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Project identification

1. Defra Project code: MH0138
2. Project title: Reducing bird stress and discomfort on the poultry shackling line
3. Contractor organisation(s):
   Silsoe Livestock Systems Ltd
   Paul Berry Technical Ltd
   The Food Animal Initiative
4. Total Defra project costs (agreed fixed price): £ 197,245
5. Project: start date .... 01 September 2006
   end date .... 31 March 2009

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Executive Summary

7. The executive summary must not exceed 2 sides in total of A4 and should be understandable to the intelligent non-scientist. It should cover the main objectives, methods and findings of the research, together with any other significant events and options for new work.

Reducing stress and discomfort on the poultry shackle line

Paddy Schofield, Jeff Lines, Paul Cook, Tracey Jones, Paul Berry, Jade Spence & Dave O'Neill

Executive Summary

Overall aim
To improve poultry welfare at slaughter by developing and evaluating approaches which reduce the stress and discomfort caused by leg compression during shackling, suspending birds upside down by their legs in the shackle and pre-stun shocks on entry into the stun bath.

Objectives
The objectives were to investigate practical modifications to the shackle line which can be applied to existing equipment. The specific objectives were:

1. Reduce leg compression during shackling
2. Avoid inverting and suspending the birds
3. Improve entry into the stun bath avoiding pre-stun shocks
4. Identify reliable methods to assess bird welfare
5. Assess the functionality and welfare aspects of the developments
6. Assess systems when used by processing staff
7. Initiate technology transfer

Extent to which the objectives have been met
All the project objectives have been met. A breast support conveyor system to reduce stress and discomfort on the shackle line was developed, installed and evaluated in a small commercial broiler processing plant. It was used in the daily operation of the plant for around eight months. A formal assessment of the system showed that it improved bird welfare. Presentations have been made to major UK poultry processors and interest in the system has been very encouraging.

Methods, Results and Conclusions
The use of loose fitting shackles to reduce leg compression was investigated. An effective foot retaining bar was needed at some points in the line to prevent escapes. Direct measurements of individual stunning currents were made in a high speed process line using both loose fitting and tight shackles. These show that a fine saline water spray close to the entry into the stun bath significantly improves the electrical contact between loose shackles and the legs and results in a stunning current as uniform as that achieved using tight shackles. They also show that care must be taken in the stun bath to avoid jolts to the birds since these can cause momentary loss of electrical contact.

A breast support conveyor was used to enable birds to be transported on the shackle line without

suspending them upside down. Direct and video observations showed that when birds were placed on the conveyor they struggled less than when hung on a conventional shackle line. At the stun bath entry point the birds swing off the conveyor directly into the stun bath (Figure 1). Observations showed that use of the conveyor resulted in a faster and cleaner stun bath entry than was achieved using the conventional shackle line. The amount of wing flapping and pre-stun shocks at this point was significantly reduced by the breast support conveyor. Use of the conveyor was also associated with significantly lower incidence of red wingtips and blood in the wing wrist joints. An ergonomics assessment indicated that the conveyor was unlikely to cause any problems for the shackling team.

Careful setting of the conveyor height and speed relative to the shackle line and stun bath is needed to optimise the benefits of the breast support conveyor. The conveyor design that was used enabled the shackle line and conveyor to turn through a 90 degree bend between the hang on point and the stun bath. However, the welfare assessment indicated that, as with a conventional shackle line, such corners should be avoided wherever possible. The system is suitable for use in new shackle lines or as a modification to established lines provided they have few corners between hang-on and the stun bath.

A trial system was installed in a small processing plant and used successfully for daily operations for over 8 months.

Figure 1 Birds passing from the conveyor into stun bath

Recommendations for further work

The system development work has reached the point where it is suitable for uptake by small process lines providing that it is carefully and continuously managed. Further research and development is needed to reduce the level of management input required, in particular to optimise height and speed settings and to further reduce the risk of escape of feet from shackles.

The greatest improvements in bird welfare will be achieved if this system is installed in large high speed processing plants. The project has not yet accumulated sufficient experience with the approach to enable a system to be installed in such plants on a commercial basis. Further options need to be explored and then a closely managed system installed on a trial basis.

Options for further improving the conveyor design include the use of a sloping conveyor at the hang on point. The conveyor should then twist towards the horizontal as the birds progress down the line picking up the weight of the birds and ensuring that all birds are well positioned regardless of bird size or the care with which they are hung on the shackle line. The use of a conveyor that slopes slightly down away from the shackles during transport to the stun bath should also be investigated since this is expected to result in further improvements in bird welfare. The use of shackles with some flexibility that allow the birds' legs to be pulled past a detent so they remain un-compressed but captive should be pursued.

The application of this approach for other birds other than broilers (ducks, end of lay hens etc) should also be investigated.

This work will significantly contribute to the welfare of many millions of birds at slaughter and is of particular importance for the UK halal sectors where gas killing may not be an acceptable alternative.

Project Report to Defra

8. As a guide this report should be no longer than 20 sides of A4. This report is to provide Defra with details of the outputs of the research project for internal purposes; to meet the terms of the contract; and to allow Defra to publish details of the outputs to meet Environmental Information Regulation or Freedom of Information obligations. This short report to Defra does not preclude contractors from also seeking to publish a full, formal scientific report/paper in an appropriate scientific or other journal/publication. Indeed, Defra actively encourages such publications as part of the contract terms. The report to Defra should include:
   - the scientific objectives as set out in the contract;
   - the extent to which the objectives set out in the contract have been met;
   - details of methods used and the results obtained, including statistical analysis (if appropriate);
   - a discussion of the results and their reliability;
   - the main implications of the findings;
   - possible future work; and
   - any action resulting from the research (e.g. IP, Knowledge Transfer).

Reducing stress and discomfort on the poultry shackle line

Paddy Schofield[1], Jeff Lines[1], Paul Cook[2], Tracey Jones[3], Paul Berry[4], Jade Spence[5] and Dave O'Neill [6]

[1] Silsoe Livestock Systems
[2] The Farm Animal Initiative
[3] The University of Oxford
[4] Paul Berry Technical
[5] The Humane Slaughter Association
[6] Dave O'Neill Associates

Scientific objectives

1 To identify and develop approaches to shackling which minimise leg compression and shackling force yet maintain secure mechanical and electrical contact.
2 To identify and develop modifications to a shackle line which avoids inverting and suspending birds until the moment they enter the stun bath.
3 To identify and develop modifications to a shackle line which will rapidly immerse birds, head and neck, into the stunning bath without pre-stun shocks or disturbing the birds in a way which causes wing flapping.
4 To identify a protocol for behavioural observation for assessing bird welfare on the poultry line.
5 To evaluate and test the above developments, their functionality, their compatibility with existing equipment, and their impact on bird welfare.
6 To assess the function of the systems when being used by plant operators.
7 To begin the technology transfer processes by publication of experimental results, demonstration of the system and discussion with representatives from the industry.

Extent to which the objectives have been met

All the project objectives have been met. A breast support conveyor system to reduce stress and discomfort on the shackle line was developed, installed and evaluated in a small commercial poultry processing plant. It was used in the daily operation of the plant for over eight months. A formal assessment of the system showed that it improved bird welfare. Presentations have been made to six of the major UK poultry processors and interest in the system has been very encouraging.

Details of methods used and results obtained

1. The electrical and mechanical consequences of using loose fitting shackles. (Objective 1)

Birds can suffer pain and discomfort on the shackle line due to compression of the legs in the shackle. The use of loose fitting shackles however increases the risk that birds escape from the shackles or that they are not properly stunned in the water bath. We have shown that these problems can be overcome by the use of leg guards to prevent escapes and a saline water spray at the entrance to the water bath to ensure sufficient stunning current.

Due to the wide variation in leg sizes - in particular between males and females, the legs of many birds are too large to fit comfortably into the shackles. This results in the use of large shackling forces and probably in painful compression of the legs[1,2]. Potential solutions include the development of compliant shackles or the use of larger shackles which will be loose fitting for most birds.

