most promising form of long-term preservation is freezing of the skins. Once thawed the skins can be processed as fresh skins with their inherent advantages. Freezing and thawing appear to facilitate acetate fellmongering, presumably by physical disruption of the lysosomes. The estimated cost of storage for 3 months is $0.45 per skin which is considerably less than the cost of air drying or salting ($2.50 to $3.00 per skin). Transport overseas would be more expensive than dried skins, hence this method of long-term preservation would encourage local fellmongering. A local cold store operator (P&O Cold Storage Ltd) has indicated a willingness to cooperate in trialing frozen storage of sheepskins. However before it could be implemented on a large scale, a number of potential problems need to be resolved.

If the fresh untreated skins were simply packed on a pallet and placed in a freezer then skin damage is likely to take place in the middle of the stack before the skins reach a suitable storage temperature. From the limited trials to date, the use of the plate freezer to chill or freeze the skins prior to stacking for frozen storage would seem to be a simple and cheap option. Large scale trials cannot proceed until a plate freezer of sufficient cooling capacity is available.

Uniform thawing under ambient climatic conditions may be difficult, since the outer skins would probably reach ambient temperature whilst the skins in the centre of the pack remain frozen. Thawing may be required to be performed at a temperature which maintains preservation (eg $4^{o}C$). Preliminary experiments indicate that this would take a considerable time. Freezer burn has not been seen, short term, but it may be a problem with extended storage periods, and may affect acetate depilation and/or the quality of the subsequent pelt.

The acetate buffer may be suitable for short-term preservation prior to chilling or freezing skins. Care would need to be taken to prevent drip onto the floor as the acid would rapidly rust out any metal component used in the construction of chillers and freezers. The centre of the stack may take some time to chill or freeze, however even if it took a week, the skins would still be well preserved. Skins frozen after spraying with acetate buffer may defrost better than non-preserved frozen skins since, the preservative action of acetic acid would protect the skins at the outer edge of the pack, while the central skins were still frozen. The relative merits of plate-freezing versus acetate preservation prior to both chilling or freezing need to be evaluated.

It should be noted that acetate preservation would only be suitable for skins which are to be fellmongered whereas plate chilling or freezing are compatible with both fellmongering and wool on tanning.

(iii) Acetate fellmongering

During the course of the present study it was brought to our attention that there was a growing opinion amongst actual and potential fellmongers that acetate depilation resulted in the loss of grain, particularly with lamb skins. From discussions with processors, it seemed probable that this damage could, at least in part, be due to their attempts to maximise wool yield and ease of wool pull by increasing the incubation temperature and humidity. Also by their attempts to reduce chemical costs by reducing the concentration of chemicals in the paint and compensating for the decreased buffering capacity of the paint by lowering the pH of the paint. The preferred pH for acetate depilation paints is given as 4.2 in Samuel Graham's original patent (Graham 1957), although the patent covers the range 3.2 to 4.6.

Acetate paints in the pH range 3.5 to 4.5 showed no effect of pH on ease of depilation of mature sheepskins nor on T_s of depilated skins. Soaking skins in 1:10 paint solutions did show reduced T_s and resulted in skin damage with lower pH's. The apparent anomaly is due to the relative buffering capacities of the skin, applied paint and soaking solutions. With painted skins the pH of the skin showed little variation with the pH of the applied paint whereas the final pH of the soaked skins was close to that of the soaking solution. When shrinkage temperatures were measured at the pH of the soaking solution, the pH's that resulted in skin damage also resulted in markedly lower shrinkage temperatures of the skins. However when the shrinkage temperature was measured after soaking back in neutral buffer, as recommended by Massey University, skin damage was not reflected by a decreased shrinkage temperature.

In this study a marked dependence of animal age on the susceptibility to skin damage due to pH was observed. With young lambs, pH damage occurred with all paints with a pH of 4 or lower, with increasing damage with decreasing pH, whereas with older lambs no damage was apparent at pH 3.5.

