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THE EFFECT OF INTENSIVE AND EXTENSIVE PRODUCTION SYSTEMS ON CARCASS QUALITY IN NEW ZEALAND WHITE RABBITS

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Abstract: Forty New Zealand White rabbits weaned at 30 d were divided into 2 groups and reared under intensive or extensive production system until slaughter (91 d of age). In the extensive production system, rabbits were housed in free-standing cages on straw litter and fed farm-made feed *ad libitum*. Control rabbits were raised intensively in wire mesh slatted floor cages, indoors and on a commercial pellet *ad libitum.* Hot carcass weight was 16,6% lower (P<0.01) in extensive production. The difference of 1 point both in hot and cold dressing percentage in favour of the intensively reared rabbits was not significant (P>0.05). The higher carcass weight of the control rabbits led to heavier primal cuts, including head (P<0.05) and the fore part, intermediate part and hind part of the carcass (P<0.01). However, expressed as % of carcass weight, significantly higher ratio were only found for the head (P<0.01) and edible offal (P<0.05) in intensively produced rabbits. The production systems investigated had no significant (P>0.05) effect on the chemical composition, physicochemical properties and organoleptic characteristics of meat from New Zealand White rabbits.

Key Words: rabbits, production system, carcass, meat quality.

INTRODUCTION

Lifestyle changes observed in developed countries include changes in eating habits. Consumers tend to prefer top-quality meat products characterised by a high nutritive value, a high content of easily digestible protein and low concentrations of fat and cholesterol, as well as attractive organoleptic properties (Resurreccion, 2003). According to Salvini *et al.* (1998), the mean calorific value of rabbit meat is 618 kJ per 100 g fresh tissue. Compared with red meat, rabbit meat contains less fat (6.8 g on average) and cholesterol (53 mg on average), and more protein (21 g on average). Rabbit meat also has a highly desirable fatty acid profile. It has relatively high concentrations of polyunsaturated fatty acids and low n-6/n-3 fatty acid ratio (Dalle Zotte, 2002).

An analysis of consumer expectations regarding foods of animal origin shows that consumers are concerned not only about the safety and quality of meat, but also with animal welfare. They are increasingly demanding that animals be raised under more natural conditions, which makes

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producers choose alternative, semi-intensive farming systems (Dal Bosco *et al.*, 2002; Pinheiro *et al.*, 2008). The above issues are also faced by rabbit meat producers (Dal Bosco *et al.,* 2002).

Rabbits can be raised under a wide range of production systems, from intensively in large commercial farms to extensively in small-scale farms. In the intensive system, rabbits are kept under more an less standard conditions and are fed a complete pelleted diet. In extensive systems, rabbits may be kept under more varying conditions using cages of different sizes, different stocking densities and group sizes (pens with litter, open-air pens and movable cages), and these rabbits are usually fed farm-made feed.

The aim of this study was to determine the possible effect of the intensive and extensive production system, by the comparison of 2 hypothetical scenarios, on slaughter value and meat quality in New Zealand White rabbits.

MATERIALS AND METHODS

Animals and experimental design

The study was conducted in the spring and summer, on 2 rabbit farms, A and B, located in north-eastern Poland. The experimental materials comprised 40 New Zealand White rabbits born at a similar time (±2 d), selected from litters of 6-8 young. In order to determine the effect of the intensive and extensive production systems on carcass quality parameters, the rabbits were divided into 2 groups, control and experimental, identical in terms of sex and origin.

The 30 d old weaned rabbits for the control group stayed on farm A, where they were born. The animals were kept indoor (naturally lit room with temperatures from 15 to 20°C), in wire mesh cages with a slatted floor, measuring 0.4×0.6×0.32 m in groups of 4 per cage (16.7 rabbits/m^2). As with the remaining animals on the farm, control rabbits were fed *ad libitum* a commercial pelleted diet containing 16.5% crude protein, 15.4% crude fibre and 3.1% crude fat. The diet was supplemented with 0.66 kg/t coccidiostatic robenidine. At 30 d of age, rabbits for the experimental group were transported (25 km) to a small-scale farm (B) and placed in groups of 5 in free-standing cages with wire net roof measuring 1×2×0.6 m (2.5 rabbits/m^2), on wheat straw litter. From d 30 to 60 of age, the rabbits were fed *ad libitum* farm-made feed in the following daily amounts: green forage (grass mixture) 300-400 g, barley grain and dry bread 30-40 g, hay 50-60 g. From d 60 to 90, the rations were increased to 500-600 g, 40-50 g and 60-70 g, respectively. The diet for experimental group rabbits was not supplemented with coccidiostats, and it contained approximately 16% crude protein, 14% crude fibre and 3% crude fat. Both diets were formulated so as to meet the nutrient requirements of rabbits (Maertens, 1992).

