MH0 138: Reducing stress and discomfort on the poultry shackle line

Appendix 1

Chicken Resistance Measurement Results: Measurements made at FAI

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Introduction

One of the key proposals of the Defra project is to reduce the compression on chicken legs in the shackle. It is anticipated that replacing the presently used tight fitting shackles with a loose fitting shackles would have two consequences – that the stun current applied to the birds would become more variable and that the birds could escape or be thrown out of the shackle during plucking. This experiment is designed to address only the first of these anticipated problems.

The research proposal points out that the electrical resistance in the current pathway between a dry foot resting lightly in a metal shackle is likely to be high and variable. Since the resistance between the shackle and the foot is likely to comprise a significant part of the total resistance pathway, variation in this component will result in variation in the stunning current and hence risk under stunning or over stunning individual birds with the associated welfare or quality implications. The proposal suggests the use of a saline water spray on the legs to increase the contact area between the legs and the shackle and so to improve the consistency of the stun. Some people in the industry are cautious about such a spray because of fears that wetting the birds reduces the core body current and so results in a poor stun. Gregory and Wotton (1992) found that given an 81mA stunning current, wet birds showed a quicker recovery than dry birds however if the current was 119mA no difference was observed. This trial however does not take into account the fact that the total current passing through a wet bird will be greater than that passing through a dry bird so the change in body core current would not be as great as in the Gregory trials. Perez-Palacios and Wotton (2006) also allude to this effect but offer little justification in support of this point of view.

Experiment Objectives

To investigate

1. the stunning current uniformity when shackles are loose but feet sprayed
2. whether wetting the birds feathers reduces the core body current
3. the component resistances of the chicken

Experiment description

General

Forty seven birds were killed by neck pulling and immediately (i.e. within 30 sec) hung on a large loosely fitting shackle with the chicken head in a water bath. Monitoring electrodes were inserted into each foot, into the body cavity between the legs and at the base of the neck. A 500 Hz sinusoidal, 110 V (nominal) potential was then applied between the shackle and the water bath and current and voltages were monitored.

Treatments

The experiment comprised twelve cycles each comprising four birds (A, B, C and D), and each freshly killed bird was "stunned" twice in quick succession. Treatments are given in Table 1.

Table 1 Treatment groups

	First treatment	Second treatment
Group A birds	wet feet, dry body	wet feet, dry body
Group B birds	dry feet, dry body	wet feet, dry body
Group C birds	wet feet, dry body	wet feet, wet body
Group D birds	dry feet, dry body	wet feet, wet body

- *Wet feet (Wf).* Birds were hung on the shackle, and then the feet and shackle were sprayed with saline water for about 5 seconds before the stun voltage was applied. Spraying continued during the stun.
- *Dry feet (Df).* Birds feet were not sprayed however the shackles were wet from the previous test
- *Wet body (Wb).* Birds were hung on the shackle and sprayed for about 20 seconds using the saline water spray to wet the plumage and skin.
- *Dry body (Db).* Bird bodies were not sprayed.

Bird description

The birds used were white organic free range broilers with a mean weight of 1300 g with a standard deviation about this mean of 200 g. The circumference of the left leg of each bird was measured at its narrowest point. Leg circumferences had a mean of 44 mm with a standard deviation about this mean of 4 mm.

Equipment description

The shackle used had a minimum gap between the bars of 11 mm and a 14 mm gap in the return. This allowed all the chicken legs to hang in the shackle without pressure.

The spray water and water bath water used had a conductivity of 20 mS/cm (i.e. about half the conductivity of sea water). This water was sprayed onto the shackles, legs and bodies using a fine fan spray and applied at a rate of about 7ml/s.

