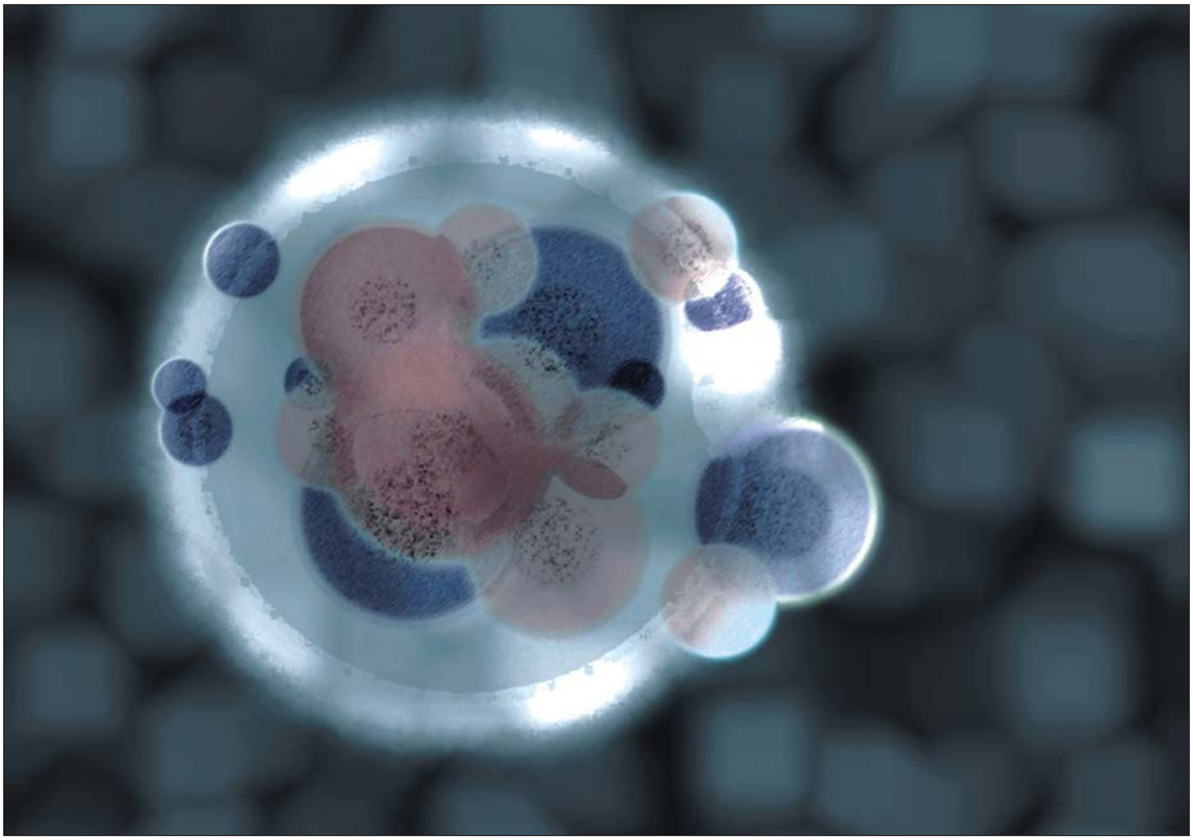

Journal of Biological Sciences

ISSN 1727-3048

Journal of Biological Sciences 7 (7): 1112-1120, 2007
ISSN 1727-3048

Effects of Additional Space During Transport on Pre-slaughter Traits of Pigs

[1]M. Becerril-Herrera, [2]D. Mota-Rojas, [3]I. Guerrero-Legarreta, [2]M. González-Lozano, [2]P. Sánchez-Aparicio, [4]C. Lemus-Flores, [5]S.C. Flores-Peinado, [2]R. Ramírez-Necoechea and [2]M. Alonso-Spilsbury
[1]Doctorate Program in Biological Sciences at the Universidad Autónoma, Metropolitana Iztapalapa-Xochimilco, Mexico
[2]Laboratorio de Etología, Producción Porcina y Fauna Silvestre, Área Ecodesarrollo de la Producción Animal, Departamento de Producción Agrícola y Animal, Universidad Autónoma Metropolitana-Xochimilco
[3]Laboratorio Bioquímica de Macromoléculas, Departamento de Biotecnología, Universidad Autónoma Metropolitana-Iztapalapa
[4]Facultad de Medicina Veterinaria y Zootecnia, Universidad Autónoma de Nayarit (UAN)
[5]Taller de Carnes. Facultad de Estudios Superiores de Cuautitlán (FESC), UNAM

Abstract: The objectives of the present study were to evaluate the effects of increasing space in transportation at different distances, on live weight loss in pigs and to determine the effects of fasting and pre-slaughter lairage period on both live and carcass weights by sex and on pork quality. Seven hundred and twenty pigs Pietrain x (YorkshirexLandrace) were divided into two experimental conditions (EC_1 and EC_2). EC_1 pigs were divided in three groups of 120 animals each and were transported for 8, 16 and 24 h (loading density: 0.35 m^2/100 kg). EC_2 pigs were divided in three groups of 120 animals, the transport duration was the same as in EC_1 (loading density: 0.68 m^2/100 kg). Transport duration and space allowance significantly affected ($p<0.01$) the posture of the pigs on arrival to the slaughterhouse; there were significant differences ($p<0.01$) between genders. When transport time was shorter, a higher number of pigs arrived in a standing posture, more females arrived in a standing position in the group shipped for 8 h. Pig position affected carcass yield, when transportation time was shorter carcass yield was higher. There was a higher percentage ($p<0.01$) of pigs at pH 5.8-6.2 in animals transported for 8 h, compared with 16 and 24 h period, independently of the space allowance. Additional space provided to pigs during transportation lead to a better animal welfare in transit and had no decisive influence in the quality of the carcass; nevertheless, the quality of meat improved.