There are a very large number of shackles in every poultry plant, they are intensively used and have the potential to stop the processing plant operation if they fail. As such it is vital that they are robust, simple and reliable. Any change to shackle design needs to be approached with caution. In this project we investigated compliant shackles but focused mainly on the use of loose fitting shackles since this option appeared more likely to be rapidly accepted by the industry. The main issues with loose fitting shackles are to avoid poor electrical contact and to prevent birds' legs escaping. Measures to ameliorate poor electrical contact are dealt with in this section. Measures to prevent birds' legs escaping from the shackle are dealt with in the description of the conveyor installation.

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[1] Sparrey J 1995 Aspects in the design and operation of shackle lines for the slaughter of Poultry. MPhil thesis University of Newcastle on Tyne.

[2] Gentle M J, Tilston V L, 2000. Nociceptors in the legs of poultry: implications for potential pain in pre-slaughter shackling. Animal Welfare, 9:3,227 – 236.

Research into the electrical contact between bird's legs and loose shackles commenced with measurements of the electrical resistance between a shackle and detached broiler legs supplied by a poultry plant. This led to further investigations using recently killed broilers and finally to a set of trials at a high speed poultry processing plant. Comparisons were made between the stunning currents experienced by individual broilers shackled tightly in the standard way, broilers shackled loosely, and broilers shackled loosely but then sprayed on their feet and legs with a saline solution of water for about 5 seconds commencing 2 or 3 seconds before the birds entered the water bath.

Some earlier research on spraying birds' legs in shackles was published by Perez-Palacios and Wotton[3] which suggested that spraying birds' legs did not result in significant changes to the stunning current. However in their research only the average stunning current for all the birds in the water bath was measured rather than individual stunning current time histories, so any increase in the uniformity of the current could not be observed. In addition the birds being investigated were shackled using tightly fitting shackles so the poor electrical contact, that saline spraying improves, may not have existed. Earlier, Gregory and Wotton[4] had also found that wet birds entering the stun bath supplied with a fixed stun current were less well stunned than dry birds, because some of the current tracked over the plumage. Perez-Palacios and Wotton used this finding to suggest that birds' legs should not be sprayed on entry to the water bath lest the birds become wet and consequently are poorly stunned. This suggestion was however not supported by evidence and is not relevant to the normal situation where birds are supplied with a fixed stun voltage rather than a fixed stun current. Experimental evidence from the research reported here suggests that current tracking is unlikely to be a problem.

Measurements of the resistance between legs of recently killed broilers and the shackle in which they were located showed very large variability, but that as the feet were pressed harder into the shackle this resistance both decreased and became much less variable. Forces of up to 50 N per leg (5 kg force) were used to press the legs into the shackle. The use of this force appeared to cause tissue damage to the legs which showed as a residual indentation in the leg and a smoother surface to the skin in that indentation. The change in electrical contact appeared to be due at least in part to this leg tissue damage since once this damage was caused, the leg could be loosened in the shackle but the contact resistance continued to remain low while in contact with the crushed part of the leg. It seems possible therefore that the good electrical contact currently being achieved in processing plant shackles is due at least in part to tissue damage to the legs.

Spraying legs fitted loosely in a shackle with a saline spray was found to result in a decrease in the resistance between shackle and leg of the order of 50%, however as the water drained away over the following few seconds, some of this benefit was lost.

To understand the significance of the electrical resistance at the interface between the shackle and the bird's foot, measurements were made of the resistance of various components of the bird being stunned on a shackle line. These trials were done on extensively reared broilers that had just been killed by neck pulling. The birds were hung on a shackle with their heads in a water bath. A 500Hz sinusoidal ac voltage of 110v rms was applied between the shackle and the water bath which resulted in an electrical current through the carcass. Voltage monitoring electrodes were inserted into each foot pad, at the base of the legs and at the base of the neck. The voltage measurements together with the current flowing through the bird were used to identify the bird's electrical resistance. A fuller report on this work is given in Appendix 1.

Measurements were made using 47 loosely shackled broilers. The shackles and feet of some of these birds were sprayed with a fine spray of saline water (conductivity 20mS/cm) for several seconds before measurement.

The resistance (± sd) of parts of the bird were as follows:

Shackle to Foot (sprayed, loose shackle)	400 ± 200 Ω each foot	(a)
Shackle to Foot (unsprayed, loose shackle)	1500 ± 800 Ω each foot	(b)
Legs (i.e. Foot to body)	1500 ± 250 Ω each leg	(c)
Body (i.e. legs to base of neck)	200 ± 100 Ω	(d)
Neck and head (i.e. body to water bath)	200 ± 100 Ω	(e)

The overall resistance of the birds was found to be

Unsprayed feet loose shackle:	2032 ± 599 Ω	(10 birds)
Sprayed feet loose shackle:	1355 ± 210 Ω	(20 birds)

[3] S Perez-Palacios, SB Wotton, (2006) "Effects of salinity and the use of shackle/leg sprays on the electrical conductivity of a commercial waterbath stunner for broilers". The Vet Record May 13 2006.

[4] NG Gregory, SB Wotton. (1992) Effect of wetting a chickens feathers on the effectiveness of electrical stunning. Research In veterinary Science 53 250 – 251

These results show that the water spray results in a clear decrease in the mean resistance between the shackle and the bird's foot and also in a decrease in the variation in this resistance. This will result in greater stunning current for any given voltage and a smaller variation in stunning current between birds.

The results also show that the shackle/foot/leg resistance is a large component of the total electrical resistance of the bird. A bird with only one leg engaged in the shackle would have a resistance of 2300 Ω (i.e. a+c+d+e) while a bird with both legs in the shackle would have a resistance of only 1355 Ω (i.e. ½a+½c+d+e). This difference means that a bird with only one foot in a shackle will receive only 60% of the stunning current that it would have received with both legs engaged in the shackle. Such a bird is unlikely to be properly stunned.

Following these measurements the plumage of some of the birds was deliberately wetted by spraying for 10 – 20 seconds and the resistance was re-measured. The resistance of these sprayed birds decreased by only 7 ± 4% while the resistance of control birds which were not sprayed decreased by 3 ± 3%. This small change due to spraying the plumage indicates that any additional electrical pathways created (such as over the plumage) were very small and unlikely to impact on bird welfare even with a constant current stunner. This is probably because even after 10 or 20 seconds of deliberate spraying the plumage was not wet enough to provide a significant continuous current path. This amount of wetting was however far more than would occur incidentally as a result of spraying the feet.

Measurements were next made in a high speed commercial poultry processing plant which was processing a mixed sex flock of intensively grown broilers. The stun currents to which individual birds were exposed were measured when the birds were shackled in a normal way using wet, tight shackles (12 birds), shackled using wet loosely fitting shackles (18 birds) and shackled using wet loosely fitting shackles which were then sprayed at the entrance to the water bath (13 birds). The spray used had a conductivity of 10 mS/cm (approximately 30% the salinity of sea water) and was applied at a rate of about 8 ml/s for about 5 seconds commencing 2 or 3 seconds before the birds entered the water bath.

The results presented in Figure 1a show that the tightly shackled birds experienced a mean stunning current of 47mA and that there was a wide variation between the largest and smallest currents. The largest stunning current was over four times the smallest stunning current. The standard deviation of the currents was 51% of the mean. The stun currents rapidly rose to a stable level and remained at that level until the birds reached the end of the stun bath.

The loosely shackled birds that were not sprayed at the entrance to the stun bath (Figure 1b) experienced a mean stunning current of 31mA (standard deviation 48% of the mean). The notable characteristic of these current time histories was their instability. For two thirds of the birds the current rose and fell significantly in an apparently random fashion. For one bird the current varied over a few seconds from 2mA to 70 mA.