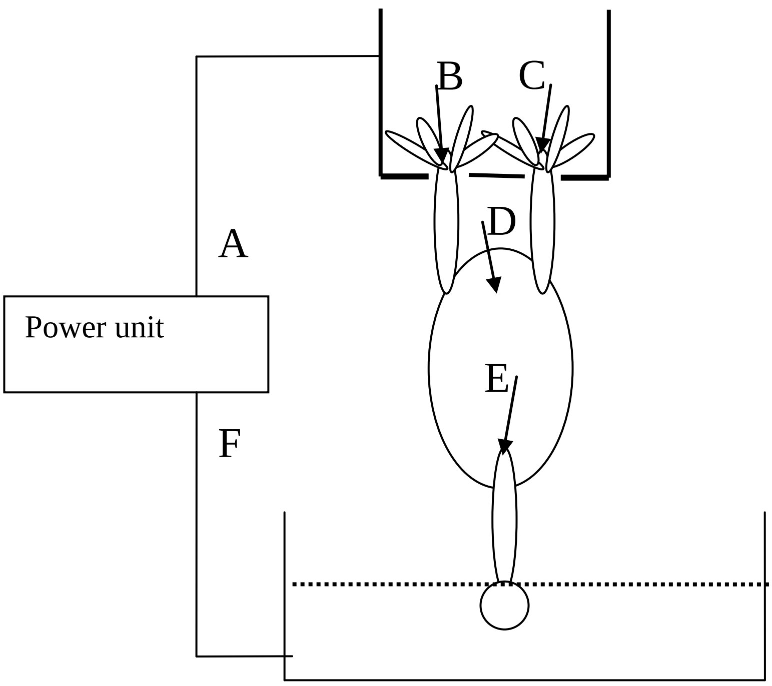
Electrodes used were hypodermic needles insulated using a varnish to within 5 mm of the tip. These were pushed into the pads of the feet, into the body cavity directly between the legs, and into the body at the base of the neck. Following insertion a small quantity (0.5ml) or saline solution was injected through the needles to ensure good contact was made between the body and the needles. These electrodes were connected to high impedance volt meters measuring rms voltage.

Procedure
Each bird was taken from its transport crate. Its neck was pulled, and within about 20 seconds it was hung on the shackle with it head in the water bath. Where the feet were to be sprayed, this spray was applied from 5 seconds before the stun voltage was applied. The stun voltage was applied to the shackle for 20 seconds. Current and voltages were detected by a set of digital multimeters and the readings were noted by hand in the following order: Total current, shackle voltage, foot1 voltage, foot 2 voltage, body voltage, neck voltage, total current (repeat measurement). This was achieved within the 20 seconds stun duration.

For the wet body birds (groups C and D) the body was then sprayed. The leg spray was then returned to its position, the legs sprayed for 5 seconds and the second stun voltage applied for another 20 seconds during which current and voltage measurements were again made.

Data
The results from cycle1, birds A, B and C were not used in the analysis because lack of familiarity with the process meant the mistakes were made and delays resulted from these mistakes. The results from the last three birds (cycle 11 Bird D and cycle 12 birds A, Band C were also rejected because very variable shackle voltages suggested a developing power unit problem. Analysis is therefore made of 40 birds, ten from each treatment group.

Calculation of component resistances



It is necessary to assume that the leg resistances are equal $R_{BD} = R_{CD}$

total current $I_{AF} = V_{BD}/R_{BD} + V_{CD}/R_{CD} = (V_{BD} + V_{CD}) / R_{BD}$

Therefore $R_{CD} = R_{BD} = (V_{BD} + V_{CD}) / I_{AF}$

Since the current going through each foot is the same as that going through the leg,

$V_{AB}/R_{AB} = V_{BD}/R_{BD}$

and $V_{AC}/R_{AC} = V_{CD}/R_{CD}$

so $R_{AB} = V_{AB}R_{BD}/V_{BD} = V_{AB} (V_{BD} + V_{CD}) / I_{AF} V_{BD}$

and $R_{AC} = V_{AC}R_{CD}/V_{CD} = V_{AC} (V_{BD} + V_{CD}) / I_{AF} V_{CD}$

if all voltages are now referenced to F, so for example $V_{AB} = V_A-V_B$, these relationships become:

