Animal Welfare 2004, 13: 409-418
ISSN 0962-7286

Welfare aspects of chick handling in broiler and laying hen hatcheries

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Abstract

Six commercial hatcheries were visited in the United Kingdom, three of which processed laying hen chicks and three of which processed broiler chicks. The accelerations experienced by the chicks passing through the handling systems were evaluated using miniature data logging accelerometers, which were sent through the systems. The lengths, speeds, and heights of drops of the pathways within each system were also measured. The response of the chicks to the handling was measured in terms of mortality, orientation, righting time (as a measure of disorientation) and tonic immobility. The study showed there to be a range in the physical severity of handling across the hatcheries that could also be seen in terms of differences in the measurements made on the chicks. Nonetheless, the welfare of the chicks passing through the automated systems appeared to be generally acceptable. However, given the velocities and accelerations within these handling systems, there is scope for considerable damage to the chicks, and for poor welfare, if systems are not properly set up or maintained.

Keywords: *animal welfare, broiler, chick, handling, hatchery, laying hen*

Introduction

Modern hatcheries have become very large, with single hatcheries capable of producing upwards of one million chicks per week. To enable this increased output the process has become highly automated with chicks being handled in large numbers and at high speed. In most areas of animal husbandry the potential for poor welfare to occur generally increases with increased throughput. This project was carried out in order to investigate the welfare implications of the use of automated handling systems for newly hatched chicks.

The degree of automation varies between hatcheries. Broiler chicks are produced in much greater numbers than laying hen chicks, and broiler hatcheries tend to be more fully automated. Typically, in a fully automated system, the handling of the live chicks begins with an egg separator, a device that empties the chicks onto a series of carefully spaced rollers that separate the live chicks from unhatched eggs and egg shell. At the time of the study, the RSPCA Welfare Standards (RSPCA 1999), which must be met by Freedom Food accredited hatcheries, did not allow the use of an automated egg separator, therefore separating was carried out by hand at all of the hatcheries visited. Live chicks are transferred from the shell separation stage, usually past a manual quality control inspection point, to the sexing carousel by a rising, moving belt, and deflector plates. Operators pick chicks from the carousel and drop them into one of two chutes depending on the sex of the bird. The chicks are then carried from the chutes by a further rising belt. In order to automate the counting of the chicks, they are passed onto a series of increasingly narrower and faster-moving horizontal belts (accelerator belts) until they are moving in single file and at an increased velocity, which is necessary to maintain the throughput. At the end of the last accelerator belt, the chicks are counted as they break a beam of light directed at a photosensitive transducer. They then fall directly into a static collecting basket, which is moved by conveyor once a set number of chicks are in the basket. Spray (aerosol) vaccination usually takes place along the conveyor once the chicks are in the basket moving away from the counter. Laying hen chicks are often subjected to additional manual subcutaneous vaccination at some point within the system.

Few studies have investigated the welfare of chicks during automated handling. Svedberg (1996, 1997, 1998) evaluated chick separators and chick counters as individual components of the system. Svedberg (1997, 1998) assessed the acceptability of one type of chick separator (RRAL-200), in terms of welfare, for use in Sweden. The conclusion of these studies was that, with adjustment and monitoring, the use of these machines could be acceptable. The recommended adjustments included reducing the height through which chicks fell, and alterations to ensure that few chicks fell from the machine or became caught and trapped in the mechanisms.

The aim of the work reported here was to quantify and compare the physical and psychological stresses imposed on chicks, and the duration and intensity of disorientation, by a range of the automated handling systems currently in commercial use. Specific stages within the different systems were also investigated with regard to their acceptability in terms of welfare.

Materials and methods

Six hatcheries were visited: three hen hatcheries and three broiler hatcheries. One of the broiler hatcheries was not Freedom Foods accredited. The overall approach taken to quantify the handling systems and their effect on the chicks was to take physical measurements of the different aspects of the systems and then to look at the effect of these parts of the system on the chicks in a non-invasive manner. Measurements were made of the lengths, speeds and slopes of belts, the angles between belts, the heights of drops, and the accelerations imposed by the various parts of the systems. The effect on the chicks was measured in terms of the righting time, the percentage of chicks able to stand at points within the system, the cumulative mortality at seven days after placement, and the tonic immobility response (Jones 1986).

Accelerations

The accelerations imposed by the different stages within the handling systems were measured using Tinytag Plus Shock data loggers (Gemini Data Loggers UK Ltd). The shock data loggers (accelerometers) provide a proxy measure of the shock accelerations imposed by the systems, rather than an absolute measurement of the accelerations experienced by the chicks. They record the maximum acceleration within 1 s intervals along a single spatial axis against a time base. In order to obtain an accurate representation of the accelerations, the loggers were sent through the system ten times in different starting orientations, and the average used as a measure of the acceleration. The loggers were sent through each individual section of interest in a system and also through the system as a whole, from start to finish, without chicks present. Where it was possible for broiler chicks to follow different paths through the system, each path was measured. For example, chicks could go through sexed or unsexed, and the pathways for males and females could be different. With layer chicks, only the female pathway was measured because the male pathway after sexing was generally just a single, slow-moving, wide belt.