The reason why the damaged skins had areas of obvious damage and grain loss whereas other areas appeared to be unaffected is not clear. It may be that the paint was unevenly distributed or may lie in pockets where high local paint concentrations, at lower pH, cause damage in the immediate vicinity and that other areas of the pelt are relatively unaffected. It is possible that more even application of the paint may minimise damage, however this would be difficult to achieve in practice. Localised variations in paint penetration and buffering capacity due to variations in skin thickness and the amount of adhering fat and muscle may have a role in determining the extent of damage.

An unexpected finding was that severe damage was not reflected in the shrinkage temperatures of the skins and pickled pelts measured using the procedure recommended by Massey University.

Although gross damage could not be seen in older skins at pH 3, it is possible that microscopic or submicroscopic damage is occurring which may affect the quality of the pickled pelt and the subsequent leather.

Depilation and pelt quality were good in the pH range 4.0 to 4.5 and it would make more sense to utilise acetate depilation paints in this range, rather than at 3.5 to 4.0 which appears to be the current practice.

In our experiments, 20% paint appeared to be as good as 40% in the pH range 4.0 to 4.5. There is therefore no justification for reducing the paint pH to compensate for the reduced acid concentration. Halving the cost of the dearest ingredient of the paint would lead to significant savings in the fellmongery, but further work needs to be done using lower strength paints. It is necessary to investigate the effects of varying application rates and different aged skins.

The experiments on incubator conditions demonstrated that, provided the painted skins were folded side to side, high relative humidities were not necessary to prevent the skins drying at the edges. The observation that skin temperature lies between the wet and dry bulb temperature and that it approaches the latter as relative humidity increases has some important implications in the design and control of incubators. This was highlighted during the incubator trials when attempting to run at 95% relative humidity led to the humidifiers producing more heat than that required to maintain the temperature during the initial warm up period. The dry bulb temperature exceeded 40°C briefly and the skin temperature closely followed leading to extensive damage. At lower relative humidity this is unlikely to occur as humidifier heating is much less than that required to maintain dry bulb temperature and should the dry bulb temperature exceed the set point, then skin temperature is more likely to approximate wet bulb temperature. At 30°C depilation was harder at lower relative humidities, however this was most likely due to the lower skin temperatures observed as the relative humidity decreased.

Skins can be incubated at ambient temperatures during warmer weather, provided that they are protected from flystrike. The size of the area needed for ambient incubation is considerably larger than for incubation at 35°C, being in direct proportion to the time taken for the wool to become sufficiently loose for depilation. In winter some heating would almost certainly be needed although it need not be continuous as it is not necessary to maintain constant high temperatures for successful depilation. The temperature of a glass greenhouse could well be sufficient. Further work needs to be done on incubator conditions as significant energy savings could result by running longer at lower temperatures and relative humidities.

Incubation conditions for skins which have been stored chilled or frozen were similar to fresh skins. At 30°C depilation was easier with folded skins compared to hung skins. Hanging the skins over poles may have allowed the skins to reach the incubator temperature faster, but it also promoted drying. At high humidities skin drying was minimised and skins hung over poles could be easily depilated. As for fresh skins, it is recommended that chilled skins be incubated folded at 35°C.

The relatively poor correlation between the mechanically measured and manually assessed depilation index is as yet unexplained and warrants further examination. To properly assess fellmongering procedures, an objective quantitative measurement of the ease of depilation is required. Such a measurement would greatly simplify the quantitative comparison of results obtained by different researchers.

(iv) Alternate fellmongering techniques and evaluation in terms of costs and environmental acceptability

Sweating

Sweating can be applied to fresh skins and to skins preserved by a variety of processes including traditional air drying or salting. However there are considerable costs, both economic and environmental, involved in processing air dried or salted skins (see later). As discussed previously, in our experience sweating is a very noxious process and it is considered that it is highly unlikely to be revived as a commercial process in this country. Fly strike occurred frequently. The use of physical barriers to exclude flies would be difficult and may not have a marked impact on the problem since the speed at which maggots appeared in the skins suggests that often the eggs were in the skins prior to processing. Therefore the only option would appear to be the use of insecticides.