At 91 d of age, 10 males of the control and experimental group were sacrificed. Before slaughter the animals were fasted for 24 h and their live body weight was determined.

Controls

Slaughter value: After slaughter, hot carcass weight (without skin, feet, paws, thoracic cage organs, liver, kidneys, genital organs, urinary bladder and digestive tract) and the weight of: skin, digestive tract with genitourinary system, lungs with trachea and heart, liver and kidneys were control. Cold carcass weight (without liver and kidneys) was determined after chilling at 0-2°C for 24 h in a chilling chamber with no air circulation. Each carcass was dissected into: head (cutting through the occipital joint), fore part (cutting between the last thoracic vertebra

and the 1st lumbar vertebra), intermediate part (cutting behind the last lumbar vertebra), hind part (carcass part that remains after the intermediate part has been cut off the fore part; it comprises the sacral area and the rear feet). All cuts were weighed and their percentage share of the carcass was calculated. Carcass dressing percentage was determined using the following formulas:

Hot dressing percentage (%)=hot carcass weight with head/pre-slaughter weight×100

Cold dressing percentage (%)=cold carcass weight with head/pre-slaughter weight×100

Meat quality: Both dorsal muscles (*Longissimus dorsi*) were cut out from the intermediate part of the carcass to evaluate meat quality. Samples of *Longissimus dorsi* were analysed in the laboratory immediately after delivery to determine the chemical composition and physicochemical and sensory properties of the meat. The analysis of the proximate chemical composition of meat included the determination of dry matter content, total protein content by the Kjeldahl method, fat content by the Soxhlet method and ash content (AOAC, 1990). The content of nitrogen fractions in the water extracts of meat (total nitrogen and non-protein nitrogen) was determined according to the Kjeldahl method. The water extracts of meat were prepared as described by Herring *et al.* (1971). The TBARS value was determined as described by Pikul *et al.* (1989). The TBARS value was expressed as mg of malondialdehyde per kg of meat. The pH of *Longissimus dorsi* (at the last rib) was measured *in situ* using a combination Double Pore electrode (Hamilton) and a pH 340i pH-meter equipped with a TFK 150/E temperature sensor (WTW). The measurement was performed 45 min (pH_1) and 24 h (pH_{24}) *post mortem*.

Meat colour was determined based on the values of CIELAB coordinates, *L*, a*, b** and *C** (CIE, 1978). The colour space parameters *L*, a** and *b** were measured 3 times by the reflectance method with a MiniScan XE Plus instrument (HunterLab), at different points over the minced meat area. Prior to measurement, samples wrapped in oxygen-permeable and water-impermeable foil were stored for 0.5 h at 4 °C. The water-holding capacity of meat, including drip loss and cooking loss (Honikel, 1998), was determined by the Grau and Hamm method (Van Oeckel, 1999). The shear force of meat was measured using a Warner-Bratzler head (500 N, speed 100 mm/min) attached to an Instron universal testing machine (model 5542). Preparation of meat samples and shear force measurement were performed as described by Honikel (1998).

The sensory properties (taste, juiciness, tenderness) of cooked meat (Baryłko-Pikielna *et al.*, 1964) were rated by 5 trained panellists on a 5-point scale to the nearest 0.5 point, where 1=the worst result, and 5=the best result. Warm, coded meat samples (2×2 cm) were presented to panellists under fluorescent light. Water was made available to the panellists for palate cleansing.

Statistical analysis

Statistical calculations were performed using the STATISTICA software (data analysis software system), version 9.0 (StatSoft, Inc., 2009) and Student's t-test.

RESULTS AND DISCUSSION

The control rabbits kept intensively were 353 g heavier at pre-slaughter than the experimental rabbits reared extensively, but this difference was not significant (Table 1). This was due to concurrence of high individual variability in slaughter weight of animals and small group size to evaluate performance traits. The higher live body weight of control rabbits resulted in higher carcass weight (Table 1), being the hot carcasses of the control rabbits significantly heavier

Table 1. Pre-slaughter weight and carcass traits (mean and standard deviation) of New Zealand White rabbits slaughtered at 91 d of age.