The stunning current for the loosely shackled birds which were sprayed as they entered the water bath (Figure 1c) had a mean value of 54mA with a standard deviation of 27% of the mean. Five of the thirteen time histories showed some variation but to a much lesser extent than with the unsprayed birds. Inspection of the graphs suggests that these variations occurred at fixed points in the line (e.g. 3 s after entry) which appeared to be related to mechanical discontinuities in the earthing bar. This may have caused the shackle to jump and so the bird temporarily lost electrical contact. Attention will need to be paid to this if loose shackling with a water spray comes into commercial use. The stun currents experience by these birds had the same mean value as the tightly shackled birds however there is a suggestion in the data that there is less inter-bird variation in the current.

In summary both the tight shackles and the sprayed loose shackles were associated with a good stun current profile but the loose shackles which were not sprayed generated highly erratic and unsuitable current profiles. If sprayed loose shackles can provide an effective stun and reduce the compression of birds' legs in the shackle, this is a potentially great benefit to animal welfare.

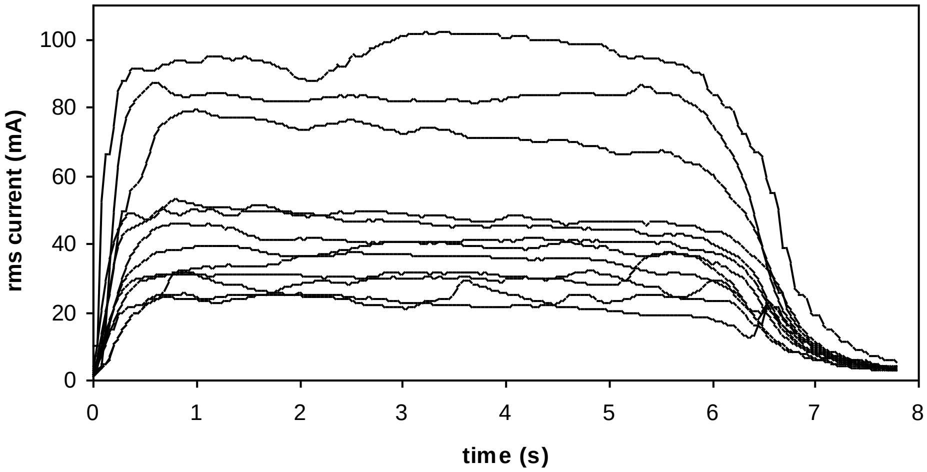

Figure 1a   Stunning current using tight shackles (12 birds)

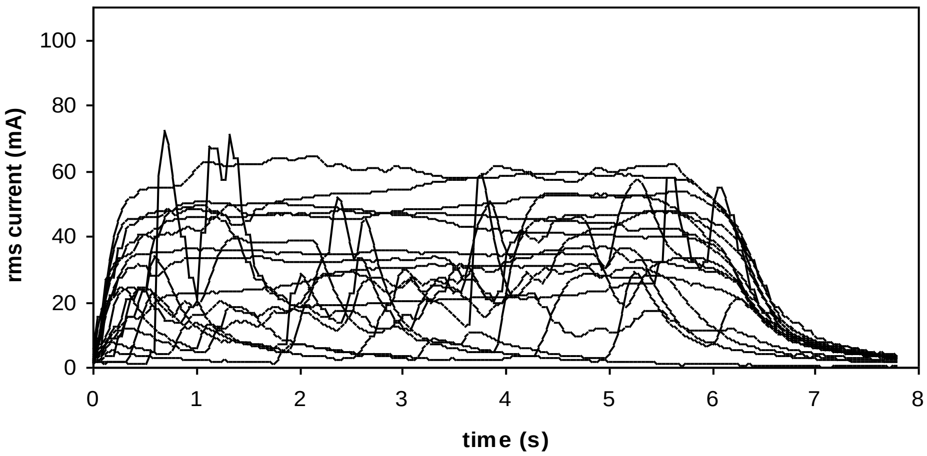

Figure 1b   Stunning current using loose shackles (18 birds)

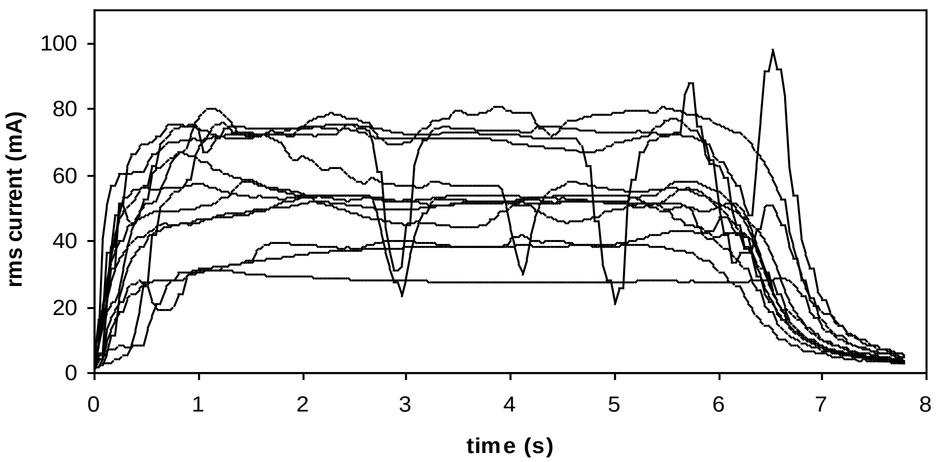

Figure 1c   Stunning using sprayed loose shackles (13 birds)

Figure 1   Stunning currents measured for tight, loose and sprayed loose fitting shackles

2. Breast support conveyor design and installation. (Objectives 2 and 3)

Birds can suffer stress and discomfort on the shackle line because they are suspended upside down by their legs. We have developed a system where the shackled birds rest on their breast in a horizontal position from the point of shackling until entry to the stun bath.

2.1 The breast support conveyor concept

Instead of suspending birds from a shackle by their feet, birds' feet are located in the shackle and the birds are supported on their breast on the breast support conveyor. The conveyor moves with the shackle line from hang-on point to the stun bath entry. At the stun bath entry the birds swing off the end of the conveyor and their heads fall rapidly into the stun bath. It was anticipated that the birds' would show less behaviour indicative of distress or discomfort since they are not inverted and suspended by their legs. A schematic diagram showing the shackled bird on the conveyor and entering the water bath is given in Figure 2.

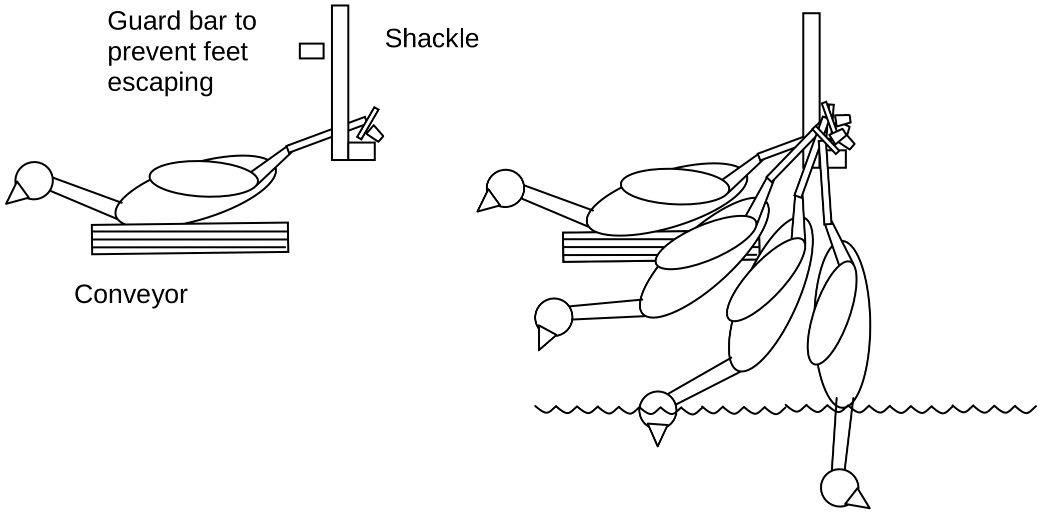

Figure 2 Birds are transported with their legs located in the shackle but supported on the conveyor. They enter the stun bath by swinging off the end of the conveyor directly into the water

