Article

Warm weather transport of broiler chickens in Manitoba. II. Truck management factors associated with death loss in transit to slaughter

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Abstract — This observational study was conducted to identify the cause of death and load level factors associated with mortality in 1 090 733 Manitoba broiler chickens transported to slaughter in spring and early summer. Death loss in transit was 0.346% and accounted for 19% of the total carcass condemnation. The death loss pattern was clearly bimodal, with a low death loss in 180 of 198 shipments. Cumulative death loss during the growing phase of production was consistently associated with increased transport mortalities in load level models and when comparing high death loss with low death loss truckloads. High ambient temperature at the time of slaughter and loading density of the truck were the major factors associated with exceptional death loss.

Résumé — Transport des poulets à griller par temps chaud au Manitoba. II. Facteurs de gestion des camions associés à la mortalité dans le transport vers l'abattoir. Cette étude a été réalisée pour identifier la cause de mortalité et les divers facteurs de chargement associés à la mortalité chez 1 090 733 poulets à griller du Manitoba transportés vers l'abattoir au printemps et au début de l'été. La mortalité au cours du transport a été de 0,346 % et représentait 19 % du total des carcasses condamnées. Le scénario des pertes dues à la mortalité était clairement bimodal, avec de faibles pertes dans 180 des 198 transports. La mortalité cumulative au cours de la phase croissante de la production était régulièrement associée à une augmentation de mortalité dans le transport selon les modèles de niveau de chargement et dans la comparaison des chargements à haut et bas taux de mortalité. La température ambiante élevée au moment de l'abattage et la surcharge des camions lors du transport étaient les principaux facteurs associés à une mortalité exceptionnelle.

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Introduction

The welfare of chickens in broiler production is becoming a consumer concern (1,2), as reflected in a recent European Commission Review (3), and has resulted in a proposal for European Union (EU) regulatory standards (4), which has targeted a goal of less than 0.5% mortality during transport to slaughter. Work in other countries with similar production systems suggests that 0.1% to 0.2% transport mortality is common in the broiler industry and generally less than 0.5% of birds loaded (2,5–8).

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A positive relationship has been identified previously between mortality in transit and distance traveled, ambient temperature, mean body weight, compartment stocking density, and time waiting in lairage (7–17). The relative importance of these and other risk factors in relation to transport of broiler chickens in Manitoba has not been documented.

Broiler production is under supply management in Canada (18) and the geographic location of new operations can be controlled by the industry itself. Information related to fixed infrastructure risk for death, such as distance traveled to slaughter, is important to responsibly manage the welfare of poultry production during its expansion in Canada.

The purpose of this project was to identify risk factors for broiler chicken death during transit to slaughter under late spring and summer weather conditions in Manitoba.

Materials and methods

This observational study was conducted over 2 consecutive broiler production cycles; the methods of flock selection have been reported previously (19). Data were captured by using standardized forms where existing record keeping systems did not provide the necessary information. Sources of data were as follows:

1. on-farm flock records related to the production cycle;

2. daily temperature and relative humidity in the hours immediately preceding the time of slaughter (collected from Environment Canada sources [20] and verified from truck reports);
3. individual bird weight calculated from truck scale tickets;
4. birds from each flock were inspected at the time of slaughter by the staff of the Canadian Food Inspection Agency (CFIA) and information contained in the condemnation certificate was included in the data set;
5. information derived from postmortem examination of broilers identified as dead at unloading (DAU).

Chickens arriving at the processing plant were presumed to be alive at the time of loading.

At abattoir 1, establishment staff collected DAU birds in plastic containers, which were identified to truckload of origin by the truck number permanently painted on the side of the container. Truck number was identified to the flock of origin, and the sequence of unloading, truck scale report, condemnation certificate, and other data were tracked through document management at the abattoir. The DAU birds were picked up at least twice a day for postmortem at the provincial laboratory. Document-based data, such as the condemnation certificate and truck scale ticket, were delivered to the laboratory by plant management on the following day.

At abattoir 2, postmortem of transport mortalities was done at time of unloading in the live receiving area by the authors (MD, TW). Document-based data were retrieved from the plant on the day of slaughter.