Lime/sulphide depilation

Lime/sulphide depilation can be applied to fresh skins and to skins preserved by a variety of processes including traditional air drying or salting.

The conventional treatment using lime/sulphide depilation is well documented, eg Frapple and Snowden, 1992. Briefly, dried or salted skins are wet back prior to application of the depilant paint. Fresh skins are washed to remove dirt and blood from the wool and to reduce the temperature of the skin to around 20°C prior to painting. The skins are then painted and left until the wool has loosened sufficiently. After removing the wool, the pelts are limed, de-limed and pickled. The heavily contaminated wool is washed, dried and then baled. The uncontaminated and lightly contaminated wool is dried and baled.

There are considerable costs, both economic and environmental, involved in processing air dried or salted skins. Wetting back of dried skins involves soaking the skins in a paddle with water, generally containing a small quantity of alkali and/or detergent, for a considerable time, 16 to 48 hours. This results in large quantities of effluent with similar characteristics, albeit less concentrated, to that obtained from wool scours. Most scours are under scrutiny from the various regulatory authorities because of concerns with effluent. Salted skins are treated in a similar manner to air dried skins except the wetting back time is shorter. The effluent from salted skins is even more difficult to handle in a land based process because of the high concentration of salt present and presence of the antimicrobial agents in the salt. These may kill the beneficial flora of ponds. Washing of fresh skins to reduce the body heat also consumes large quantities of water, approximately 140m^3/1000skins, hence produces large quantities of effluent.

The use of alternate preservation techniques such as chilling or freezing and the use of the plate freezer to chill fresh skins prior to painting would eliminate or at least greatly diminish the effluent problems associated with pre-painting processing. Additional benefits would be easier skin handling and reduced costs, particularly wool drying costs. The question as to whether the wet wool is required as a heat sink to avoid heat damage to the pelt would need to be examined.

Until recently, there appears to have been little if any questioning by New Zealand fellmongers of using a depilant paint composed of lime, as the source of alkali and sodium sulphide, as the

sharpening agent. Perceived advantages of using these chemicals have been simplicity and cost. However, once applied these chemicals greatly restrict the options available for further processing. Once used in the depilation paint, there appears to be no sensible option but to use lime and sodium sulphide in the liming process. To avoid lime blast, $CaCO_3$ formation, the calcium must be removed from the pelt during deliming and pickling. The sulphide must be removed prior to pickling to avoid excessive production of hydrogen sulphide. The low solubility of many calcium salts restricts the number of suitable deliming agents available. The deliming agent must be an acid, in order to reduce the pH, and the anion of the acid used must form a soluble salt with calcium. Also the acid must be a weak acid, eg ammonium chloride or sulphate, or be applied with great care to avoid the generation of excessive quantities of hydrogen sulphide. The ammonium salts largely fulfil these requirements but restrictions on the levels of ammonia allowed to be released to the atmosphere during deliming and to be present in the effluent have made their use unattractive or unacceptable. Carboxylic acids, in particular citric acid, have been used but they are relatively expensive. Recently, there has been revived interest in the use of carbon dioxide as a deliming agent. Virtually all problems discussed in relation to carbon dioxide deliming are associated with the presence of calcium and sulphide in the liming solution, ie the possibilities of lime blast and hydrogen sulphide emission.

Because sulphide is the pollutant of major concern, the sulphide rich streams are initially treated separately from other effluent. The sulphide stream is pumped in aerated holding tanks where manganese sulphate is used to catalyse the sulphide ions to thiosulphite ions. In a land based operation, considerable care would have to be taken to ensure that the reduction of thiosulphite back to sulphide ions did not occur in the ponds. Washing of contaminated wool requires a considerable amount of water and produces a sulphide rich effluent.

It may be possible to preserve de-limed pelts by drying rather than pickling, however, this would probably be more expensive and the acceptance of the product by tanners would have to be established.

Recycling of liming and pickling liquors reduces effluent problems but the cost of the equipment and storage facilities required add significantly to the cost of establishing a plant. Also, adequate analytical facilities and personnel would have to be provided. It would seem likely that only large scale plants, processing several thousand skins a day, would be able to afford to put in the recycling equipment and effluent treatment plant required to make a land based lime/sulphide fellmongery environmentally acceptable in the near future.