Key words: Pig, transport, slaughter, pork quality, pH, *Longissimus dorsi*

INTRODUCTION

The minimum conditions for pig transportation vary from one country to another, expecting deficiencies during and after transportation, according to time of fasting, loading and unloading methods used, stocking density, transport duration and weather conditions among others (Nanni-Costa *et al.*, 1999; Mota *et al.*, 2006; Warriss *et al.*, 2006).

It is well known that physiological responses of pigs as a consequence of transportation result in physiological stress and/or physical fatigue. Injuries produced during the journey or at lairage affect some carcass traits, as temperature and pH leading to alterations in both, carcass yield and shelf-life (Schaefer *et al.*, 1997; Gallo *et al.*, 2001, 2003; Mota *et al.*, 2000, 2004).

Without any doubt, transportation is one of the most important stages in pigs handling before slaughter, since it influences meat quality and quantity; poor handling causes economic losses to farmers, transporters and slaughter plants (Gallo *et al.*, 2001). Animal commingling, contact with strangers, speed variations, vibrations, space, establishment of new hierarchies, humidity and high temperatures, noises and strange scents are stress factors affecting welfare of transported animals (Grandin, 1994; Martoccia *et al.*, 1995; Grandin, 1997; Tadich *et al.*, 2000; Gallo *et al.*, 2001; Grandin, 2003). The intensity of these negative factors and transport duration affect the welfare of transported pigs (Wajda and Denaburski, 2003).

Several strategies have been developed to reduce stress during transportation, some of them are to avoid mixing pigs from unknown farms and to unload animals in

Corresponding Author: D. Mota-Rojas, Department of Animal Production and Agriculture, Universidad Autónoma Metropolitana-Xochimilco, Calzada del Hueso 1100. Col. Villa Quietud. Del. Coyoacán. 04960. México D.F. Mexico

the slaughterhouse using appropriate equipment and hydraulic platforms. The stocking density during transportation to the slaughter plants plays an important roll in increasing stress levels, high density (0.4 m^2/100 kg) increases fighting among pigs leading to a major incidence of lesions and skin bruises (Nanni-Costa *et al.*, 1999). It has been shown that with a density of 0.50 m^2/100 kg, pigs can not control their body balance on curved roads and usually animals have to change posture (Barton and Christensen, 1998). Appropriate stocking densities may vary depending on the distance traveled and the temperature, therefore it is necessary to differentiate between short and long journeys (Grandin, 2003).

Currently, information regarding the effects of stocking density, on pigs' welfare and meat quality for short and long commercial journeys in Mexico is scarce (Mota *et al.*, 2006). This information is essential for Mexican policy makers in order to change the transport norm in favor of a good welfare of animals in transit. The objectives of the present study were to study the effects of space increase during pig transportation by several distances, on live weight loss and to study the effects of fasting and pre-slaughter lairage period in live and carcass weight as well as on meat quality (pH, color and temperature).

MATERIALS AND METHODS

Animals: The study was carried out in a municipal slaughterhouse in Hidalgo state during August 2006. A total of 720 pigs (360 barrows and 360 females) Pietrain x (YorkshirexLandrace) were studied. Animals were brought from 3 States of the Mexican Republic. Transportation was done by six similar cattle trailers, with straw bedding, according to the animal care regulations in Mexico (Official Mexican Regulation, NOM-024-Z00, 1995). Pigs were transported without stops and were not fed, nor provided with water.

Treatments: Animals were divided in two experimental conditions (EC_1 and EC_2).

Experimental condition 1 (EC_1): Animals were transported in three groups of 120 pigs each for: 8, 16 and 24 h and were randomly distributed by sex, as shown in Table 1. Pigs from the three groups were loaded using a space allowance of 0.35 m^2/100 kg during transportation.

Experimental condition 2 (EC_2): Animals were transported in three groups of 120 pigs each for: 8, 16 and 24 h and were randomly distributed by sex, as shown in Table 2. Pigs from the three groups were loaded using a space allowance of 0.68 m^2/100 kg during transportation.

Table 1: Pigs from the three groups (control) loaded using a space allowance of 0.35 m^2/100 kg during transportation

	Groups					
	G_1 8*		G_2 16*		G_3 24*	
Treatments	1M	1H	2M	2H	3M	3H
Sex	Male	Female	Male	Female	Male	Female
No. of animals per group	60	60	60	60	60	60
Total No. of animals	120		120		120	

*Traveling time (h)

Table 2: Pigs from the three groups (experimental) loaded using a space allowance of 0.68 m2/100 kg during transportation

	Groups					
	G_1 8*		G_2 16*		G_3 24*	
Treatments	4M	4H	5M	5H	6M	6H
Sex	Macho	Hembra	Macho	Hembra	Macho	Hembra
No. of animals per group	60	60	60	60	60	60
Total No. of animals	120		120		120	

*Traveling time (h)

Experimental design: Table 1 and 2 show the experimental design applied to these studies.

Transportation for both experimental conditions were carried out in different days during August; departure time from the farm for the six groups was 12:00 pm to avoid the confusion of the effect of daylight and the time of transportation, according to the criteria of Gallo *et al.* (2003). Arrival at the abattoir for the EC_1 was for Group G_1, 8:31 h; for Group G_2 at 15:50 h and for Group G_3, 23:35 h. In the CE_2, for Group G_4, 7:42 h; for Group G_5, 16:21 h, whereas for Group G_6, 24:28 h. Distances traveled were 512, 985 and 1,392 km for groups transported during 8, 16 and 24 h, respectively.

Abbatoir: After arrival at the slaughter plant, the position of the pigs in the trailer was identified, recording their posture: standing, sitting and lying. Hyperventilation occurrence was recorded if respiratory frequency was above 50 breaths per min

To know the extent of weight losses during transport, pigs were weighed in groups before departure from the farm and also on arrival at the slaughter plant. Immediately after unloading, animals were weighed individually weighed. After 8 h of lairage in pre-slaughter pens, pigs were again individually weighed using a digital Elec-Weighing scale FTW-150K 150×0.05 kg. Carcass weight was obtained using a Roman scale for 300 kg. Weights were then included in calculation of weight loss during transport and in pre-slaughter pens. A detailed evaluation of body condition was also performed, recording the presence of bruises, erythema and tremor in hind limbs, recording the degree of lesions and number of times they were presented. Bruises were classified as follows: bruise 1 (b1) affects skin and subcutaneous tissue; bruise 2 (b2) affects subcutaneous and muscular tissues and bruise 3 (b3) affects subcutaneous, muscular and bone tissue, according to the criteria used by Gallo *et al.* (2001). Erythema was identified as localized (LE1) by well-defined hyperemic borders in loin and peri-anal regions. A generalized erythema (GE 2) was considered when an 80% or greater area of the body surface of the pig showed hyperemia and congestion.