Each abattoir owned 2 hatcheries providing day-old-chicks. Producers tend to associate long-term with either one or the other abattoir-based production system. Date of slaughter was approximately known at the time of chick placement.

Abattoir management employed and scheduled dedicated manual catching crews and owned the trucks. One abattoir used loose interlocking plastic crates with a flapped opening (Plastiques GPR, St-Felix-de-Valois, Quebec), the other used drawer modules and a forklift system (American Autoflow, Charlotte, North Carolina, USA).

Both abattoirs had similar covered truck holding facilities equipped with high volume fans to move air between the loaded trucks. Chickens were held in the transport crates on the truck until immediately prior to shackling for slaughter.

Postmortem examination of chickens followed standard procedures. Each DAU chicken was weighed on a portable electronic scale (Ohaus CS-5000; Ohaus Corporation Florham Park, New Jersey, USA), which was calibrated weekly.

Postmortem changes compatible with cause of death in DAU broilers was limited to 1 of 5 dispositions; congestive heart failure (ascites); acute heart failure/suffocation (pulmonary edema, dilated heart, pericardial effusion without ascites); pneumonia, pericarditis, airsaculitis complex; trauma; and unknown (no visible lesions). Death by severe trauma was subcategorized into 5 causes: head trauma; dislocated or fractured leg-hip; ruptured liver; intraperitoneal bleed out; and other. Both abattoirs in this study operated at line speed of about 100 birds per minute. When more than 40 birds died on a single load, not all birds could be subjected to postmortem, as the DAU rate exceeded the postmortem examination capacity (20 birds/h/person).

Ambient temperature and ambient relative humidity (RH%) at time of slaughter were taken from the Environment Canada weather station recording hourly data that was closest to the abattoir (Winnipeg Airport or Morden Manitoba) (20). Hourly data were graphed by using a spreadsheet computer program (Excel, Microsoft Corporation, Redmond, Washington, USA), and ambient temperature and relative humidity at the time of slaughter were estimated by visual inspection of the graph.

Other variables potentially associated with the percentage of birds DAU were the number of broilers on a truck load (LoadSize); average bird weight (BirdWeight); CratePressure (calculated as the total weight of birds on a load divided by the cumulative floor area of all the crates used to transport those birds [$kg \cdot m^{-2}$]); the time of day loading was initiated on the farm (TimeLoadStart) (24 h time); the time unloading was initiated for that truck at the abattoir (TimeStartKill) (24 h time); the time in transit to the abattoir (TravelTime) (h:min); the time spent waiting at the abattoir (WaitTime) (h:min); and the ambient temperature at the start and end of slaughter (TempStartKill [°C] and TempKillEnd [°C], respectively). Temperature and humidity inside the transportation crates was not measured.

For evaluation, the flock-based factors CondemRate, AgeAdjMort, and ShrinkOnFarm from the previous study (19) were carried through as cofactors in load-based data and loads were treated as independent events in data analysis. "Plant," a dichotomous variable representing the uncontrollable differences in production complexes, was included as a weighted variable in variance analysis.

All data were entered weekly (Friday) in a computer database program (Access; Microsoft Corporation, Redmond, Washington, USA) and reviewed for omissions and errors. Database information was exported into software (Excel; Microsoft Corporation) for manipulation and analyzed by using a statistical analysis program (Statistix 8 for Windows; Analytical Software, Tallahassee, Flordia, USA).

Load variables associated with the percentage of birds DAU at $P = 0.20$ (Pearson correlation) were analyzed by stepwise linear regression to eliminate highly correlated variables and arrive at a final model.

Results

During the 20 surveillance days, 1 090 733 broiler chickens originating from 94 flocks arrived for slaughter in 198 loads. Slaughter volume was roughly equivalent for both abattoirs, 511 618 from 98 loads (40 flocks) verses 579 115 from 100 loads (54 flocks). The aggregate DAU rate was 0.346% (3778 birds).

