The effect of water sprinkling market pigs transported during summer on pig behaviour, gastrointestinal tract temperature and trailer micro-climate

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ABSTRACT

THE EFFECT OF WATER SPRINKLING MARKET PIGS TRANSPORTED DURING SUMMER ON PIG BEHAVIOUR, GASTROINTESTINAL TRACT TEMPERATURE AND TRAILER MICRO-CLIMATE

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There has been little research into the use of water cooling methods for pigs during transport to slaughter under conditions of high ambient temperature. The aim of this study was to examine the effects of water sprinkling pigs before departure from the farm and before unloading at the plant on behaviour during transport, unloading and lairage using live and remote observations, and on pig gastrointestinal tract temperature (GTT) and trailer micro-climate measured by data loggers. Above 23°C, the use of water sprinkling tended to decrease GTT upon arrival and significantly decreased drinking bouts during lairage. There were no detrimental effects of the water sprinkling on unloading behaviours (e.g. slips and falls) or on trailer micro-climate conditions in terms of temperature, humidity or ammonia. Water sprinkling to wet the skin of pigs can therefore be used to cool pigs during transport and lairage under high ambient temperatures.
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TABLE OF CONTENTS

ABSTRACT ................................................................................................................................................ II

ACKNOWLEDGEMENTS ............................................................................................................................. III

TABLE OF CONTENTS ............................................................................................................................ V

LIST OF TABLES .................................................................................................................................. VII

LIST OF FIGURES .............................................................................................................................. VIII

CHAPTER 1: INTRODUCTION .............................................................................................................. 1

CHAPTER 2: LITERATURE REVIEW ...................................................................................................... 3

2.1 Pig Thermoregulation .................................................................................................................. 3

2.1.1 Behavioural Mechanisms of Thermoregulation in Hot Environments ....................... 8

2.1.2 Physiological Mechanisms of Thermoregulation in Hot Environments ..................... 9

2.2 Impact of Heat Stress on the Pig ............................................................................................... 11

2.3 Measuring Heat Stress in Pigs .................................................................................................. 12

2.3.1 Measuring Behavioural Thermoregulation ........................................................................ 12

2.3.2 Measuring Body Temperature ............................................................................................. 13

2.3.3 Measuring Physiological Changes in the Blood ................................................................. 14

2.4 Additive Effects of Other Stressors .......................................................................................... 15

2.5 Transporting Pigs ........................................................................................................................ 16

2.5.1 Trailer Design ........................................................................................................................ 16

2.5.2 Transport Duration and Driving Style ............................................................................... 17

2.5.3 Trailer Ventilation and Micro-Climate ............................................................................... 18

2.5.4 Stocking Density .................................................................................................................... 19

2.5.5 In-Transit Losses Related to Hot Weather ........................................................................ 20

2.5.6 Pig Responses to Transport ............................................................................................... 21

2.5.6.1 Physiological Responses ................................................................................................. 22

2.5.6.2 Behavioural Responses ................................................................................................. 23
# LIST OF TABLES

**Table 4.1** Ethogram of pig behaviour recorded at unloading.......................................................... 49

**Table 4.2** Least squares means (± SEM) of trailer temperature (T, °C), change in temperature (DT, °C), relative humidity (RH, %), change in relative humidity (DRH, %), temperature-humidity index (THI), and change in temperature-humidity index (DTHI) by treatment at each event (loading, departure, arrival and unloading). (n = 12 replicates) .......................... 50

**Table 4.3** Least squares means (± SEM) of trailer temperature (T, °C), change in temperature (DT, °C), relative humidity (RH, %), change in relative humidity (DRH, %), temperature-humidity index (THI), and change in temperature-humidity index (DTHI) by compartment at each event (loading, departure, arrival and unloading). (n = 24 replicates) ...................... 51

**Table 4.4** Least squares means (± SEM) of unloading time and behaviour of pigs during lairage by sprinkling treatment and compartment. Values for n differ for compartment 8 due to technical issues during one repetition................................................................. 52
LIST OF FIGURES

**Figure 4.1** Pot-belly trailer compartment designations (1-10); circled numbers indicate test compartments selected for micro-climate data collection (temperature (°C), relative humidity (RH; %), ammonia (ppm)) and behavioural observations during transport (still photos); 4 test pigs were randomly assigned in each of the 4 test compartments for gastrointestinal tract temperature (°C) data collection. ................................................................. 53

**Figure 4.2** ANCOVA heterogeneous slopes model of the interaction of ambient temperature (°C) and sprinkling treatment on percentage of time (LSMEANS; % ± SEM) pigs spent standing during transport (* P < 0.05). ................................................................. 54

**Figure 4.3** Changes in gastrointestinal temperature (LSMEANS DGTT; °C ± SEM) from baseline (500 h the day of transport) by event (loading, departure, arrival, unloading and slaughter) and by compartment group location (* P < 0.001; a,b P < 0.001)........................ 55

**Figure 4.4** ANCOVA heterogeneous slopes model of the interaction of ambient temperature (°C) and sprinkling treatment on change in gastrointestinal tract temperature (LSMEANS DGTT ± SEM; °C) upon arrival at the slaughter plant (* P = 0.08). ................................................................. 56
CHAPTER 1: INTRODUCTION

Globally, concern for the welfare of animals throughout the food production chain continues to grow, and the transport of animals remains one of the most visible points where poor welfare conditions often occur, particularly under climatic extremes. In Ontario, approximately 85,000-100,000 pigs are transported to slaughter every week, or approximately 5 million annually. They are transported in trailers that are not climate controlled, often at temperatures either above or below comfortable limits for these animals. Currently, we rely on the natural ventilation created by movement of the trailer to cool pigs during the summer and closing of punch holes in the sides of the trailer to contain body heat released by the pigs in the winter to maintain the internal conditions of the trailer at a comfortable level. These methods can sometimes be inadequate to maintain thermoneutrality for the pigs, and they must then adapt behaviourally and physiologically, often leading to reduced welfare and increased death losses, particularly in the summer (Haley et al., 2008a). Signs of poor welfare during transport can be directly observed; under cold conditions, pigs can be seen shivering and huddling to conserve heat, while under hot conditions, pigs will pant and decrease activity in order to increase heat dissipation and reduce heat production (Curtis, 1983). Currently, death losses in transit are ~0.07% of pigs marketed annually in Ontario (F. Wood, Conestoga Meat Packers Ltd., personal communication), or ~3,500 animals. Besides the obvious poor welfare of those animals prior to mortality, the loss in revenue for the farm is ~$600,000, in addition to costs of labour and disposal for the packers (G. Wilson, Conestoga Meat Packers Ltd., personal communication). As well, meat quality of pigs surviving thermal stress through transport can be negatively affected, leading to potential losses to the meat packer in sales value (F. Wood, Conestoga Meat Packers
Loved, personal communication). Besides the economic impacts, improving animal well-being during all stages of production and handling is just the responsible thing to do.

With the unstable economic status of the pork industry in the last 10 years, pressure remains high to keep costs of transporting pigs to slaughter reasonable for the producer. As a result, there has been little room for transporters and producers to invest in the modification of trailer conditions to try to reduce losses. As an industry, the focus needs to continue to be on economical and efficient ways to improve conditions for pigs during transportation (Speer et al., 2001). This can be accomplished first by familiarizing pigs with people and handling (Abbott et al., 1997; Geverink et al., 1998b; Krebs and McGlone, 2009), which would help to decrease the overall stress of handling and transport, regardless of climatic conditions. Modifications to the schedules of loading, transporting and receiving pigs can also be made in order to reduce exposure to the hottest or coldest parts of the day, though this is not always possible due to production schedules and lairage space availability at the packing plant. Currently, there is research showing the positive effects of water cooling in barns and lairages with forced ventilation (Weeding et al., 1993; Haeussermann et al., 2007), but the pairing of sprinkling pigs on trailers with the natural ventilation created during transport has not been thoroughly examined. If methods of cooling pigs on trailers using water can be shown to be beneficial and practical, it should be added to the knowledgebase for producers, transporters and packers as another tool in improving animal welfare throughout the production chain.
CHAPTER 2: LITERATURE REVIEW

2.1 Pig Thermoregulation

Like all homeothermic mammals, pigs must maintain a constant core body temperature (~39°C) in order to help ensure proper biological functioning; this process is called thermoregulation. Core body temperature is regulated by the central nervous system, in particular the hypothalamus, via the inputs of thermoreceptors throughout the core and periphery of the body (Curtis, 1983; Yousef, 1985). The central nervous system then translates this information to heat loss or heat production effector cells (Curtis, 1983; Yousef, 1985). In fact, localized cooling of the hypothalamus or spinal cord can induce heat seeking behaviour in the absence of external cold stimuli (Carlisle and Ingram, 1973). Measurement of core body temperature can be done at many sites within the body, though the site reported to be the most consistent and indicative of actual regulated core body temperature is the temperature of the blood in the pulmonary artery (Brengelmann, 1987, as cited by Hanneman et al., 2004).

The ‘thermo-neutral zone’ is the range of ambient temperature where the least amount of energy is required to balance heat gain (from the environment and biological functioning) and heat loss from the body to maintain core body temperature and homeostasis. For market-weight pigs (~100 kg), this range is approximately 10-21°C, dependent on the presence of group mates and the level of feeding (Curtis, 1983; Zulovich, 2012). When the effective environmental temperature falls outside the range of the lower and upper critical temperatures (LCT and UCT, respectively), the pig must then adapt behaviourally and/or physiologically, dependent on the degree of deviation from the critical temperature, using means that require the expenditure of
energy either to generate or dissipate heat and maintain core body temperature. Within the boundaries of the LCT and UCT, the pig uses passive mechanisms for heat loss and heat conservation (Curtis, 1983).

Heat is gained and lost via sensible and latent heat transfers. Sensible heat transfer is dependent on the temperature gradient between the pig and its environment and occurs by radiation (electromagnetic waves generated by the sun or transferred between the animal and other animals/objects in proximity to the animal), conduction (transfer of heat directly between the animal and another surface with which the animal is in contact), and convection (heating of the air adjacent to the animal, creating thermal air currents that pull heat away from the skin) (Curtis, 1983; Louw, 1993). Latent heat transfer is dependent on the vapour pressure gradient and is accomplished by either evaporation or condensation of water and transfers thermal energy in terms of change of state rather than temperature (Curtis, 1983; Louw, 1993). As ambient temperatures exceed the UCT and approach core body temperature, heat loss necessary to maintain core body temperature becomes more reliant on latent heat transfer by evaporation as the temperature gradient required for heat transfer via sensible means is reduced or eliminated (Curtis, 1983). Therefore, net heat flow between the animal and its environment, and the effective environmental temperature, is governed by the ambient temperature, air flow, the temperature of the surfaces surrounding the animal, relative humidity, the effective surface area exposed to the environment, presence or absence of group mates and solar radiation if the animal is outdoors (Curtis, 1983; Louw, 1993). Due to the large number of influencing factors, the effective environmental temperature is hard to quantify (Curtis, 1983), but the heat stress load can be estimated through simple or complex formulas using ambient temperature and relative
humidity values to generate a temperature-humidity index, or THI (Fitzgerald et al., 2009). There are upper limits for the THI value for market weight pigs, where over 23.9, an ‘alert’ status is observed, ‘danger’ status at 26.1, and ‘emergency’ beyond 28.9, and these limits can be used to estimate time spent under different heat stress loads (Lucas et al., 2000; Haeussermann et al., 2007).

The thermo-neutral zone changes over different stages of growth, production and activity. Very young pigs weighing ~2 kg have a very high surface area to mass ratio, which reduces their ability to conserve heat, as well as proportionately less heat production (van Milgen et al., 1998), which translates to a thermo-neutral zone that is much higher and narrower (~31-33°C) than that previously described for 100 kg pigs (Schrama et al., 1996). Since muscles require energy to contract and enable movement, and the conversion of energy stores into ATP also generates excess heat, greater activity increases overall heat production (van Milgen et al., 1998), and the UCT will be decreased accordingly. Feed intake and composition can also affect the limits of the thermo-neutral zone as all digestion is accompanied by the ‘heat increment of feeding’, which is the energy released by inherent inefficiencies in the process of digestion, varying by nutrient type, with fats having a much lower heat increment than carbohydrates and proteins (Curtis, 1983). This can be beneficial in cold environments, where the extra heat can help keep the body warm, but detrimental in hot environments where heat loss methods may already be maximized. In high ambient temperatures, pigs have been shown to voluntarily reduce feed intake, presumably to reduce the amount of extra heat produced (Collin et al., 2001a, 2001b, 2001c). In relation to transporting pigs in hot conditions, feed withdrawal prior to transport helps to
minimize any additional heat added to the body by digestion during a period of heat stress and exercise (Bertol et al., 2005).