The speed of conveyor belts was estimated by measuring their length and recording the transit times of coloured chicks or chick-sized expanded foam. The difference in speed between consecutive belts and components in the system was calculated as the absolute value of the difference of the speeds. The normal handling rate of each system was taken from the hatcheries' own records.

Righting time

During handling, chicks are often tumbled and flipped, especially after drops and when guided by deflector plates. The amount of time it took a chick to right itself when placed on its back on an open and stable surface was used as a measure of the degree of disorientation of the chicks in the various parts of the handling systems. Birds were individually tested by being removed from the system and immediately placed on their back, in close proximity to where they had been removed. The time taken for them to regain their feet was measured by another researcher. The same two researchers took all measurements within a system. Ten measurements were taken of individual chicks at each position of interest and this was repeated four times from the beginning to the end of the handling system. This gave four replicates of ten readings from each position and ensured that replicates covered different hatches, and different times within a hatch.

Tonic immobility

The tonic immobility (TI) response was used as a measure of the psychological response of the chicks to the different handling systems. The TI response is found in a wide range of animals. Although it is well recognised and documented in adult poultry, it is also found in chicks (Jones *et al* 1995). When a bird is temporarily restrained and then released it does not immediately escape but will remain immobile — it 'plays dead'. The duration of the period for which it remains frozen has been shown to correlate with the animal's 'fear' of the preceding event. The more fearful the event, the longer the bird will remain in TI. This behaviour has been explained as an innate evolutionary response that enhances the chance of escape from a predator (Jones 1986). The TI measurements were distinct from those of righting time because the chicks had to be restrained until immobile. With righting time, chicks were handled only momentarily, and potentially were struggling when released. TI was measured immediately before the start of the automatic handling system and immediately after handling, using different chicks. The chicks were induced in a cardboard box (approximately 25 × 25 × 20 cm) in order to isolate them, as far as possible, from movement and noise within the hatchery. Chicks were restrained by hand for a period of 5 s and then released. Induction was attempted a maximum of three times and measured for a maximum of 10 min. Two replicate sets of measurements were made by the same researcher within each hatchery to cover variation across and within hatches.

Orientation

The orientation of the chicks after passage through specific parts of the system was recorded on video camera. The camera was held above the part of the system of interest for approximately 2 min on two different occasions. The degree of disorientation was measured as the percentage of birds that were not on their feet at five random freeze frame points within each recording. An average value was obtained from the individual counts at each position.

Mortality rates

Placement mortality rates (mortality rates occurring in the days following delivery) were provided by hatcheries from their own records on a confidential basis.

Statistical analysis

A natural log transform was used to transform the data on righting time to a normal distribution for statistical analysis.

Table 1 General details of the six hatcheries that participated in the study.

Hatchery	Bird type	System type	Hatchery output per operating hour (male and female)	Notes
1	Layer	Manual	14 000	–
2	Broiler	Breuil	60 000	Maximum with 2 manual graders
3	Broiler	Kuhl	22 000	When not sexing
4	Broiler	Breuil	30 000	Slower when not sexed
5	Layer	Breuil	24 000	Maximum 30 000
6	Layer	Breuil	30 000	–

Table 2 Mean (± SE) accelerometer readings (g) (1g = 9.8 m s^{-2}) from the major events encountered passing through the handling systems from beginning to end. Values are the mean of five to ten readings. The number of major events and the sum of the accelerations (cumulative acceleration) within the system are shown.

Hatchery	Path	1	2	3	4	5	6	7	8	No. of events	Cumulative acceleration
1	Layers	4.9	3.3	5.0	4.5	–	–	–	–	4	17.6
		(0.2)	(0.4)	(0.1)	(0.5)	–	–	–	–		(0.7)
2	Belt 1	8.1	59.9	53.1	48.1	–	–	–	–	4	169.2
		(2.4)	(15.0)	(14.5)	(19.8)	–	–	–	–		(23.9)
	Belt 2	12.0	84.1	28.6	56.0	–	–	–	–	4	180.6
		(5.1)	(9.7)	(9.6)	(19.9)	–	–	–	–		(32.8)
3	Not sexed	61.3	22.6	25.8	18.9	16.8	13.0	–	–	6	158.3
		(20.7)	(10.0)	(8.4)	(6.3)	(7.6)	(2.9)	–	–		(25.6)
	Sexed	65.4	38.8	72.7	15.1	51.1	9.6	23.7	–	7	276.4
		(12.4)	(19.4)	(7.2)	(5.4)	(16.6)	(3.1)	(6.5)	–		(29.4)
4	Not sexed	68.9	66.4	73.0	39.2	49.6	50.5	–	–	6	347.7
		(9.2)	(10.0)	(17.4)	(15.7)	(14.4)	(15.9)	–	–		(33.4)
	Male	86.4	55.7	87.3	65.7	35.8	21.4	33.9	41.6	8	428.0
		(10.2)	(12.8)	(7.3)	(8.3)	(16.4)	(6.9)	(15.0)	(13.6)		(10.7)
	Female	93.9	88.4	52.2	46.3	32.4	53.8	40.5	–	7	407.6
		(5.1)	(10.9)	(13.4)	(11.4)	(8.8)	(12.3)	(16.7)	–		(43.6)
5	Layers	51.9	15.9	42.7	10.8	–	–	–	–	4	121.4
		(9.3)	(4.3)	(9.3)	(1.5)	–	–	–	–		(14.1)
6	Layers	55.9	83.0	57.9	28.9	38.9	50.2	43.2	–	7	358.0
		(8.0)	(8.9)	(9.5)	(6.4)	(8.1)	(11.2)	(11.6)	–		(23.9)

The tonic immobility durations were natural-log transformed for the statistical analysis. An independent-samples *t*-test was carried out on the data from each hatchery to test for an increase or decrease in the duration of TI after handling. Analysis of variance, regression and independent and paired *t*-tests were used to analyse other results, as appropriate.