More than 40 DAU per load occurred in 18 of 198 loads. The 18 exceptional loads accounted for almost 50% of the DAU birds (1861 DAU on 18 exceptional loads versus 1917 DAU on 180 other loads). Of the 3778 DAU broilers, 2415 were subjected to a complete postmortem (Table 1), 630 were only weighed and sexed by comb development, and 697 were only counted. For birds sexed by internal examination (data missing on 36 individual records), 65.2% (1575/2415) were

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Table 1. Loss of carcasses to further processing by cause: cumulative dead at unloading (DAU) broilers and disposition of condemned carcasses (arrived alive and were slaughtered)

Dead at unloading	Acute heart failure		885
	Airsacculitis/pneumonia		24
	Chronic heart failure/ascites		288
	Unknown		527
	Trauma	Head/neck	398
		Hip dislocation/femur fracture	169
		Liver rupture	66
		Interperitoneal bleed	31
		Other	63
		Not examined by postmortem	1327
		DAU sub-total	3778
Condemned at slaughter	Cellulitis		8098
	Ascites		2762
	Hepatitis		1748
	Peritonitis		1026
	Emaciation		983
	Valgus/varus leg deformity		330
	Airsaculitis		20
	All other dispositions		1444
		Postmortem condemnations sub-total	16 411
		Total	20 189

Table 2. Load factors associated with the percentage of broilers dead at unloading

	Stepwise linear regression[a] Adjusted R^2 0.1748				
Variable	Coefficient	$s_{\bar{x}}$	T	*P*	VIF
ShrinkOnFarm	0.03915	0.1228	3.19	0.0017	1.0
TempStartKill	2.827^{-4}	9.873^{-5}	2.86	0.0047	1.2
BirdWeight	7.47^{-3}	3.25^{-3}	2.30	0.0235	1.0
TimeLoadStart	3.136^{-4}	1.147^{-4}	2.21	0.0280	1.2

Unforced variables in analysis: RelativeHumidity, TravelTime, TimeStartKill, WaitTime, FlockCondRate, LoadSize, TempEndKill

[a] Abattoir as the weighting variable, Stepwise linear regression retains only 1 of highly correlated variables such as temperature at the start of killing and end of killing approximately one hour later.
$s_{\bar{x}}$ = standard error of the mean, T = T statistic, tests the hypothesis that a regression coefficient is 0,
VIF = Variance Inflation Factor
ShrinkOnFarm — flock level variable — the difference between the number of chicks placed on day 1 and the number delivered to the slaughterhouse
TempStartKill — ambient temperature at the start of unloading a truck
BirdWeight — average live weight of birds in the truck load
TimeLoadStart — time of day loading was initiated on the farm for that truck load
RelativeHumidity — ambient relative humidity at time of slaughter
TravelTime — time taken to convey broilers from farm to lairage
TimeStartKill — time of day slaughter was initiated
WaitTime — duration that animals were held in lairage
FlockCondRate — percent of broilers condemned which were presented alive for normal slaughter
LoadSize — number of birds loaded at the farm per truck
TempEndKill — ambient temperature at the end of unloading a truck

male. In birds sexed by comb, all from the 18 exceptional loads, 74.6% (469/630) were male. High death loss loads had a greater proportion of male DAU, with a male to female ratio of 851:278 (2.97:1) for the 18 high death loss loads versus 1194:722 (1.65:1) for low death loss loads (Chi-square, 54.93, $P > 0.001$). For the 2415 DAU birds weighed, the males were not significantly heavier than the females (1.923 kg male versus 1.913 female) (two-sample *t*-test, $P = 0.493$). When the mean body weight of the group of DAU birds was compared with the mean body weight of all the birds on the same load (DAU birds included in load weight), the difference was not significant (paired *t*-test $P = 0.373$, $n = 191$, 6 loads had no death loss and 1 load had missing weight data).

The factors, BirdWeight, ShrinkOnFarm (19), the time the truck initiated loading on the farm (TimeLoadStart), and ambient temperature at the start of kill (TempStartKill), were associated with load specific DAU rate, in the final stepwise linear regression model, accounting for 17.5% of the variability in the percentage of birds DAU among loads (Table 2).