Rectal temperature at arrival: Rectal temperature was measured with a digital rectal thermometer immediately after disembarking; each of the transported pigs was marked with a marker on the cervical region in order to identify them before slaughter. Pigs were divided in groups of 60 animals per pre-slaughter pen, 10×6 length and with 60 m^2 surface, providing 1 m^2 per pig.

Rest period: Lairage time for the 3 groups was of 8 h; during this period animals were supplied with water *ad libitum*.

Fasting: Periods of fasting for the 3 groups corresponded to the transportation period plus 8 h of lairage period: 16, 24 and 32 h for Group 1, 2 and 3, respectively. Animals were taken to the slaughter box according to their identification number and the slaughter procedure was followed with the aim of not losing their identification. Pigs were slaughtered following the commercial practice in municipal abattoirs in Mexico (NOM-033-ZOO, 1995).

Carcass pH and temperature determination (45 min): Carcass pH is an indicator of carcass quality (Guise *et al.*, 1998), after slaughter it has a particular influence in sensorial quality characteristics and in meat processing attributes (Velasco, 2001), if pH decrease is accelerated and is associated with an excess of body temperature (> 40°C), the result is PSE meat (Bonelli and Schifferli, 2001). Final pH value for PSE muscles is very close to normal, therefore, pH measurement was carried out 45 min after slaughter and not at the resolution of the *Rigor mortis* process (Velasco, 2001). Carcasses were identified in slaughter sequence for temperature sampling (TC_{45}) and pH at 45 min post-mortem (pH_{45}). Both measurements were taken in *Longissimus dorsi* (central area of the loin) following a similar procedure and sample sites by McPhee and Trout (1995) and Brown *et al.* (1999), on the right carcass half, between 10 and 11th ribs. For pH_{45} measurements a potentiometer (Penetration pH electrode, HI8314, membrane pH meter. 115V/60Hz. Cod. 1.1176) was used. Carcass temperature was measured with a digital thermometer. In order to study the effect of transport time on pork acidity, carcasses were separated in three ranges: pH_{45} lower than 5.7 (meat with a likelihood of occurrence of PSE); pH_{45} from 5.8 to 6.2 (normal pH range) and pH_{45} higher than 6.3 (meat with a likelihood of occurrence of DFD).

Color measurement: Subjective color evaluation was done on *L. dorsi* surface immediately after pH and temperature measurements (Gallo *et al.*, 2001). Meat was subjectively classified according to color, using a standard scale according to the NPPC (1991), therefore five colors were distinguished: pale (1), slightly pink (2), greyish rose (3), light red (4) and dark red (5).

Statistical analysis: In order to measure trauma variables b1, b2 and b3, LE1 and GER, as well as position at arrival (standing, sitting and in sternum recumbency), tremor of the hind limbs and hyperventilation, Chi square test (χ^2) was used. Carcass yield, temperature, color, pH and rectal temperature were analyzed with Kruskal-Wallis test and significant differences were determined using orthogonal contrasts.

Results obtained for the following traits: live-weight at arrival, pre-slaughter live-weight, live-weight during lairage and hot carcass weight were analyzed using a completely randomized design including a factorial 2^2 arrangement which model was as follows:

$$Y_{ijk} = \mu + A_i + B_j + (AB)_{ij} + Eijk$$
$$I = 1,2,3$$
$$j = 1,2$$

Where:

Yijk	=	Response variable (animal weights, carcass yield, etc.)
μ	=	General mean
Ai	=	Effect of the factor A at level I (transport duration)
Bj	=	Effect of the factor B at level j (sex)
(AB)ij	=	Effect of interaction AB at level ij
Eijk	=	Random error on the k repetition, level j of B and level I from A

In order to find the differences among treatments means, Tukey test was used. The significance level considered for all the statistical tests was $p<0.05$. SAS program was used in the analysis of the treatment effect analysis on the different traits (SAS, 1997).

RESULTS

Results for traits studied on arrival to the slaughterhouse are shown in Table 3a and b. Space and duration during transportation had no significant influence ($p<0.01$) in the presence of bruises type: 1, 2 and 3; differences observed in bruising percentage were only numerical. No significant differences ($p<0.01$) in the presence of erythemas among treatments were found due to transport time and space; numerical differences were observed in both LE1 and GER. Also, no significant differences ($p<0.01$) among treatments for tremor in hind limbs; traveling time and space did not affect the incidence of this variable.

Significant differences ($p<0.01$) in hyperventilation incidence were observed; it is outstanding that for those animals transported for 16 h and a space allowance of 0.35 m^2, the presence of hyperventilation was higher, specially in males. Nevertheless, hyperventilation incidence did not show significant differences between genders for 8 and 24 h transport period and for 0.35 and 0.68 m^2 space allowance.

Transport duration and space allowed significantly affected ($p<0.01$) the animals posture on arrival at the slaughterhouse; moreover, there were significant differences ($p<0.01$) according to the sex. When transport time was shorter, a higher number of pigs arrived standing. More females arrived standing in the groupshipped for 8 h. On the other hand, males were more fatigued and arrived lying (sternum recumbency) after 16 or 24 h journeys.

