Influence of the rest time on carcass quality and pork meat characteristics

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The influence of two rest times: long rest (20-22 h) and short rest (3-4 h) on carcass quality and pork meat characteristics was studied. Two hundred pigs (120 castrated males and 80 females) of similar genetic composition and age were evaluated. Animals were divided and sent to the slaughterhouse in groups of 50 pigs (two lots per treatment). pH and temperature at 45 min and 24 h after slaughtering (pH 45 min, pH 24 h, temp. 45 min., temp. 24 h) were measured. Also, the water holding capacity (WHC), dripping losses (DL), color, muscle profile, weight, length and carcass backfat, besides the defects (fractures, hemorrhages and contusions) in chop, shoulder and ham were calculated. The rest period did not affect ($P = 0.6$) pH 45 min, or the color. However, there were changes ($P < 0.001$) in the pH 24 and in the temperature at 45 min. and at 24 h, as well as in WHC and DL. Meat from animals with long rest time had higher pH 24 h value (5.80), lower DL (1.82%) and greater WHC (15.64%) regarding the values obtained in animals with short rest time (5.68, 3.44 % and 17.24 %, respectively). The highest meat frequency (73 %) with high pH 24 h (≥ 6.0) was produced with the long rest time, while with the short rest time was obtained 93 % of carcasses, with normal pH 24 h range (5.6- 5.9) with greater proportion of flawless chops and ham. Results demonstrate that with the short rest time the incidence of carcass quality problems (dark cut and flaws) related to mistakes in the animal welfare decreased.

Key words: *quality, meat, pigs, animal welfare, pH, rest time*

Considering the quality requirements presently demanded for pig meat production, the processes integrating the meat production chain to guarantee the final product need to be controlled. These processes involve from the production in the farm (including aspects such as health, biosecurity, handling, genetics, and feeding) to the transportation, slaughter and later processing, conservation and distribution (Hambrecht *et al*. 2003) of the end product.

Among the most important management factors that must be taken into consideration are the fast time, the transportation conditions, trip time, loading and unloading, kind treatment of the workers and the rest period prior to slaughter. Each one of these elements plays an important role to guarantee the adequate animal welfare, the reduction of the pre-slaughter stress and to assure meat quality (Álvarez-Álvarez 2010).

The stress is an accumulative response of the animal to the environment. Certain factors, such as the transportation, fast and slaughter can, at a short term, produce stress in the animals. These elements constitute psychological and physical stimuli that can result adverse for the animals. The responses to these stimuli include behavioral and physiological changes that allow facing the unfavorable situations that provoke the stress. If the recuperation or adaptation fails, the consequences could be very serious, from mortality or total loss of the animal, weight loss to affections in carcass and meat quality flaws (Zanardi *et al*. 2007 and Nanni Costa 2009).

Rest for the animals before slaughter allows the recuperation of the physiological conditions lost during the loading, transportation and unloading processes. In this way the metabolic conditions are normalized, as the renewal of the muscular glycogen levels and the muscular tone, which favors the relaxation of the most affected animals by the previous handling conditions (Nanni Costa *et al*. 2002 and Nanni Costa 2009). However, the excessive rest time can exhaust the muscular glycogen reserves and favor the incidence of dark meats with high pH, besides increasing the exposure of the animals to fights and stress. In Venezuela there are no previous studies that could serve as basis for documenting and recommending a rest time more adequate to our production and management conditions.

The objective of this research was to study the influence of the rest time prior to slaughtering (long rest 20-22 h and short rest 3-4 h) on the carcass quality and pork meat characteristics.

Materials and Methods

Animals. The study was carried out in the farm and facilities of the slaughterhouse, packing and processing plant of a pig production enterprise, located at the municipality of San Francisco, State of Zulia, Venezuela. Four lots of animals, of 50 pigs each, were sent to slaughter and processing for four consecutive weeks (one per week). Two lots of pigs were left to rest in the

corrals of the slaughterhouse during 3-4 h (short rest); the other two, during 22-24 h (long rest). The rest times were evaluated according to what was established by the slaughterhouse, packing and processing plant. The exact time was determined from the lodging of the animals in the corrals of the slaughterhouse until the moment when they were taken to the dazing place. The transportation time ranged between 20-30 min. The temperature in the waiting corrals ranged between 25 and 30º C during the waiting time.

Once finished the rest time established for each group, the animals were sent to the numbing area, where they received a slight water shower and they were deprived of consciousness by the electro-narcosis method without subjection, for approximately three seconds. Animals bled immediately after they became insensible. The slaughter process followed the industrial standards established in Venezuela.