If the 18 loads with exceptional death loss were removed from the data set, leaving 180 loads with less than 40 birds DAU per load, TimeStartKill, ShrinkOnFarm, and TravelTime remained in the final stepwise linear regression model. These variables accounted for 10.5% of the variability in the percentage of birds DAU in the nonexceptional loads (Table 3). If trauma was removed as a contributor to the percentage of birds

Table 3. Load factors associated with the percentage of broilers dead at unloading, exceptional loads removed from dataset ($n = 180$)

	Stepwise linear regression[a] Adjusted R^2 0.1054				
Factor	Coefficient	$s_{\bar{x}}$	T	*P*	VIF
TravelTime	3.124^{-4}	1.001^{-4}	3.12	0.0021	1.1
ShrinkOnFarm	1.036^{-2}	3.46^{-3}	2.99	0.0032	1.0
TimeStartKill	1.11^{-4}	4.38^{-5}	2.53	0.0121	1.1

Unforced variables in analysis: BirdWeight, LoadSize, TempStartKill, TempEndKill

[a] Abattoir as the weighted variable
$s_{\bar{x}}$ = standard error of the mean, T = T statistic, tests the hypothesis that a regression coefficient is 0,
VIF = Variance Inflation Factor
TravelTime — time taken to convey broilers from farm to lairage
ShrinkOnFarm — flock level variable — the difference between the number of chicks placed on day 1 and the number delivered to the slaughterhouse
TimeStartKill — time of day slaughter was initiated for that truck load
BirdWeight — average live weight of birds in the truck load
LoadSize — number of birds loaded at the farm per truck
TempStartKill — ambient temperature at the start of unloading a truck
TempEndKill — ambient temperature at the end of unloading a truck
TimeStartKill and TempStartKill were highly correlated (Pearsons correlation $P = 0.0001$) and when TimeStartKill was removed from this model it was replaced with TempStartKill

Table 4. Load factors associated with the percentage of broilers dead at unloading when trauma related deaths removed from the dataset and exceptional loads removed from dataset ($n = 180$)

	Stepwise linear regression[a] Adjusted R^2 0.1167				
Factor	Coefficient	$s_{\bar{x}}$	T	*P*	VIF[2]
ShrinkOnFarm	1.188^{-2}	2.75^{-3}	4.33	0.0001	1.0
TempStartKill	4.236^{-5}	1.866^{-5}	2.27	0.0244	1.1

Unforced variables in analysis: AgeAdjMort, BirdWeight, TimeStartKill, TravelTime, FlockCondemRate

[a] Abattoir as the weighted variable
$s_{\bar{x}}$ = standard error of the mean, T = T statistic, tests the hypothesis that a regression coefficient is 0,
VIF = Variance Inflation Factor
ShrinkOnFarm — flock level variable — the difference between the number of chicks placed on day 1 and the number delivered to the slaughterhouse
TempStartKill — ambient temperature at the start of unloading the truck
AgeAdjMort — ratio of percentage of broilers dying prior to market age over the European Council proposed target for that age (19)
TimeStartKill — time of day that slaughter was initiated for that truck load
TravelTime — time taken to convey the broilers from the farm to the lairage
BirdWeight — average weight of birds in the truck load
FlockCondemRate — percentage of broilers that were slaughtered and subsequently condemned at postmortem inspection

DAU in the 180 nonexceptional loads, then ShrinkOnFarm and TempStartKill remained in the model, accounting for 11.7% of the variability in nontrauma related DAU (Table 4).

Stepwise linear regression of load type indicated that broilers in the 18 loads with exceptional death loss originated on farms with higher cumulative mortality during production, were loaded at a significantly higher ambient temperature, were unloaded later in the day, and traveled at a higher stocking density but shorter distances than the 180 loads with lower mortality accounting for 20.9% of the variability (Table 5).