Results

A summary of the six hatcheries studied is given in Table 1. Three broiler hatcheries were visited with throughputs ranging from 22 000 to 60 000 birds per hour; two with Breuil designed systems (http://www.breuil-automation.com/) and one with a Kuhl system (http://www.kuhlcorp.com/poultry.html). Hatcheries 3 and 4 had systems that could be used to sex chicks. Hatchery 2 was not set up to sex chicks but had three separate chick counters with a line that split into separate accelerator belts leading to each, only two of which were in use during the study. Hatchery 1 contained no motor-driven conveyors. All measurements made in the layer systems were made on female chicks after sexing. The measurements made in broiler Hatcheries 3 and 4 were made on chicks that were being sexed and these were balanced for sex.

Accelerations

The average accelerations recorded from the major 'events' within each handling system are shown in Table 2. These are the measurements taken from the data loggers passing through one complete pathway through the entire system chosen to best represent the system. The number of events recorded within each system is shown, whilst the sum of the accelerations is given as an overall measure of the relative 'roughness' of a system. As an example of the output from

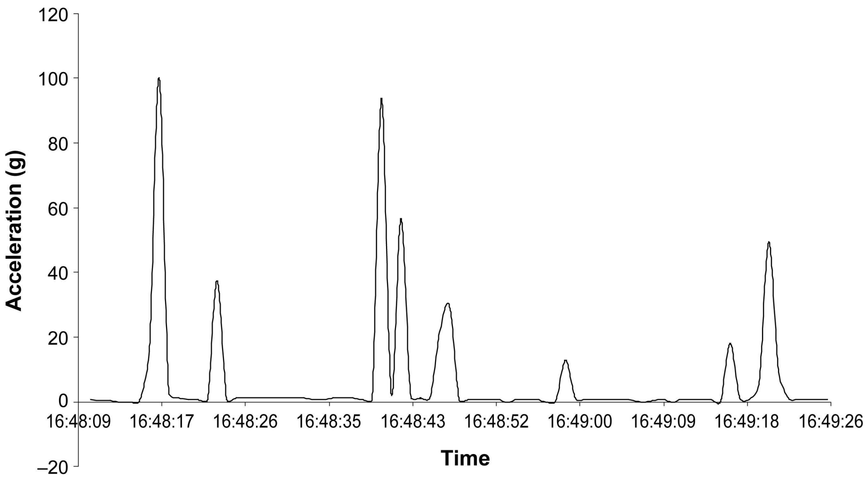
Table 3 The number of positions subjectively identified as likely to produce accelerations, and the minimum, maximum and sum of the results for all those positions within a hatchery (g) (1g = 9.8 m s⁻²).

Hatchery	Number of positions	Minimum acceleration (g)	Maximum acceleration (g)	Cumulative acceleration
1	4	3.3	5.0	17.6
2	5	25.6	81.6	217.7
3	5	26.0	75.9	213.3
4	7	44.8	90.2	394.5
5	4	13.2	67.0	148.0
6	7	37.9	63.1	348.8

Table 4 The minimum and maximum height of drop between conveyor belts, the changes in speed of conveyor belts at specific transition points, and the percentage of 'birds not standing' at these transition points.

Hatchery	Height (cm)		Difference in speed ($m\ s^{-1}$)		% birds not standing	
	Min	Max	Min	Max	Min	Max
1	–	–	–	–	0	0
2	17	45	0.322	1.892	0	100
3	8	35	0.006	1.011	0	100
4	18	53	0.043	1.297	0	100
5	15	55	0	1.84	0	53
6	7	50	0	0.972	0	100

Figure 1



An example of the output from a data logger. The graph shows levels of acceleration experienced during transit along the male pathway of Hatchery 4's handling system.

a data logger, the measurement from a single pass through one handling pathway within Hatchery 4 is shown in Figure 1. Table 3 shows the number, minimum, maximum and sum of the averaged acceleration measurements taken from all the positions within each system likely to cause an acceleration when each point in the system was measured in isolation. A comparison of Tables 2 and 3 shows that there was good agreement between the two approaches (as shown by the rank order of the cumulative accelerations).

Other measurements made at the specific positions in each system summarised in Table 3 are shown in Table 4, which details the maximum and minimum height of drops, the differences in the speed of consecutive belts, and the percentage of 'birds not standing' in each hatchery.

Across all systems, there was a linear increase in acceleration with increasing drop height, which was, on average, approximately 0.7g per cm ($F = 4.86$; $P = 0.037$). However, there was no apparent relationship between acceleration and change of velocity between belts within the systems.