Skins can be chemically depilated and processed without the use of lime or sulphide but generally at a cost. Depilant paints without lime are available, eg the new quickpul paints are composed of NaOH, NaS_2 and a thickening agent and a non-lime liming is currently being used at Dubbo. Non-lime liming requires more careful control but has been reported to have several advantages over lime liming of sheep skins, eg the absence of lime soap formation (Sharphouse, 1971). An additional advantage of using a non-lime liming is that a greater range of potential deliming agents is available and CO_2 deliming becomes very much easier to control and less CO_2 would be required.

Sodium sulphide and sodium hydrosulphide are the most dangerous chemicals used in the fellmongering industry. Considerable effort has been expended in trying to eliminate them from skin processing. The BASF corporation has developed a proprietary product Mollescal SF as a replacement for sulphide. The active sharpening agent in Mollescal has been identified as the

sodium salt of mercaptoethanol which is readily oxidisable. The pelt quality is at least equivalent to that produced using sulphide but at present it costs between 10 and 15 cents per skin more to use than sulphide. Other sharpening agents which are potentially even safer and more environmentally acceptable have been identified, including the thioglycolates and a sulphur amino acid. Limited studies have been performed but further work is required.

It became rapidly apparent that to evaluate alternative sharpening agents by using them in depilant paints or during the liming of acetate depilated pelts would be a very time consuming exercise. The development of a model system for evaluating liming and unhairing procedures has simplified the investigation of alternative fellmongering methods. The effects of these procedures can now be quantitated thus allowing selection of optimal conditions prior to laboratory scale experiments on dewooled pelts. Care needs to be exercised in performing and interpreting the model dehairing and liming system when it is used to test one chemical effect followed by another. A preliminary experiment, where pretreatment was with 1 mL of lime, showed little effect on wool hydrolysis. It was noticed that solutions containing the sharpening agent were drawn up the wool fibres by capillarity, hence the fibres adjacent to the hardened tip were softened and broke. At least 2 mL is required for pre-incubation and no more than 1 mL for subsequent incubation.

It would be possible to develop a modified version of the present procedure for use by fellmongers as a simple routine test for measuring depilation strength of paints and the concentration of sharpening agent in recycled liquors. The potential for a commercial firm to produce standards for day to day calibration in the fellmongery would seem worthy of investigation.

Acetate depilation

Acetate fellmongering gives much greater flexibility in the size and complexity of plant required to remove the wool and produce a preserved pelt. The only apparent safety issue involved in acetate fellmongering is to ensure that the level of acetic acid in the air is maintained below the maximal permissible limit (<10 ppm). This could be achieved by providing adequate ventilation and if required the partial replacement of the acetic acid with lactic acid.

A very simple low cost operation discharging minimal effluent is possible. The skins could be fleshed and sprayed at the abattoir with the fleshings going straight into by-products. Alternatively the skins could be plate chilled at the abattoir and sprayed at the fellmongery then incubated in a low cost sweat box. As discussed previously precise temperature and humidity control, whilst desirable, is not essential. The skins could be dewooled and the wool dried and baled. The pelts could then be transported to a centralised plant with adequate effluent treatment facilities for further processing. If the pelts were to be processed in the next few days the acetate paint would provide sufficient preservation, provided the skins were kept cool. If long term preservation was required the pelts could be air dried to produce slats. The results obtained to date with this form of slat have been very encouraging but further work is required. A potential advantage that a slat has over a pickled pelt is that it would allow a tanner to "lime" a pelt to his own requirements rather than tan a pelt that has had a general purpose liming.

Acetate depilated pelts are compatible with a non-lime liming using an "alternative" sharpening agent.