Genetics can also affect the thermo-neutral zone. Renaudeau (2005) found that the Large White breed, common in North American and European herds, had a lower UCT than the Creole breed, common to the Caribbean islands (31 vs. 33°C, respectively), likely due to selection pressures for performance in the climate regions in which they are typically raised. Zumbach et al. (2008) also observed reasonable heritability values for carcass weight performance under heat stress, suggesting that appropriate selection of parent stock can improve overall herd performance by increasing the UCT of the offspring. Genetic abnormalities, like the known mutation of the ryanodine receptor gene (also known as the halothane gene), can lead to greatly increased susceptibility to heat stress and exercise (malignant hyperthermia), leading to a lower UCT (MacLennan and Phillips, 1992). This mutation alters the flow of Ca\(^{2+}\) in the muscle cells, where if pigs over-exert the muscles, the normal build-up of Ca\(^{2+}\) in the cell promotes continued release of Ca\(^{2+}\), resulting in an over-accumulation in the muscle cells, leading to muscle rigidity, acidity and hyperthermia (Ohta et al., 1989; MacLennan and Phillips, 1992). These stress-susceptible pigs may also have elevated heart rates and increases in body temperature compared to stress-resistant pigs (D’Allaire and DeRoth, 1986; Geers at al., 1994). This mutation has been largely bred out of the North American herds (Ritter et al., 2008b), but since the mutation often coincides with increased muscle deposition, some carriers likely still remain in the breeding herds (MacLennan and Phillips, 1992). As a result of all of these contributing components on heat production, it is very difficult to firmly delineate the thermo-neutral zone for a pig at any given time (van Milgen et al., 1998). Therefore, we must minimize exposure to the extremes of
any of these contributing factors and maximize the time spent within the thermo-neutral zone. When this is not possible and pigs are kept outside of their thermo-neutral zones, they rely on their behavioural and physiological mechanisms of thermoregulation to maintain homeostasis.

Thermoregulation in pigs under conditions outside of the thermo-neutral zone is accomplished first by using behavioural adaptations, which are less energetically demanding, and then by physiological adaptations, which often require more energy to accomplish (Yousef, 1985). Behavioural adaptations include postural and activity level changes, either individually or in groups (Olsen et al., 2001; Huynh et al., 2005a). Physiological changes include the control of peripheral and visceral blood flow (vasodilation and vasoconstriction; Whittow, 1971) and the alteration of heart rate (Marple et al., 1974) and respiration rate (Brown-Brandl et al., 2001) to either conserve or dissipate heat through the skin and respiratory system. Unlike most other livestock species, pigs lack functional sweat glands (Fraser, 1974; Bligh, 1985). Changes in feed (Nienaber et al., 1996) and water intake (Huynh et al., 2005b) are both behavioural and physiological, as the behavioural act of altering ingestive behaviour results in the physiological change in heat production due to digestion. In cold environments, pigs will first alter postures to reduce the surface area of the skin from which heat is lost and reducing peripheral blood flow (Curtis, 1983). When cold stress continues, there is a shift towards increased thermogenesis by increasing metabolic rate through increased feed intake, muscle contractions (shivering or non-movement muscle tonus) and catabolism of body reserves (Curtis, 1983). In hot environments, pigs first alter behaviours, spending less time active (Blackshaw and Blackshaw, 1994), decreasing contact with pen mates (Hillmann et al., 2004) and increasing contact with cooler surfaces or wallowing if water or mud is available (Huynh et al., 2005a). As ambient temperature
increases, blood flow is re-directed to the skin and respiratory tract (Collin et al., 2001a) and extremities, particularly the ears (Andersen et al., 2008). The heart and respiration rates also increase (Curtis, 1983) in order to facilitate heat loss from the periphery and respiratory tract (Collin et al., 2001a). As this thesis will be focusing on pigs in hot environments, the behavioural and physiological mechanisms will be described in more detail in the following sections.

2.1.1 Behavioural Mechanisms of Thermoregulation in Hot Environments

During hot weather, pigs in extensive outdoor conditions will modify their behaviour, first by spending more time inactive, especially in the shade (Blackshaw and Blackshaw, 1994; Olsen et al., 2001), and then by wallowing, particularly in mud (Ingram, 1965; Fraser, 1974; Lambooij and van Putten, 1993). Pigs of all sizes decrease overall activity as temperature increases in order to reduce heat production due to exercise (Heitman and Hughes, 1949; Hicks et al., 1998) and wallowing in mud helps to decrease respiration rate and reduce body temperature via the extended cooling provided by the wet material that clings to the hair and skin (Ingram, 1965; Fraser, 1974; Ingram and Dauncey, 1985). The evaporation rate when mud is applied to the skin is ~20 times greater than that of passive evaporation from the skin of a clean pig (800 v. 40 g/m²/h; Ingram, 1965; Curtis, 1983). When housed indoors, pigs will spend more time lying in the dunging area in the manner of wallowing as air temperature rises (Hillmann et al., 2004; Huynh et al., 2005a). Lying posture also changes with increasing temperature, where pigs will spend more time lying in a lateral position rather than a sternal or half lateral (leaning) position (Huynh et al., 2005a), thereby increasing overall contact of the body with the cooler
floor surface. They will also spend less time in contact with pen mates to increase heat lost by convection, conduction and radiation (Huynh et al., 2005a; Sutherland et al., 2007). Lying and wallowing behaviours show temperature thresholds, where market-weight pigs increased lying behaviour at ambient temperatures above 17°C and increased ‘wallowing’ by lying in the dunging area at ambient temperatures above 22°C (Hillmann et al., 2004). In intensive systems, pigs will also make use of alternative cooling systems such as sprinklers (Huynh et al., 2006), drip coolers and cooling pads when provided (Bull et al., 1997). In lairage environments, sprinkling pigs during times of high ambient temperature has been shown to reduce the time spent inactive, suggesting behavioural mechanisms of thermoregulation were no longer necessary (Weeding et al., 1993; Knowles et al., 1998). Furthermore, Colleu and Chevillon (1999) found that sprinkling pigs in one deck of a trailer helped to reduce skin surface temperature by 10% compared to the non-sprinkled pigs in the other deck, indicating there may also be benefits to wetting pigs during transportation in hot ambient conditions. In addition, water intake is increased under heat stress, especially if no other means of cooling is available (Whittow, 1971; Huynh et al., 2006). Due to the physiological limitations on heat dissipation compared to other ungulates, behavioural adaptations are even more critical for pigs in order to maintain homeostasis in high temperature environments.

2.1.2 Physiological Mechanisms of Thermoregulation in Hot Environments

Physiologically, pigs are more limited in their ability to dissipate heat than many other mammals since they lack functional sweat glands and breeds common to North America have little loose skin in order to increase skin surface area from which to radiate heat (Fraser, 1974;
Bligh, 1985). Despite this, under heat stress, pigs increase their heart rate (Marple et al., 1974; Gaffin et al., 1998) and regulate blood flow to the extremities, particularly the ears (Whittow, 1971; Collin et al., 2001a; Andersen et al., 2008), as well as dilating blood vessels at the surface of the skin (Curtis, 1985; Lambooij and van Putten, 1993) and mucus membranes of the tongue and nose (Rübsamen and Hales, 1985; Collin et al., 2001a), in order to transfer excess heat away from the vital organs. Using thermal imaging, Brown-Brandl et al. (2012) observed that for 40-50 kg growing pigs, blood flow to the skin increased at ~21.6°C. Collin et al. (2001a) found that at 33°C compared to 23°C, the blood flow in growing pigs was increased towards the dorsal skin, ear skin and lungs and reduced to the muscle and adipose tissue and some visceral organs (e.g. the liver). Since domestic pigs have little hair cover compared to other ungulates, it is of minimal significance in the transfer of heat away from the skin (Whittow, 1971). Respiration rate increases in order to promote evaporative heat loss across the mucous membranes of the oro-nasal cavity (Bligh, 1985; Lopez et al., 1991; Brown-Brandl et al., 2001). The ability to lose heat by evaporation in this manner can be limited by humidity (Whittow, 1971; Huynh et al., 2005b), as well as secondary genetic selection for domesticated breeds with shorter snouts, which have a reduced capacity for heat loss (Lambooij and van Putten, 1993). The pig also uses behavioural changes to support physiological mechanisms, including reducing feed intake to slow its metabolic heat production (Heitman and Hughes, 1949; Nienaber et al., 1996; Brown-Brandl et al., 1998) and increasing water intake to offset water loss due to respiratory evaporation (Brown-Brandl et al., 1998; Huynh et al., 2005b). Each of the physiological responses have been shown to have a given UCT, above which heart and respiration rates increase and metabolic heat production decreases, and this temperature limit is variable dependent on pig size, where smaller
pigs have a higher UCT, and breed, where tropical breeds (e.g. Creole) have higher UCTs than European breeds (e.g. Large White) (Aberle et al., 1974; Hillmann et al., 2004; Renaudeau, 2005). For market weight pigs of 100 kg, respiration rate begins to increase past 22-24°C, feed intake is depressed past ~24°C, and heat production begins to decrease at 24-26°C (Brown-Brandl et al., 1998; Huynh et al., 2005b).

2.2 Impact of Heat Stress on the Pig

On-farm, heat stress will limit the productivity of both the grow-finish and breeding stocks. Since feed intake decreases while water intake increases (Brown-Brandl et al., 1998; Huynh et al., 2005b), average daily gain in finishing pigs is negatively impacted, leading to increased days to market at the cost of the producer (St-Pierre et al., 2003). Also, heat stressed sows show increased weaning-to-estrus intervals (St-Pierre et al., 2003), as well as decreased lactation linked to reduced feed intake, leading to reduced weight gain in the litter prior to weaning (Black et al., 1993; Prunier et al., 1997). This then negatively impacts annual productivity for the sow and delays the early growth of the litter. Heat stress in combination with either dominant or submissive social status (but not intermediate status), may also negatively impact immune function (Morrow-Tesch et al., 1994), which could lead to increased susceptibility to disease, which further compromises growth and reproductive functions.

During transport, heat stress can compound the stressors inherent with transport, such as handling, novelty and in some cases, mixing of unfamiliar pigs (Huyn et al., 2005; Ritter et al., 2009a). When pigs become over-stressed during transport, either due to heat or other stressors, they can become what are called ‘non-ambulatory, non-injured’, or NANI pigs. NANI pigs are
unable to stand and walk on their own due to fatigue, but are otherwise uninjured (Ritter et al., 2006). Besides becoming non-ambulatory, NANI pigs often present clinical signs such as open-mouth breathing, muscle tremors, skin discolouration, and in some cases abnormal vocalization (Anderson et al., 2002 as cited by Ritter et al., 2009b). These signs are connected with increased lactate levels, lower blood pH and lower liver glycogen and muscle glycolytic potential, suggesting muscle metabolic acidosis (Anderson et al., 2002 as cited by Ritter et al., 2009b; Ivers et al., 2002, as cited by Ritter et al., 2009b). If the pigs are unable to rest and recover from these metabolic changes, they can lead to death (Hamilton et al., 2004). Sutherland et al. (2008) also found elevated levels of creatinine in NANI pigs, suggesting increased levels of muscle and protein breakdown. In-transit mortality is often due to cardiac arrest, although post-mortem analyses of dead-on-arrival (DOA) pigs found that a large percentage of pigs dying of heart failure during transport had some pre-existing sub-clinical heart defect (Clark, 1979; Bergmann et al., 1988). Pigs that are heat-stressed immediately prior to slaughter also have a higher risk of producing poor quality pork that has low pH and is pale, soft and exudative (PSE) (Santos et al., 1994), due to stress-induced glycolysis producing lactate that builds up in the muscle (Álvarez et al., 2009).

2.3 Measuring Heat Stress in Pigs

2.3.1 Measuring Behavioural Thermoregulation

Behavioural observations are often time consuming to collect, but can often provide important information on how a pig is dealing with the sum of the stressors in its environment. In studies of heat stress through transport and lairage, respiration rate, postural behaviour and water
intake indicate how a pig is coping. Respiration rate can demonstrate the attempt to lose heat through panting (Curtis, 1983), and is measured by visual counts of flank movement (Lopez et al., 1991; Huynh et al., 2005b) or by using acoustic sensors (Brown-Brandl et al., 2001). Since the presence of human observers often disrupts behaviour in any environment, remote video observations are most commonly used in order to determine behavioural time budgets under different environmental conditions via scan-sampling (Brown et al., 1999; Huyn et al., 2005). Behaviours useful in heat stress studies are the percentage of time spent standing, sitting and lying (Fraqueza et al., 1998), as well as feed and water intake (Huynh et al., 2005b), as postural position and ingestive behaviours are often altered under differing environmental conditions (Curtis, 1983). Upon unloading at the slaughter plant, live observations of open-mouthed breathing (panting), skin discolouration (blotchy, red hot spots), and incidences of NANI pigs are also used to indicate stress and metabolic acidosis, particularly in hot environments (Ritter et al., 2009b).