Leg resistance $R_{CD} = R_{BD} = (V_B + V_C - 2 V_D) / I_{AF}$

Foot B resistance $R_{AB} = (V_A - V_B) (V_B + V_C - 2 V_D) / I_{AF} (V_B - V_D)$

Foot C resistance $R_{AC} = (V_A - V_C) (V_B + V_C - 2 V_D) / I_{AF} (V_C - V_D)$

Body resistance $R_{DE} = (V_D - V_E) / I_{AF}$

Neck, head and bath $R_{EF} = (V_E - V_F) / I_{AF}$

Measurement results

Table 2. Resistances measured on experimental birds (based on first current measurement)

	Whole bird resistance		Foot resistance		Leg resistance		Body resistance		Neck & head resistance	
	Mean(Ω)	sd/mean	Mean(Ω)	sd/mean	Mean(Ω)	sd/mean	Mean(Ω)	sd/mean	Mean(Ω)	sd/mean
Wf & Db	1407	15%	443	40%	1494	18%	238	33%	205	35%
Wf & Db	1303	13%	360	32%	1430	14%	219	31%	185	52%
Wf & Wb	1339	14%	360	33%	1507	16%	208	28%	205	25%
Df & Db	2032	29%	1502	55%	1570	15%	256	30%	262	39%

Table 3. Resistances measured on experimental birds using second current measurement (column headings as Table 1a)

Wf & Db	1385	15%	438	43%	1469	16%	234	31%	202	35%
Df & Db	1711	21%	1242	50%	1345	16%	219	31%	220	35%

Intermittent measurement of the water bath voltage close to the birds head showed it to be very close to the base electrode voltage.

The average of the second current readings was only 0.6% greater than the average of the first current reading for the wet feet measurements; however for the dry feet measurements the second current reading was 18% greater than the first current reading. Comparison however between the comparable groups in Tables 2 and 3 show that although the current dropped significantly during the measurement procedure for the birds with dry feet, the same general results are indicated by both sets of calculations.

Tables 2 and 3 give the variation in foot resistance as the standard deviation related to the mean. The absolute range in foot resistances is as follows

Wet feet, dry body Minimum resistance 204 Ω. Maximum resistance 838 Ω

Dry feet, dry body Minimum resistance 368 Ω. Maximum resistance 3679 Ω

Examination of the correlation between leg diameter and foot resistance indicates no significant trend for either wet or dry feet. This is the expected consequence of using a shackle which was always larger that the leg size, so the legs were never compressed into the shackle.

Some measure of confidence in the measurements presented in Tables 2 and 3 can be gleaned from the observation that the total resistance as measured, does not differ from the sum of the component resistances by more than 1.5 % for any of the conditions, where whole bird resistance is calculated from the sum of component resistances as:

Whole bird resistance = ½(foot + leg) + body + head and neck

Table 4. Decrease in resistance due to change in condition

Change from	to		Whole bird	feet	legs	body	head
Wf & DB	Wf & Db	mean	3%	10%	-2%	5%	14%
		sd	3%	13%	4%	11%	9%
Df & Db	Wf & Db	mean	35%	103%	9%	13%	-6%
		sd	17%	39%	7%	26%	72%
Wf & Db	Wf & WB	mean	7%	19%	2%	12%	-8%
		sd	4%	25%	6%	20%	72%
Df & DB	Wf & WB	mean	48%	121%	12%	23%	30%
		sd	22%	35%	8%	19%	16%

An alternative way of looking at the changes is to consider the mean change in resistance of individual birds due to the change in condition and also the standard deviation of that mean (Table 4).

The first two lines of the Table 4 (Wf & Db to Wf & Db) show that the resistances during the second exposure do not differ significantly from the resistance during the first exposure where the conditions have not been changed. The changes shown are both small and of low statistical significance. We can therefore assume differences observed in the Table 2 are not primarily determined by whether the resistance was measured during a first or second stun.