Carcass and meat evaluation. pH and temperature measurements in the *Longissimus dorsi* muscle, were made at the tenth intercostal space, at 45 min. and 24 h after slaughter. For this purpose, a potentiometer, portable instrument for pH and temperature measurement, mark Testo® model 230, manufactured in Germany, was used. This was gauged with buffer solutions at pH 4 and pH 7, at the beginning of each evaluation in the chamber where carcasses were placed.

At 24 h in refrigeration after slaughter, the half carcasses were evaluated for determining different quantitative and qualitative characteristics, according to the National Pork Producer Council (NPPC 1991). The muscles profile was measured by pre-established patterns: 1) very thick, 2) thick, 3) moderately thick, 4) slightly thin and 5) thin. Carcass length (cm) was attained by a tape measure, determining the distance between the front border of the pubis and the front border of the first rib in its articulation point with the first thoracic vertebra. Backfat thickness (cm) was obtained by measuring with a small graduated rule on the carcass, at three levels from the back, in opposite position to the first rib, last rib and last lumber vertebra. Muscles color was established by a visually determined color scale, where:

1= Pale gray pink to white
2= Grayish pink
3= Reddish pink
4= Dark reddish pink
5= Dark purple red (NPPC 1991)

At 24 h after slaughter, before and during the cutting up, the presence of contusions, fractures (of shoulder, column and pelvis) ecchymosis and petechias in the carcasses and their cuts were determined.

Once extracted the chop cut, samples of the *Longissimus dosi* muscle were collected to evaluate the water holding capacity (WHC), dripping loss (DL) and color. These assessments were carried out in the Laboratory of Foodstuff Technology of the Agronomy Faculty of the University of Zulia.

For DL determination, meat cuts in steak form of 80 and 100 g were made. After registering the weight, each portion was identified and placed separately in a hermetic plastic bag and stored under refrigeration at 2º C for 48 h. At the end of this period, the weight of the meat sample was registered. The dripping loss was expressed by the percentage of water released from the original sample (Honikel 1998).

The water holding capacity (WHC) was analyzed as stated by Barbut (1996), using 1.6 g of fresh sample for submitting it to refrigerated centrifugation. Later, the percentage of water lost by the sample was obtained, due to the centrifugation action by weight difference expressed in percentage.

Statistical analysis. Data were analyzed by the GLM procedure (General Linear Model) of the statistical package Statistical Analysis System (S.A.S. 2004). The sexual condition, the rest time, the rest time x sexual condition interaction and the slaughter lot were considered as fixed effects. When the effects resulted statistically significant ($P < 0.05$) mean test by the least significant difference (LSMEANS) was applied. The frequency analysis was conducted for identifying the proportion of PTE (pale, tender, exudative) meat, normal and DFD (dry, firm and dark) and carcass flaws.

Results

The analysis of variance determined that the sexual condition and the sexual condition x rest time interaction did not affect the carcass characteristics or the meat. Neither was there significant effect of the slaughtering lot on the variables studied. In table 1 are shown the descriptive statistics of the evaluated variables for all pigs of the study, with the objective of showing the general characteristics of the animals used.

The analysis of variance demonstrated that the rest time did not affect the pH 45 min. However, it was significant for pH 24 h. In meats from animals submitted to long rest time was higher (5.80) regarding those subjected to short rest times (5.68). Nonetheless, the rest time did not change the muscle color. In both treatments, the muscle color evaluated 24 h after slaughter was placed in the scale corresponding to grayish pink.

The rest time also affected the carcass temperature measurements at 45 min. and 24 h after slaughter ($P < 0.001$). Carcass temperature at 45 min was lower in the carcasses of animals with short rest time than in the carcasses with long rest time (31.0ºC vs. 33.3ºC, respectively). At 24 h after slaughter, the carcasses of short rest time attained a final temperature higher than their opposing parts (6.48ºC vs. 4.48ºC).

The ANOVA found significant effect of the rest time on the water holding capacity (WHC) and dipping losses

Table 1. Descriptive indicators of the studied variables for all animals studied[1]

Variables	Means	DE	Minimum	Maximum
pH 30 min	6.43	0.28	5.43	6.82
pH 24 h	5.72	0.17	5.24	6.01
Temperature, 45 min	32.10	3.90	24.00	38.50
Temperature, 24 h	3.98	1.20	1.90	8.33
Dripping loss, %	2.65	1.54	0.00	8.33
WHC [2], %	16.71	4.44	4.19	24.00
Color [3]	2.18	0.64	1.00	4.00
Carcass weight, kg	73.66	6.79	57.80	85.00
Carcass length, cm	78.41	2.62	69.00	85.00
Musculature profile[4]	1.95	0.66	1.00	3.00
Backfat thickness, cm	1.71	0.53	0.33	3.00

SD: standard deviation

[1] 120 castrated males and 80 females

[2] Water holding capacity, expressed in percentage

[3] Color measured by visual scale (1: pale gray pink to white; 2: grayish pink; 3: reddish pink; 4: dark reddish pink; and 5: dark purple red (NPPC, 1991),

[4] According to the muscularity profile (1: very thick; 2: thick, 3: moderately thick, 4: slightly thin and 5 thin) according to NPPC (1991).