2.2 Conveyor survey

A survey to investigate the types of conveyor available and suitable for the breast support task was carried out under sub-contract by Silsoe Technology Ltd. The conveyor survey remit was to investigate what conveying systems are currently available that could provide the following requirements:

- Move shackled birds smoothly from vertical hanging to horizontal conveyor support
- Potential for conveyor to run at a side-slope angle
- Ability to turn inside and outside corners
- Avoid sharp movements, drops etc to the birds
- Meet industry hygiene and reliability standards
- Handle 10,000+ birds per hour at 150mm spacing, 20 hours per day

The main conclusions of this survey are:

- Conveyor assisted transition of birds from the vertical to the horizontal position may be possible using an array of cord belts or modular chain belting systems.
- Changes of contour of the shackle line will be difficult to follow with the conveyor so should be avoided or minimised
- Corners will be manageable but are best avoided if possible. Care will be needed to ensure that turn radii are as large as feasible and the centres of the birds are aligned with the shackle conveyor through the corner to synchronise travel speed.

2.3 Preliminary trials

Trials using flat conveyors under the experimental shackle line at FAI, Oxford were carried out using dead birds. These demonstrated that birds could readily be attached to the shackles and positioned on the flat conveyor such that they were supported on their breasts and travelled parallel with the shackles without problem. The dead birds were also observed to swing neatly off the end of the conveyor into the conventional (vertical) position as would be needed for entry into a stun bath.

2.4 Prototype design and installation

A full scale system was commissioned and installed in a small scale processing plant which specialises in killing and processing small batches of extensively grown broilers and turkeys.

A commercial poultry processing plant is a difficult environment in which to do development work because it is intensively used and when in use the process cannot be stopped due to the cost of staff and the welfare implications for the animals. In this project we benefited from very strong support from the plant owner who from the outset saw the benefits of the conveyor approach. After installation, the processing plant used the conveyor system for all its operations for more than eight months.

Figure 3 shows the conventional shackle line and breast rub strip setup that existed before the conveyor was installed and Figure 4 shows the breast support conveyor after installation.

Figure 5 presents a schematic diagram showing the layout of the processing plant. The conveyor was positioned as shown by the shaded area running under the hang-on area (2.5 meters), round the 90 degree corner and then straight (3.5 meters) to the stun bath entrance. This diagram also identifies the positions of the data collection points (cameras and operatives) used for the bird welfare assessment.

The breast support conveyor was built by Intertech Process Machinery Ltd (Stroud, Gloucestershire). It comprised a collapsible chain link belt driven at one edge by an electronic speed controlled motor. The unit was mounted on extendable legs to enable the height of the conveyor to be adjusted relative to the shackles. When the conveyor was installed the breast rub strip was removed since it no longer had any function.

Shackles in the processing plant were mounted at 150mm spacing and the shackle line moved very slowly (0.06 m/s). This low speed was used because after killing and plucking the birds were dressed by hand. This low speed is not typical for commercial plants - line speeds can be 8 times faster than this. As a consequence of this low speed, the birds were shackled for longer than is normal prior to stunning. Due to this low speed, the dynamics of the birds as they slip from the conveyor into the stun bath will be different from those for a high speed line.

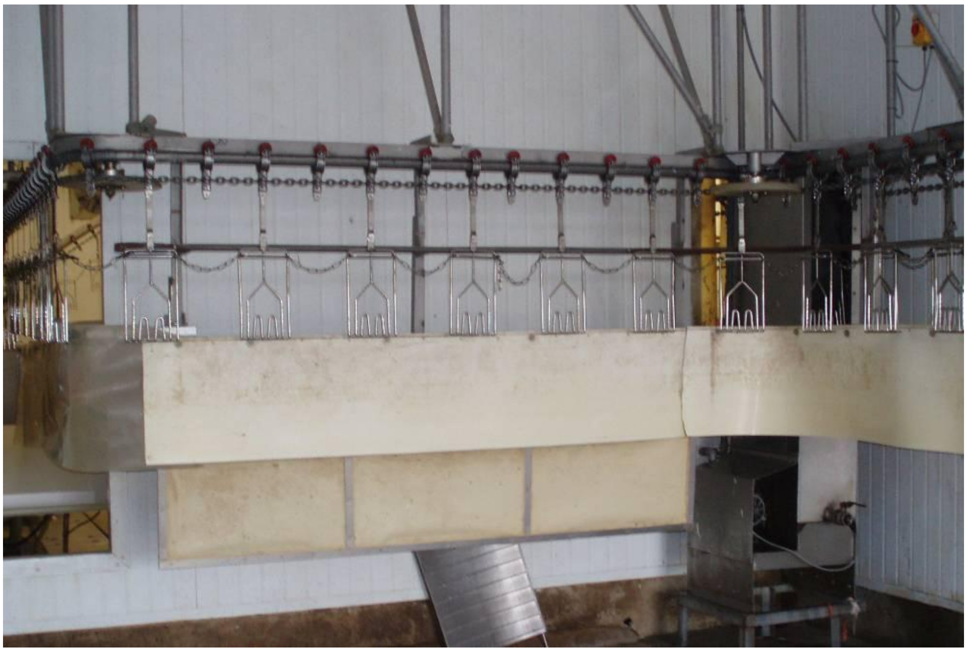

Figure 3 Conventional shackle line and breast rub strip in the plant before conveyor installation. (Note – shackle spacing was halved prior to all trial work for unrelated operational reasons – see Figure 4)