Mean and standard error of the mean for traits monitored during slaughter are shown in Table 4a and b. Rectal temperature of pigs at arrival was influenced mainly by the travel duration and in practice allowed space did

Table 3a: Number and percentage of pre-slaughter traits from animals on arrival at the abattoir

Traits	Treatment 1 (F8) n = 60	Treatment 2 (B8) n = 60	Treatment 3 (F16) n = 60	Treatment 4 (B16) n = 60	Treatment 5 (F24) n = 60	Treatment 6 (B24) n = 60
	Observation (%)					
Bruises 0	51 (85)	45 (73.77)	52 (86.66)	41 (68.33)	46 (76.66)	27 (45)
Bruises 1	5 (8.33)	7 (11.47)	6 (10)	12 (20)	6 (10	14 (23.33)
Bruises 2	2 (3.33)	6 (9.83)	1 (1.66)	6 (10)	7 (11.66)	12 (20)
Bruises 3	2 (3.33)	3 (4.91)	1 (1.66)	1 (1.66)	1 (1.66)	7 (11.66)
Without erythema	55 (91.66)	54 (88.52)	55 (91.66)	48 (80)	53 (88.33)	47 (78.33)
Localized erythema	6.66	9.83	3.33	11.66	5	6.66
Generalized erythema	1.66	1.63	5	8.33	6.66)	15
Without tremor	59 (98.33)	58 (95.08)	58 (96.66)	53 (88.33)	56 (93.33)	51 (85)
Hindlimb tremor	1 (1.66)	3 (4.91)	2 (3.33)	7 (11.66)	4 (6.66)	9 (15)
Without hyperventilation	58 (96.66)	57 (93.44)	34 (56.66)	10 (16.66)	59 (98.33)	55 (91.66)
With hyperventilation	2 (3.33)	4 (6.55)	26 (43.33)	50 (83.33)	1 (1.66)	5 (8.33)
Arrival position						
Standing	43 (71.66)	28 (45.90)	7 (11.66)	4 (6.66)	5 (8.33)	2 (3.33)
Sitting	17 (28.33)	27 (44.26)	38 (63.33)	28 (46.66)	34 (56.66)	18 (30)
Lying (sternum recumbency)	0 (0)	6 (9.83)	15 (25)	28 (46.66)	21 (35)	40 (66.66)

Table 3b: Number and percentage of pre-slaughter traits from animals on arrival at the abattoir

Traits	Treatment 7 (F8) n = 60	Treatment 8 (B8) n = 60	Treatment 9 (F16) n = 60	Treatment 10 (B16) n = 60	Treatment 11 (F24) n = 60	Treatment12 (B24) n = 60
	Observation (%)					
Bruises 0	60 (100)	57 (95)	57 (95)	50 (83.33)	53 (88.33)	49 (81.66)
Bruises 1	0 (0)	1 (1.66)	2 (3.33)	7 (11.66)	5 (8.33)	5 (8.33)
Bruises 2	0 (0)	1 (1.66)	1 (1.66)	2 (3.33)	1 (1.66)	2 (3.33)
Bruises 3	0 (0)	1 (1.66)	0 (0)	1 (1.66)	1 (1.66)	4 (6.66)
Without erythema	58 (96.66)	55 (91.66)	58 (96.66)	49 (81.66)	56 (93.33)	49 (81.66)
Localized erythema	3.33	3.33	1.66	6.66	5	11.66
Generalized erythema	0	5	1.66	11.66	1.66	6.66
Without tremor	60 (100)	56 (93.33)	58 (96.66)	53 (88.33)	57 (95)	47 (78.33)
Hindlimb tremor	0 (0)	4 (6.66)	2 (3.33)	7 (11.66)	3 (5)	13 (21.66)
Without hyperventilation	58 (96.66)	56 (93.44)	51 (85)	48 (80)	58 (96.66)	53 (88.33)
With hyperventilation	2 (3.33)	4 (6.55)	9 (15)	12 (20)	2 (3.33)	7 (11.66)
Arrival position						
Standing	44 (73.33)	20 (39.16)	8 (13.33)	2 (3.33)	3 (5)	1 (1.66)
Sitting	16 (26.66)	32 (48.95)	40 (66.66)	32 (53.33)	30 (50)	21 (35)
Lying (sternum recumbency)	0 (0)	8 (11.88)	12 (20)	26 (43.33)	27 (45)	38 (63.33)

F = Female; B = Barrow; 8, 16 and 24 h of transport time; n = No. of animals observed

Table 4a: Means and standard error of the means of slaughter performance

Traits	Treatment 1 (F8) n = 60	Treatment 2 (B8) n = 60	Treatment 3 (F16) n = 60	Treatment 4 (B16) n = 60	Treatment 5 (F24) n = 60	Treatment 6 (B24) n = 60
	Mean±SEM					
Rectal temperature at arrival (°C)	38.94 ± 0.04^{B}	38.84 ± 0.04^{BC}	39.24 ± 0.04^{A}	39.17 ± 0.04^{A}	38.74 ± 0.04^{CD}	38.51 ± 0.04^{E}
Carcass temperature (°C)	38.64 ± 0.08^{A}	38.91 ± 0.08^{A}	38.73 ± 0.08^{A}	38.78 ± 0.08^{A}	38.58 ± 0.08^{A}	38.77 ± 0.08^{A}
LW on arrival (kg)	93.97 ± 0.15^{C}	94.81 ± 0.15^{B}	93.88 ± 0.15^{C}	95.33 ± 0.15^{AB}	93.90 ± 0.15^{C}	95.06 ± 0.15^{AB}
LW gained during lairage (kg)	94.48 ± 0.15^{EF}	95.31 ± 0.15^{CD}	94.74 ± 0.15^{DEF}	96.04 ± 0.15^{AB}	95.11 ± 0.15^{CDEF}	96.07 ± 0.15^{AB}
LW pre-slaughter (kg)	0.51 ± 0.03^{G}	0.49 ± 0.03^{G}	0.86 ± 0.03^{CDE}	0.71 ± 0.03^{EF}	1.21 ± 0.03^{A}	1.01 ± 0.03^{BC}
Hot carcass weight (kg)	76.07 ± 0.14^{B}	76.78 ± 0.14^{A}	75.83 ± 0.14^{BC}	75.89 ± 0.14^{BC}	75.02 ± 0.14^{D}	75.27 ± 0.14^{CD}
Carcass yield (%)	80.51 ± 0.08^{A}	80.55 ± 0.08^{A}	80.03 ± 0.08^{B}	79.01 ± 0.08^{C}	78.86 ± 0.08^{C}	78.35 ± 0.08^{D}