### 2.3.2 Measuring Body Temperature

Measuring body temperature at different places on or in the body is a relatively non-invasive and inexpensive way to study changes in core body temperature without having to implant sensors into the pulmonary artery to measure the temperature of the blood (Hanneman et al., 2004). Sites in the body that are easier to access for measurement are the tympanic membrane of the ear, the skin, the rectum and the bladder, though they may be slower to respond to core temperature changes and are more susceptible to localized differences, particularly when close to the surface of the body (Hanneman et al., 2004). Skin temperatures have been measured using ear tag data loggers (Andersen et al., 2008), radiant thermometers (Huynh et al., 2006) or
thermal imaging (Schaefer et al., 1989; Nanni Costa et al., 2011; Brown-Brandl et al., 2012); rectal temperatures via temperature probe (Marple et al., 1974; Huynh et al., 2005b); or gastrointestinal tract temperatures by orally administered data loggers (Davidson et al., 2003; von Borell and Schäffer, 2005; Carr et al., 2008; Tamminga et al., 2009). Measuring skin temperature serves to illustrate changes in peripheral blood flow, which is often increased under heat stress to dissipate heat from the blood through the skin (Curtis, 1983; Andersen et al., 2008; Brown-Brandl et al., 2012). Rectal and gastrointestinal tract temperatures have been shown to reflect changes in core body temperature more closely than skin temperatures, and are used when the study of the impact of stressors on true core body temperature rather than changes in thermoregulatory measures is required (Hannemann et al., 2004).

2.3.3 Measuring Physiological Changes in the Blood

Increases in lactate (Gaffin et al., 1998), creatine phosphokinase (CPK) (Warriss et al., 1998b) and cortisol concentrations (D’Allaire and DeRoth, 1986) have been consistently demonstrated under stressful conditions, including heat stress and handling. Lactate and CPK are associated with physical stress, and cortisol with both physical and psychological stress (Warriss et al., 1992). Lactate, CPK and cortisol levels in studies involving pre-slaughter transport and handling have primarily been measured by blood sample collection at exsanguination and subsequent laboratory analysis (D’Allaire and DeRoth, 1986; Warriss et al., 1998b; Ritter et al., 2009a), although more recently lactate has been measured by handheld meters requiring small amounts of blood from samples collected from live animals or immediately post-slaughter (Edwards et al., 2010a, 2010b). In some cases, the overall changes in lactate from pre-handling baseline levels were calculated, using blood samples collected either from the jugular vein for
large volume samples (Ritter et al. 2009a) or peripheral veins of the ear for small instantaneous reading samples (Edwards et al. 2010b). Care must be taken in interpreting results of lactate, CPK and cortisol levels with regard to transport, since the response is a summation of responses to all stressors and differences may be the result of factors unrelated to transport conditions (e.g. experience with handling, characteristics of lairage environments) (Warriss et al., 1998a). As well, although both lactate and cortisol levels can be good stress indicators, cortisol often shows diurnal variation and lactate often shows postprandial variation (Koopmans et al., 2005). As a result, relying on exsanguination blood samples to specifically measure lactate and cortisol responses to stressors due to transport conditions is not recommended when lairage times are more than 2 to 3 h or if pigs have been recently fed (Warriss et al., 1998a; Warriss et al., 1998b). CPK has a longer half-life in the bloodstream, and so exsanguination blood samples can be used in studies where transport and/or lairage times are extended (Warriss et al., 1998b).

2.4 Additive Effects of Other Stressors

A ‘stressor’, like thermal stress, is a characteristic of the pig’s environment that elicits any form of adaptive response, either behavioural or physiological (Curtis, 1983). During transport, stressors can include climatic conditions, handling, novelty, feed and water deprivation, interaction with group mates, motion sickness and duration of transport (Broom, 2003). It has been demonstrated that responses to multiple stressors from different sources are additive in nature. As pigs are subjected to one, two or three stressors (aggressive handling, restricted floor space on the trailer and longer distance moved), rectal temperature and blood and muscle lactate concentrations increase linearly (Ritter et al., 2009a). As well, Hyun et al. (2005)
found that compounding stressors of heat, social mixing and restricted floor space in barns increased lying behaviour. The response to stressors can also be influenced by genetic predisposition. Indeed, this additive effect is particularly important in genetically stress-susceptible animals when heat stress can exacerbate the stress responses resulting from handling and transport. Selection pressures for production characteristics, such as fast growth rate and increased lean deposition, has reduced the heart to body weight ratio from 0.6% in wild pigs to 0.3% in domesticated pigs, decreasing the capacity of the heart and muscles to deal with physical stressors, like exercise (Niewold et al., 2000). As well, breeds selected over time with calmer dispositions may have decreased stress responses and breeds selected for larger muscles may be more easily stressed due to increased distance of the muscle centre from major blood vessels (Grandin, 1997; Broom, 2000).

2.5 Transporting Pigs

Commercially reared pigs are transported in trailers at least once in their lifetime and the impact of this procedure on the overall welfare of healthy, market-weight pigs is multi-factorial. Factors include characteristics of trailer design, trip duration and driving style, ventilation and micro-climate within the trailer, and stocking density. Pigs are susceptible to negative effects of all of these factors, and their welfare in transit is reflected in their condition during and after transport (e.g. prevalence of panting, NANI pigs), as well as the overall death losses reported.

2.5.1 Trailer Design

In Canada, trailer types that are used most often to transport pigs are either double deck straight trailers or ‘pot-belly’ trailers consisting of 2 straight decks and a smaller deck (the
‘belly’) between the front and rear tires (e.g. Figure 4.1). In order to load the upper decks of both type of trailer, and the belly of the pot-belly trailer, pigs must climb up and down steep ramps. Ramps exceeding an angle of 20° have been shown to be more difficult for pigs to navigate, particularly if cleats are spaced far apart (>25 cm) (Grandin, 1990; Warriss et al., 1991), as they often are in trailers that alternately haul cattle. Pigs have also been observed to display more open-mouth breathing when transported in pot-belly trailers rather than flat deck trailers, presumably due to the exercise required to navigate the extra ramps (Kephart et al., 2010; Correa et al., 2012). There has also been some data to suggest a numerical increase in death losses and NANI pigs in pot-belly vs. straight trailers (Correa et al., 2012).

2.5.2 Transport Duration and Driving Style

Currently, there appears to be conflicting data on the impact of transport duration on pig welfare, where in some cases, increasing duration appears to have little impact on welfare (Mitchell et al., 2010), while others found significant negative impacts via increases in bruising and rectal temperature (Mota-Rojas et al., 2006) and death losses (Haley et al., 2008b). As a result, it is more likely that duration itself is not detrimental; rather it exacerbates poor welfare when conditions of transport, such as temperature or stocking density, are unfavourable, or animals are not fit for transport (Cockram, 2007; Nielsen et al., 2011). It has also been shown that salivary cortisol levels in pigs vary with the driver, as well as the ‘style’ of driving, though the effects are inconsistent (Peeters et al., 2008). It is generally accepted that rough style driving has a more negative effect on welfare during transport than careful or normal driving (Bradshaw et al., 1996a; Broom, 2003; Peeters et al., 2008).
2.5.3 Trailer Ventilation and Micro-Climate

At any time of year, the micro-climate of each compartment is closely related to the ventilation created by the movement of the trailer. When pigs are held within the trailer, they are constantly releasing heat and moisture into the contained environment, due to their resting heat production as well as any additional heat production due to movement (Mitchell and Kettlewell, 2008). Ventilation systems are employed in barns and lairages in order to remove this extra heat and moisture in order to maintain a constant, thermo-neutral environment (Curtis, 1983; Randall, 1983). During times of high ambient temperatures, trailers that lack forced ventilation mechanisms rely on natural ventilation created by the trailer movement to remove heat and moisture from the internal environment and maintain temperatures as close to thermo-neutral as possible. Close et al. (1981) demonstrated that even a 5 cm/s increase in air flow was equivalent to a 1°C decrease in dry-bulb temperature. Unfortunately, due to the design of North American trailers and inconsistent effects of prevailing winds, air flow in different compartments within trailers are often dissimilar and the resultant temperatures and relative humidity values are often different, with typically warmer, more humid environments in the lower, front compartments than in the upper back compartments (Brown et al., 2011; Weschenfelder et al., 2012). In studies of poultry trailers, it has been found that air flows up and over the trailer, re-connects along the roof and flows back in the rear of the trailer, providing greater ventilation in the rear sections than in the front sections (Kettlewell et al., 2001). Although the designs of poultry trailers are somewhat different, Ellis et al. (2010) also demonstrated reduced air velocities in the front compartments in pig trailers. Pigs in these front compartments also demonstrate higher peripheral body temperatures, suggesting increased requirements for peripheral heat loss.
(Warriss et al., 2006). It must be noted as well that this maintenance of micro-climate conditions in hot external environments by natural ventilation is solely reliant on the movement of the trailer; as soon as the trailer is stationary, the trailer temperature and humidity quickly begin to rise (Hayne et al., 2008; Ellis et al., 2010; Lewis et al., 2010). Without the removal of the water vapour created by the pigs’ biological functioning as well as panting, the micro-climate eventually becomes saturated and evaporative heat loss becomes impeded (Curtis, 1983). To ensure this situation is avoided as much as possible, measures must be made by the transporter and the plants to ensure minimal wait times at the farm or assembly yard and at the slaughter plant. In cold environments, the effect of ventilation becomes negative when heat is already easily dissipated. To offset this, removable panel boards are inserted to close up the ventilation holes and the micro-climate is maintained by pig body heat production.

2.5.4 Stocking Density

The stocking density of each compartment, either in terms of kg/m$^2$ or m$^2$/pig, influences pig welfare during transport, particularly during times of high ambient temperature. Stocking densities higher than ~0.45m$^2$/pig (~245 kg/m$^2$) have been linked to increased CPK levels in the blood (Warriss et al., 1998b; Kim et al., 2004), an indicator of physical stress, likely due to reduction in the ability to lie down to rest easily (Lambooy and Engel, 1991). Also, by increasing stocking density, the amount of heat added to the trailer due to the greater numbers of pigs is increased, which at high ambient temperatures further compounds overall heat stress (Dewey et al., 2009). Death losses and rates of NANI pigs also increase with increasing stocking density (Ritter et al., 2006). Haley et al. (2010) also found that at temperatures above 21°C, increasing stocking density from 0.52 to 0.44 m$^2$/pig more than doubled death losses.
2.5.5 In-Transit Losses Related to Hot Weather

Besides being of concern to animal welfare, death losses during summer transport are a significant cost to the pork industry (Speer et al., 2001). In-transit death losses in Ontario are reported to range from 0.08-0.15% of all pigs marketed annually (Haley et al., 2010). More recent data from one federally inspected plant in Ontario shows that approximately 60% of death losses are dead on arrival, another 20% being NANI or injured pigs that are euthanized on arrival, with peaks in losses occurring from May to August concurrent with known heat waves (F. Wood, Conestoga Meat Packers Ltd., personal communication). In a retrospective analysis, it has been determined that when internal trailer temperatures exceed 26°C, the percentage of market pigs dying during transport is 4 times greater than at 10°C (Haley et al., 2008a). However, Sutherland et al. (2009) found lower death losses in the summer than in the fall, though they speculate that increased weights of animals in the fall due to feeding of new corn may have influenced losses more than temperature. Compartment location could also be a factor, where differences in air flow and resultant temperature and relative humidity can put additional strain on the pigs in the front compartments, resulting in increased death loss rates (Sains, 1980; Correa et al., 2012). The impact of hot weather on losses is further compounded if the pigs are not withdrawn off feed (Averós et al., 2008), due to the increased metabolic heat production associated with digestion (Curtis, 1983), and also by stocking densities above the recommended limits (Ritter et al., 2006; Haley et al., 2010). Transport duration was sometimes seen as a factor impacting death losses (Gonsálvez et al., 2006), and in other cases it was not important (Pilcher et al., 2011), likely related to the point that duration appears to be a negative factor for welfare only when in combination with sub-optimal conditions for transporting pigs (i.e. extremes of
temperature, high stocking density), as described previously. There also appears to be a link
between sub-clinical cardiovascular pathology and deaths during transport, as Clark (1979) and
Bergmann et al. (1988) both found that the majority of pigs identified as dying of heart failure
had some sort of chronic inflammatory or degenerative disorder. Clearly the cardiovascular
systems of some pigs are unable to cope with transport conditions, particularly under heat stress
conditions. Genotype can also influence death loss rates, where it has been shown that
heterozygous carriers of the halothane gene were 5 times more likely to die and homozygous
recessive carriers of the halothane gene were 200 times more likely to die in transit (Murray and
Johnson, 1998; Fàbrega et al., 2002). This factor has become less important as the halothane
gene has been largely selected out of the Canadian herds, though certainly some carriers still
exist (Ritter et al., 2008b).