Ambient temperature and relative humidity considered simultaneously have been previously identified as a risk factor for transport mortality. Cockram and Mitchell (21) postulated that the graph of ambient temperature and relative humidity could be divided into 4 zones of increasing risk for livestock stress during transportation. As ambient temperature and humidity increase, the risk conditions for livestock in road transit change from safe (low temperature, low humidity), through alert, to danger, to emergency situations (high environmental temperature and humidity, which exceeds thermoregulatory compensation mechanisms available to animals in transit). There was considerable overlap between exceptional death loss loads and other loads when this risk construct was applied to the data generated in this study (Figure 1). There was an increased risk for loads transported in the "alert" zone to be an exceptional death loss load, odds ratio (OR): 7.0; 95% confidence interval (95%CI): 2.24–21.9. No loads fell into the danger or emergency risk zones.

Discussion

Previous studies of broiler death in transit have focused largely on the causes of death or individual risk factors associated with transport. This study attempted to include farm production variables that may contribute to transport-related mortality, in addition to these factors.

Table 5. Comparison of load parameters among loads with exceptional death loss and loads without

	Two sample t-test				
	Low Death Loss n = 180		High Death Loss n = 18		
Variable	Mean	s	Mean	s	P^a
TempStartKill (°C)	19.53	4.75	25.00	2.86	0.0001^b
TempEndKill (°C)	20.53	4.64	25.23	3.02	0.0001^b
CratePressure (kg·m^{-2})	121.6	19.72	138.3	19.46	0.0007
TimeStartKill	9:51 AM	2:39 h	10:47 AM	3:02 h	0.0012^b
TravelTime (h:min)	1:24	1:05	0:46	0:49	0.0191
BirdWeight (kg)	1.907	0.149	1.985	0.122	0.0329
AgeAdjMort (Ratio)	1.92	0.893	2.65	1.54	0.062^b
ShrinkOnFarm (%)	6.37	3.02	8.78	5.36	0.077^b
TimeLoadStart	3:33 AM	3:07 h	5:14 AM	5:05 h	0.181
LoadSize	5466	1511	5934	1593	0.213
WaitTime (h:min)	4:09	1:47	3:58	1:14	0.513^b

[a] P values with [b] indicate unequal variances of samples
s = standard deviation
TempStartKill — ambient temperature at the start of unloading the truck
TempEndKill — ambient temperature at the end of unloading the truck
CratePressure — weight of all the broilers in a truck divided by the combined floor area of all the crates or drawers used to carry the birds
TimeStartKill — time of day slaughter commenced for a truck load
TravelTime — time taken to convey the broilers from the farm to the lairage
BirdWeight — average weight of birds in the truck load
AgeAdjMort — ratio of percentage of broilers dying prior to market age over the European Council proposed target for that age (19)
ShrinkOnFarm — flock level variable — the difference between the number of chicks placed on day 1 and the number delivered to the slaughterhouse
TimeLoadStart — time of day loading commenced on the farm
LoadSize — number of broilers on a truck
WaitTime — time the broilers were held in lairage prior to slaughter

Individual broiler cause-of-death was similar to that of previous reports where ascites, heart failure, "stress," and trauma were implicated (5–8). As in previous studies, a significant portion of freshly examined DAU broilers were free of gross visible lesions. Death in transit of broiler chickens without detectible postmortem lesions has been explained, theoretically, by acute thermal stress due to uneven ventilation of the truck (2,21–24). High environmental temperatures in the transport container will likely subject birds to heat stress; the birds respond with thermal panting. Panting generates heat from muscle contraction, increases the moisture load within the vehicle, and becomes ineffective as a thermoregulatory mechanism. Ineffective thermal panting and acid base homeostatic mechanisms become antagonistic; death results from a combination of uncontrolled hyperthermia and acid-base imbalance (2). Likely, some birds on low mortality loads with no visible lesions and most of the birds on high mortality loads suffered from this microenvironmental stress and died from the hyperthermia-hypocapnia syndrome.

Ambient temperature has an effect on the temperature experienced by the transported broiler. A recent 3-year British study identified that broiler mortality increased significantly when the ambient temperature exceeded 18°C and there was a limited effect up to 18°C (17). This study supports that conclusion in that no exceptional load losses occurred below this threshold (Figure 1).

Data in this study support previous work showing that male broilers appear to be at increased risk of death in transit (7); however, flocks were not sexed as day olds and data on sex ratio of surviving birds was not collected, but it is assumed to be near 50:50. The gender-based risk of death was not related to the excess body weight of male broilers over female broilers in this study.