A, B, C, D in the same row are statistically different, Tukey ($p<0.05$), F = Female; B = Barrow; 8, 16 and 24 are transportation times; n = No. of observed pigs; LW = Live Weight; W = Weight; SEM = Standard Error of the Mean

Table 4b: Means and standard error of the means of slaughter performance

Traits	Treatment 7 (F8) n = 60	Treatment 8 (B8) n = 60	Treatment 9 (F16) n = 60	Treatment 10 (B16) n = 60	Treatment 11 (F24) n = 60	Treatment 12 (B24) n = 60
	Mean±SEM					
Rectal temperature at arrival (°C)	38.86 ± 0.04^{BC}	38.94 ± 0.04^{BC}	39.24 ± 0.04^{A}	39.26 ± 0.04^{A}	38.60 ± 0.04^{DE}	38.57 ± 0.04^{DE}
Carcass temperature (°C)	38.58 ± 0.08^{A}	38.86 ± 0.08^{A}	38.61 ± 0.08^{A}	38.67 ± 0.08^{A}	38.55 ± 0.08^{A}	38.75 ± 0.08^{A}
LW on arrival (kg)	93.92 ± 0.15^{C}	95.11 ± 0.15^{AB}	93.95 ± 0.15^{C}	95.50 ± 0.15^{AB}	94.04 ± 0.15^{C}	95.59 ± 0.15^{A}
LW gained during lairage (kg)	94.44 ± 0.15^{F}	95.64 ± 0.15^{BC}	94.79 ± 0.15^{DEF}	96.24 ± 0.15^{AB}	95.17 ± 0.15^{CDE}	96.59 ± 0.15^{A}
LW pre-slaughter (kg)	0.52 ± 0.03^{G}	0.53 ± 0.03^{FG}	0.83 ± 0.03^{DE}	0.74 ± 0.03^{E}	1.13 ± 0.03^{AB}	0.99 ± 0.03^{BCD}
Hot carcass weight (kg)	76.09 ± 0.14^{B}	77.00 ± 0.14^{A}	75.75 ± 0.14^{BC}	75.99 ± 0.14^{B}	75.05 ± 0.14^{D}	75.74 ± 0.14^{BC}
Carcass yield (%)	80.56 ± 0.08^{A}	80.50 ± 0.08^{A}	79.91 ± 0.08^{B}	78.95 ± 0.08^{C}	78.85 ± 0.08^{C}	78.42 ± 0.08^{D}

A, B, C, D in the same row are statistically different, Tukey ($p<0.05$), F = Female; B = Barrow; 8, 16 and 24 are transportation times; n = No. of observed pigs; LW = Live Weight; W = Weight; SEM = Standard Error of the Mean

Table 5: Number and carcass percentage which presented low, normal and high pH at 45 min post-mortem

Treatments	pH < 5.7 Low (PSE)	pH 5.8-6.2 Normal	pH > 6.3 High (DFD)
	Observation (%)		
Treatment 1 (F8)	4 (6.66)	49 (81.66)	7 (11.66)
Treatment 2 (B8)	12 (19.67)	32 (52.45)	17 (27.86)
Treatment 3 (F16)	8 (13.33)	29 (48.33)	23 (38.33)
Treatment 4 (B16)	11 (18.33)	22 (36.66)	27 (45)
Treatment 5 (F24)	2 (3.33)	38 (63.33)	20 (33.33)
Treatment 6 (B24)	6 (10)	14 (23.33)	40 (66.66)
Treatment 7 (F8)	2 (3.33)	49 (81.66)	9 (15)
Treatment 8 (B8)	11 (18.33)	35 (58.33)	14 (23.33)
Treatment 9 (F16)	3 (5)	43 (71.66)	14 (23.33)
Treatment 10 (B16)	6 (10)	18 (30)	36 (60)
Treatment 11 (F24)	0 (0)	42 (70)	18 (30)
Treatment 12 (B24)	6 (10)	29 (48.33)	25 (41.66)

F = Females; B = Barrows; 8, 16 and 24 are transportation times

Table 6: Number and percentage of the color trait in carcasses

Treatments	Meat colour				
	Grayish pink	Light red	Grayish pink	Light red	Dark red
	Observation (%)				
Treatment 1 (F8)	4 (6.66)	1 (1.66)	54 (90)	0 (0)	1 (1.66%)
Treatment 2 (B8)	11 (18.03)	2 (3.27)	46 (75.40)	1 (1.63)	1 (1.63%)
Treatment 3 (F16)	7 (11.66)	2 (3.33)	43 (71.66)	1 (1.66)	7 (11.66%)
Treatment 4 (B16)	7 (11.66)	4 (6.66)	38 (63.33)	1 (1.66)	10 (16.66%)
Treatment 5 (F24)	1 (1.66)	3 (5)	46 (76.66)	1 (1.66)	9 (15%)
Treatment 6 (B24)	6 (10)	1 (1.66)	29 (48.33)	1 (1.66)	23 (38.33%)
Treatment 7 (F8)	2 (3.33)	1 (1.66)	56 (93.33)	0 (0)	1 (1.66%)
Treatment 8 (B8)	8 (13.33)	3 (5)	39 (65)	0 (0)	0 (0%)
Treatment 9 (F16)	2 (3.33)	0 (0)	58 (96.66)	0 (0)	1 (1.66%)
Treatment 10 (B16)	3 (5)	0 (0)	40 (66.66)	0 (0)	7 (11.66%)
Treatment 11 (F24)	0 (0)	2 (3.33)	55 (91.66)	0 (0)	3 (5%)
Treatment 12 (B24)	3 (5)	3 (5)	45 (75)	1 (1.66)	8 (13.33%)

F = Females. B = Barrows. 8, 16 and 24 are transportation times

not have any influence. No significant differences were found between males and females, except for treatments 5 and 6.