($P < 0.05$). The meats from the long rest time treatment, with 1.6 % less of water loss, indicated greater WHC regarding those with short rest time (table 2).

Table 3 shows the effect of the rest time on carcass characteristics. The carcasses from animals submitted to short rest time had longer carcasses and with lower (thick) musculature profile ($P < 0.05$) than those from animals with long rest time. However, for carcass weight and backfat thickness, there were notdifferences between treatments.

The proportion of meats PTE, normal and DFD for each group of treatment, was ascertained using the classification published by Castrillón *et al*. (2007). According to these authors, for pork meat, values of pH 45 min ≤ 5.8 or of pH 24 h ≤5.5 indicate PTE meats; values of pH 45 min ≥6.3 or of pH 24 ≥ 6.0, are considered DFD meats, while values of pH 45 min between 5.9 and 6.2 or of pH 24 h between 5.6 and 5.9 indicate normal meats. With a sub-total of 100 animals in each treatment, the analysis of frequency demonstrated

Table 2. Effect of the rest time before slaughter on the pork quality meat

Variables	Short rest (3-5h)	Long rest (20-22h)	P Value
pH 45 min	6.35 ± 0.03	6.37 ± 0.03	0.616
pH 2 h	5.68 ± 0.02	5.80 ± 0.02	0.001
Temperature 30 min	31.00 ± 0.38	33.27 ± 0.40	<0.0001
Temperature 24 h	6.48 ± 0.14	4.38 ± 0.14	<0.0001
Dripping loss, %	3.44 ± 0.12	1.82 ± 0.24	0.0001
WHC[1]	17.24 ± 0.70	15.64± 0.46	0.05
Color[2]	2.16 ± 0.07	2.21 ± 0.07	0.575

[1]Water holding capacity, expresses the percentage of water lost by centrifugation effect

[2]Visual scale (see table 1)

Table 3. Effect of the rest time before slaughter on carcass characteristics

Variables	Short rest (3-5h)	Long rest (20-22h)	P Value
Carcass weight, kg	72.70 ± 1.03	74.56 ± 1.03	0.277
Carcass length, cm	77.93 ± 0.62	78.91 ± 0.61	0.009
Musculature profile[1]	2.13 ± 0.28	1.76 ± 0.40	0.002
Backfat thickness, cm	1.73 ± 0.13	1.69 ± 0.14	0.445

[1]According to the muscularity profile (1: very thick; 2: thick, 3: moderately thick, 4: slightly thin and 5 thin) according to NPPC (1991).

Table 4 Proportion (%) of PTE, DFD and normal meats for each rest time

Indicators	Short rest (3-4 h)	Long rest (22 -24 h)
PT, at pH 45 min	13	8
DFD, at pH 45 min	1	72
Normal, at pH 45 min	86	20
PTE, at pH 24 h	4	3
DFD, at pH 24 h	3	73
Normal, at pH 24 h	93	24

N = 100 for each treatment

Table 5. Proportion (%) of defects found at cutting for each rest time

Indicators	Short rest (3-4 h)	Long rest (22 -24 h)
Chop fractures	2	9
Flawless chops	98	91
Petechias in ham	8	11
Hemorrhages in ham	4	33
Flawless ham	82	66
Flawless shoulder	100	100

N = 100 for each treatment

a greater meat proportion with normal pH in the group with short rest time. On considering only the group of long rest time, there was 73 % of meat with high pH defined as DFD, with pH determination at 24 h (table 4).

Likewise, the frequency distribution of carcass flaws was obtained. Carcasses coming from animals with short rest time had great proportion of flawless hams. In the group with long rest there was greater proportion of chops without defects. The percentage of petechias and hemorrhages in the ham was higher in the carcasses of the long rest time treatment (table 5).

Discussion

In Venezuela there is no guideline available for pig rest time. Generally, animals transported to short distances are slaughtered almost immediately on arriving to destination, while pigs from more distant places, are moved away for more than 24 h before slaughter.

The studied rest times are the two ways used in the slaughtering-packing-processing plant and in the zone, in general. Since there was no local references on the effect of these times on carcass quality and pork meat, their evaluation was required.