Righting time

A one-way analysis of variance showed a difference in overall mean righting time between hatcheries (mean [±SE] righting times [s] for hatcheries 1–6 were 0.86 [0.08], 0.86 [0.04], 0.74 [0.07], 0.91 [0.03], 0.82 [0.07] and 0.88 [0.05]; $F_{5,1285} = 7.8$; $P < 0.001$), with Hatchery 3 having the fastest righting time.

There was no detectable difference in righting times between broiler and layer chicks. Analysis of variance

https://doi.org/10.1017/S0962728600028669 Published online by Cambridge University Press

Table 5 Mean TI durations pre- and post-handling. The difference between the means and the lower and upper 95% confidence intervals (LCI and UCI, respectively) of the estimate of the differences are shown together with the significance of an independent samples t-test. Calculations are based upon the natural logarithm of the duration measured in seconds.

Hatchery	n	Pre-handling	Post-handling	Difference	LCI	UCI	*P* value
1 Layer	48	25.2	11.2	−14.0	1.2	4.1	0.010 **
2 Broiler	68	11.7	21.0	9.3	0.2	1.3	0.155
3 Broiler	67	13.4	7.4	−6.0	1.1	3.1	0.027 *
4 Broiler	72	5.2	7.2	2.0	0.9	1.1	0.147
5 Layer	79	27.8	21.8	−6.0	0.8	2.2	0.291
6 Layer	80	16.2	34.5	18.3	0.3	0.8	0.002 **

* $P < 0.05$
** $P < 0.01$

showed there to be a difference in righting times between different positions within the handling systems of Hatcheries 1, 3, 5 and 6 ($F_{23,1285} = 2.5$; $P < 0.001$). The analysis also showed there to be no differences between the replicate measurements taken at each position. This indicated that the righting response was measuring a reliable effect, and that this effect was being measured in a repeatable manner. Within each hatchery, mean righting times differed according to position within the handling system, ranging between 0.55 and 1.13 s. However, comparing these times across hatcheries would be meaningless given the uniqueness of each position within a hatchery.

Regression analysis showed there to be a linear decrease in righting time with increasing movement through the handling system in Hatchery 1 ($F_1 = 16.0$; $P < 0.001$). Within Hatchery 3, Position 6 had a greater righting time than other positions. Positions 2 and 4 in Hatchery 5 had greater righting times than Position 1, and in Hatchery 6, Position 2 had a greater righting time than Position 1.

Tonic immobility

Table 5 shows the pre- and post-handling mean durations of the untransformed data for each hatchery. There was a reduction in TI duration following handling in Hatcheries 1 and 3, and an increase in Hatchery 6. The differences within Hatcheries 2, 4 and 5 were not significant (Table 5).

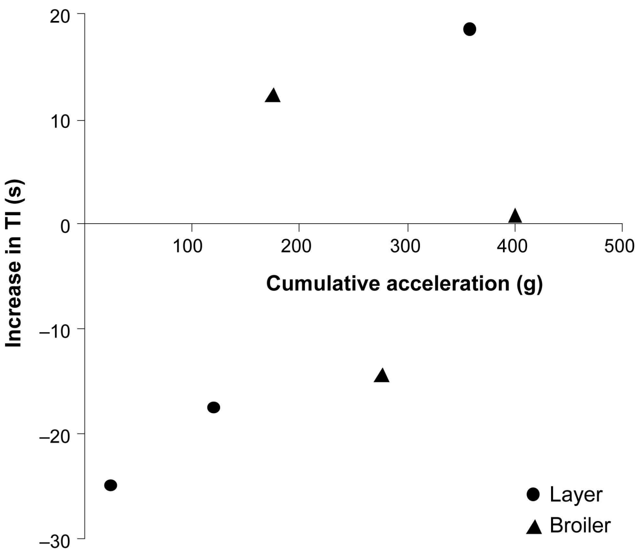
There were overall differences in TI duration between broiler and layer chicks and also between the hatcheries within type of chick. Overall, TI durations were longer in layer chicks than in broiler chicks, 16.6 and 9.4 s respectively ($t_{424} = 6.561$; $P < 0.001$).

Figure 2 shows a plot of the change in TI duration within hatchery plotted against the cumulative acceleration from the data in Table 2. There is the suggestion of an increase in TI duration with increasing cumulative acceleration but, given the small amount of data, this relationship is not statistically significant ($F_{1,4} = 2.86$; $P = 0.17$).

Orientation

Hatchery 3 used very low levels of light when processing chicks. This meant that we were unable to use the video camera at all positions within the system and the data for this hatchery were therefore not as complete as for other hatcheries.