Figure 4 Breast support conveyor installed in processing plant

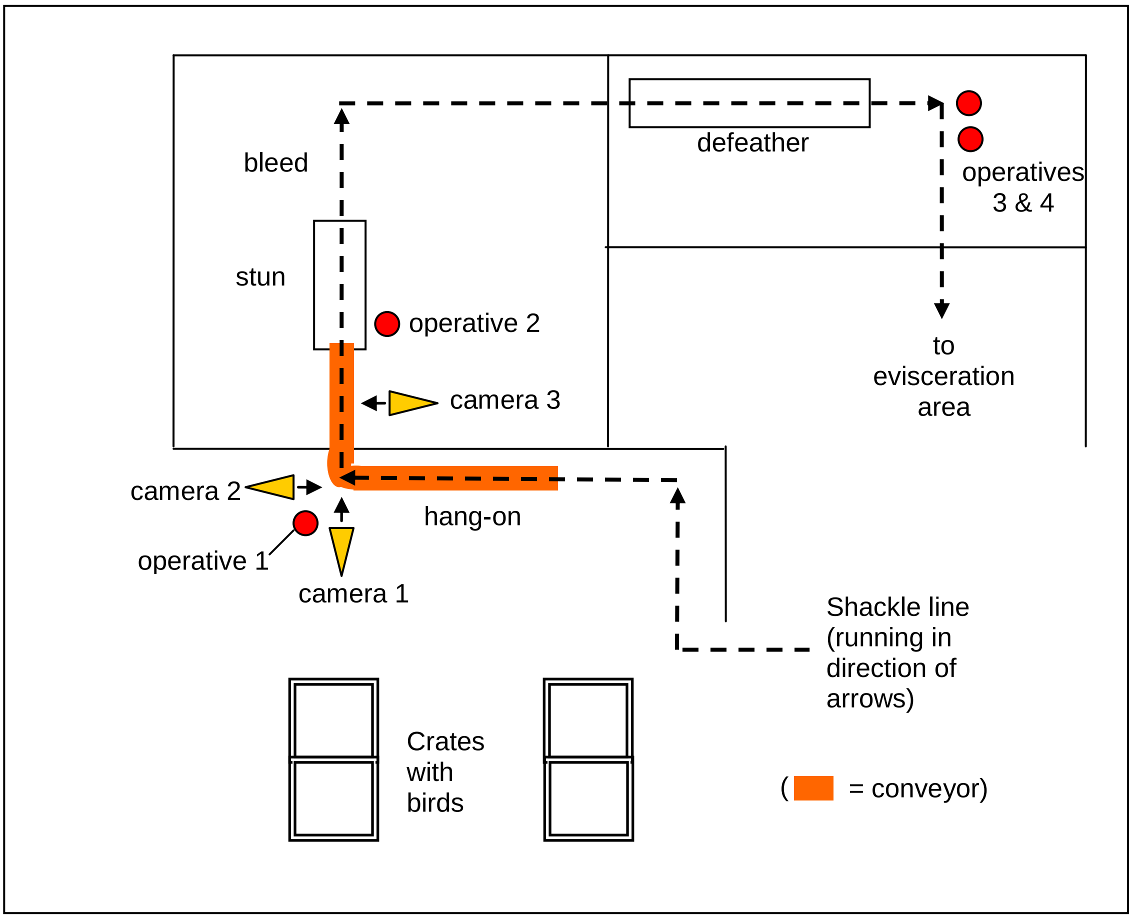

Figure 5 Schematic of shackle line layout

Figure 6 The hang-on section. The conveyor is too low in this photo, which results in some birds resting on their crops rather than on their breast

The layout of the processing plant required the conveyor to turn through a 90 degree corner immediately after the hang-on section. This corner is visible in Figures 4 and 7. During the installation of the conveyor, the existing shackle line corner was modified to increase the turning radius to 1.1 m to match the minimum turning radius of the centre-line of the conveyor.

In order to turn the corner the conveyor belt is driven at the outer edge only. This outer edge maintains a constant linear speed round the corner while the remaining width of the conveyor belt contracts in on itself to travel more slowly. Since the birds rest on the centre of the conveyor their linear speed reduces at the corner. The speed of the shackles and of the birds cannot therefore remain perfectly matched on both the straight sections and at the corner.

The conveyor was fitted with an electronic speed controller so that its speed could be synchronised with the shackle line. Careful adjustment of the conveyor speed to minimise the effect of this differential speed ensured that the relative movement was never large enough to drag the birds over the conveyor. A conveyor where the centre line of the belt (rather than the edge) runs at a constant speed would reduce the problem with corners but such equipment is not, to our knowledge, currently available.

The best design for shackle lines both with and without a breast support conveyor is to maintain a straight path from hang-on to stun bath. Some processing plants have been re-designed to achieve this however for many more, space constraints prevent this.

Figure 7 Birds on corner section of the conveyor

2.5 Entry into the stun bath

On a normal shackle line, birds enter the stun bath either by being lowered into the bath by a dip in the shackle line or by being dragged over an entry ramp and allowed to swing into the bath. Both approaches provide the birds with warning of an imminent change and so can result in wing flapping. Wing flapping commonly allows the wings to touch the water before the head and so results in pre-stun shocks and wing damage. Contact with poorly designed entry ramps can also result in pre-stun shocks.

Entry to the water bath from the breast support system occurs as the bird slips off the end of the conveyor. It swings head first into the stun bath, pivoting around the attachment point with the shackle and/or the hock joint (Figures 2 and 8). The transition from resting securely on the conveyor to falling into the stun bath is not instantaneous because of the width of the birds and the radius of the end roller of the conveyor. The shackle line in the processing plant where this system was tested moved slowly (0.06 m/s) so the process of passing over the end of the conveyor occurred relatively slowly, giving the birds time to react if the set up was not correct. In most large processing plants the shackle speed is much higher (up to 0.45 m/s). We anticipate that with a higher speed line it should be easier to generate a clean entry into the stun bath because the birds would have less time to react.

With the slow conveyor speeds used in this trial the quality of entry of the bird into the stun bath appeared to be controlled by the angle of the bird's body to the direction of travel. Entry into the stun bath seemed to be best when the head of the bird was slightly ahead of the body and feet. This usually resulted in a rapid and clean entry into the stun bath with the bird sliding head first over the final roller of the conveyor and into the stun bath, moving slightly faster than the shackle line. Where the bird was positioned so its feet were over the stun bath before the head left the conveyor, the birds could anticipate the fall and responded by bridging the gap with its body and by wing flapping. This commonly resulted in a wing entering the stun bath before the head. The angle of the birds on the conveyor was controlled by adjustments to the relative speed of the conveyor and the shackle line.

It had been anticipated that the birds in the stun bath might swing back and forth due to their entry momentum resulting in the need for a wide stun bath. In practise little swinging was observed so a standard width stun bath appears suitable for this application.

There was no evidence of pre-stun shocks caused by tracking of charge along the support conveyor. Since the conveyor is a plastic chain mesh which is continuously advancing towards the stun bath such tracking is unlikely to occur.

Figure 8 Birds passing from conveyor into stun bath

2.6 Weight distribution between legs and breast for birds when supported on the conveyor

The conveyor system was designed so that the distance between the conveyor surface and the bottom of the shackles could be adjusted by raising or lowering the conveyor on telescopic legs. This enabled the system to be optimised for broilers of different weight and size and also to facilitate using the line with turkeys as is occasionally required by the commercial operators of the pilot plant site.

Measurements were made of the distribution of load between the leg and the breast of birds at different shackle heights in order to understand the effect of this variation on the experience of the bird. The results for four sample birds are presented in Figure 9. The test results show that while any part of the keel (breast bone) is in contact with the conveyor, the proportion of bird weight supported on the legs is less than 40% of the total bird weight. As the vertical distance between conveyor and shackle point is reduced, the load on the legs reduces further. Only 20% of the bird's weight is on its legs when the rear end of the keel is in contact with the conveyor.

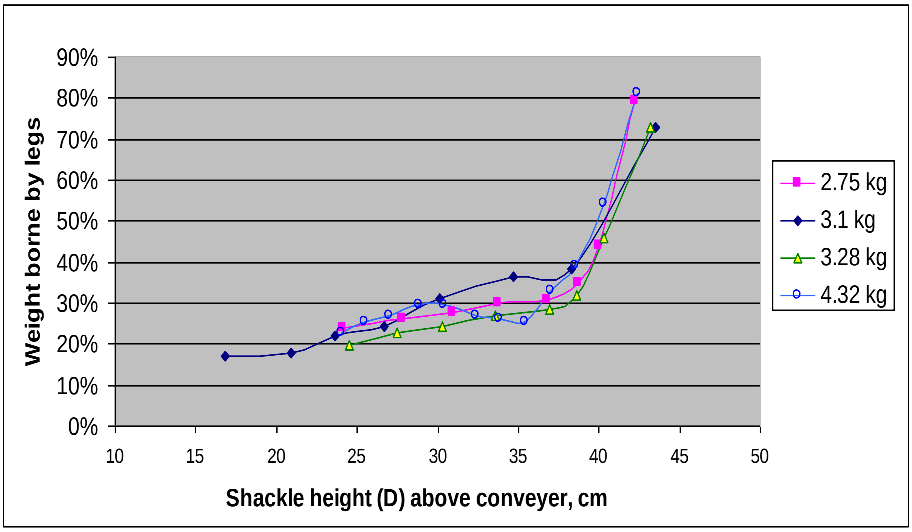

Figure 9 Percentage of bird weight borne by the bird's legs

The range of distances from the shackle to the tail and head ends of the keel for a sample of 42 birds is given in Table 1. Due to the length of the keel bone, all the birds examined in the weight range 1.9 to 5.4kg had some part of their keel bone resting on the conveyor if the vertical separation of conveyor and shackle was between 20 and 29 cm. With the conveyor set 25 cm below the shackles, between 70% and 80% of the bird weight rested on the conveyor for all the birds tested. Because of the broad weight band, fine adjustment of the conveyor height should not be required once the system has been set up. Adjustment should only be required when large changes are made to the weights of the birds being handled.