Live-weight at the arrival was not affected by journey duration, neither by allowed space. Conversely, sex did affect this variable, where male weight was statistically different from female weight. Hot carcass weight was negatively affected by journey duration. This was also evident in carcass yield; when traveling time was shorter, pigs had better yields. Significant differences were observed between genders in treatments 1, 2, 7 and 8. In both variables, space given to pigs during transportation did not have a significant effect.

There was a higher number of pigs with pH 5.8-6.2; this fact was more evident in females ($p<0.01$). Although there was higher pH ($p<0.01$) between 5.8 and 6.2 in pigs transported during 8 h, as compared to those transported during 16 and 24 h, independently of space allowance. Chi square test showed significant differences ($p<0.01$) among treatments at pH>6.3, in this case effects were due to traveling time, space allowance and sex (Table 5).

Table 6 shows the journey duration and space effects on carcass color χ^2test showed significant differences ($p<0.01$) only for some color classifications within different treatments. Color classifications 3 and 5, light red and dark red, respectively, significant differences were found among treatments. There were more grayish-pink carcasses especially in females and there was a higher percentage of dark red meat in males ($p<0.01$), the incidence of non desirable colorations in carcasses, such as pale and dark red ($p<0.01$), was smaller.

DISCUSSION

Transport: Results of this study showed relatively slight effects of the stocking density on meat quality traits, in agreement with results obtained in previous studies on commercial transports (Barton and Christensen, 1998). Transport time and space provided to the animals, did not influence the incidence of skin and subcutaneous tissue lesions (bruises 1, 2, 3); on the other hand, incidence was more evident in males (numerical differences), independently of the transport duration as shown in Table 3a. It is worth mentioning that although not significantly, the more the space allowed during transportation, the incidence of bruises in animals decreased. Nevertheless, Barton and Christensen (1998), concluded that, when pigs are transported with restricted movement in compartments, physical wounds can be avoided; variations in behavior responses can contribute to the incidence of skin lesions when animals have more than 0.35 m^2 per animal during transport. When animals have more space in trucks the risk of injuries caused by trample and/or fights among animals increases.

According to Guise *et al*. (1998) treatment effects (0.47, 0.39, 0.34 and 0.30 m^2/100 kg) on skin damages were not significant, 67% of the carcasses showed light damage. They stated that values 1 (with no damage) and 4.5 (severe and very severe damages) were of interest. McGlone *et al*. (1993) indicated that after 4 h of transportation shy and subordinate pigs suffer more stress than dominants. Geverink *et al*. (1996) and Warris *et al*. (1998) concluded that a cause of skin damage is the result of pre-slaughter fights among pigs and these take place to a higher degree among males than among females. It is a common practice to mix different groups of pigs from different farmers during transport and moreover, in the resting period, at lairage. Pigs in general, do not fight while being transported; they mainly establish social dominance in the pre-slaughter pens (Geverink *et al*., 1996).

During transportation, balance loss and falling of animals can happen; this situation can be associated with the truck structure and the load density (Tarrant *et al*., 1988; Gallo *et al*., 2001), or with the way in which the driver handles the vehicle when coming to a stop. Results of this study agree with those reported by Gallo *et al*. (2001); the longer the journey, the more contusions animals will show, this situation causes greater economic losses due to the serious commercial problem that skin lesions cause (Warriss *et al*., 1998).

According to Grandin (1994), factors such as transportation during the summer (>30 min), overcrowding and mixing of pigs from different places, produce an increase in the incidence of pale-, soft- and exudative meat (PSE) and therefore, recommends that animals weighing around the 100 kg should have at least 0.35 m^2 space during transport; these densities are similar to those used in the present study: 0.35 m^2/100 kg for Groups G_1, G_2 and G_3 and agree with the Mexican Regulation (NOM-024-Z00, 1995). In Groups G_4, G_5 and G_6 that had 0.68 m^2 space decreased in a drastic way the hyperventilation incidence, mainly, in those animals transported for 16 h. In several places, the densities more commonly used are 0.35- 0.39 m^2/100 kg that correspond to 286 and 256 kg m^{-2}, respectively; there is no relationship between the stocking density and the mortality rate during transportation (Barton and Christensen, 1998), as was observed in this study. However, the overloading of trucks is a major cause of increased stress and death losses in transported animals (Grandin, 2003).

Through recording and observing transported animals at different densities it has been shown that for pigs weighing 90-100 kg it is adequate to use 0.4 m^2/100 kg (Barton and Christensen, 1998); a slight increase in the load density can be permitted for very short distances, while a density of 0.3 m^2/100 kg is physically uncomfortable for the animals (Wajda and Denaburski, 2003).

Higher rates of animals showing hyperventilation were observed in G_2 transported for 16 h (38%), especially in the males; this could have been influenced by the arrival timing, since this group arrived at 16:00 h and animals had undergone a 5 h period under extremely hot conditions.

When traveling time was shorter (8 h), a higher number of pigs arrived in a standing position; significant differences were observed between genders, more females arrived on their feet compared with males. At arrival to the slaughterhouse, 80% of the pigs remained in a standing position and only 20% were sitting after being transported for an average of 2 h 38 min, at a density of 0.50 m^2/100 kg (Barton and Christensen, 1998). The longer the trip took, the greater the number of animals arriving in a sternum recumbency position increased, this was more evident in males, showing statistical differences compared with the females transported during the same period. Grandin (1994) stated that after a long journey by highway, animals tend to lie down for the last hours of their transportation, regardless the load density. According to Barton and Christensen (1998) pigs monitored 45 min before arrival, traveling on short trips (3 h) at a density of 0.35 m^2/100 kg were found in the following positions: 40% standing, 40% sitting and 20% lying.