Figure 2

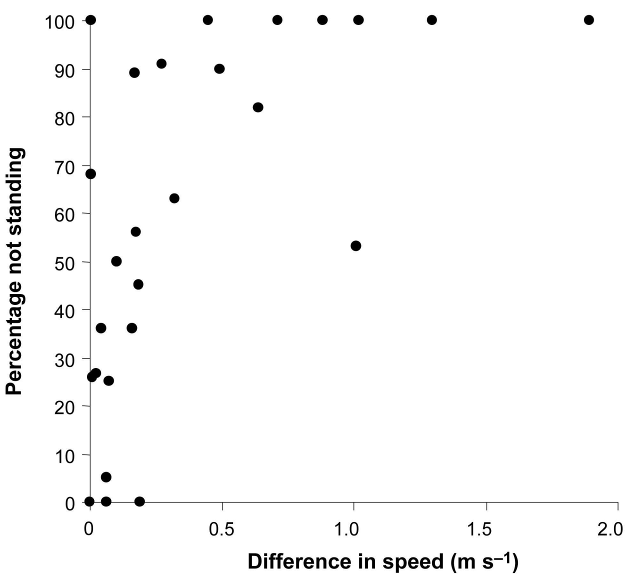


The change in average TI duration (between pre- and post-handling) (untransformed) plotted against the cumulative acceleration within each of the six hatcheries.

Table 4 shows the minimum and maximum percentage of chicks not standing at the selected transition points in the handling systems. All systems had points where all chicks were standing. In Hatchery 1, the manual layer system, chicks were generally always able to stand. The only other system not to have a point at which all chicks were off their feet was the layer system in Hatchery 5. This system also had the lowest cumulative acceleration of the automated systems (Tables 2 and 3) and the lowest change of speed within the systems (Table 4).

Inspection of the data from all of the hatcheries showed that there was a marked relationship between the percentage of chicks not standing and the change in speed at the different

Figure 3



Scattergram of the percentage of chicks not standing against the change in speed at points within the systems.

points within the system. This is shown in Figure 3, from which it can be seen that at a difference in speed above 0.4 m s^{-1}, few chicks were able to remain standing. There did not appear to be a relationship between the number of chicks standing and the height of a drop, but a linear relationship between the acceleration and the percentage of chicks not standing was just detectable. For every 1 g increase in acceleration there was an approximate 0.6% increase in the number of chicks not standing ($F_{1,27}$ = 4.4; P = 0.045).

Mortality rates

Mortality data were provided by the hatcheries. The records from the broiler hatcheries were complete and comparable but the records from the layer hatcheries were incomplete, with inconsistent returns from producers. On account of these inconsistencies, the layer chick mortality data were not analysed because there were likely to be intrinsic biases. It was thought that the more conscientious producers were those that regularly sent in mortality returns. Hatchery managers reported that other producers tended to feed back data to the hatchery only if they were unhappy with bird performance.

For the broiler hatcheries, overall mortality at seven days after placement was 1.271%. This figure is based on the unweighted mortality for each crop reported by growers and a weighting for hatchery annual production.

Two of the broiler hatcheries were managed by the same company. This allowed a better comparison between two handling systems because many of the management practices were similar, leading to some reduction in variation which might otherwise disguise differences between the handling systems. A full year of all throughput data from each of these hatcheries, both of which were major hatcheries supplying multiple producers, was used for the comparison. One of these hatcheries was Hatchery 4, which measurements showed to be the hatchery with the 'roughest' overall handling system. The day seven mortality for these two hatcheries, broken down by month, is shown in Figure 4. The actual numbers given in the figure have been altered to maintain the confidentiality of these potentially commercially sensitive data, but the pattern of differences between the two hatcheries has been maintained. It can be seen that there is the hint of a cyclic change in mortality common to the two systems but there are no obvious overall differences in mortality rate between the two hatcheries. A paired *t*-test was used to compare the hatchery results. This was justified on the grounds that the difference in the severity of handling between the two hatcheries should have remained constant over time, whilst disease and similar factors were likely to vary synchronously within the same company. There were no significant autocorrelations within the data across time, thus the monthly figures were treated as independent measurements of each system.

The paired *t*-test gave a 95% confidence interval for the difference in mortality between the hatcheries of –0.277 to 0.123%, indicating that the difference in 'roughness' between handling systems did not have any measurable effect on mortality (t_{11} = 0.84; P = 0.42).

If the assumption that monthly measurements could be paired was not justified, an independent samples *t*-test should have been performed. The results from this test were similar to those from the paired *t*-test (t_{22} = 1.1; P = 0.30).