2.5.6 Pig Responses to Transport

For many pigs, the experience of transportation to slaughter is one of the most stressful
events of their lives where they are moved from their home pens into an unfamiliar trailer, often
with unfamiliar pigs. The pigs’ physiological and behavioural stress responses result from both
the novelty of the experience and the exercise of moving up and down ramps (Lambooij and van
Putten, 1993). These stressors can then also be compounded by extremes of temperature and
humidity. The motion and vibration of the trailer in itself can also be found aversive to pigs
(Perremans et al., 1998) and given the choice, pigs will choose to turn off a simulated source of
vibration (Stephens et al., 1985; Stephens and Perry, 1990).
2.5.6.1 Physiological Responses

Pigs show a similar physiological response to transport stress as to heat stress, characterized by increased heart rate (Stephens and Perry, 1990; Knowles and Warriss, 2000; Correa et al., 2010, 2012), body temperature (Brown-Brandl et al., 2001; Huynh et al., 2006; Carr et al., 2008), respiration rate (Knowles and Warriss, 2000; Huynh et al., 2006), and blood lactate, cortisol, adrenaline (Pérez et al., 2002; Yoshioka et al., 2004; Ritter et al., 2009b) and CK (Warriss et al., 1998b; Kim et al., 2004). This is particularly important since compounding sources of stress can magnify the overall physiological stress response (Ritter et al., 2009a). Additionally, transport can sometimes induce increases in vasopressin, which has been linked to vomiting during transport (Bradshaw et al., 1996b), though whether this is also connected to a lack of feed withdrawal prior to transport is unclear (Riches et al., 1996). It has also been shown that some habituation to transport can occur where heart rate (Stephens and Rader, 1982; Stephens and Perry, 1990; Geverink et al., 1998a) and blood lactate (Pérez et al., 2002) decrease as transport time progresses. Pre-sorting of pigs into shipping rooms prior to the transport day also serves to reduce the impact of group mixing on overall stress response (open-mouth breathing, muscle tremors and skin discoloration) when pigs are loaded and unloaded (Gesing et al., 2010). The effects of handling and transport on physiological responses often carry through the unloading procedure, but given a lairage time of 2 h or more, heart rate and levels of cortisol return to pre-transport levels (Warriss et al., 1992; Warriss et al., 1998b). Lactate changes in lairage appear to be more variable; in some studies it was unchanged (Warriss et al., 1992), while in others it was reduced with increased lairage time (Warriss et al., 1998a). This
may have been the result of differences in lairage micro-climate or in activity levels, as both have been shown to elevate lactate.

2.5.6.2 Behavioural Responses

Currently, there are conflicting results on what constitutes normal pig behaviour during transport, quite likely as a result of the nature of the transport, either in terms of season (Torrey et al., 2009a, 2009b; Goumon et al., 2012), stocking density (Barton Gade and Christensen, 1998; Kim et al., 2004), duration (Pérez et al., 2002) and the smooth or rough style of driving (Bradshaw et al., 1996a; Peeters et al., 2008). It has been observed that it often takes 1 h or more for pigs to lie down during transport, and so short duration transports are often insufficient for pigs to adapt behaviourally to transport conditions (Lambooy, 1988; Lambooy and Engel, 1991). Barton Gade and Christensen (1998) demonstrated that the stocking density appears to show non-linear effects on lying behaviour, and by varying the stocking density between 0.35 m$^2$ and 0.5 m$^2$ per 100 kg pig, there was minimal lying at each extreme, but increased lying at intermediate densities. Also, the style of driving, when rough, can lead to reduced lying behaviour due to the aversive nature of the increased vibrations (Stephens et al., 1985; Stephens and Perry, 1990), as well as increasing the chance of vomiting (Bradshaw et al., 1996a).
CHAPTER 3: OBJECTIVES AND HYPOTHESES

The objective of this thesis was to examine if sprinkling water onto pigs in trailers before and after transport affects the responses of pigs during transport and lairage prior to slaughter in times of high ambient temperature, when pigs easily become heat-stressed and mortalities can increase. It is hypothesized that by wetting the skin of the pigs immediately prior to transport, evaporative heat loss will increase during transport where natural ventilation is present, therefore increasing pigs’ ability to maintain homeothermic balance. By water sprinkling immediately before unloading, it is expected that the cool water on the skin might prevent increases in body temperature related to the stress of handling while unloading into lairage at the slaughter plant. To this end, body temperature should remain stable and behavioural adaptations to heat stress (open-mouth breathing at unloading; increased lying and water intake in lairage) should be reduced during transport and lairage prior to slaughter. Secondarily, the temperature and relative humidity inside the trailer was measured in order to assess the impact of the introduction of water into the trailer on the trailer micro-climate with the expectation that the temperature will be reduced and humidity increased. As well, incidences of slips and falls at unloading were observed in order to assess the impact of introducing water into the trailer on unloading procedures, with the expectation that minimal water run-off would have little impact on unloading behaviours.
CHAPTER 4: THE EFFECT OF WATER SPRINKLING MARKET PIGS TRANSPORTED DURING SUMMER ON PIG BEHAVIOUR, GASTROINTESTINAL TRACT TEMPERATURE AND TRAILER MICRO-CLIMATE

4.1 Abstract

Pigs are often transported to slaughter under conditions outside their thermo-neutral zones, which can lead to reduced welfare and increased in-transit losses. Water sprinkling in barns and lairages is used to control micro-climate, resulting in pig body temperature reduction and improved welfare; however there is little research into the use of water sprinkling during transport. The aim of this study was to observe if sprinkling pigs in trailers before and after transport decreased signs of heat stress, as well as to observe the effects on trailer micro-climate. Each wk for 12 wk, 208 pigs in each of 2 pot-belly trailers (n = 4,992) were transported 2 h to slaughter. One trailer was equipped with a custom-made sprinkler system that ran for 5 min (~125 L) before departure from the farm and before unloading at the plant. In each trailer, 4 test compartments (1 on the top deck, 2 on the middle deck, and 1 on the bottom deck) were outfitted with cameras, ammonia detectors and temperature/humidity data loggers, and the gastrointestinal tract temperature (GTT; °C) of 4 randomly chosen pigs (n = 384) in each compartment was recorded using orally administered iButton data loggers. Trailer and deck loading order were randomized. Behaviour during transport, unloading and lairage was recorded from video or live observations. Data were analyzed through ANCOVA with ambient temperature external to the trailer (AmbT) as a covariate. AmbT averaged 19.5°C ± 3.8°C (range: 14 to 26°C). Sprinkled
trailers showed smaller \((P = 0.002)\) net increases in temperature from loading to unloading, smaller \((P < 0.001)\) decreases in humidity at departure and unloading, no differences in temperature-humidity index (THI) upon arrival and unloading \((P > 0.10)\), and no difference in ammonia levels \((P = 0.34)\) than non-sprinkled trailers. At \(\text{AmbT} > 23^\circ \text{C}\), there was no effect of sprinkling on behaviour on the trailer, but at \(\text{AmbT} < 23^\circ \text{C}\), more pigs stood on sprinkled trailers \((P < 0.05)\). Sprinkling did not affect slips or falls during unloading \((P > 0.10)\). In lairage, latency to rest was reduced as \(\text{AmbT}\) increased for all compartments \((P < 0.05)\); sprinkled pigs spent more time lying and less time sitting \((P < 0.05)\) and had fewer drinking bouts than controls \((P < 0.001)\) regardless of \(\text{AmbT}\). GTT increased between loading and departure and decreased during transit for all pigs \((P < 0.001)\) and sprinkling tended to further reduce GTT at arrival at \(\text{AmbT} > 24^\circ \text{C}\) \((P = 0.08)\). Therefore, sprinkling pigs when ambient temperature exceeds \(23^\circ \text{C}\) can help to alleviate transport-related heat stress without detrimental effects on behaviour during unloading.

### 4.2 Introduction

Transportation is one of the most stressful experiences in a pig’s life, particularly when it occurs during environmental extremes (Ritter et al., 2009b). As pigs do not sweat, they are limited in their physiological capacity to maintain core body temperature in hot environments and easily become heat stressed (Bligh, 1985). Haley et al. (2008a) found that when internal trailer temperature exceeded \(23^\circ \text{C}\), death losses during transport increased 3-fold. Furthermore, the frequency of heat stress indicators (such as panting or skin discoloration) has been shown to increase in warmer months (Ritter et al., 2008a), demonstrating poorer welfare for pigs transported under warmer conditions. As ambient temperature increases, pigs modify their behaviour to reduce heat production and increase heat dissipation by reducing activity (Hicks et
al., 1998; Brown-Brandl et al., 2001) and increasing contact with cool or moist surfaces (Hillmann et al., 2004; Huynh et al., 2005a). Water sprinkling systems in barns with forced ventilation have been shown to increase the evaporative cooling capacity, thereby decreasing the temperature-humidity index (Haeussermann et al., 2007), but there are currently few methods available to cool pigs during transport besides natural ventilation created by trailer movement. Colleu and Chevillon (1999) found that sprinkling pigs in one deck of a trailer helped to reduce skin surface temperature by 10% compared to the non-sprinkled pigs in the other deck. However, considering the differences in micro-climate within a trailer (Schwartzkopf-Genswein et al., 2012), these results must be validated. The aim of this study was to examine the effect of sprinkling on full trailers of pigs before departure from the farm and before unloading at the plant on trailer conditions, pig behaviour and gastrointestinal tract temperature with the expectation that the increased cooling capacity would reduce pig responses to heat stress.

4.3 Materials and Methods

All experimental procedures performed in this study were approved by the Agriculture and Agri-Food Canada (AAFC) Animal Care Committee at Sherbrooke (QC) based on the current guidelines of the Canadian Council on Animal Care (2009).

4.3.1 Experimental Design and Sprinkling Treatment

In each of 12 wk from May to September 2011, 2 pot-belly trailers (PSDCL308 Silver Star Trailer, Wilson Trailer, Sioux City, IA, USA) of 208 market-weight pigs each (~115 kg live weight, n = 4,992) traveled 2 h from a commercial finishing farm to a slaughter plant within Ontario. All pigs came from the same herd and were a cross of York x Landrace maternal line
and Duroc sire line. One of the trailers was equipped with a custom-made water sprinkler system (Weeden Environments, Woodstock, Canada) and the other identical trailer served as the control. The treatment consisted of sprinkling the pigs for 5 min immediately before departure from the farm and for 5 min immediately before unloading, after a 30 min wait in the receiving yard of the slaughter plant. Before loading, the sprinkler system was run for ~30s in order to wet the bedding and prime the sprinklers to remove any air pockets that might disrupt water delivery during the sprinkling treatment of the pigs. Based on a pilot trial, 5 min was deemed sufficient to wet the pigs’ skin without creating unmanageable water run-off. Each sprinkling session delivered approximately 125 L of water evenly throughout the trailer from a ~40 psi water source through twenty-two (22) 180° spreader nozzles emitting 1.14 L/min each directed inwards from each side of the trailer. Droplet size of the water was 900-1000 microns.

Four compartments on each of the trailers were chosen for data collection based on previous results showing compartmental variations in micro-climate (Brown et al., 2011). Test compartments were compartment 4 (top deck, back: L-shaped, 2.51 x 5.18 m; less the vacant space left for ramp loading: 1.26 x 2.59 m), compartment 5 (middle deck, front; 2.51 x 3.05 m), compartment 8 (middle deck, back; 2.51 x 5.18 m) and compartment 9 (bottom deck, front; 2.51 x 3.76 m) (Figure 4.1). Trailer decks were bedded evenly with wood shavings approximately 0.5-1.0 cm deep. Stocking density was ~245 kg/m², resulting in 21 pigs in compartment 4, 16 pigs in compartment 5, 28 pigs in compartment 8 and 20 pigs in compartment 9. Loading and unloading orders of trailers and top and bottom decks within the trailers were randomized to avoid the confounding effects of the ambient temperature variation and wait time in each deck, though due to trailer design, the centre deck was always loaded last. Trailer compartment was used as the
experimental unit. Ambient temperature data were collected from an Environment Canada weather station (Region of Waterloo International Airport) and the average ambient temperature was calculated as the average of the temperatures at both the farm and the plant locations during the time of transport. Ambient temperatures averaged 19.5°C ± 3.8°C, with a range of 14 to 26°C. Trials were not conducted in weeks where the ambient temperature was ≤ 10°C as it has been shown that at these temperatures showering pigs in lairage results in shivering (Knowles et al., 1998). The driver of each trailer and the handlers at the farm were the same throughout the 12 wk. At loading at the farm, pigs were loaded in small groups using paddles and plastic sort boards. Electric prods were used in the trailer on a few occasions only when it was absolutely needed to prevent excessive back and forth movement of pigs along the decks. Trailers departed from the farm immediately after loading and departures were approximately 30 min apart. On arrival at the plant, pigs were unloaded using paddles and driven into separate lairage pens based on the transport compartment. After ~90 min of lairage, pigs were driven single file to a CO₂ stunner (Combi 77, Butina, Denmark) and exsanguinated.