Care is needed to ensure that the vertical separation of the conveyor and the shackles is not too great, since this results in some of the weight of the birds being taken on the crop. This situation is likely to lead to distress and possibly to suffocation and so needs to be carefully avoided.

Table 1 Shackle to keel end distances for 42 birds with a range of weights

Measurement	Min	Max	Average
Bird weight, kg	1.91	5.44	2.98
Shackle to keel tail end, Kt, cm	15	20	18
Shackle to keel head end, Kh, cm	29	37	33

3. Assessment of the functionality, bird welfare and human factor implications of the breast support system (Objectives 4, 5 and 6)

The breast support conveyor system has been used extensively and successfully by the processing plant. A structured assessment has shown that welfare of the birds is improved at the point of hang-on and at the stun bath entrance. An ergonomics assessment of the altered procedure for placing birds on the process line indicates that no new ergonomic problems for the staff are created by this development.

3.1 Functionality

The clearest evidence of the functionality of the equipment is that the processing plant owners chose to use the conveyor system on a daily basis for eight months and paid for further improvements to the equipment.

The reason for this interest was that the birds processed in this plant were almost entirely from small free range, predominantly organic flocks. At slaughter, free range birds are at least 56 days old and the organic birds 70 days, as compared to 38 – 40 days with intensively reared birds. These extensively reared birds are generally much more active and responsive and so react more strongly to the shackle line than the less mature intensively reared birds.

The installation of the breast support conveyor did not significantly increase the work load for the process plant staff – either during the process of shackling or when cleaning the plant. However birds that escaped prior to shackling could be more difficult to pick up because of the additional equipment in the hang on area. Design changes to reduce the number of refuges the equipment provides beneath and behind the conveyor supports should be considered in future designs.

The presence of the corner in the conveyor increased the complexity and cost of the system, and increased the difficulty of selecting the best speed for the conveyor relative to the shackle line. Observation of the birds on the conveyor suggested that the corner initiated most of the unrest and struggling that was observed on the conveyor. Additional corners in the line would have complicated the system even more, possibly to the point where a breast support conveyor was no longer advantageous. Changes of level in the shackle line would have posed new problems for the conveyor design and would probably have resulted in additional struggling. The use of a straight shackle line from hang-on to stun bath therefore seems to be even more important for systems using the conveyor than for the traditional shackle line.

The shackles used in the plant were relatively loose and the shacklers were not encouraged to pull the birds hard down into the shackles. This looseness in the shackles, together with the presence of the conveyor meant that birds could pull themselves under the shackles then kick up and release one or both legs. Adjustment of the relative height of the conveyor to the shackle line was found to be effective in preventing the birds releasing their legs. Leg guards were also placed after the corner where most struggling seemed to occur. These ran along the shackles prevented the feet lifting out of the shackles. These guards were sprung to allow them to be pushed aside to release the birds in the event of a line stoppage.

The conveyor introduces a range of new adjustments that can be made to the system. These include the relative speed, height and lateral position of the conveyor. The introduction of a system such as this therefore requires more care, observation and initial adjustment than is necessary for a standard shackle line. Subtle changes in the setup can lead to significant effects on the quality of transportation, hence the apparent stress levels, of the birds. However observations in the trial plant indicated that the plant management quickly learn how to use these adjustments to achieve their goals.

3.2 Bird Welfare

3.2.1 Approach

A behavioural approach was adopted to assess the effectiveness of the breast support conveyor at the point of shackling (hang-on), when travelling to the stun bath on the shackle line, and at entry to the stun bath. The shackle line included a hang-on area, a straight section to a 90^o corner, the corner, and a second straight section to the stun bath. In the conveyor system (CON) the second straight was enclosed and there was no ramp leading into the stun bath. An unmodified shackle line with a breast rub strip system (BS) was used as the control. Here, the straight section to the stun bath was open, and there was a ramp leading to the stun bath. Figure 5 shows a schematic diagram of the processing plant with the observation points and camera points marked. A full report of the welfare assessment is given in Appendix 2.

Direct observations were made of every 25^{th} bird from hang-on to stun and the percent incidence of birds struggling (vigorous body movements with or without wing flapping) and vocalising were recorded along with the average duration of struggling bouts, and the location of each struggling bout on the line. In addition, indirect observations of every 4^{th} bird were recorded via 3 cameras positioned at strategic points on the line. Every bird was directly observed at the entrance to the stun bath, and the entry scored as ‘good’, ‘intermediate’ or ‘poor’ defined by the behaviour of the birds on entry and how long it took for an effective stun. Post killing and plucking, every 5^{th} carcass was examined for wing and leg damage.

Assessment of the conveyor took place over two days with birds from 6 different farms. Assessment of the breast rub strip system occurred 2 weeks later, after the conveyor had been removed and the original system installed, with birds from 5 farms. Four of the source farms were common to each assessment.

The birds supplied for processing were from free range and organic flocks. At slaughter, free range birds are at least 56 days old and the organic birds 70 days, as compared to 38 – 40 days with intensively reared birds. The extensively reared birds are generally much more active and responsive (flighty), and hence are more difficult to manage on the shackling line than intensively reared birds.

3.2.2 Welfare indicators at point of shackling

Use of the breast support conveyor (CON) resulted in a reduced proportion of birds struggling at hang-on ($p<0.05$) and in birds struggling for shorter bout lengths ($p=0.058$). The direct observations indicated that only 1.4% of the birds struggled immediately after shackling with the conveyor system (CON) and the average duration of struggling was 0.7sec. In contrast 11.4% of the birds that were hung onto the unmodified shackle line with the breast rub strip (BS) struggled and the average duration of struggling was 2.1 sec.

3.2.3 Welfare indicators while travelling to the stun bath

The welfare indicators indicated a more complex situation than at the point of shackling and direct observations apparently gave results that contradicted those obtained from video recordings. Direct observations were made of every 25th bird while indirect observations were made of every 4th bird; however a system failure meant that no video recordings were made of 2 of the 6 flocks of birds on the conveyor.

Direct observations indicated that 14.7% of birds struggled at some point on the conveyor (CON) but 42.4% of the birds struggled at some point on the unmodified shackle line with the breast rub strip (BS). This difference is significant at $p<0.01$. See Figure 11. There was no significant difference in the incidence of bird vocalisations for birds on the conveyor (40.9%) or the unmodified line (50.6%). 9.5% of birds on the conveyor were considered to be in a poor position – they were tipped too far forwards and so supported on the neck or crop. This was mostly dependant on the care with which the birds were arranged on the conveyor during shackling.

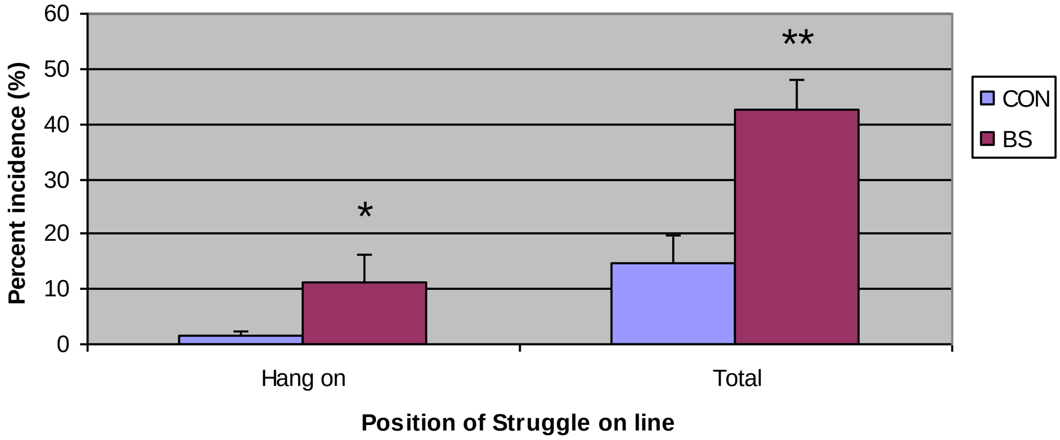

Figure 11 The incidence of struggling at hang-on and whilst travelling the length of the live bird line. Results are from direct observation in the lairage

After hang-on, there was no difference in the incidence of struggling in birds on the conveyor (CON) or un-modified shackle line (BS) systems along the straight to the 90° corner using either the direct or the video observations.