Rest and slaughter: Transport duration significantly ($p<0.05$) affected live weight gain during the resting period (hydration), percentages of weight gain were: 0.52, 0.81, 1.16, 0.55, 0.81 and 1.1%, for Groups 1, 2, 3, 4, 5 and 6, respectively. It is important to highlight that females drank significantly ($p<0.05$) more water than males in Group 3. Physiologically, since females have more body fat and lower percentages of water, water consumption during lairage was higher.

As expected, live weight gained during the resting period (hydration) affected the pre-slaughter live weight, males from all treatments showed the highest values and were statistically different compared with the females. Brown *et al.* (1999) observed that the most severe dehydration occurred in the pigs transported for 24 h; this group drank more water in the pre-slaughter pens and also exhibited an increase in protein- and total albumin in plasma. Leheska *et al.* (2003) reported that meat from pigs transported for 8 h showed low lactate levels ($p<0.05$).
Hot carcass weight was negatively affected by transport time. Groups 1 and 4 showed the highest values, whereas Groups 3 and 6, the lowest. No significant differences were observed in Groups 2, 3, 5 and 6 regarding carcass yield between genders; nevertheless this was different for Groups 1 and 4 ($p<0.05$). This difference can be explained by studies from Eikelenboom *et al.* (1991), who found statistical significance ($p<0.05$) on the effect of sex on the live weight of pigs fasted for 16 and 24 h. Results indicate that females showed lower hydration compared with males.

Animals which drank greater amounts of water during lairage were transported for the longer periods. These also showed lowest carcass yields since the imbibed water was lost during slaughtering causing weight loss. Gallo *et al.* (2003), concluded that carcass weight in pigs tend to be lower after long journeys and long periods in the pre-slaughter pens.

pH, temperature and carcass color: Transport in relatively long periods significantly increased the incidence of lower pH_{45} (13.16% pigs of G_1 and 10.83% pigs of G_4). When an animal is subjected to acute stress, a quick glycolisis takes place and therefore, meat pH decreases more rapidly than normal, increasing PSE incidence. Traveling time for 36 h significantly affected meat pH (49.99% for pigs of Group 3 and 35.83% for pigs of Group 6), increasing incidence of DFD meat; therefore, the origin of this abnormality is due to prolonged or chronic stress leading to limited post-mortem glycolisis and a pH decrease. On the other hand, when comparing meat low pH between genders, highly significant differences were found, somehow indicating a higher resistance of females to stress. It is important to note that the space provided to pigs affected significantly ($p<0.01$) final pH.

Warris *et al.* (1990), did not find differences between sexes for pH_{45} or water holding capacity; nevertheless, meat color in female carcasses was significantly ($p<0.05$) paler. Variation between TC_{45} influences individual pH values due to the fact that at higher temperatures, anaerobic glycolisis processes are accelerated and when the backfat is thicker, heat dissipation is slower. In this case, temperature did not show significant differences among treatments. Brown *et al.* (1999), reported that there were no effects on pig carcass temperature in 8, 16 and 24 h journeys with or without a 6 h recovery period.

Meat quality is affected when pigs are transported for long distances under high density conditions, due to a decrease of muscular glycogen that can lead to animal fatigue (Wajda and Denaburski, 2003).

Transport duration, space provided and sex had an effect on the meat color. In general terms, most of the carcasses showed a normal or desirable coloration (pink-greyish) in all the treatments: 82.7% in animals of G_1; 67.49% in animals of G_2; 62.49% in animals of G_3; 76.16% in those of G_4 and 81.66 and 83.33% for Groups 5 and 6, respectively. When pigs were subjected to an acute stress (8 h of transport) the incidence of a pale coloration (presumably PSE) was higher; a higher incidence occurred in males. On the other hand, when pigs were subjected to a chronic or prolonged stress, the number of carcasses with a dark red coloration was higher (presumably DFD).

Gallo *et al.* (2003) have also demonstrated that meat color in steers is influenced by the muscular glycogen levels before slaughter which affects the decrease of both the post-mortem and the final pH. Brown *et al.* (1999) found a progressive increase in the pH of pigs *Longissimus dorsi* muscle after a prolonged journey (>24 h). Leheska *et al.* (2003) reported that exhaustive exercise in pigs produce dark and firm muscles with high pH values and low glycogen concentrations.

de Smet *et al.* (1996) reported fasting prior to slaughter may reduce muscular glycogen in the skeletal muscle because it is mobilized as an energy source during that period. Prolonged fasting can also reduce carcass yield as it can be influenced by transportation and waiting time in the slaughterhouse when animals are transported for 488, 976 and 1,464 km. Guise *et al.* (1998) determined that density had no significant effects on meat quality when animals were transported at 0.47, 0.39, 0.34 and 0.30 m^2/100 kg.

CONCLUSION

Pork quality is affected by various factors: Transport duration, space allowed for an animal during transport, sex, lairage time and slaughtering method. Additional space provided to pigs during transportation lead to a better animal welfare in transit and did not have a dramatic effect on the carcass quality. A larger space during the transport leads to a low incidence of undesirable colors in the meat; although it is necessary to consider that in some countries the final quality of the meat is not taken in consideration because there is not an economic remuneration that motivates this practice.

ACKNOWLEDGMENTS

This study is the pilot study from the first author, as a member of the Doctorate Program in Biological Sciences at the Universidad Autónoma Metropolitana Iztapalapa-Xochimilco. Marcelino Becerril-Herrera was supported by the scholarship from CONACYT, Mexico. Daniel Mota-Rojas, Isabel Guerrero-Legarreta, Clemente Lemus-Flores and María Alonso-Spilsbury, were supported, as members, by the Sistema Nacional de Investigadores (SNI) in Mexico.

REFERENCES

Barton, G.P. and L. Christensen, 1998. Effect of different stocking densities during transport on welfare and quality in Danish slaughter pigs. Meat Sci., 48: 237-247.

Bonelli, A.M. and C.R. Schifferli, 2001. Porcine stress sindrom (In spanish). Arch. Med. Vet., 33: 125-135.