4.3.2 Trailer Temperature, Relative Humidity, Temperature-Humidity Index and Ammonia

The 4 test compartments on each trailer were prepared the day before transport with 5 temperature and relative humidity iButton data loggers (DS1923 Hygrochron Temperature/Relative Humidity Logger, Maxim Integrated Products, Inc., Sunnyvale, CA) and an ammonia detector (GasAlertClip Extreme; BW Technologies by Honeywell, Calgary, Canada). iButtons were suspended from the ceiling, one in the centre and one 46 cm towards the interior at the midpoint of each of the four walls. iButtons were pre-programmed to record temperature (T, °C) and relative humidity (RH, %) data every min from 600 h the day of
transport until after unloading was completed. The temperature humidity index (THI) of each compartment was calculated according to the NRC (1971) formula:

\[
\text{THI} = \left[\left( T - [0.55 - (0.0055 \times RH)] \right) \times (1.8 \times T) - 26 \right] - 32 \times 5/9
\]

where T is in °C and RH in %, as described by Weschenfelder et al. (2012). THI was calculated only at events where pigs were on the trailer (departure, arrival, and unloading). The change in THI (DTHI) was calculated as the differences in THI from departure to arrival and departure to unload. Ammonia detectors were suspended from the ceiling at the centre of the compartment. Ammonia detectors were not pre-programmable and were turned on to record ammonia levels in parts per million (ppm) every 5 s from installation until after unloading was completed and power was turned off. Data from each iButton were downloaded using OneWire Viewer software (Maxim Integrated Products, Inc., Sunnyvale, CA) and data from each ammonia detector were accessed using Fleet Manager software (BW Technologies by Honeywell, Calgary, Canada) to generate Excel files. 11 min averages of temperature and humidity data, centered on the events of start of loading, departure from farm, arrival at plant and start of unloading were used in the analyses. Similarly, 5 min averages were calculated at the same events for the ammonia data. Due to the fact that the accuracy of this model of iButton data logger is ± 0.5°C and ± 5% RH and individual data loggers were not calibrated against each other, temperature and relative humidity data at each event were converted to delta values as the increase in temperature (DT; °C) and relative humidity (DRH; %) from the start of loading to each event and all data were analyzed using these values.


4.3.3 Behavioural Observations

To record behaviour during transport, a camera (Pentax Optio W90, 12.1 megapixels, Pentax Canada) was placed in one corner of the compartment along the stationary, un-gated wall of each test compartment using a C-clamp screwed into the camera base and angled to capture as much of the compartment in the field of view as possible. The cameras were pre-programmed to take a digital image of the compartment every 5 min, starting at 700 h the day of transport, and pictures were used to calculate the percentage of total time (%) spent standing (upright, no part of torso in contact with the floor), sitting (upright, hindquarters in contact with floor), and lying (resting, full torso in contact with floor) during transport. The remainder of pigs were classified either as ‘other’ (fighting, overlapping other pig(s)), ‘unclassified’ (in view, but otherwise unable to define posture) and the balance as ‘missing’ (outside of frame), to account for 100% of pigs in the compartment in each image. Due to the ambiguous nature of the latter 3 designations, only results for standing, sitting and lying postures are reported. Compartment 9 was excluded from behaviour analysis because pigs were unable to be observed or accurately classified more than 70% of the time due to the low ceiling, leading to shifting or obstruction of the camera’s field of view. Similarly, any compartment repetition where pigs were unable to be observed or accurately classified more than 50% of the time due to shifting or obstruction of the camera field was excluded from the analysis.

At the unloading dock, live observations of unloading behaviour were made to count all incidences of slips, falls, overlaps, open-mouth breathing, splotchy skin, NANI pigs, and death losses (Table 4.1). Unloading time (s) for each test compartment was recorded from the time the first foot until the last foot landed on the dock. All events and times were standardized on a per
pig basis to account for differences in group size. The same observer was present for 9 of 12 repetitions; the other 3 were completed by one of the trainers to reduce observer variation.

During lairage, each pen containing one test compartment group was video recorded (Sony Handycam, 4 x model DCR-SR68 and 4 x model HDR-CX110, Sony of Canada, Toronto, Canada) and scan samples every 2 min were used to calculate the percentage of time (%) spent standing (upright, no part of torso in contact with the floor), sitting (upright, hindquarters in contact with floor), and lying (resting, full torso in contact with floor). Stocking density in lairage was 213 kg/m² for all compartment groups and average lairage time was 90 min. Latency to rest was calculated using the video stills as the time (min) from the start of lairage until the time when at least 75% of pigs were lying down. The total number of drinking bouts was recorded for the entire lairage period using continuous observations and the total was standardized on a per pig basis. A drinking bout was defined as any occurrence of a pig placing its mouth on a nipple drinker for any duration. A new bout was recorded if the pig’s mouth was off of the drinker for at least 5 s. The observer was constant across all repetitions and was blind to the treatment.

4.3.4 Gastrointestinal Tract Temperature

For each test compartment, 4 pigs were randomly chosen for collection of gastrointestinal tract temperature (GTT) data (n = 384). Attempts were made to split sex with a final representation of 57% castrated males and 43% females. On the day before shipment, each pig was ear-tagged for identification and had an iButton data logger (High Resolution Thermochron iButton DS1921H, Maxim Integrated Products, Inc., Sunnyvale, CA) administered orally using a balling gun (Partnar Animal Health, Ilderton, Canada) and a pig snout snare and gag. iButtons
were pre-programmed to record temperature data (°C) every min from the time it was administered through slaughter. iButtons were recovered from the viscera after slaughter by identification, segregation and dissection of the gastrointestinal tract and manual location of the iButton. Approximately 75% of the iButtons administered were recovered and of those recovered, 43% were located in the stomach, 28% in the caecum and 29% in the intestines. Data from each iButton were downloaded using OneWire Viewer software (Maxim Integrated Products, Inc., Sunnyvale, CA) to generate an Excel file and analyzed using an 11 min average of the temperature readings centred around the time of each event: baseline (500 h the day of transport), start of loading, departure of the trailer from the farm, arrival of the trailer at the plant, end of unloading into lairage and end of lairage before slaughter. In the event that the iButtons failed at any point during the measurement window, either resulting in no data or temperature readings <30°C, data from those iButtons were excluded and the faulty iButton removed from use. This occurred in 11 of the 288 iButtons recovered. Due to the fact that the accuracy of this model of iButton data logger is ± 1°C and individual data loggers were not calibrated against each other, each event temperature was converted to a delta value (DGT; °C) as the increase from the baseline temperature and all data were analyzed using these values.

4.3.5 Statistical Analysis

Data from individual pigs within a compartment and micro-climate data were pooled as required for each of the measures to create a single value for each compartment group of pigs, and statistical analyses were completed with the MIXED procedure in SAS (SAS Institute Inc., Cary, NC) with compartment group of pigs as the experimental unit for all variables. The main effects analyzed were sprinkling, compartment location and the interactions of sprinkling and
compartment location. Ambient temperature was analyzed as a covariate using ANCOVA and week was used as a random block effect. When ambient temperature was not significant, no further ANCOVA analysis was completed and results were reported as \( P > 0.10 \). When the ambient temperature covariate effect was significant, the results from either an equal slopes or an unequal slopes model were reported, depending on the presence of interactions of ambient temperature with sprinkling, compartment or sprinkling by compartment. When ambient temperature was not significant, ANOVA exact significance values were reported. When compartment effects were found in ANCOVA or ANOVA, pair-wise multiple comparisons with a Tukey adjustment were performed. Where interactions between sprinkling and compartment were suspected, the SLICE effect of the interaction was performed for each compartment. Due to the non-normal distribution of the ammonia data, data was back-transformed after log transformation and variation is described using 95% confidence intervals. Due to the low numbers of occurrences, unloading behavioural data (except for unloading time per pig) were converted into a binary formation of a value of '1' for 1 or more occurrences of the behaviour or '0' for no occurrences and a Fisher's exact test was performed to test the effect of the sprinkling treatment. When unloading behaviours showed sufficient occurrences, data were analyzed through logistic modeling using PROC GLIMMIX to test the effects of sprinkling, compartment and the interaction of sprinkling*compartment. A probability level of \( P < 0.05 \) was chosen as the limit for statistical significance in all tests, whereas probability levels of \( P \leq 0.10 \) were considered as a tendency.
4.4 Results

4.4.1 Trailer Micro-Climate Conditions

4.4.1.1 Trailer Temperature

Least squares mean (± SEM) compartment temperatures for all compartments in both treatments combined were 16.92 ± 1.17°C at loading, 24.01 ±0.78°C at departure, 24.08 ± 1.15°C at arrival, and 25.24 ± 1.31°C at unloading. As ambient temperature increased, trailer temperature at each event increased ($P = 0.001$; Table 4.2), but there was no effect of ambient temperature on the change in temperature from loading to any subsequent event ($P > 0.10$). As shown in Table 4.2, the sprinkled trailers showed larger increases in temperature from loading to departure ($P = 0.0001$), but smaller increases from loading to unloading ($P = 0.002$). Treatment did not affect net increase in temperature from loading to arrival ($P = 0.63$). As there were no sprinkling treatment*compartment interactions on DT ($P > 0.10$), data were pooled across sprinkling treatments and presented according to the single effect of the compartment. At the times of departure and arrival, compartments 4 and 8 had the smallest increases in temperature and compartments 5 and 9 had the greatest increases in temperature ($P < 0.001$; Table 4.3). At the time of unloading, compartment 5 had the largest increases in temperature and compartment 8 the smallest increases in temperature, with compartments 4 and 9 being intermediate ($P < 0.001$; Table 4.3).

4.4.1.2 Trailer Relative Humidity

Least squares mean (± SEM) relative humidities for all compartments in both treatments were 90.20 ± 2.10% at loading, 83.15 ± 2.50% at departure, 65.50 ± 4.00% at arrival and 65.55 ± 4.30% at unloading. There was no effect of ambient temperature on compartment RH ($P > 0.10$; Table 4.2) or changes in compartment RH from loading to any subsequent event ($P > 0.10$).
DRH values from loading to each event were always negative values. The sprinkled trailers had a smaller \((P < 0.001)\) DRH values at departure and unloading (Table 4.2), but there was no difference in DRH values between treatments at arrival \((P = 0.68;\) Table 4.2). As there were no sprinkling treatment*compartment interactions on DRH variation \((P > 0.05)\), data were pooled across sprinkling treatments and presented according to the single effect of the compartment. There were no compartment differences in DRH values by departure or arrival \((P = 0.27\) and \(P = 0.64\) respectively; Table 4.3). However, by the time of unloading, compartments 8 and 9 had the smallest DRH values and compartment 4 the largest DRH value, with compartment 5 being intermediate \((P = 0.002;\) Table 4.3).

4.4.1.3 Trailer Temperature-Humidity Index (THI)

Least squares mean \((\pm\) SEM) compartment THI for all compartments in both treatments combined were 23.09 \(\pm\) 0.70 at departure, 22.09 \(\pm\) 0.88 at arrival, and 22.98 \(\pm\) 0.99 at unloading. As ambient temperature increased, trailer THI at each event increased \((P = 0.001;\) Table 4.2), but there was no effect of ambient temperature on the change in THI from loading to any subsequent event \((P > 0.10)\). The sprinkled trailers had larger THI values at departure \((P < 0.001;\) Table 4.2), but there were no differences in THI upon arrival or unloading \((P > 0.10;\) Table 4.2). There was a larger negative DTHI in sprinkled trailers both upon arrival and unloading \((P <0.001;\) Table 4.2). As there were no sprinkling treatment*compartment interactions on THI variation \((P > 0.10)\), data were pooled across sprinkling treatments and presented according to the single effect of the compartment. At departure and unloading, compartments 4 and 8 had smaller THI values than compartments 5 and 9 \((P < 0.05;\) Table 4.3). Upon arrival, compartment 9 had the largest THI value, compartments 4 and 8 the smallest, with compartment 5 being intermediate \((P < 0.05;\)
Table 4.3). Upon arrival, compartments 5 and 9 showed the largest negative DTHI values, compartment 8 the smallest DTHI values, with compartment 4 being intermediate ($P < 0.05$; Table 4.3). Upon unloading, compartments 4 and 8 had the largest increases and compartment 9 the largest decrease in DTHI, with compartment 5 being intermediate ($P < 0.05$; Table 4.3).

### 4.4.1.4 Trailer Ammonia Levels

Ammonia levels (ppm) were unaffected by sprinkling treatment ($P = 0.34$) or ambient temperature ($P > 0.10$). Differences in ammonia levels only occurred at the time of unloading, resulting from differences between compartments. At unloading, compartments 5 and 9 had the largest mean levels of ammonia (5.04 ppm [95% CI: 3.43 to 7.41 ppm] and 7.16 ppm [95% CI: 4.83 to 10.61 ppm], respectively), compartment 4 was intermediate (2.95 ppm [95% CI: 1.95 to 4.46 ppm]) and compartment 8 had the lowest levels (1.46 ppm [95% CI: 0.89 to 2.37 ppm]; $P < 0.05$). Measurements never exceeded the 8 h occupational exposure limit of 25 ppm (Ontario Ministry of Labour, 2010), and the highest single measurement recorded was 17.6 ppm.