The video data indicates that the incidence of struggling was however greater for birds on the conveyor (CON) as they exited the corner ($p<0.01$) and travelled through an enclosed straight section to the stun bath ($p<0.05$). The incidence of struggling increased from 11.5% to 33.5% with the conveyor (CON) on exit of the corner and from 8.1% to 30.4% in the enclosed straight section. 25.8% and 14.2% of birds were considered to be poorly positioned on the conveyor up to the corner and on exit of the corner, respectively.

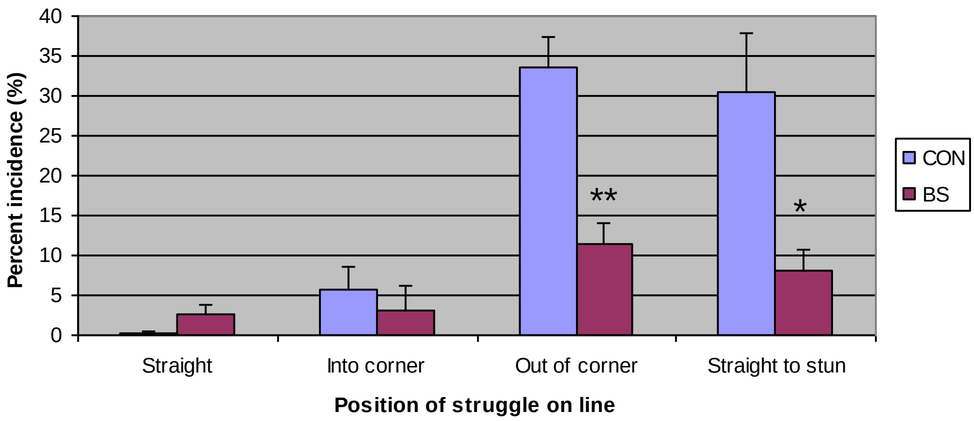

Figure 12 The incidence of struggling at the four sections of the shackle line to the stun bath. Results are from indirect observation taken from video records

3.2.4 Welfare indicators at entry to the stun bath

Observations of over 5000 birds entering the stun bath showed that 55% of the entries from the conveyor (CON) were good, 39% intermediate and only 7% poor, while from the un-modified shackle line (BS) only 13% of the entries were judged to be good, 51% intermediate and 36% poor. The differences in the prevalence of good and poor stun bath entries was significant at p<0.01 and p<0.001 respectively. A good entry was defined as one where the bird's head falls straight into water bath, so that the bird is stunned rapidly with no struggle, while a poor entry was indicated by several seconds of struggling and pre-stun shocks.

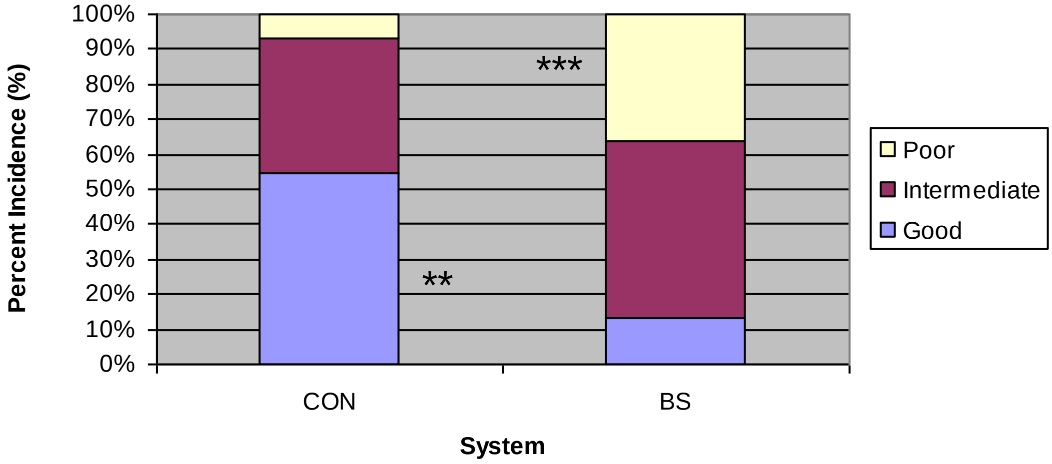

Figure 13 The incidence of good, intermediate, and poor stun entries off the conveyor and breast rub strip lines

The causes of intermediate and poor entries to the stun bath were significantly different between systems. With (CON) intermediate and poor entries were mostly due to birds struggling on the conveyor prior to entry to the stun bath, often leading to the release of one leg from the shackle. With (BS) entries were almost entirely due to wing flapping as the birds travelled and came off the ramp to the stun bath, resulting in the lead wing touching the water first. Both intermediate and poor entries would have contributed to pre-stun shocks in the birds.

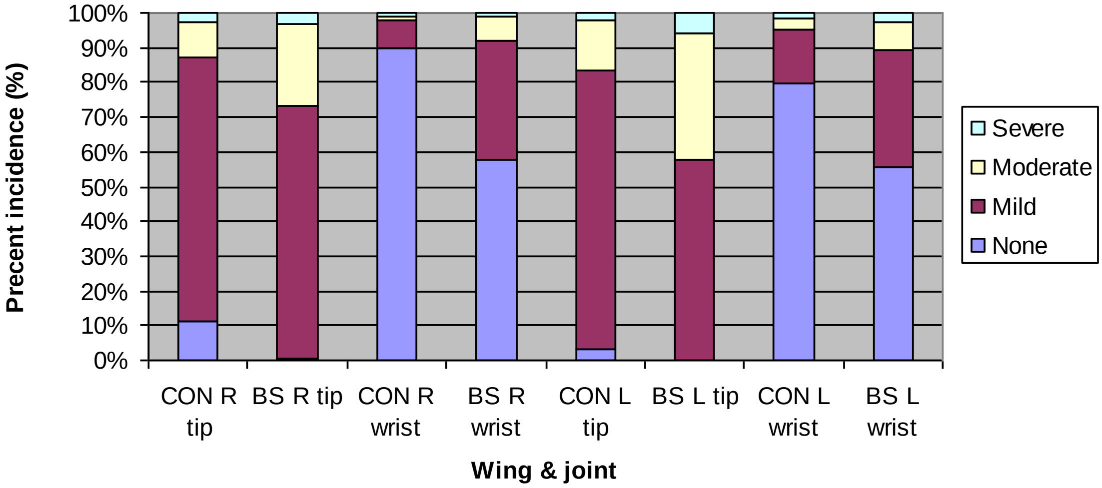

Figure 14 The incidence and severity of red wingtips and blood in the carpometacarpus / ulna joint (wrist) of the right (lead wing) and left wings of birds having travelled to stun on the CON and BS shackle lines

There were significant differences in the incidence of red wingtips and blood in the wrist joint (carpometacarpus /ulna) of birds travelling to the stun bath on the (CON) and (BS) lines. Fewer birds from (CON) exhibited red wingtips and blood in the wing joints than birds from (BS), and the incidence was of milder severity. Birds from (BS) had a significantly lower incidence of blood free wingtips (p<0.01) and wrist joint (p<0.05) in both wings, a higher incidence of birds with mild levels of blood in the wrist joint (both wings, p<0.05) and a higher incidence of moderate red tips in the left wing (p<0.05). There was no difference between systems in the levels of severe red wingtips and joints

In summary, the prototype conveyor system demonstrated that it was at least as effective at moving birds from shackling to stun as the existing breast rub strip system. There was evidence that the conveyor performed better at hang-on and on entry to the stun bath. Corners however were less effective with the conveyor than the breast rub strip, and correct positioning of the bird on the conveyor was deemed important.