In evaluating the different procedures for short or long term storage, for alternative fellmongering or for effluent management, the quality of the skin and the pelt needs to be assessed at each stage and not judged solely on the quality of the finished leather. The importance of this approach is highlighted by recent requests to explain the loss of grain on several pieces of merino leather. It was impossible to say at which stage this damage occurred, since at each stage of the process from skin take-off to finished leather there is the potential for such damage, and no monitoring of the individual stages was undertaken. The demonstration that measurement of shrinkage temperature does not necessarily reflect damage to skins or pelts means that appropriate monitoring procedures for each stage of production need to be developed. In addition, these procedures should be performed under the conditions of the process.

It would be beneficial to fellmongers to have a handbook illustrating the effects of incorrect processing at each stage of production, eg. low pH or elevated temperature, on the properties of the pelt and finished leather. Ideally such a handbook could also contain details of a series of simple tests that could be used to monitor the effectiveness of each stage of processing.

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SUCCESS IN ACHIEVING OBJECTIVES

(i) To develop procedures for the short term preservation (5-7 days) of sheep skins which are compatible with acetate fellmongering.

ACHIEVED

Two procedures have been developed.

(ii) To evaluate procedures which are found to be technically feasible in terms of cost and environmental acceptability.

ACHIEVED

The above two procedures are economical and environmentally acceptable.

(iii) To investigate and develop procedures for fellmongering long term (3-4 months) preserved skins which are compatible with acetate fellmongering. (This is secondary to short term preservation since it would confer no particular advantage to the Australian sheep skin industry).

ACHIEVED

A procedure has been developed and tested at laboratory scale.

(iv) To evaluate procedures which are found to be technically feasible in terms of cost and environmental acceptability.

ACHIEVED

The above procedure is economical and environmentally acceptable.

(v) To develop alternative fellmongering techniques, and to evaluate all depilation development work in terms of cost and environmental acceptability. The development of environmentally acceptable techniques for depilation of fresh, short and/or long term preserved skins will seek to minimise water consumption and produce an effluent that is suitable for low cost land based treatment and disposal.

SUBSTANTIALLY ACHIEVED

Several alternative techniques for depilation and subsequent processing have been evaluated.

PROGRESS IN COMMERCIALISATION

Short term acetate preservation and fellmongering are currently being used commercially by two Western Australian fellmongers. W.A. Pelt Processors use this process to preserve skins during transportation from Perth to Wongan Hills (250 km). Mr N. Panton of W.A. Pelt Processors considers the product obtained from treated skins to be far superior to that obtained from untreated skins, even when skins are to be held for only a few hours before fellmongering. Katanning Wool and Pelts use acetate preservation to even out day to day fluctuations in supply. Both fellmongers use the process to hold skins over the weekend. Each processor estimated that they used acetate preservation on 30,000 skins during 1992.

Two fellmongers in New South Wales are currently trialing acetate preservation and depilation.

Mr B. Lee of Connectica International has been appointed by MRC to develop a plan for the commercialisation of the plate freezer. A number of skin processors, throughout Australia, have expressed keen interest in using plate freezing for skin preservation. To enable this a plate freezer with a much greater capacity has been constructed and will be available for commercial trials in 1993.

Commercialisation of long term preservation, by freezing, could not be undertaken because of the inadequate capacity of the prototype plate freezer.

The feasibility of producing slats by air drying acetate depilated skins, as a form of medium to long term preservation of partially processed skins is being trialed by Katanning Wool and Pelts. Several thousand skins have been treated in this manner and the results are encouraging.

Katanning Wool and Pelts anticipate future problems with disposal of their sulphide effluent and have expressed a keen interest to trial alternative sharpening agents.

IMPACT ON THE MEAT AND LIVESTOCK INDUSTRY

The fellmongering industry is growing rapidly, from one fellmonger producing 1,500 pelts per day to five producing 15,000 pelts per day in the last two years, and continued rapid growth is expected. The development of processes and procedures specifically designed for Australia skins and conditions will facilitate this expansion.

It is anticipated that acetate preservation and rapid chilling techniques developed during this study will be quickly and widely adopted by the skin processing industry. Their use will allow the transport of skins from small processors to a centralised fellmongery without significant deterioration and also help to even out day to day fluctuations in supply.