### 4.4.2 Behavioural Observations

#### 4.4.2.1 Behaviour during Transport

The least squares mean ($\pm$ SEM) percentage of time pigs spent standing during transport across all treatments and compartments was 47.75 $\pm$ 1.70%. As ambient temperature increased, the percentage of time pigs spent standing on sprinkled trailers decreased ($P < 0.05$), while the percentage on non-sprinkled trailers was unchanged (Figure 4.2). Below ambient temperatures of 23°C, the percentage of time spent standing on the trailer was greater ($P < 0.05$) on sprinkled than non-sprinkled trailers, but at 23°C and higher, there was no difference between treatments in the percentage of time pigs spent standing ($P > 0.10$; Figure 4.2). The least squares mean ($\pm$
SEM) percentage of time spent sitting during transport across all treatments and compartments was 6.45 ± 0.50%. There was no effect of ambient temperature on the percentage of time pigs spent sitting during transport ($P > 0.10$). There was more time spent sitting by pigs in compartment 5 than pigs in compartment 8 (7.5 vs. 5.3 ± 0.70% respectively; $P = 0.001$), with compartment 4 being intermediate (6.5 ± 0.70%). The least squares mean (± SEM) percentage of time spent lying during transport across all treatments and compartments was 8.55 ± 0.70%. There was no effect of ambient temperature on the percentage of time spent lying on the trailer ($P > 0.10$). There was an effect of the sprinkling treatment where sprinkled pigs spent a smaller percentage of time lying than non-sprinkled pigs (6.9 vs. 10.2 ± 0.70%, respectively; $P = 0.0001$). There was a compartment effect wherein pigs from compartment 8 spent less time lying compared to pigs from compartment 5 (6.8 vs. 9.7 ± 0.90%; $P = 0.01$), with pigs from compartment 4 being intermediate (9.2 ± 0.90%).

4.4.2.2 Behaviour during Unloading and Lairage

As there were no treatment*compartment interactions, behaviour data at unloading and in lairage were pooled across treatments and presented according to the effects of each single factor. At unloading for the sprinkled vs. non-sprinkled treatments, respectively, slips occurred in 58.33 vs. 62.50% of the compartment groups, falls occurred in 10.42 vs. 12.50% of the compartment groups, and overlaps occurred in 37.50 vs. 31.25% of the compartment groups. There were no significant effects of treatments, compartment group or ambient temperature on unloading behaviours ($P > 0.10$). There were no compartment groups showing blotchy skin, 2 compartment groups showing open-mouth breathing (1 from each treatment), 1 incidence of a NANI pig on one of the sprinkled trailers, and 1 dead on arrival on one of the non-sprinkled
trailers. Unloading time (s/pig) was only affected by compartment, where compartment 8 had shorter ($P < 0.001$) unloading times than all other compartments (Table 4.4). Apart from latency to rest, which was reduced as ambient temperature increased ($P = 0.04$), no effect of ambient temperature on lairage behaviours was found in this study ($P > 0.10$). Sprinkling increased the percentage of time spent lying ($P = 0.03$) and reduced the percentage of time spent sitting ($P < 0.001$), but did not change the percentage of time spent standing ($P = 0.40$; Table 4.4). Behaviour in lairage also varied according to compartment of origin, with pigs from compartment 8 spending a smaller ($P < 0.001$) percentage of time lying than pigs from all other compartments and a larger ($P < 0.005$) percentage of time standing than pigs from compartments 4 and 5 (Table 4.4). Furthermore, pigs from compartment 9 spent a larger ($P = 0.01$) percentage of time standing than those from compartment 4 (Table 4.4). The least squares mean ($\pm$ SEM) latency to rest was $33.47 \pm 2.75$ min and was unaffected by the sprinkling treatment ($P = 0.20$; Table 4.4). As ambient temperature increased, the latency to rest was reduced for pigs from all compartments ($P = 0.04$). Groups of pigs from compartments 4 and 5 had shorter ($P < 0.05$) latencies to rest than those from compartment 8, with groups of pigs from compartment 9 being intermediate (Table 4.4). There was no effect of ambient temperature on the number of drinking bouts per pig. Pigs from sprinkled trailers performed fewer ($P < 0.001$) drinking bouts than those from non-sprinkled trailers (Table 4.4). As well, pigs from compartment 4 performed fewer drinking bouts per pig than all other compartments regardless of treatment ($P < 0.05$; Table 4.4).

### 4.4.3 Gastrointestinal Tract Temperatures

Least squares mean ($\pm$ SEM) baseline GTT for all pigs was $39.73 \pm 0.09^\circ$C. For all pigs regardless of treatment or compartment, there was an increase in GTT from loading to departure
(P < 0.001) and a reduction to below baseline by arrival at the plant (P < 0.001; Figure 4.3), but no further changes from arrival to slaughter. There was an interaction between compartment and pre-slaughter event, with pigs transported in compartment 4 experiencing a greater (P < 0.001) increase in GTT from baseline to departure compared to pigs in compartment 8, and tending to have a greater increase compared to pigs in compartments 5 and 9 (P = 0.07 for both; Figure 4.3). There were no compartment differences at any other pre-slaughter event (P > 0.10; Figure 4.3). At ambient temperatures above 24°C, there tended to be a greater (P = 0.08) decrease in GTT from baseline to arrival on sprinkled trailers than non-sprinkled trailers (Figure 4.4). As ambient temperature increased, there were greater decreases in GTT from baseline to slaughter regardless of treatment or compartment (P < 0.05).

4.5 Discussion

To our knowledge, this is one of the first studies to examine the effects of sprinkling pigs on trailers on micro-climate conditions, behaviour and GTT. It is one of a series of Canadian studies that have been examining extremes in temperature and humidity within trailers (Brown et al., 2011; Weschenfelder et al., 2012), and transport effects on GTT (Tamminga et al., 2009) and meat quality (Correa et al., 2009). Our results indicate that there are some beneficial effects of sprinkling pigs at temperatures exceeding 23°C in terms of GTT at arrival and drinking behaviour in lairage. The majority of differences in micro-climate conditions were the result of compartmental variation, and the potential negative effects of introducing water to the trailer in terms of humidity, ammonia and slips and falls during unloading were not observed in this study. During transport below 23°C, pigs were more active on sprinkled trailers, likely due to the novelty of the water introduced. In lairage, sprinkled pigs spent more time lying down and
showed fewer drinking bouts than non-sprinkled pigs. There was also a tendency toward greater reductions in GTT upon arrival at the plant.

Consistent with Brown et al. (2011) and Weschenfelder et al. (2012), trailer microclimate characteristics were most impacted by compartment location, with compartments 4 and 8 displaying smaller increases in air temperature than compartments 5 and 9. This is most likely the result of differences in air flow, since during transport air flows up and over the trailer and enters from the rear, moving towards the front, thereby allowing greater air flow in the rear compartments (i.e. 4 and 8; Kettlewell et al., 2001). As suggested by Brown et al. (2011), there may also be the confounding effect of the proximity of the engine to the front compartments (5 and 9), which generates heat that could have been transferred to the trailer environment, both during transport and during the wait time at the plant. There may have been another confounding effect of the distance of the data loggers from the level of the pigs as well as differences in compartment air volume. All data loggers were affixed directly to the ceiling of the compartments rather than suspended a consistent height from the floor. Compartment 8 had the highest ceiling (1.52 m), compartment 9 the lowest (0.99 m) and compartments 4 and 5 were intermediate (1.32 and 1.27 m, respectively). The low ceiling of compartment 9 allowed closer proximity to the pigs, likely resulting in greater impact of pig body heat and moisture on the temperature and humidity readings of the data loggers, as well as impeding air flow (Weschenfelder et al., 2012). Additionally, these differences in the ceiling heights resulted in different volumes of air in each compartment, where compartments 4 and 5 each had ~0.61 m$^3$ of air per pig, compartment 8 had 0.86 m$^3$ of air per pig (including the vacant air space created by the stowed ramp loading area), and compartment 9 had 0.47 m$^3$ of air per pig. These differences
in air volume could have resulted in a dilution factor for the changes in temperature, humidity and ammonia and therefore the smallest changes in compartment 8 and the largest ones in compartment 9 might be expected. Our findings for compartments 8 and 9 might support this, except for the fact that compartments 4 and 5, with similar heights and air volumes, often demonstrated different results. This may be related to the air flow differences between the compartments and the proximity of compartment 5 to the engine. Excluding compartment effects, changes in the trailer temperatures through loading, transport, arrival and unloading found in the non-sprinkled trailers in this study were similar to those reported in other recent studies (Ritter et al., 2008a; Lewis et al., 2010). The change in temperature was larger by departure, similar upon arrival and smaller by unloading for sprinkled versus non-sprinkled trailers. The sprinkled trailers also had smaller decreases in RH at departure and unloading, which is expected because these were the points where the water was introduced into the compartment. Although one might expect an increase in RH after pigs are loaded onto the trailer, the temperature at each event subsequent to loading was always higher, and as warmer air has a greater saturation vapor pressure and will hold more water, the result was a negative DRH value. After sprinkling immediately before unloading at the plant, air temperature in the sprinkled trailer was lower and RH was greater compared to the non-sprinkled trailer because pigs would be losing more latent vs. sensible heat after they had been wetted (Curtis, 1983). It is unclear why the air temperature in the sprinkled trailer was greater at departure than the non-sprinkled trailer. It is interesting to note as well that there were no compartmental differences in the change in RH until unloading, where compartment 4 had the greatest decreases compared to compartments 8 and 9, with 5 being intermediate. THI values were only different at departure
where sprinkled trailers had higher values, but values were not different between treatments upon arrival or unloading. If the results had followed the temperature results, we would have expected to see lower THI values at unloading, but it appears that the increased humidity is offsetting the reduction in temperature. Compartments 5 and 9 had generally higher THI values than compartments 4 and 8 at all events, which is consistent with the increased temperatures observed in those front compartments compared to the rear compartments. In this study, average THI only just exceeded the ‘Alert’ threshold of 23.9 at the time of departure in compartments 5 and 9 (Lucas et al., 2000; Haeussermann et al., 2007). There were some individual compartment repetitions that did exceed this threshold, but they were not specific to compartment location or treatment, rather they occurred during weeks with higher average ambient temperature. The sprinkling treatment did not affect ammonia levels, which is encouraging as the introduction of water may volatilize components of urine and feces, which would be a concern for pigs and handlers.

In the sprinkled trailer, the novelty of the sprinkling stimulates activity during transport at ambient temperatures below 23°C, resulting in pigs spending more time standing and less time lying throughout the duration of transport than in the non-sprinkled trailers. Previous research had demonstrated greater exploratory behaviour and general activity in pigs sprinkled in lairage pens (Weeding et al., 1993). However, as ambient temperature increases, the tendency for pigs to reduce activity (Blackshaw and Blackshaw, 1994; Brown-Brandl et al., 2001; Huynh et al., 2005a) may be overriding the effect of novelty, in this case by increasing sitting behaviour. Care needs to be taken when interpreting behaviour during transport in this study because the percentage of pigs visible by the camera was not consistent over time due to the angle and field
of the cameras. Compartments where less than 50% of the pigs were able to be classified throughout transport (either the posture was unclear or the pig was out of frame) were removed, which ultimately lead to excluding compartment 9 from the data analysis completely. In the literature, there are conflicting results as to what postures pigs primarily spend their time in during transport, some observing primarily lying (Lambooy, 1988; Bradshaw et al., 1996a) and others primarily standing (Barton Gade and Christensen, 1998). This is likely the result of the fact that behaviour during transport is affected by a variety of factors including stocking density (Barton Gade and Christensen, 1998), season (Torrey et al., 2009a, 2009b; Goumon et al., 2012), duration (Pérez et al., 2002) and the smooth or rough nature of the driving (Bradshaw et al., 1996a; Peeters et al., 2008). In this study the stocking density was held constant, the same drivers were used throughout the trials and the duration, season and the transport route were consistent. Therefore, we conclude that differences in behaviour between the trailers were due to the sprinkling treatment.

At unloading, there were no differences in the incidence of slips, falls, indicators of heat stress, or NANI pigs as a result of ambient temperature or treatment and there was only 1 pig that died during transport on one of the non-sprinkled trailers, though it is unknown if this was a result of heat stress. These parameters had not been examined in a previous assessment of effects of sprinkling at loading on pig physiology and meat quality (Colleu and Chevillon, 1999). One prediction that proved to be unfounded was that wetting the pigs and floors of the trailer would make floors and ramps slippery and increase rates of slipping and falling as pigs were unloaded, which would decrease welfare and increase the chance of failing welfare audits (Grandin, 2012). Unloading time was only affected by compartment, with compartment 8 taking the least time to
unload. This result is similar to that in Torrey et al. (2009a) and was expected because pigs from compartment 8 were located adjacent to the door and had little distance to walk compared to all other compartments.

Once the pigs were in lairage, ambient temperature had no effect on postures or drinking behaviours, but did decrease the latency to rest. The reduction in latency to rest is likely a result of the tendency for pigs to want to lie down under hotter ambient conditions (Fraqueza et al., 1998; Hicks et al., 1998; Brown-Brandl et al., 2001). Torrey et al. (2009b) found similar, though slightly longer, values for latency to rest in lairage after transportation under summer conditions. The sprinkling treatment did affect behaviour in lairage. The increase in time pigs from sprinkled trailers spent lying vs. sitting is likely related to the fact that pigs from non-sprinkled compartments performed more drinking bouts, which resulted in pigs spending more time active near the drinkers. It was also observed that pigs from compartment 8 spent less time lying than all other compartments, more time standing than pigs from compartment 4, while pigs from compartments 5 and 9 behaved similarly. This could have resulted from two potential confounding factors: drinker locations and group size differences. To standardize the number of drinkers available to the number of pigs in each group, there were 4 nipple drinkers in the lairage pens that held pigs from compartment 8 (2 on either side), whereas the other lairage pens only had 2 drinkers on one side of the pen, possibly resulting in an increase in overall activity by splitting up the drinker locations. To standardize the stocking density in the compartments, the group sizes were not identical, with groups from compartment 8 having the largest number of pigs (28), groups from compartment 5 the smallest number of pigs (16), and groups from compartments 4 and 9 being intermediate (21 and 20, respectively). Rabaste et al. (2007)
demonstrated that pigs in larger group sizes (30 vs. 10 pigs/group) and similar stocking densities spent more time standing and fighting. Drinking behaviour occurred less frequently in pigs from sprinkled trailers, but pigs from compartment 4 also showed the fewest drinking bouts per pig, regardless of treatment. It may be assumed that the overall effect of the sprinkling is reducing the drive to relieve heat stress through drinking water. The low numbers of drinking bouts by pigs in compartment 4, regardless of treatment, may be indicative of increased fatigue due to the movement up and down ramps during loading and unloading and this is also reflected in smaller percentages of time spent standing and reduced latency to rest, particularly compared to compartment 8, which required much less physical effort to load and unload.