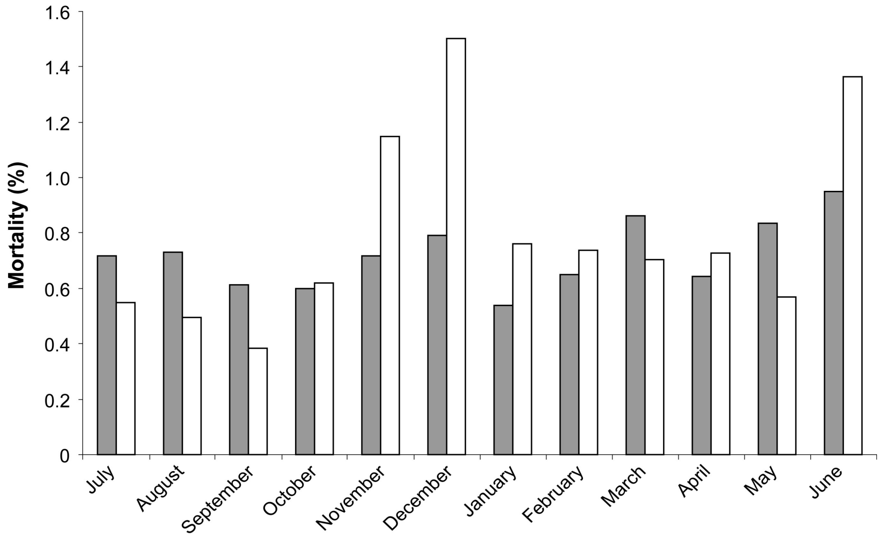
Discussion

Rates of mortality — since they are likely to be associated with pre-mortem suffering — are generally an important index of welfare. If a survey approach is used, as was the case here, it is often difficult to encompass a wide enough variation in the variable of interest, in this case handling systems, to pick up effects on mortality and even more so when the measurements of mortality are unreliable, as was the case with the data from the layer hatcheries. It was fortunate that one company owned two hatcheries at either end of the range of 'roughness' of handling within the broiler hatcheries, and that they also kept the most reliable records. The company already perceived that there were differences in the 'roughness' with which the two systems handled the chicks, which was borne out by the acceleration measurements. The managers at the broiler hatcheries reported that 95% of mortalities that were due to hatchery problems occurred within the first seven days of placement, generally peaking at around day 4. The interpretation of the confidence interval from the paired *t*-test of the mortality rates between these hatcheries is that the overall differences between these two system in terms of 'roughness', as summarised by the figures for cumulative acceleration from Tables 2 and 3, did not result in a difference in mortality that could have been greater than 0.277% (note that, within the

https://doi.org/10.1017/S0962728600028669 Published online by Cambridge University Press

Figure 4

Day seven placement mortality figures from two hatcheries run by the same company. As a result of their commercial sensitivity, exact values have been altered; however, the relative pattern of differences in mortality between the two hatcheries has been retained.



precision of this study, it cannot be discounted that mortality could have been 0.123% lower within the rougher system).

From Figure 4 it can be seen that in terms of the size of the fluctuations in mortality from month to month, probably a result of disease, even if a difference of 0.277% (and this is the upper 95% confidence limit of the estimate [mean difference]) were to exist because of an extra 180 g in cumulative shock accelerations, this difference is relatively minor in relation to overall mortality and fluctuations due to disease. However, it should be remembered that the comparison between the two systems does not rule out the possibility of a large effect on mortality of a handling procedure that was common to both systems. If further studies are to be carried out, it should be borne in mind that there are likely to be intrinsic differences in mortality rates between broiler and layer chicks and also between strain within type. Svedberg (1996) noted differences in mortality rate between hybrid and pure strains of chick. No account was taken of strain of chick within this analysis. The ranking of the broiler hatcheries was 3, 4, 2, in order of increasing mortality.

As part of a study to investigate automated chick counters, Svedberg (1996) collected all chicks that died shortly after placement. The chicks were examined post-mortem by radiography to identify any physical trauma. Svedberg's study followed 572 667 chicks, of which 0.11% died at placement. In total, 130 chicks were judged to have died from trauma, mostly involving fractures and/or haemorrhage. These injuries could have been caused at any stage in the system from hatch to placement.

It should be taken for granted that badly designed components of a system, which cause obviously poor welfare, require immediate improvement; for example, parts of a system that allow chicks to become caught, trapped, crushed or smothered. These aside, the points in a system most likely to damage or distress chicks are those that involve a change in velocity; for example, where the chicks fall over a drop, hit a deflector plate, fall from a belt onto another moving at a different speed, are caught in a basket after passing through a counter, etc (personal observation). The shock data loggers provided a proxy measure of the shock accelerations imposed by the systems. It should be understood that they do not provide an absolute measurement of the accelerations experienced by the chicks. Chicks weigh approximately 45 g and are covered in fluff, which will to some extent act as a 'parachute' during a fall and will cushion the body of the chick when it lands. The surface on which the chicks land is also likely to decelerate a data logger and a chick in a different manner. It would be useful to be able to record the true accelerations experienced by a chick but this would require a tri-axial data logger encapsulated in a model with all the physical similarities of a chick, all weighing 45 g. Such equipment was beyond the budget of the project.

There were many intrinsic differences in the systems that were surveyed. The three layer hatcheries were very different in terms of the amount of automation they involved. Hatchery 1 was fully manual and had approximately half the throughput of the other layer hatcheries, but only four acceleration events, each less than 5 g. Hatchery 5 contained a simple automated system, essentially only two belts leading to a carousel, which resulted in only four acceleration events and the lowest cumulative acceleration of all of the automated hatcheries. Layer hatchery 6 contained as much automation as the broiler hatcheries, including a chick counter. This hatchery had seven acceleration events and the second highest cumulative acceleration in the survey.

Broiler hatcheries 3 and 4 sexed chicks and contained a similar amount of automation. Hatchery 3 had a lower throughput than 4, lower cumulative acceleration, and fewer events. Broiler hatchery 2 was different from 3 and 4 in that it did not sex chicks. This meant that the amount of equipment and the number of events and cumulative

https://doi.org/10.1017/S0962728600028669 Published online by Cambridge University Press

acceleration were reduced, whilst maintaining twice the throughput of the other hatcheries.