In the absence of significant preservation costs it is anticipated that it will be economic to further process, fellmonger or wool on tan, a significant proportion of skins currently considered to be of no commercial value (NCV). Currently large numbers of NCV skins are dumped as land fill, often at considerable cost to the industry, eg Robb Jetty abattoir charge 30 cents/skin to dump NCV skins. Many NCV skins are short woolled merino skins that have insufficient wool to economically justify the cost of conventional preservation, estimated at around $2.50 per skin,

and transportation prior to further processing overseas. Although at certain times former Eastern Bloc countries, eg Yugoslavia, have imported large quantities of these skins, presumably for the production of low cost, warm clothing.

Some potential fellmongers have argued that the ability to process long term preserved skins is important to the economic viability of the operation. This is to compensate for the cyclic nature of the sheep kill in many parts of Australia by having feed stock available in times of low sheep kill. This study has shown that the storage of frozen skins is potentially an attractive alternative to traditional methods (air drying or salting) which are incompatible with acetate fellmongering. However, at the present time there is insufficient information to make any reasoned estimates on, or to what extent, the adoption of rapid freezing of skins by industry will be achieved.

If preserving acetate depilated skins by producing air dried slats proves to be a practical proposition, then their use may provide an alternative strategy for dealing with long term fluctuations in the supply of skins. The capital investment required for a fellmonger to have the flexibility to be able to deal with peaks in skin supply in terms of acetate depilation and wool handling is low since these processes contribute little to the effluent load. This is not true of subsequent processing, liming, deliming and pickling. With these processes the effluent treatment and recycling capacities have to be matched with production. The use of slats would allow the further processing capacity to be based on yearly throughput rather than peak demand. This option would not be available to a fellmonger using lime/sulphide depilation.

As the industry expands it will become increasingly necessary to replace noxious chemicals with safer and more environmentally acceptable alternatives. Na_2S and NaHS are the most dangerous chemicals used in the fellmongering industry. Considerable effort has been, and will continue to be, expended in trying to eliminate them from skin processing. The model liming system developed in this project should facilitate the investigation into alternative sharpening agents.

TOTAL FUNDING AND MRC CONTRIBUTION

MRC	91,900
WADA	131,500
Total	223,400

A significant contribution to the project was made by Mr S. Skevington of the W.A. Department of Agriculture, in particular with regard to the design and construction of the plate freezer.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

1. Acetate fellmongering gives much greater flexibility in the size and complexity of plant required to remove the wool and produce a preserved pelt than lime/sulphide fellmongering.

2. It is becoming apparent that to ensure pelt quality, some form of short term preservation of skins is required even if there is a relatively short time (>3 hours) between take off and processing.

3. Acetate preservation and/or rapid chilling of skins will be rapidly and widely adopted by the skin processing industry.

4. The expansion of the fellmongering industry will result in increasing pressure to develop safer and more acceptable chemicals and processes.

5. The cost of the recycling equipment and effluent treatment plant required to make a land based lime/sulphide fellmongery environmentally acceptable will restrict this form of fellmongering to large scale plants, processing several thousand skins per day, in the near future.

6. Sweating of skins is unlikely to be revived as a commercial process in this country.

Recommendations for further work

1. Development of simple procedures to monitor fellmongering operations from skin delivery to the dispatch of pickled pelts.

2. Production of a fellmonger's "mistakes" handbook.

3. Continue the investigation into alternative sharpening agents, including the preparation of cysteine from waste wool.

4. Large scale plate freezer and frozen storage trials be undertaken.

5. Continued development to improvement the performance of the plate freezer.

6. Development of improved pelt preservation procedures particularly with regard to improving the heat stability of the preserved pelts. This study should also include the development of simple procedures to monitor the deterioration of the preserved pelts.

7. Development of a reliable, reproducible objective depilation index.

8. Development of improved acetate depilant paints, mainly to reduce odour and corrosion.

9. A study into the effects of animal age on the susceptibility of the skins to damage during processing and on the properties of the leather produced should be undertaken.

10. The study into the practicality of using air dried slats should be continued and expanded.