The fifth and sixth lines of the Table 4 (Wf & Db to Wf and Wb) show that when the condition of the birds body is changed from dry to wet but the feet remain wet, the total resistances of the birds decreases by only 7 ± 4 %. Other implied changes in resistance are resistance are uncertain since the measured changes are substantially smaller than the inter-bird variation.

The third and fourth lines of Table 2 (Df & Db to Wf & Db) show that the really substantial change in apparent bird resistance occurs when the feet are wetted. The reduction in foot resistance is 103 ± 39% and the reduction in total bird resistance is 35 ± 17%. This is because the wetted feet have a larger contact area with the shackle.
Table 5 gives the mean and standard deviation of bird resistances calculated from 13 commercial poultry line tests conducted by Paul Berry Technical Ltd. These resistances and variations in resistance are the best estimate available of the current industry norm.

Table 5. Bird resistance results from routine poultry line monitoring tests.

	voltage	# birds	Bird resistance (Ω)	sd/mean
test1	55	12	1121	12%
test2	62	12	906	12%
test3	50	12	1153	19%
test4	53	12	1351	29%
test5	112	10	1202	10%
test6	93	10	1250	14%
test7	104	10	1211	10%
test8	120	10	1467	24%
test9	139	10	1083	16%
test10	110	10	1152	20%
test11	98	10	1164	16%
test12	95	10	979	15%
test13	110	11	1301	13%
average	**92**		**1180**	**21%**

The data generated by this experiment suggests:

1. That the measured whole body resistances of the birds with wetted feet are within the range which Table 5 suggests may be normal commercial conditions. Thus the looseness of the shackle is compensated for by the improved electrical contact caused by the saline spray.

2. The variation in the whole body resistance of the birds with wetted feet is below the average variation indicated in Table 5. This small variation should allow the stun voltage to be set so that it delivers an appropriate stun to the majority of birds.

3. In contrast with the above, Table 2 indicates that for birds with dry feet placed into a loosely fitting wet shackle, the whole body resistance is significantly higher than normal current industrial practise and the variation in resistance between birds in similar to the worst case identified in Table 5.

4. Measurements in Table 2 made on the wet birds give no indication that current is tracking across the surface of the bird.

These four conclusions suggest to me that the use of loosely fitting shackles and a saline spray on the birds’ legs could successfully be used instead of tightly fitting shackles during stunning if the other related problems can be solved.

5. The resistance of poultry on a poultry line comprises approximately

Foot (wet feet, loose shackle)	400 ± 200 Ω each
Foot (dry, loose shackle)	1500 ± 800 Ω each
leg	1500 ± 250 Ω each
total both feet and legs	950 Ω
body	200 ± 100 Ω
neck and head	200 ± 100 Ω

These values of resistance prompt several observations.

It is interesting to compare the resistance of the legs and neck. Although nominally of similar sizes the latter is clearly better supplied with electrically conducting material.

Initially I guessed that the leg resistance might be dominated by the electrical flow through the blood supply system, however a simple estimate (blood 15mS/cm (Gabriel et al 1996), length 100 mm cross-sectional area 4 mm^2) gives a resistance of ten times the actual measured resistance, the blood supply system is therefore probably not the main electrical conduit even though loss of blood pressure is the most obvious change in body composition during the first 20 minutes after death.

It is of interest to speculate on where the electrical current exits the body. Since the bird is stunned this exit point is clearly not primarily through the skin otherwise the current would exit through the skin on the neck and the brain would not be affected. I assume the exit point is through the mucus membrane in the mouth, nostrils and eyes. The low head and neck resistance suggests that conduction at the exit point is good.

Conclusion

Close similarity between the experimental results and those gleaned from routine poultry line testing suggest that the reported experiment represents a good indication of the behaviour of the proposed system under normal conditions. These results indicate that the use of a saline spray and loose fitting shackles should result in stunning currents as consistent as those currently measured and require no change from the stun voltages currently used.