The standard of no more than 0.5% DAU was met by 169 (85%) of the truck loads in this study, suggesting that this standard is probably an achievable goal in Manitoba.

Angular bone deformity (valgus-varus limb deformity), a major animal welfare concern in broiler production (3,25), was a rare cause of condemnation in this study. Only 300 birds in more than 1 000 000 birds slaughtered were condemned for angular bone deformity, indicating that leg health in Manitoba broilers is either very good or that birds suffering skeletal disorders are identified early and culled on-farm, reducing the animal welfare impact. Therefore, angular bone deformity does not appear to be a significant welfare concern in Manitoba production.

In this study, there were fewer than 1000 birds condemned for emaciation in more than 1 000 000 birds slaughtered. Comparative data is limited; however, in farms with a high condemnation rate, emaciation has accounted for about 20% of the losses (26). In assessing a management system for broiler chickens with overall criteria for animal welfare, one with early on farm culling may be more animal friendly than one that rewards maximal survivability to slaughter age. Identifying production-based measurable targets that adequately reflect animal welfare has been recognized previously as a problem (27).

The persistence of ShrinkOnFarm being significantly associated with DAU rate in load models (Tables 2–4) is difficult to explain. The postmortem of DAU birds indicated that most

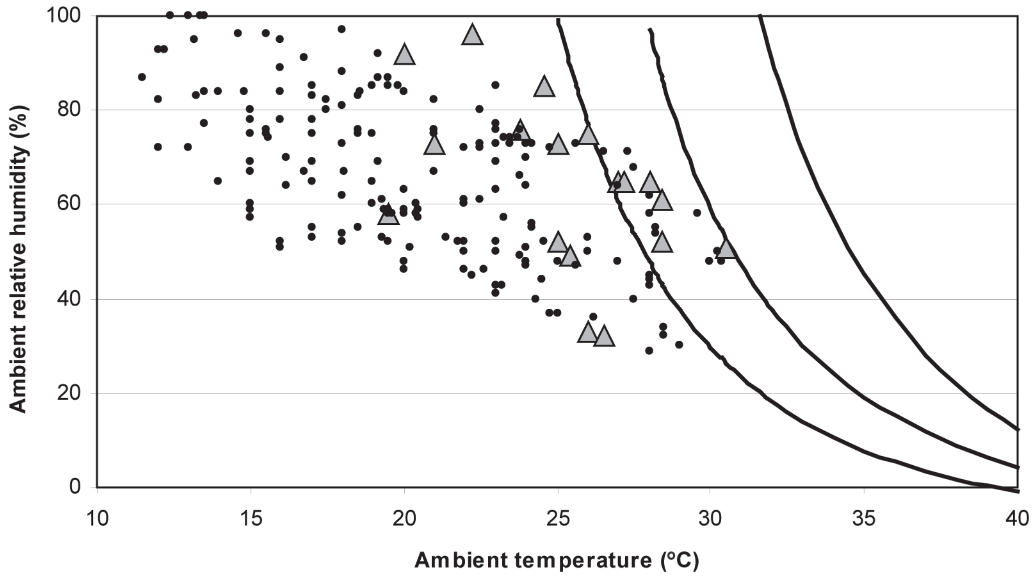

Figure 1. Scatter diagram of ambient relative humidity and ambient temperature at start of unloading for slaughter for each of 198 loads (● are loads where less than 40 broilers were dead at unloading, ▲ are loads with more than 40 broilers dead at unloading). The 3 curved lines are redrawn from Figure 2 in reference (21) and divide the Cartesian plain into 4 theoretical environmental risk zones starting from the left and identified as Safe, Alert, Danger, and Emergency. In this study, 12 of 18 exceptional death loss loads fell in the "Safe" zone of this risk construct. No loads fell in the Danger or Emergency zone.

birds die of acute events, such as transport stress or trauma, unrelated to underlying lesions. With the exception of ascites, the causes of death at unloading and the causes of poultry whole-carcass condemnation appear to be unrelated (Table 1).