	Control group[1]	Experimental group[2]
Pre-slaughter weight (g)	2320±248	1967±165
Hot carcass weight (g)	1215^{A}±131	1013^{B}±117
Cold carcass weight (g)	1182±129	981±115
Hot dressing percentage (%)	52.4±1.2	51.5±3.3
Cold dressing percentage (%)	51.0±1.2	49.8±3.2
Skin (g)	365.5^{A}±52.6	295.9^{B}±38.9
Digestive tract (g)	523.7±61.7	476.8±78.2
Liver (g)	70.80±8.76	64.60±9.24
Lungs, trachea, esophagus, heart (g)	25.40±5.14	22.10±2.88
Kidneys (g)	13.30±2.26	16.00±4.59
Head (g)	126.7^{a}±11.5	113.7^{b}±9.8
Fore part of carcass (g)	392.2^{A}±49.8	315.4^{B}±36.2
Intermediate part of carcass (g)	230.0^{A}±32.2	184.9^{B}±26.2
Hind part of carcass (g)	420.0^{A}±47.2	351.0^{B}±47.6
Edible offal (liver, kidneys, heart, lungs) (g)	109.5±10.8	102.7±10.7
Ratio of carcass parts to the pre-slaughter weight of rabbit (%)		
Skin	15.72±1.02	15.01±1.17
Digestive tract	22.99±1.53	24.28±3.93
Liver	3.05±0.19	3.32±0.64
Lungs, trachea, esophagus, heart	1.09±0.21	1.23±0.13
Kidneys	0.58^{A}±0.11	0.81^{B}±0.19
Percentage of carcass parts in the cold carcass (%)		
Head	10.89^{A}±0.76	11.8^{B}±0.7
Fore part of carcass (g)	33.6±1.6	32.7±0.4
Intermediate part of carcass (g)	19.6±1.3	19.1±1.1
Hind part of carcass (g)	35.9±1.1	36.3±1.2
Edible offal (liver, kidneys, heart, lungs)	4.73^{a}±0.25	5.26^{b}±0.73

[1] Control group: intensive production system (No.10). [2] Experimental group: extensive production system (No.=10). Values within a row with different superscript letters are significantly different, ^{AB}: $P<0.01$; ^{ab}: $P<0.05$.

(+202 g; $P<0.001$) then those from the experimental group. In a study by Niedźwiadek *et al.* (1996), the body weight of New Zealand White rabbits aged 90 d ranged from 2224 to 2978 g. The average pre-slaughter weight of control rabbits (fed a complete pelleted diet) was similar to the value (2310 g) reported by Piórkowska (2008) for rabbits slaughtered at 91 d of age. Higher body weight (2437 g and 2534 g) of New Zealand White rabbits slaughter at 85 and 91 d of age was noted by Chiericato *et al.* (1996) and Metzger *et al.* (2003), respectively. An analysis of literature data shows that the live body weight of rabbits slaughtered at the same age is affected not only by feeding intensity, but also by housing conditions. Metzger *et al.* (2003) demonstrated

that the body weight of caged rabbits was by 5% higher than the body weight of rabbits kept on deep litter. In experiments carried out by Dal Bosco *et al.* (2000) and Canquil *et al.* (2001), the above difference exceeded 10%. According to Maertens and Van Herck (2000) and Pinheiro *et al.* (2008), this could result from the increased physical activity of animals raised at lower stocking densities associated with increased expenditure of energy intended for body weight gain.

No significant ($P>0.05$) differences were found between the control and experimental rabbits as regards the hot and cold carcass dressing percentage, although they were 1 percentage point better for the control animals (Table 1). Research data show that the dressing percentage of rabbits slaughtered at the same age may vary widely. This results from the fact that the above indicator can be calculated by various methods (where carcass weight may be inclusive of the weight of head and offal, or not), as well as from the impact of genetic factors (breed, line) and environmental factors (feeding regime, housing conditions). In the present study, the hot dressing percentage of New Zealand White rabbits fed a complete pellet and those on farm-made feed mixture, both slaughtered at 91 d, were respectively 0.9 and 2.4 percentage points higher than the values obtained by Bielański (2000) for identical rabbit groups. The carcass dressing percentage of New Zealand White rabbits reported by Rymkiewicz and Lewczuk (1999) was substantially lower (47.4%) than in our experiment, which most probably resulted from extensive production conditions. In a study by Piórkowska (2008), the carcass dressing percentage of New Zealand White rabbits fed a complete pelleted diet was by 1.3 percentage point higher than in the present experiment. High values of the dressing percentage of New Zealand White rabbits (over 60%) were reported by Kujdowicz *et al.* (2000) and Metzger *et al.* (2003).