Attention must now be transferred to developing a loose fitting shackle which will not loose the bird during plucking.

References

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Perez_Palacios A., Wotton S.B. Effects of salinity and the use of shackle/leg sprays on the electrical conductivity of a commercial waterbath stunner for broilers. Vet Record May 13 2006.

Gabriel, S., Lau, R.W., Gabriel, C., 1996. The dielectric properties of biological tissues: II. Measurements in the frequency range 10 Hz to 20 GHz. Physics in Medicine and Biology 41 (1996), 2251– 2269.

Experimental measurements

Cycle/group	Condition	Current (mA)	Shackle (V)	Foot1 (V)	Foot2 (V)	Body (V)	Neck (V)	Current (mA)
1d	Df & Db	64	113.7	72.7	76.5	31.2	10.5	74
1d	Wf & Wb	85.6	108.2	82	93.9	33.5	10.2	
2a	Wf & Db	73.6	109.3	98.1	89	35.8	11.6	78.9
2a	Wf & Db	80.1	109.2	97.4	92	34.8	9.9	
2b	Df & Db	78.3	110.1	92.7	83.9	32.6	12.5	81.1
2b	Wf & Db	88.2	107.6	95.5	91.7	34	11.5	
2c	Wf & Db	90.1	106.8	93	96.7	33.6	12.3	88.2
2c	Wf & Wb	99	103.6	94.4	93.7	31.7	11.5	
2d	Df & Db	54	113.1	53	83.6	28.8	12.5	63.8
2d	Wf & Wb	79.6	102.4	90.1	88.7	35.5	14.7	
3a	Wf & Db	69.9	105.3	90.9	75.5	30.2	10.2	68.8
3a	Wf & Db	73.1	108.2	93.1	79.6	30.9	10.5	
3b	Df & Db	81.6	108	91.1	78.3	34.3	11.1	84
3b	Wf & Db	90.5	105.2	92.4	92.6	37.2	10.5	
3c	Wf & Db	76.9	109	96.2	90.4	34.7	12.7	78
3c	Wf & Wb	79.9	107	95	92.3	32.5	11.3	
3d	Df & Db	52.3	114.9	86	61.2	25.7	10.1	55.5
3d	Wf & Wb	71.4	108.3	89.9	91.1	29.3	11.4	71.2
4a	Wf & Db	63	111.4	91.7	88.2	30.6	9.6	65.8
4a	Wf & Db	66	109.6	92.2	86.9	28.6	8.3	
4b	Df & Db	50.1	113.4	64.5	58.9	21.3	10.5	63
4b	Wf & Db	87.4	104.2	91	87.8	34.1	15.8	88.4
4c	Wf & Db	72.9	107.9	84	94.7	27.8		77.8
4c	Wf & Wb	79.3	106.6	85.6	96.6	28.2	12.4	
4d	Df & Db	74.4	106.5	81.5	79.7	24.6	15.4	74.3
4d	Wf & Wb	89	103.2	95.1	87.9	27.1	16.5	
5a	Wf & Db	77	105.5	94.1	97.9	37	18.3	74
5a	Wf & Db	79.1	105	94.5	97.9	34.6	15.8	79
5b	Df & Db	51.8	99.7	55.9	67	23.6	10.1	56
5b	Wf & Db	70.3	92.4	75	78.3	29.8	10.7	
5c	Wf & Db	101.1	106.7	86.1	81.7	36.6	19.7	107.6
5c	Wf & Wb	104.5	106.7	89	85.4	35	17.9	
5d	Df & Db	48.9	120.7	80.2	88.9	33.7	15	54
5d	Wf & Wb	66.8	116.7	101.8	99.6	40.2	17.8	
6a	Wf & Db	94.5	113.7	96.9	89.2	37.9	21.1	95
6a	Wf & Db	98.8	113.6	95.7	90.9	33.7	17.2	99.8
6b	Df & Db	44.1	127.1	66.6	70.8	28.3	25	50.1
6b	Wf & Db	72.8	119.5	110.9	102	43.9	37	72
6c	Wf & Db	65.1	120.3	101.7	102	34.4	17.2	69.3
6c	Wf & Wb	71.4	119.4	104.4	102.6	34.7	16.4	71.9
6d	Df & Db	58.1	122.2	83	88.6	31.1	16	69.9
6d	Wf & Wb	80.8	116.3	105.2	99.7	33.6	16.5	81.5
7a	Wf & Db	80.4	125.5	113.7	108.8	45.5	15.8	82.7
7a	Wf & Db	81.9	124.3	113	107.7	39.5	15.1	85.6
7b	Df & Db	70.1	125.4	91.2	86.8	31.7	14.2	79.9
7b	Wf & Db	88.7	121.7	100.2	106	34.6	24.4	89.9
7c	Wf & Db	88.6	123.4	113.1	110.6	42.2	26.3	90.9
7c	Wf & Wb	91.1	122.1	107.3	105.9	38.1	22.7	92.6
7d	Df & Db	55	128.8	72.4	89.4	34.1	22.2	81.8
7d	Wf & Wb	104.6	117.7	104.8	101.9	34.5	22.5	104.6
8a	Wf & Db	105.8	116.9	94.9	103.6	33.2	9.2	100.1