Trauma mortality (as a percentage of LoadSize) was positively correlated with TravelTime (Pearson correlation, $P = 0.04$), which has a biological basis in that broilers injured at the time of catching may die at some time post injury, so the time in transit would have a positive effect on the number of injured birds that died prior to unloading. Trauma mortality had a negative correlation with LoadSize (Pearson correlation, $P = 0.003$); this association may be spurious and not have a biological basis. Trauma was not correlated with any other variable. These data are compatible with death by trauma being a random event in this study.

From the perspective of loss of poultry meat value, more than 4-fold as many birds were condemned for reasons of preexisting disease as those dying during transit to slaughter. Even conditions thought to predispose to transport stress did not often result in death, as fewer than 1 in 10 birds (288/[288 + 2762]) with preexisting chronic heart failure and ascites died in transit as survived transit and were condemned at slaughter.

Time in transit to slaughter is a major animal welfare concern (28). In North America, there has been significant centralization of cattle and swine slaughter facilities in the past 20 y (29), potentially providing the average animal with an increased distance between place of birth and place of slaughter. Travel time for broiler chickens was short in this data set (1.34 h, $s = 1.08$ h, max = 6 h), and was found to be associated with load-based nonexceptional death in transit (Table 3). In economic studies in the USA, broiler abattoir catchment areas larger than a 20 mile (32 km) radius are rare, as the cost of transporting feed, chicks, and finished birds has a negative impact on overall efficiency (30). Economic constraints limit the risk that long distance transport has for the welfare of broiler chickens. This study provides animal welfare risk considerations that support management decisions to locate new production facilities geographically as close to slaughter facilities as good biosecurity and land use restrictions will allow.

Factors associated with exceptional death loss, increased loading density, and slaughter later in the day under higher environmental temperature are subject to management control. In Manitoba, a change in the daily poultry slaughter operation to an earlier start time could provide some protection against heat stress and mortality in broiler chickens during hot weather conditions. Conversely the addition of an afternoon shift would be expected to have negative impacts on the welfare of poultry in transit and awaiting slaughter in the summer months.

Loading density is difficult to adjust, as the precise number and weight of broilers is unknown prior to loading and reducing the loading density requires incremental reduction in the number of birds per crate. Individuals catching poultry manually catch and carry either 5 or 6 birds at a time, resulting in loading crates or drawers populated for transport at multiples of the standard single catch number. Reducing the individual number of broilers caught/carried at a time has a multiplied effect at the crate level and may result in significant overcompensation in CratePressure and result in significant associated cost related to time to load and the requirement to partially fill another truck. This logistic constraint with manual catching results in empty crates on most truck loads shipped. In this study, all of the crates were used in 31 of 198 loads.

In Manitoba, an abattoir essentially purchases the broiler at the farm gate (condemnation at postmortem inspection

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excluded) and absorbs the financial cost of in-transit mortality. It is possible that data were confounded by intensive management of transportation and partial compensation for recognized risk factors previously identified as being associated with death loss in transit. Management can identify loads in thermal distress at the time of arrival and expedite their unloading, behavior that was supported by anecdotal observation at the abattoir. The negative correlation of TravelTime with both StartKillTime (Pearsons correlation, $P = 0.0001$), TempStartKill ($P = 0.03$) and WaitTime ($P = 0.04$) suggests that poultry traveling a greater distance did not have to wait as long after arrival at the abattoir for unloading to be intitiated and were killed earlier in the day than were poultry from farms in closer proximity to the abattoir. The scheduling of truck loading on farm and unloading at the plant was completely in control of the abattoir management.

Data in this study are compatible with there being 3 broad contributors to mortality in broiler chickens during transit to slaughter. A small group of chickens die randomly of trauma related to accidents of catching and loading; a 2nd group die in transit associated with unidentified factors common to the risk of increased death loss during the grow out period; and a 3rd group die in particular loads where the ventilation of the load becomes ineffective and birds die of hyperthermia and acid-base imbalance. The association of death loss during the production cycle and death loss in transit to slaughter has not been reported previously. Additional research is required to identify if this association can be supported by independent studies, and if so, what the biological basis of this association is.

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