Control rabbits, in comparison with experimental rabbits, had a 19% significantly ($P<0.01$) higher skin weight (Table 1). There were no significant ($P>0.05$) differences between the groups with respect to the digestive tract and offal weights (Table 1). The total weight of edible offal (heart, lungs, liver and kidneys) in control and experimental rabbits (109.50 g and 102.70 g, respectively) was similar to the value (119 g) obtained by Piórkowska (2008). The average total weight of skin, digestive tract, liver, kidneys, heart, lungs, trachea and esophagus is comparable to the value reported by Gómez *et al.* (1998) for rabbits of five lines selected for various traits, with similar pre-slaughter weight. The ratio of the skin and digestive tract to pre-slaughter weight revealed no significant differences between the control and experimental rabbits (Table 1). In the experimental rabbits, the ratio of the kidneys to pre-slaughter weight was significantly ($P<0.01$) higher (Table 1).

The higher carcass weight of the control rabbits led to heavier primal cuts, including head and the fore part, intermediate part and hind part of the carcass than the experimental rabbits (Table 1). Except for the 1 and 0.5 percentage point higher ratios of the head and edible offal to carcass of the experimental rabbits as compared to the controls, the ratios of the other cuts to cold carcass were unaffected (Table 1). The present results, regarding the weight and proportions of cuts in the carcass, are hard to compare with the findings of other authors due to differences in the carcass dressing techniques applied. Zając (2002) noted higher values for crossbreed rabbits, in the range of 27.9 to 28.8% for the intermediate part, and 37.1 to 37.9% for the hind part.

The meat of the control rabbits had a 0.4, 0.6 and 0.15 percentage point higher dry matter, total protein and ash contents, respectively, but the difference was significant ($P<0.01$) only for the latter trait (Table 2). A high content of total protein and ash and a low fat content of rabbit meat (*Longissimus dorsi*), observed in the present experiment, were also reported by other authors

Table 2. Quality characteristic of *Longissimus dorsi* (mean and standard deviation) from New Zealand White rabbits slaughtered at 91 d of age.

	Control Group[1]	Experimental group[2]
Dry matter (%)	24.27±0.40	23.88±0.49
Total protein (%)	22.78±0.53	22.18±0.10
Ratio between water-soluble N and total N (%)	26.40±2.75	26.04±1.05
Ratio between water-soluble non-protein N and total N (%)	12.52±0.99	13.20±0.62
Fat (%)	0.33±0.15	0.27±0.10
Ash (%)	1.36^{A}±0.07	1.21^{B}±0.08
pH_1	6.54±0.26	6.51±0.35
pH_{24}	5.78±0.17	5.77±0.15
*L**	59.80±2.39	61.02±2.70
*a**	1.90±0.92	1.62±1.51
*b**	13.14±0.68	12.90±1.09
*C**	13.30±0.75	13.07±1.27
Drip losses (%)	1.59±0.83	1.41±0.51
Water-holding capacity - Grau and Hamm method (cm^2)	7.69±0.62	7.45±1.29
Cooking losses (%)	32.13±3.00	30.26±2.03
TBARS value (mg malondialdehyde/kg meat)	0.67±0.45	0.43±0.28
Taste - intensity (points)	4.15±0.34	4.00±0.00
Taste - desirability (points)	4.85±0.24	4.85±0.24
Juiciness (points)	3.80±0.42	3.65±0.24
Tenderness (points)	4.10±0.84	4.50±0.67
Shear force (N)	22.85±4.82	22.30±4.58

[1] Control group: intensive production system (No.10). [2] Experimental group: extensive production system (No.=10). Values within a row with different superscript letters are significantly different, ^{AB}: $P<0.01$.

(Dal Bosco *et al.*, 2002; Maj *et al.*, 2008; Metzger *et al.,* 2003; Szkucik and Libelt, 2006). In their studies, the concentrations of protein, fat and ash in rabbit meat were in the following ranges: 21.36-23.91%, 0.65-1.74% and 1.16-1.30%, respectively.

The water extracts of rabbit meat were characterised by a high content of nitrogen compounds (Table 2). No significant ($P>0.05$) differences were found between mean values in groups. For comparison, in an experiment performed by Daszkiewicz and Wajda (2003) in beef meat stored for 3 d at 0-2 °C, water-soluble nitrogen and non-protein nitrogen constituted only 25.79% and 12.39% of total nitrogen, respectively. One of the reasons for a high content of low molecular weight nitrogen compounds in fresh meat from rabbits could be the increased activity of the of proteolytic enzymes in the muscles.