8a	Wf & Db	102.8	115.9	94.5	100.4	29.2	6.9	106.9
8b	Df & Db	64	125.6	69.5	93.2	40.1	18.2	85.6
8b	Wf & Db	91.1	118.5	99.5	99.7	42.4	17.3	91.7
8c	Wf & Db	89.9	121.3	108.9	109.4	46.1	21.5	93.6
8c	Wf & Wb	96.8	119.2	110.7	110.8	44.7	20.6	98.6
8d	Df & Db	59	128.1	74.5	76.1	32.5	18	73
8d	Wf & Wb	94	117	99.6	102	39.1	19	94.1
9a	Wf & Db	99.4	108.9	90	84.5	31.5	10.2	101.8
9a	Wf & Db	102.6	107.9	90.3	87.5	28.4	9.4	101.8
9b	Df & Db	93.8	133.1	112.3	97.6	39.4	22.1	96.7
9b	Wf & Db	84	101.7	94.5	85.9	34.8	22.1	87.6
9c	Wf & Db							
9c	Wf & Wb	79	107.6	93.8	92.8	34	20.5	80.5
9d	Df & Db	75.7	119.2	83.8	98.3	41.8	17.1	77.8
9d	Wf & Wb	91.9	114.8					
10a	Wf & Db	90.6	115.4	104.2	103.4	36	12.6	92.6
10a	Wf & Db	92	115.3	105.3	103.8	33.4	12.1	94.7
10b	Df & Db	69	121.6	87.4	71.8	30.8	17	83.9
10b	Wf & Db	98.8	114.3	100.8	93.3	35.4	17.9	98.8
10c	Wf & Db	80.1	111.5	98.2	89.9	29.8	19	81
10c	Wf & Wb	79.9	109.2	92.8	88.8	27.8	15.8	82.1
10d	Df & Db	30.6	120.3	65.8	42.6	23.7	12.6	47.8
10d	Wf & Wb	75.3	107.3	94.5	97.2	37.7	21.1	75.3
11a	Wf & Db	72.6	108.5	89	85.4	29.9	21.7	73.3
11a	Wf & Db	73.4	105.8	91.6	91.4	31.5	21.1	73.1
11b	Df & Db	61.3	111.2	72.8	81.4	30	16.9	78
11b	Wf & Db	92.8	103.9	89.6	93.2	31.3	16.5	92
11c	Wf & Db	62.7	107.5	88.6	82.1	31.1	21.7	67
11c	Wf & Wb	63	100.3	88.7	82.3	25.6	17.2	66.7