According to Tarrant (1989), the rest of the animals before slaughter does not only make more feasible the work of organizing the lots of animals, but also allows the pigs' recovery from the stress provoked by the loading, transportation and unloading to which they were subjected for their transfer from the production unit to the slaughterhouse plant. However, an excessive rest time can provoke animal welfare problems and exhaustion of the muscular glycogen reserves, besides favoring the appearance of dark meats or DFD (Gregorym 2007; Álvarez *et al*., 2009). The short periods are associated with PTE meats; while the long periods are related to DFD meats and more contusions caused by fights and lower carcass yield (Warriss 2003).

Results of this study demonstrate that meats from long rest time had pH values higher than the meats from animals with short rest time, greater water holding capacity, lower dipping loss, without resulting statistically different for the color.

Various studies conducted in different countries coincide regarding the direct relationship between rest length and final pH. Nonetheless, there is no general recommendation on the best rest time.

Warris (2003) reported that pH values increased with the rest time. Therefore, the meats with lower rest (< 1 h) showed values of 5.55 and the samples of longer rest (24 h), values of 5.61 at 24 h after slaughter. Nanni Costa *et al*. (2002) reported higher pH values in meats from animals submitted to long rest periods (22 h) regarding the meats from their opposing parts, exposed to short rest periods (2 h) without affecting meat quality. In this way, PTE meat reduction is attained, but the extent of skin damages due to fights increases.

Pérez *et al*. (2002) stated that three hours of rest before slaughter reduce the stress in pigs, which allows obtaining meats of better quality on comparing them with those of long rest time (24 h) and without rest. Later, Carr *et al*. (2008) on contrasting rest times of 3 h and 45 min. associated the desirable pH and WHC values with the rest time of 3 h. These authors recommended that animals require, at least, 3 h of rest so as not to affect meat quality.

There were no papers related to the rest time on carcass temperature. Carcasses from the long rest time treatment registered lower final temperatures than their opposing parts. Carcasses corresponding to the short time treatment, showing higher temperature at 24 h after slaughtering, had lower pH value.

The highest fall in temperature in carcasses from the treatment with long rest time could be probably attributed to a greater space disposition between carcasses of these lots in the cooling chambers. This allows adequate circulation of the cool air and fast hot dissipation. Regrettably, it was not possible to control the density in the cooling chambers, although is known that temperature affects the pH drop, and that high temperatures favors it, an aspect related to PTE meat condition (Garrido *et al*. 1995 and Hui *et al*. 2006).

The water holding capacity defines meat quality. Specially, that destined for pork products requires water or brine incorporation. Also, it directly affects cooking losses and the amount of exuded water while present in a refrigerated counter.

Nanni Costa *et al*. (2002) on comparing long rest times (22 h) vs. short rest (2 h), found that DL decrease

with long rest time. Silva *et al*. (2005) reported in a study where various rest times (0, 2, 4 and 6 h), were evaluated, increasing pH 45 min. and WHC values as the rest was extended. These authors concluded that pH, WHC and color values, more close to expected normal values for good quality pork meat, were obtained with 2 h of rest prior to slaughter and closer transport distances (1.5 h).

In this study, WHC improved in meats with high pH coming from the long rest time treatment. The direct relationship between pH and WHC, known as effect of net charge, is extensively identified and studied. In various reviews it is stated that as pH increases, also does the meat capacity of holding or collecting immobilized water, and thus, dripping losses decrease (Warriss 2003 and Huff-Lonergan and Lonergan 2005).

Lot disparities could account for the differences found between treatments for carcass length and muscularity, since rest time lots were separated by working day.

On realizing the distribution frequency to establish the percentage of PTE, normal and DFD meats for each treatment in line with the description of Castrillon *et al*. (2007), there was greater meat percentage with normal pH in the group of short rest time, and higher frequency of meats with high pH or DFD meats in the group with long rest time. Defect incidence in the ham, that could indicate possible problems of animal welfare before slaughter, as hemorrhages and contusions, was also higher with longer rest time.

These results indicate that the best treatment was the short rest time, since animals have sufficient time for recovering from the trip stress, without reaching to be excessive, which could compromise the animal welfare. Also, the prolonged fast could exhaust the glycogen reserves and will create meats with high pH (> 5.8 at 24 h after slaughter), which will increase the incidence of dark meats or DFD. None of the treatments affected (or influenced on) the frequency of PTE (pale, tender and exudative) meats, which are linked to a sudden pH decrease due to the chronic stress before slaughter (Garrido *et al*. 1995 and Hambrecht *et al*. 2004).

It is concluded that 3 h are sufficient to calm the animals from the transport and unloading stress, allow attaining desirable pH values, besides decreasing the animal welfare problems. Increasing excessively this time enhances the possibility of dark meat occurrence with high final pH (> 6.0), since muscular glycogen reserves are more drained and the incidence of blows and contusions are higher.

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