Broiler hatcheries 2, 3, 4 and Layer hatchery 6 all used chick counters. Subjectively, this appeared to the roughest part of these systems, and in all of these hatcheries delivery to the basket after counting was responsible for the maximum difference in speed (Table 4). Additionally, the maximum righting times in the broiler hatcheries all occurred after the counters. These were Positions 5, 6 and 6 in Hatcheries 2, 3 and 4, respectively. In Layer hatchery 6, Position 5 was located after the counter. Despite the counters resulting in the greatest changes in velocity, and the greatest righting times in the broiler hatcheries, they led to accelerations of only around 50 g or less on the shock loggers. The final events for Hatcheries 2, 3, 4 and 5 in Table 2 are those that resulted from the counters. The maximum shocks measured by the loggers tended to be caused by high vertical drops, for instance at the start of systems 3, 4, 5 and 6 (Event 1, Table 2), where chicks were placed into vertical chutes after manual sorting, and Event 2 in Hatchery 2, where chicks fell down a chute onto one of the three accelerator belts. The shock accelerations measured after the counters were less, despite the greater change in speed of the different parts of the system. This was because the loggers were thrown horizontally and did not stop abruptly. However, the righting times indicate that the counters had a greater effect on the chicks than did the vertical drops.

Svedberg (1996) noted that in the days following the installation of automatic chick counters to replace manual counting there was a discernable increase in chick mortality, but, by the following year, overall mortality rate had decreased to below that of the previous manual systems. However, the decrease in mortality could not be attributed to the automated system with certainty because of other changes to the system as a whole over time. On a number of occasions he collected chicks that appeared to have trouble balancing following automated counting. Post-mortem examinations showed large subcutaneous haemorrhages on the side of the head. These were attributed to badly set up counters, particularly at one site where two streams of chicks from parallel counters collided in mid air. However, he reported that the counters could be modified in an obvious way to reduce the occurrence of traumatic events. At one site this required modifications that ensured that the two streams of chicks did not collide and, at another hatchery, strips of hanging plastic material slowed the chicks down and ensured that they collided with the catching basket only at an oblique angle. In the present study, staff were keen to point out where equipment had been modified from the original installation. From our own observations and from the studies of Svedberg (1996, 1997, 1998), it seems that real improvements in welfare can be effected by a critical, informed, subjective analysis of the functioning of the automated systems and the implementation of, often minor, adjustments. However, we suggest that the physical and the behavioural measurements used in the present study also provide objective tools for identifying key points within each system.

Where chicks were mostly off their feet, where there were greater changes of speed within the system such as at the accelerator belts, the accelerations measured by the shock loggers were not great and the righting times were not extreme. Again, because the changes in the speed of the component parts of the system were all in the horizontal plane, there tended to be no shock accelerations on the loggers as they could tumble or skid before gaining/losing speed. However, it is not possible to untangle the cumulative effects of the systems. For instance, although the righting times of birds from the accelerator belts were not extreme, it is possible that the extended righting times following counting are a consequence of the cumulative effects of the accelerator belts followed by the exit from the counter.

The effect of the differences in horizontal speed of the components in the systems was clearly demonstrated by the relationship apparent in Figure 3, which shows that in order for chicks to be able to maintain their feet there should be a change in velocity no greater than 0.4 m s^{-1}. At changes in velocity above 0.4 m s^{-1}, on average, 82% of birds were not standing, whilst below 0.4 m s^{-1}, on average, 40% of birds were not standing. It is difficult to quantify, in terms of welfare, what it means for a chick to be able to maintain its balance. However, realistically, an ability to maintain balance rather than to be tumbled will probably lead to some improvement in welfare. This feature could be readily incorporated into the design of future systems.

The relative angle of the belts and the presence or absence of a gradient were recorded. The results from this survey did not suggest any strong effect on the response measurements taken. However, it was apparent when visiting the hatcheries that chicks found it more difficult to remain on their feet on the steeper gradients. It would be worthwhile to quantify the effect of belt gradient as part of a controlled experimental study.

When measuring the righting times of chicks, the occasional wet chick would stick to the surface and be unable to regain its feet. Data from these chicks were discarded. It is possible that the roughly linear decrease in righting time seen in Hatchery 1, where no automation was present, was a reflection of the decreasing stickiness of the chicks with time. Alternatively, it may have been the effect of the chicks gaining better coordination with time after hatching. Even if this effect was underlying the measurements made within the automated handling systems, the methodology appears to be useful: the results were consistent across time and across hatches, and the longest righting times coincided with what subjectively appeared to be the roughest process within the handling systems.

Measuring tonic immobility is a relatively time-consuming process and was reserved for comparison of the systems in each hatchery as a whole. However, as can be seen in Figure 2, the possibility of a relationship between TI and the roughness inherent in the handling systems cannot be discounted.

All of the hatcheries in the study took great interest in the efficiency of their systems and many had modified their equipment after installation in an attempt to improve the systems; for instance by fixing extra guards, as mentioned above, or reducing the severity of a drop from one belt to another by the addition of sloping fingers.