GTT in all pigs was significantly affected by event. There was a positive change in temperature from baseline by the end of loading and departure from the farm followed by a negative change from baseline by arrival at the plant, regardless of treatment, and no significant changes from arrival to slaughter. Similar trends in GTT (Carr et al., 2008; Tamminga et al., 2009) and rectal temperatures (Yoshioka et al., 2004) have previously been observed for pigs transported during the summer. Due to the negligible impact of ambient temperature or treatment at loading and departure, this rise in temperature is likely the primary result of the exercise (D’Allaire and DeRoth, 1986) experienced by the pigs during loading. This is particularly evident in pigs from compartment 4 (top deck, rear), which experienced greater increases by departure than compartment 8 (middle deck, rear), as well as a similar trend when compared to compartments 5 and 9 (middle and bottom decks, front, respectively). This could be due to the fact that pigs in compartment 4 pigs had to go up a 30° ramp to the top deck, make a 180° turn, then go up a smaller 20° ramp to enter the rear compartment, requiring more exertion than pigs in
any other compartment. Pigs in compartments 5 and 9 experienced loading exercise more in terms of distance moved, though pigs in compartment 9 also had to go down a 20° ramp to enter the lower deck. Pigs in compartment 8, on the rear of the trailer, required the least movement to load, and this is reflected in the smallest GTT changes by the end of loading. Results from Warriss et al. (2006) showed similar increases in blood and skin temperatures for pigs transported in the front compartments (equivalent to compartments 5 and 9) versus the rear compartments (equivalent to compartment 8). It has also been suggested that there may be a fear response associated with negotiating ramps and unfamiliar flooring on trailers, which may impact the overall stress response to loading, leading to increases in body temperature (Lambooij, 2000). The response to multiple stressors, whether related to heat, distance moved, floor space, social mixing or handling, has been shown to be additive (Huyn et al., 2005; Ritter et al., 2009a), and so the increased GTT at loading for pigs in compartment 4 could be the result of the exercise of loading, negotiating the ramps and increased handling required (Tamminga et al., 2009; Torrey et al., 2009a). Although there were no significant differences in GTT at loading or departure between treatments, it is interesting to observe that at high temperatures (> 25°C) when pigs are at a significantly greater risk of mortality during transport (Haley et al., 2008a; Sutherland et al., 2009), the sprinkling treatment showed a trend towards greater reductions in GTT by arrival at the plant. This could indicate that the sprinkled pigs are likely experiencing greater evaporative heat loss capacity when the trailer is in motion and air flow is maintained. The results were extrapolated from a heterogeneous slopes model generated from the ANCOVA, and so it may have given stronger results if there had been more than the 3 repetitions at temperatures above 25°C. Sprinkling could then enable greater control of core body temperature
under hotter ambient conditions where temperature control becomes more critical and physiological heat dissipation means, such as panting and peripheral vasodilation, become less effective (Marple et al., 1974; Robertshaw, 1985).

4.6 Conclusions

Water sprinkling in stationary trailers before departure from the farm and before unloading at the abattoir can help to alleviate some of the stress indicators associated with transport at high ambient temperatures (>23°C) in terms of GTT upon arrival at the plant and drinking behaviour in lairage, without detrimental effects on unloading procedures. Due to the practical limitations of installation and maintenance of sprinkler systems in trailers, further research should be done to examine the efficacy of sprinkling stationary trailers from the exterior, perhaps in combination with forced ventilation to improve air flow and evaporative cooling in compartments that experience greater increases in temperature and relative humidity or impose greater stress on the pigs during loading and unloading.
Table 4.1 Ethogram of pig behaviour recorded at unloading.

<table>
<thead>
<tr>
<th>Pig Behaviour</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slip</td>
<td>Pig’s leg splits away from the other legs</td>
</tr>
<tr>
<td>Fall</td>
<td>At least 2 legs buckle under</td>
</tr>
<tr>
<td>Overlap</td>
<td>Pig mounts the back of another pig with its two front legs</td>
</tr>
<tr>
<td>Open-Mouth Breathing</td>
<td>Pig panting with mouth open, labored breathing</td>
</tr>
<tr>
<td>Splotchy Skin</td>
<td>Red patches on any area of the body</td>
</tr>
<tr>
<td>Non-Ambulatory, Non-Injured</td>
<td>Any pig unable to rise on trailer or on receiving dock but otherwise uninjured</td>
</tr>
</tbody>
</table>
Table 4.2 Least squares means (± SEM) of trailer temperature (T, °C), change in temperature (DT, °C), relative humidity (RH, %), change in relative humidity (DRH, %), temperature-humidity index (THI), and change in temperature-humidity index (DTHI) by treatment at each event (loading, departure, arrival and unloading). (n = 12 replicates)

<table>
<thead>
<tr>
<th>Parameter¹</th>
<th>Event</th>
<th>Loading</th>
<th>Departure</th>
<th>Arrival</th>
<th>Unloading</th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td>Sprinkled</td>
<td>17.0</td>
<td>24.6</td>
<td>24.1</td>
<td>24.9</td>
</tr>
<tr>
<td></td>
<td>Non-Sprinkled</td>
<td>16.8</td>
<td>23.5</td>
<td>24.0</td>
<td>25.6</td>
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<tr>
<td></td>
<td>SEM</td>
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<td>0.78</td>
<td>1.15</td>
<td>1.31</td>
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<tr>
<td></td>
<td>P-value</td>
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<td>&lt;0.001</td>
<td>0.63</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>AmbT Covariate P-value</td>
<td>0.001</td>
<td>0.0002</td>
<td>&lt;0.001</td>
<td>0.001</td>
</tr>
<tr>
<td>DT</td>
<td>Sprinkled</td>
<td>-</td>
<td>7.56</td>
<td>7.11</td>
<td>7.90</td>
</tr>
<tr>
<td></td>
<td>Non-Sprinkled</td>
<td>-</td>
<td>6.62</td>
<td>7.20</td>
<td>8.73</td>
</tr>
<tr>
<td></td>
<td>SEM</td>
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<td>0.82</td>
<td>1.12</td>
<td>1.32</td>
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<tr>
<td></td>
<td>P-value</td>
<td>-</td>
<td>0.0001</td>
<td>0.63</td>
<td>0.002</td>
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<tr>
<td>RH</td>
<td>Sprinkled</td>
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<td>65.9</td>
<td>69.3</td>
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<td>SEM</td>
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<td>4.3</td>
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<td>P-value</td>
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<td>AmbT Covariate P-value</td>
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<td>0.17</td>
<td>0.39</td>
<td>0.25</td>
</tr>
<tr>
<td>DRH</td>
<td>Sprinkled</td>
<td>-</td>
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<td>-24.88</td>
<td>-21.45</td>
</tr>
<tr>
<td></td>
<td>Non-Sprinkled</td>
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<td>-24.58</td>
<td>-27.89</td>
</tr>
<tr>
<td></td>
<td>SEM</td>
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<td>4.02</td>
</tr>
<tr>
<td></td>
<td>P-value</td>
<td>-</td>
<td>&lt;0.001</td>
<td>0.68</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>THI</td>
<td>Sprinkled</td>
<td>-</td>
<td>23.8</td>
<td>22.1</td>
<td>22.9</td>
</tr>
<tr>
<td></td>
<td>Non-Sprinkled</td>
<td>-</td>
<td>22.4</td>
<td>22.0</td>
<td>23.0</td>
</tr>
<tr>
<td></td>
<td>SEM</td>
<td>-</td>
<td>0.70</td>
<td>0.88</td>
<td>0.99</td>
</tr>
<tr>
<td></td>
<td>P-value</td>
<td>-</td>
<td>&lt;0.001</td>
<td>0.24</td>
<td>0.58</td>
</tr>
<tr>
<td></td>
<td>AmbT Covariate P-value</td>
<td>-</td>
<td>0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>DTHI</td>
<td>Sprinkled</td>
<td>-</td>
<td>-</td>
<td>-1.62</td>
<td>-0.83</td>
</tr>
<tr>
<td></td>
<td>Non-Sprinkled</td>
<td>-</td>
<td>-</td>
<td>-0.38</td>
<td>0.62</td>
</tr>
<tr>
<td></td>
<td>SEM</td>
<td>-</td>
<td>-</td>
<td>0.49</td>
<td>0.60</td>
</tr>
<tr>
<td></td>
<td>P-value</td>
<td>-</td>
<td>-</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

¹DT and DRH were calculated as the change from loading and DTHI was calculated as change from departure to each subsequent event
### Table 4.3 Least squares means (± SEM) of trailer temperature (T, °C), change in temperature (DT, °C), relative humidity (RH, %), change in relative humidity (DRH, %), temperature-humidity index (THI), and change in temperature-humidity index (DTHI) by compartment at each event (loading, departure, arrival and unloading). (n = 24 replicates)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Compartment</th>
<th>4</th>
<th>5</th>
<th>8</th>
<th>9</th>
<th>SEM</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td>Loading</td>
<td>16.8</td>
<td>16.9</td>
<td>16.9</td>
<td>17.1</td>
<td>1.17</td>
<td>0.58</td>
</tr>
<tr>
<td></td>
<td>Departure</td>
<td>22.9&lt;sup&gt;a&lt;/sup&gt;</td>
<td>25.1&lt;sup&gt;b&lt;/sup&gt;</td>
<td>22.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>25.3&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.80&lt;sup&gt;&lt;/a&gt;&lt;/sup&gt;</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>Arrival</td>
<td>23.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>24.8&lt;sup&gt;b&lt;/sup&gt;</td>
<td>23.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>25.3&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.16</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>Unloading</td>
<td>24.8&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>26.2&lt;sup&gt;c&lt;/sup&gt;</td>
<td>24.1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>25.7&lt;sup&gt;b,c&lt;/sup&gt;</td>
<td>1.33</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>DT</td>
<td>Departure</td>
<td>6.10&lt;sup&gt;a&lt;/sup&gt;</td>
<td>8.25&lt;sup&gt;b&lt;/sup&gt;</td>
<td>5.77&lt;sup&gt;a&lt;/sup&gt;</td>
<td>8.22&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.83</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>Arrival</td>
<td>6.17&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.95&lt;sup&gt;b&lt;/sup&gt;</td>
<td>6.34&lt;sup&gt;a&lt;/sup&gt;</td>
<td>8.16&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.13</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>Unloading</td>
<td>8.02&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>9.39&lt;sup&gt;c&lt;/sup&gt;</td>
<td>7.22&lt;sup&gt;a&lt;/sup&gt;</td>
<td>8.62&lt;sup&gt;b,c&lt;/sup&gt;</td>
<td>1.33</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>RH</td>
<td>Loading</td>
<td>90.8</td>
<td>89.7</td>
<td>90.0</td>
<td>90.3</td>
<td>2.20</td>
<td>0.32</td>
</tr>
<tr>
<td></td>
<td>Departure</td>
<td>83.1</td>
<td>81.9</td>
<td>83.9</td>
<td>83.8</td>
<td>2.60</td>
<td>0.23</td>
</tr>
<tr>
<td></td>
<td>Arrival</td>
<td>66.2</td>
<td>65.0</td>
<td>65.9</td>
<td>64.9</td>
<td>4.00</td>
<td>0.38</td>
</tr>
<tr>
<td></td>
<td>Unloading</td>
<td>63.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>64.1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>66.7&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>68.3&lt;sup&gt;b&lt;/sup&gt;</td>
<td>4.40</td>
<td>0.002</td>
</tr>
<tr>
<td>DRH</td>
<td>Departure</td>
<td>-7.76</td>
<td>-7.83</td>
<td>-6.09</td>
<td>-6.50</td>
<td>1.31</td>
<td>0.27</td>
</tr>
<tr>
<td></td>
<td>Arrival</td>
<td>-24.67</td>
<td>-24.70</td>
<td>-24.11</td>
<td>-25.45</td>
<td>3.80</td>
<td>0.64</td>
</tr>
<tr>
<td></td>
<td>Unloading</td>
<td>-27.69&lt;sup&gt;b&lt;/sup&gt;</td>
<td>-25.59&lt;sup&gt;b&lt;/sup&gt;</td>
<td>-23.38&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-22.02&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.09</td>
<td>0.002</td>
</tr>
<tr>
<td>THI</td>
<td>Departure</td>
<td>22.1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>24.0&lt;sup&gt;b&lt;/sup&gt;</td>
<td>21.9&lt;sup&gt;a&lt;/sup&gt;</td>
<td>24.4&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.72</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>Arrival</td>
<td>21.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>22.7&lt;sup&gt;b&lt;/sup&gt;</td>
<td>21.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>23.1&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.88</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>Unloading</td>
<td>22.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>23.8&lt;sup&gt;b&lt;/sup&gt;</td>
<td>22.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>23.7&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.00</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>DTHI</td>
<td>Arrival</td>
<td>-0.92&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>-1.31&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-0.48&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-1.29&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.51</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>Unloading</td>
<td>0.27&lt;sup&gt;b&lt;/sup&gt;</td>
<td>-0.26&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>0.26&lt;sup&gt;b&lt;/sup&gt;</td>
<td>-0.69&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.62</td>
<td>0.005</td>
</tr>
</tbody>
</table>

<sup>a,b</sup> Within a row, least squares means lacking a common superscript differ at P < 0.05

<sup>1</sup>DT and DRH were calculated as the change from loading and DTHI was calculated as change from departure to each subsequent event.
Table 4.4 Least squares means (± SEM) of unloading time and behaviour of pigs during lairage by sprinkling treatment and compartment. Values for n differ for compartment 8 due to technical issues during one repetition.