3.3 Assessment of systems when used by processing staff

An ergonomics assessment of the process of hanging the birds on the shackles was carried out with both the un-modified shackle line and the conveyor system by Dave O'Neill Associates Ltd. The purpose of the assessment was to determine whether the breast support conveyor had an adverse effect on the operators. The assessment found that

- The breast support conveyor had no discernible detrimental effect on operator health or safety.
- The horizontal protrusion of the conveyor towards / into the operators' working space did not appear to have any adverse effect on the comfortable reach envelope of even the shortest operator observed, however some problems might arise for particularly small operators with a limited reach.
- The conveyor support structure could make it more difficult to retrieve the escaped birds.
- The operators, very occasionally, would re-position a bird's breast on the conveyor at some stage following hanging on. Time for this additional activity might not be available on high throughput lines.

At the trial plant, the shackling operators had to collect birds from containers placed behind them. In most high speed plants, the containers are in front of the operators and beneath the shackle line. The ergonomics of collecting and hanging birds in such a system will need to be addressed in future work.

4. Technology transfer. (Objective 7)

The owners of the processing plant where the system was evaluated are keen to maintain the breast support conveyor system for use with broilers and are especially confident that the system is advantageous for turkeys. This enthusiasm has resulted in interest and enquiries about the availability of the system from other small poultry processing plants.

A PowerPoint presentation explaining the development and evaluation of the conveyor system, including video clips of the system working under commercial conditions, has been compiled and is being used to demonstrate the technique to commercial and interested parties.

Discussions are ongoing with large retail consortiums who are interested in the welfare and meat quality aspects of the development.

The system is being actively promoted by project partners, including HSA, FAI and P B Technology.

5. Implications of the project findings

The findings of the research indicate that both sprayed loose shackles and a breast support conveyor are practical measures that can be used to improve bird welfare. The benefits of the conveyor however may be compromised if it is not correctly set up. As with a traditional shackle line, corners in the line between hang-on and the water bath should be avoided whenever possible to gain the most benefit from the equipment.

5.1 The use of loose fitting shackles to reduce pain and distress should be encouraged

Pain and distress due to the use of large shackling forces and high compression forces on the legs could be significantly reduced by the use of loose fitting shackles. Loose fitting shackles must be used in conjunction with a saline water spray just prior to, during and just after entry to the water-bath. This combination has been shown to provide stunning currents at least as consistent as is currently achieved using tight shackles. Stationary guard rails may be needed to minimise the incidence of birds disengaging one or both legs from the shackle. These rails are established technology but require customising for every situation. It is important to prevent legs escaping since birds entering the stun bath with only one leg in a shackle are at risk of not being properly stunned.

5.2 A breast support conveyor is a practical means of reducing distress on the shackle line

The breast support conveyor system was found to be a practical solution to the problem of birds struggling on the shackle line. The processing plant chose to use the conveyor over the previous traditional shackle line.

An ergonomics assessment found no reason to expect this innovation to cause problems for the processing line staff when they are hanging the birds on the shackle line. However in plants where the birds are presented at a different location to that used in the trial plant, another ergonomic assessment is advisable.

Bird welfare assessments showed clearly that the conveyor resulted in less struggling at the point of hang on and in cleaner entry into the water bath. Once the birds were located on the straight shackle line differences in struggling were not significant.

5.3 Corners in shackle lines should be avoided

The plant where this equipment was installed included one tight corner in the line between hang-on and the water bath. This increased the complexity of the installation and was associated with an increased amount of struggling by the birds. It is generally accepted that corners in the shackle line between hang-on and water bath disturb the birds. Avoiding corners in the shackle line is at least as important when a conveyor breast support system is used instead of the normal breast rub strip.

5.4 The conveyor needs to be properly set up

The breast support conveyor increases the number of adjustments that can be made to the system. When these adjustments are correct bird welfare is clearly improved but if the system is poorly set up these benefits may be lost. More experience of this system in other processing plants is needed to generate sufficient experience to anticipate and avoid setup and operational problems. This system is not yet ready for un-restricted commercial release.

6. Possible future work

Further development and testing is needed before the system can considered to be ready for commercial uptake. Areas for further work include alternative ways in which the conveyor can be set up to minimise bird stress and struggling, further assessments of bird welfare and practical analysis of the implications of introducing this system into a high speed commercial processing plant. These important developments were not possible in the trial plant, so were beyond the scope of this project.

6.1 Preventing birds disengaging legs from the shackles

Some birds will struggle and in a few cases some were successful in releasing one or both legs from the shackle. This must be prevented. The relationship between the height of the shackle over the conveyor and the bird's ability to escape from the shackles should be examined in more detail since it is probably not a simple monotonic relationship. Further experience using leg guards in high speed lines should be gathered. The use of shackles with some flexibility that allow the birds' legs to be pulled past a detent so they remain un-compressed but captive should be pursued.

6.2 A sloping conveyor at hang-on

Future development should investigate the use of a conveyor that slopes down away from the shackles in the hang-on area then twists towards the horizontal beneath the birds as they advance. Providing a sloping conveyor surface could make shackling easier by allowing the workers closer to the shackle line. It should also improve the positioning of the birds on the conveyor ensuring they are placed in the normal direction of travel and resting on their breast. This would reduce the need for later adjustment to correct their position. The conveyor would then need to twist back towards the horizontal taking the weight off the bird as it progresses towards the stun bath. This modification was not made in the trial plant but should be investigated during further development.

6.3 A sloping conveyor from hang-on to stun bath entry

If the birds struggle they can change their position on the conveyor belt, potentially encroaching on another bird. This can have undesirable effects, particularly at the point where they swing into the water-bath. Additionally in struggling they can bring their bodies closer to the shackles, potentially loosening the hold on their feet by the shackles and making it easier to escape. This problem could be lessened by using a conveyor that is tilted slightly down away from the shackles. Struggling birds would tend to slide down the slope of the belt, retaining them at 90 degrees to the direction of motion and pulling their legs gently back into the shackles. This would marginally increase the load on the legs – but to a lesser extent than lowering the level conveyor. On a tilted conveyor the birds could be in a more comfortable position than on a horizontal belt because they would be parallel to the belt with less chance of placing any weight on the crop.

6.4 More detailed welfare assessment

Further comparative assessments of the apparent stress of the birds suspended on shackles and resting on the conveyor belt could be made using behavioral and physiological tests. These would be best done by simulating a processing plant in a laboratory. These trials would be difficult to do in the busy environment of a commercial plant.

7. Conclusions

This research project has demonstrated that the use of sprayed loose shackles and a conveyor to provide breast support can benefit both the operational effectiveness of a processing plant and also result in a clear welfare benefit for the birds at the point of slaughter. However the system has only been used on one small scale and slow moving shackle line and is not ready for unrestricted release. Further tests and assessments are needed on installations in higher speed plants and other options as outlined in section 7 should to be explored.

The system was developed for broilers and has been successfully used on extensively grown chickens. Observations also suggest it works well with turkeys. It has potential to improve the welfare of other poultry at slaughter – particularly end of lay hens and ducks. Dedicated trials and welfare assessments will be needed for these species.

Acknowledgements

The project contractors gratefully acknowledge the support provided by the host processing unit - Baileys Turkeys, and by other processing plants that have chosen to remain anonymous. We are also indebted to the Humane Slaughter Association for their involvement and assistance, and to the Farm Animal Welfare Trust.

References to published material

9. This section should be used to record links (hypertext links where possible) or references to other published material generated by, or relating to this project.

References to other published material

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