Recent studies (McNamee *et al* 1998, 2000; Butterworth *et al* 2001) suggest that *Staphylococcus aureus* and *Escherichia coli* may be commonly isolated in the hatchery environment, and that these pathogens play a significant role in diseases such as septicaemia and lameness in the growing bird. The sites at which *S. aureus* and *E. coli* were detected in these studies were the surfaces of belts and the sexing surfaces. Large numbers of chicks pass over these and are potentially exposed to these organisms. This suggests that it may be possible to reduce exposure to infection by improving hygiene at these critical points and by reducing the impact, rolling, and contact of chicks with deflector plates and surfaces. The lack of inter-processing cleaning of belt surfaces in most plants during the hatching and handling of chicks, which may be a period of seven hours, may mean that *S. aureus*, particularly, has a prolonged window of opportunity for contact with chicks.

A number of the observers noted that there seemed to be a lot of variation between hatcheries in the number of chicks on the floor. Chicks which fall from the handling system are an obvious welfare problem as they are immediately exposed and prone to damage from staff and equipment, can become lost under machinery, and will require additional manual catching and handling. The management at one layer hatchery believed that newly hatched layer chicks were much more active than broiler chicks and installed an additional barrier to the edges of the conveyors and other parts of their system. A limit to the rate of loss of chicks from a handling system should be made a part of recommendations for good hatchery practice and would help to pinpoint, and focus attention on, deficiencies in a system as well as improving animal welfare.

This study suggests that if more information about chick handling systems is required, a controlled, experimental approach would be the most efficient next stage. As a first step, the effects of varying just one parameter at a time (eg height of drop, rate of acceleration to the counter, velocity of exit from the counter, relative horizontal and vertical angle of belts, etc) on the response of chicks should be measured, and this should be followed by an investigation of possible interactions.

It is probable that the physical handling inherent in a system will affect the mortality rate at placement to some extent. This study suggests that the effect is relatively small; however, it would still be useful to quantify. The best approach to this would probably be to carry out a survey in cooperation with a much greater number of broiler hatcheries. Mortality should be recorded in conjunction with the pathway used within each system (sexed, male or female), the strain of chick and, if possible, some adjustment should be made for disease.

Conclusion

This study demonstrated that there is a measurable range in the severity of handling experienced by chicks passing through automated handling systems, and that the more severe the handling, the more disorientated the chicks. The faster the belts travel, the more abrupt the changes in velocity, and the steeper the gradients, the less likely it is that chicks will remain upright and in control. A difference in belt velocities of greater than 0.4 m s^{-1} was identified as consistently resulting in the majority of chicks losing their footing. However, although there were detectable differences in the degree of disorientation and a detectable relationship between the degree of disorientation and the severity of the handling, these differences were small and the overall times to recovery were relatively short. Additionally, no detectable difference could be found in mortality rate between the hatchery with the most severe handling system and one of the gentler, fully automated systems, with mortality appearing to be due to factors other than the 'roughness' of the system — perhaps instead being due to disease and daily climatic variation.

There is certainly scope for a poorly set up or poorly maintained system to damage a large number of chicks. This is demonstrated in the Swedish reports (Svedberg 1996, 1997, 1998) in which the installation of new system components resulted in increases in mortality, which appeared to reduce as the components were adjusted and modified.

Most of the automated systems in this study had been modified from the original installation in order to improve handling and to avoid chicks becoming caught and trapped in the mechanisms. The necessary modifications were, on the whole, obvious and consisted of reducing the accelerations and occurrence of direct impacts at critical points in the handling system, especially following drops at the accelerator belts and following automatic counting.

We did observe that at some hatcheries there were a number of chicks that had escaped from the systems and were on the floor. Their welfare was likely to be compromised. An obvious improvement would be to minimise chicks lost from such systems onto the floor. Again, the points at which chicks were lost were generally obvious, as were the steps necessary to remedy the situation.

Overall, the conclusion from this study is that the welfare of chicks passing through automated handling systems is acceptable. Even where automated high speed counting systems are involved, if the systems are properly set up and maintained so as to reduce accelerations and direct impacts, chick welfare can be satisfactory. This is to a large part attributable to the physical characteristics of the chick: its light weight and the cushioning effect of its down. There is, however, scope for considerable damage to the animals in a poorly set up or poorly maintained system, and constant monitoring is essential.

Animal welfare implications

The severity of handling experienced by newly hatched chicks varies considerably between hatcheries. Less severe handling appears to be associated with lower throughput and less automation. Even within high throughput, highly automated systems, there are differences in the severity of handling. Thus system design and setup are important. Differences in the severity of handling between systems were not reflected in detectable differences in mortality; however, given the numbers of chicks handled and their velocities within systems, there is scope for damage to chicks in badly set up systems. The magnitude of change in belt speed is an important factor in determining whether chicks retain their balance within a system. Chicks that accidentally escape the handling system and are left on the floor may have their welfare compromised.

Acknowledgements

The authors thank the hatcheries and their staff for their help and interest in the work. We are grateful to Jan Svedberg and Linda Keeling for supplying copies of their Swedish government-commissioned reports on automated chick counters and the chick separator. This work was wholly funded by the Royal Society for the Prevention of Cruelty to Animals.

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