<table>
<thead>
<tr>
<th>Pig Behaviour</th>
<th>Treatment</th>
<th>Compartment Group</th>
<th>SEM</th>
<th>P-Value</th>
<th>4</th>
<th>5</th>
<th>8</th>
<th>9</th>
<th>SEM</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sprinkled</td>
<td>Sprinkled</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(n=12)</td>
<td>(n=12)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unloading Time (s/pig)</td>
<td>2.37</td>
<td>2.43</td>
<td>0.16</td>
<td>0.72</td>
<td>2.36&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.79&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.62&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.85&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.20</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Standing (%)</td>
<td>21.1</td>
<td>22.3</td>
<td>1.5</td>
<td>0.40</td>
<td>17.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>19.4&lt;sup&gt;b&lt;/sup&gt;</td>
<td>26.6&lt;sup&gt;c&lt;/sup&gt;</td>
<td>23.6&lt;sup&gt;abc&lt;/sup&gt;</td>
<td>1.8</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Sitting (%)</td>
<td>7.8</td>
<td>10.5</td>
<td>0.5</td>
<td>&lt;0.0001</td>
<td>9.4</td>
<td>8.0</td>
<td>9.8</td>
<td>9.3</td>
<td>0.7</td>
<td>0.14</td>
</tr>
<tr>
<td>Lying (%)</td>
<td>60.3</td>
<td>56.4</td>
<td>2.0</td>
<td>0.03</td>
<td>65.0&lt;sup&gt;b&lt;/sup&gt;</td>
<td>64.1&lt;sup&gt;b&lt;/sup&gt;</td>
<td>45.5&lt;sup&gt;a&lt;/sup&gt;</td>
<td>58.8&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.4</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Latency to rest (min)</td>
<td>31.61</td>
<td>35.34</td>
<td>2.75</td>
<td>0.20</td>
<td>26.33&lt;sup&gt;a&lt;/sup&gt;</td>
<td>29.25&lt;sup&gt;a&lt;/sup&gt;</td>
<td>42.32&lt;sup&gt;b&lt;/sup&gt;</td>
<td>36.00&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>3.50</td>
<td>0.001</td>
</tr>
<tr>
<td>Drinking bouts (total per pig)</td>
<td>5.01</td>
<td>7.42</td>
<td>0.86</td>
<td>0.0001</td>
<td>3.58&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.11&lt;sup&gt;b&lt;/sup&gt;</td>
<td>8.13&lt;sup&gt;b&lt;/sup&gt;</td>
<td>6.06&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.97</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

<sup>a,b</sup> Within a row, least squares means lacking a common superscript differ at $P < 0.05$
Figure 4.1 Pot-belly trailer compartment designations (1-10); circled numbers indicate test compartments selected for micro-climate data collection (temperature (°C), relative humidity (RH; %), ammonia (ppm)) and behavioural observations during transport (still photos); 4 test pigs were randomly assigned in each of the 4 test compartments for gastrointestinal tract temperature (°C) data collection.
Figure 4.2 ANCOVA heterogeneous slopes model of the interaction of ambient temperature (°C) and sprinkling treatment on percentage of time (LSMEANS; % ± SEM) pigs spent standing during transport (* P < 0.05).
Figure 4.3 Changes in gastrointestinal temperature (LSMEANS DGTT; °C ± SEM) from baseline (500 h the day of transport) by event (loading, departure, arrival, unloading and slaughter) and by compartment group location (* $P < 0.001$; $^{a,b} P < 0.001$).
Figure 4.4 ANCOVA heterogeneous slopes model of the interaction of ambient temperature (°C) and sprinkling treatment on change in gastrointestinal tract temperature (LSMEANS DGTT ± SEM; °C) upon arrival at the slaughter plant (* P = 0.08).
CHAPTER 5: GENERAL DISCUSSION

This study represents the one of the first in-depth examinations of the use of water sprinkling methods to cool pigs on trailers and the impact on behavioural and physiological changes in the pig as well as the effect on the trailer micro-climate. Studies like these are increasingly important in order to improve well-being of pigs through one of the most stressful experiences of their lives.

In terms of micro-climate, it was expected that by introducing water into the trailer, there would be effects on the temperature and relative humidity within each of the compartments, but whether these effects were positive, negative or neutral needed to be assessed. Some concern was raised that introducing water into the warm trailer environment might create a ‘steam bath’ effect. Within the limits of a 5 min sprinkling session (125 L), this concern was shown to be unfounded and differences in trailer micro-climate were more affected by compartment location rather than by sprinkling treatment, where compartments to the front of the trailer were warmer in general than the rear compartments, regardless of treatment. This result is consistent with other studies and appears to be related to air flow differences between the compartments (Brown et al., 2011; Weschenfelder et al., 2012). For some unknown reason, trailer temperature was higher in sprinkled trailers by departure from the farm, though it does not seem to correlate with any observable difference in activity as all pigs were standing at departure regardless of treatment. It would have been expected that the temperature be lower in the sprinkled trailers at both departure and unloading, since the sprinkling treatment immediately prior to this event should have diverted heat loss to latent forms and minimized the overall increase in temperature due to pig body heat. Relative humidity always decreased from loading to each subsequent event.
as the temperature increased, though changes were smaller in sprinkled trailers at departure and unloading due to the introduction of water. The resultant average THI values only just exceeded the ‘Alert’ threshold of 23.9 (Lucas et al., 2000; Haeussermann et al., 2007) at departure for compartments 5 and 9, but average THI was not exceeded in any compartment by arrival or unloading. As well, the sprinkling treatment did not impact THI upon arrival or unloading. If this study had been conducted when environmental temperatures were higher, perhaps a reduction in THI to a lower level on average than the non-sprinkled trailers may have been observed. Overall, sprinkling appears to have mostly neutral effects on the trailer micro-climate.

Assessing behaviour during transport was necessary to observe whether there were any effects of sprinkling on activity level that might translate to changes in welfare. The results suggest that at lower ambient temperatures (< 23°C), sprinkling increases the activity of the pigs, but as ambient temperature increases beyond 23°C, there is little difference in activity between sprinkled and non-sprinkled pigs. This is likely due to the tendency for pigs to reduce activity as temperature increases (Brown-Brandl et al., 2001; Huynh et al., 2005a). Since there is conflicting data in the literature regarding what pigs primarily spend their time doing during transport, it can only be assumed that since the transport conditions were the same for each trailer besides the sprinkling treatment in this study, the differences in behaviour are the result of the treatment interaction with ambient temperature. Using still cameras to capture behaviour was also sometimes unreliable due to the ceiling heights and the angle of the cameras precluding images for some areas of the compartment. All data from compartment 9 and some from the other compartments were excluded from the data analysis since less than 50% of pigs were visible. Of the compartments left for the analysis, ~64% of pigs were able to be classified. Perhaps a
redundant double camera system, with views from alternate angles might have been more effective in capturing all the pigs in the compartment, though due to limitations of gate movement, this may not have been possible. Regardless, compartment 9 will continue to be a challenge due to the low ceiling height and it may be such that capturing behaviour in this compartment will remain unreliable. In general, sprinkling at higher temperatures where cooling methods would be more important (> 23°C) appears to have little effect on behaviour during transport.

At unloading, the initial concern was that the introduction of water into the trailer would increase the incidence of slips and falls at unloading, besides the potential for volatizing components of urine and feces, creating a poor environment for the pigs and the handlers. The results of this study show that these concerns were unfounded. In fact, there was no difference between the two trailers in the incidence of slips and falls, which was likely related to the fact that the duration of sprinkling was determined as enough time to wet the backs of the pigs, which resulted in little runoff water. As well, there were no differences in ammonia levels between treatments, and no levels exceeded safe exposure limits of 25 ppm (Ontario Ministry of Labour, 2010). There were no differences in the incidences of heat stress indicators (open-mouth breathing, splotchy skin, NANI or dead-on-arrival pigs), which is probably more related to the fact that pigs were transported mid-morning rather than the hottest parts of the day. Due to limitations at the packing plant, pigs had to be received before noon in order to ensure same-day slaughter. If the pigs had been loaded, transported and received in the warmer parts of the day, the hypothesis would be that we would see beneficial impacts of sprinkling on these parameters, but as such the treatment was neutral.
Observation of lairage behaviours was important to see if sprinkling altered any thermoregulatory behaviour post-transport. In lairage, activity and drinking bouts appear to be linked, as the non-sprinkled pigs spent more time active, but also were performing more drinking bouts on average than the sprinkled pigs. This suggests that non-sprinkled pigs were seeking water, but since pigs were not identified individually, it could be skewed if a few individuals were performing more than the average number of bouts. It was not possible to quantify volume of water ingested, so visual assessment is only the best estimate of water intake. Despite this, the positive impact of reduction in bouts on the average for the whole group when sprinkled is visible. Latency to rest was only affected by ambient temperature, where pigs lay down sooner as temperature increased. This is expected since as temperature increases, pigs tend to reduce activity in order to reduce heat production (Curtis, 1983; Brown-Brandl et al., 2001; Huynh et al., 2005a). It is interesting to note as well that the pigs from compartment 4 had the highest GTT values, but displayed the fewest drinking bouts regardless of treatment. This is likely due to fatigue related to ramp navigation; it required the most physical effort for the pigs that were loaded and unloaded into compartment 4 compared to the other compartments and this fatigue may be overriding any water-seeking behaviour. The effect of the sprinkling appears to be beneficial in reducing water intake for pigs from compartments that do not experience excessive exercise stress, but appears to have little effect for pigs required to navigate steep ramps.

Core body temperature data are critical to assess as changes in this temperature reflect how well the pig is maintaining homeostasis. Gastrointestinal tract temperature is a more reliable measure of true core body temperature than skin or rectal temperatures (Hannemann et al., 2004). In general, with a 75% recovery rate, the iButton method of collecting GTT data worked
well and was similar to other recent studies (Tamminga et al., 2009; Weschenfelder et al., 2012), even though the process is labour intensive in terms of administration and identification of pigs and viscera, as well as dissection and recovery of the iButtons post-slaughter. There was little significant effect of sprinkling on GTT, though there was a tendency for GTT to be reduced by arrival at the slaughter plant in sprinkled pigs compared to non-sprinkled pigs at ambient temperatures > 25°C. Again, similar to effects on the other parameters measured, if pigs had been transported in the warmer parts of the day, more positive impacts of sprinkling on GTT may have been observed under conditions when cooling would have been more critical. GTT was most impacted by event and compartment location, where pigs in compartment 4 had the greatest increases in GTT by departure, which considering the negligible impact of ambient temperature and treatment, seems to indicate that this increase was primarily the result of exercise as discussed previously (D’Allaire and DeRoth, 1986). It is interesting to note that there was no difference in GTT through lairage. Some change might have been expected through lairage since pigs were sprinkled immediately prior to unloading, though perhaps this difference was negated by the increase in drinking bouts in non-sprinkled pigs. Though we were unable to isolate the water intake of the iButton pigs in the group, it is possible that the water ingestion cooled the data logger itself and confounded the result of the GTT in lairage. The reductions in GTT by arrival indicate that the sprinkling treatment is allowing greater control of core body temperature through the increase in evaporative cooling capacity.

In general, sprinkling pigs prior to departure from the farm has some beneficial effects for the pigs in terms of GTT at arrival and reduction in drinking bouts. Further analysis under higher ambient temperatures is necessary to ensure the efficacy under conditions where cooling
methods would be most valuable to improve pig well-being. As well, since this procedure required installation of the sprinkler system onto the trailer, and it was not designed to be left on the trailer for extended periods of time, it would be recommended to design a method that would be more practical for all types of trailer. The use of forced ventilation systems with paired sprinklers on the exterior of the trailer at the packing plant may be an acceptable compromise and should be examined further.
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