Brown, S.N., T.G. Knowles, J.E. Edwards and P.D. Warriss, 1999. Behavioural and physiological responses of pigs to being transported for up to 24 h followed by 6 h recovery in lairage. Vete. Rec., 145: 421-426.

de Smet, S.M., H. Pauwels, S. De Bie, D.I. Demeyer, J. Callewier and W. Eeckhout, 1996. Effect of halothane genotype, breed, feed withdrawal and lairage on pork quality of Belgian slaughter pigs. J. Anim. Sci., 74: 1854-1863.

Eikelenboom, G., A.H. Bolink and W. Sybesma, 1991. Effects of feed withdrawal before delivery on pork quality and carcass yield. Meat Sci., 29: 25-30.

Gallo, C., M. Espinosa, C. Sanhueza and J. Gasic, 2001. Effects of trailer transportation during 36 h with and without rest, on the live weight and some carcass traits in bovines (In spanish). Arch. Med. Vet., 33: 43-53.

Gallo, C., G. Lizondo and T.G. Knowles, 2003. Effects of journey and lairage time on steers transported to slaughter in Chile. Vet. Rec., 152: 361-364.

Geverink, N.A., B. Engel, E. Lambooij and M.V. Wiegant, 1996. Observations on behaviour and skin damage of slaughter pigs and treatment during lairage. Applied Animal Behaviour Sci., 50: 1-13.

Grandin, T., 1994. Solving livestock handling problems. Vet. Med., 89: 989-998.

Grandin, T., 1997. Assessment of stress during handling and transport. J. Anim. Sci., 75: 249-257.

Grandin, T., 2003. The welfare of pigs during transport and slaughter. Pig News and Information, 24: 83N-90N.

Guise, H.J., H.L. Riches, B.J. Hunter, T.A. Jones, P.D. Warriss and P.J. Kettlewell, 1998. The effect of stocking density on transit on carcass quality and welfare of slaughter pigs. Meat Sci., 50: 439-446.

Leheska, J.M., D.M. Wulf and R.J. Maddock, 2003. Effects of fasting and transportation on pork quality development and extent of post-mortem metabolism. J. Anim. Sci., 80: 3194-3202.

Martoccia, B., G. Brambilla, A. Macri, G. Moccia and E. Cosentino, 1995. The effect of transport on some metabolic parameters and meat quality in pigs. Meat Sci., 40: 271-277.

McGlone, J.J., J.L. Salak, E.A. Lumpkin, R.I. Nicholson, M. Gibson and R.L. Norman, 1993. Shipping stress and social status effects on pig performance, plasma cortisol, natural killer cell activity, an leukocyte numbers. J. Anim. Sci., 71: 888-896.

McPhee, C.P. and G.R. Trout, 1995. The effects of selection for lean growth and the halothane allele on carcass and meat quality of pigs transported long and short distances to slaughter. Livestock Prod. Sci., 42: 55-62.

Mota, R.D., H.M. Becerril, M.L. Alonso-Spilsbury and N.R. Ramírez, 2000. Effect of the absence of stunning method on the pig carcass (In spanish). In Atlapa, Panamá, pp: 303.

Mota, R.D., H.M. Becerril, J.F.R. Gay, F.C. Lemus and N.R. Ramírez, 2004. Pork quality, public health and food safety (In spanish). Cuadernos CBS, No. 52. Universidad Autónoma Metropolitana-Xochimilco, México, pp: 353.

Mota, R.D., M. Becerril, C. Lemus, P. Sánchez, M. González, S.A. Olmos, R. Ramírez and M. Alonso-Spilsbury, 2006. Effects of mid-summer transport duration on pre- and post-slaughter performance and pork quality in México. Meat Sci., 73: 404-412.

Nanni-Costa, L., D.P. Lo Fiego, S. Dall´Olio, R. Davoli and V. Russo, 1999. Influence of loading method and stocking density during transport on meat and dry-cured ham quality in pigs with different halothane genotypes. Meat Sci., 51: 391-399.

NOM-024-Z00, 1995. Mexican Official Code of Practice NOM-024-Z00, 1995. Health specifications and characteristics for the transport of animals, their products, by-products, chemicals, pharmaceuticals, biologics and feed used for animals or eaten by animals (In Spanish). Diario Oficial de la Federación, 16 de octubre de 1995.

NOM-033-ZOO, 1995. Mexican Official Code of Practice NOM-033-ZOO, 1995. Humanitarian sacrifice of domestic and wild animals (In spanish). Diario Oficial de la Federación, 16 de julio de 1996.

NPPC, 1991. National Pork Producer Council. Procedures to evaluate market hogs. 11-16 Bulletin Des Moines IA.

SAS, 1997. Institute, Inc. Versión 6.12. Cary, North Carolina, USA.

Schaefer, A.L., S.D.M. Jones and R.W. Stanley, 1997. The use of electrolyte solutions for reducing transport stress. J. Anim. Sci., 75: 258-265.

Tadich, N., C. Gallo and M. Alvarado, 2000. Effects of 36 h transport by land with and without rest, on some blood traits indicative of stress in bovines (In Spanish). Archi. Med. Vet., 32: 171-183.

Tarrant, P.V., F.J. Kelly and D. Harrington, 1988. The effect of stocking density during 4 h transport to slaughter, on behavior, blood constituents and carcass bruising in Friesian steers. Meat Sci., 24: 209-222.

Velasco, J., 2001. pH measurement, important aspects (In Spanish). Carne Tec., 8: 48-51.

Wajda, S. and J. Denaburski, 2003. Pre-slaughter handling of pigs. Anim. Sci. Papers Rep., 21: 173-181.

Warriss, P.D., S.N. Brown, P.P. Barton-Gade, C. Santos, C.L. Nanni, E. Lambooij and R. Geers, 1998. An analysis of data relating to pig carcass quality and indices of stress collected in the European Union. Meat Sci., 49: 137-144.

Warriss, P.D., S.N. Brown, T.G. Knowles, L.J. Wilkins, S.J. Pope, S.A. Chadd Kettlewell and N.R. Green, 2006. Comparison of the effects of fan-assisted and natural ventilation of vehicles on the welfare of pigs being transported to slaughter. Vet. Rec., 29: 158: 585-588.