The mean values of pH_1 (i.e.$_{45\ min}$) and pH_{24} (i.e.$_{24\ h}$) of meat from control and experimental rabbits were similar (Table 2), pH_1 was in the 6.51-6.54 range and pH_{24} oscillated around 5.78. The average values of pH_1 and pH_{24} determined in samples of *Longissimus dorsi* were lower than those reported by Maj *et al.* (2008) ($pH_{45\ min}$ 6.74-6.87, pH_{24} 5.82-5.89) and Barròn *et al.* (2004) (pH_{24} 5.8-6.3), but higher than those noted by Pla *et al.* (1998) (pH_{24} 5.61-5.63). According to Dal Bosco *et al.* (2000, 2002), the pH of rabbit meat may be affected by various factors, including pre-slaughter handling (transportation, loading and unloading, stocking density), carcass cooling rate and housing conditions during fattening.

No significant differences were observed between the control and experimental rabbits as regards the mean values of meat colour parameters *L**, *a** and *b** and the water-holding capacity of meat (Table 2). Meat from control rabbits was characterised by a slightly darker colour, a higher contribution of the red and yellow components and higher colour saturation (*C**). Similar colour lightness (*L**) of rabbit meat (*Longissimus dorsi*) was noted by Dalle Zotte *et al.* (2009) and Maria *et al.* (2004) (61.4-62.0 and 57.95-59.36 respectively), while lower *L** values were obtained by Failla *et al.* (2004) 54.68-56.79, Dal Bosco *et al.* (2002) 48.36-50.84 and Hernández *et al.* (2006) 56.1. The cited authors reported widely varied values of redness *a** (from 2.34 to 4.64) and yellowness *b** (from 1.05 to 4.18) for rabbit meat, which indicates that the above parameters may be influenced by a number of factors. The colour of meat predominantly depends on the chemical state of myoglobin (Brewer, 2004; Mancini and Hunt, 2005), which is affected by the partial pressure of O_2, the concentration of hydrogen ions (pH), temperature, light access, tissue structure, the presence of substrates and cofactors, the activity of reducing enzymes and lipid oxidation (peroxide radicals) (Mancini and Hunt, 2005). As in all slaughter animals, the colour of rabbit meat may be indirectly influenced by environmental factors related to production conditions (Dal Bosco *et al.*, 2002), pre-slaughter stress (Maria *et al.*, 2004) and muscle activity in live animals (Dalle Zotte *et al.*, 2009).

In the present study, the *b** values were 3 and more times higher than obtained by the cited authors. This is most likely due to different colour measurement devices (Hunter *vs* Minolta), which use different methods to collect and calculate colour parameters. The difference between these 2 methods is in the calculation of the values from the reflected light data. This information is incorporated into each instrumental algorithm used for calculation of colour values. These calculated values (*L**, *a**, *b**) may or may not be the same for a particular object and may or may not reflect colour changes to the same degree (Brewer *et al.*, 2006).

There were no significant differences in the TBARS value of rabbit meat between the control and experimental groups (Table 2). Meat from control rabbits was marked by an insignificantly higher content of malondialdehyde, a secondary product of auto-oxidation of polyunsaturated fatty acids. Higher TBARS values of meat (*Longissimus lumborum*) from rabbits slaughtered at 85 d of age were reported by Dal Bosco *et al.* (2002) (1.08-3.56 mg MDA kg^{-1}). The cited authors demonstrated that housing conditions (conventional bicellular cages, straw bedded-pens, wire-netted pens) affected the TBARS value of rabbit meat. They hypothesised that the lowest oxidative status of *Longissimus lumborum* in rabbits held on straw bedding was probably due to their greater locomotor activity and a more stressful environment causing enhanced production of ROMs (reactive oxygen molecular substances).

Differences in the mean values of the analysed organoleptic parameters of meat from control and experimental rabbits were statistically non-significant (Table 2). Meat from experimental rabbits was characterised by not significant higher tenderness and lower shear force. According to Dalle Zotte (2002), rabbit meat is considered by the traditional consumer to have positive sensory properties: it is tender, lean, and delicately flavoured. Nevertheless, the main cause of refusal is its typical taste of wild game meat, sometimes perceived by the consumer (De Carlo, 1998), as well as its fat content and fatty acid composition. It should be stressed that the sensory properties of rabbit meat depend on rabbit breed, muscle type (Szkucik and Pyz-Łukasik, 2008) and the age of animals (Gondret *et al.*, 1998).

CONCLUSIONS

An analysis of the effect of extensive and intensive production systems on the slaughter value of New Zealand White rabbits showed that extensive conditions contributed to a decrease in the weight of the most valuable carcass cuts. An analysis of the proximate chemical composition of rabbit meat confirmed its high nutritional value, health-promoting properties and attractive organoleptic attributes. The production systems investigated had no significant effect on the chemical composition, physicochemical properties and organoleptic characteristics of meat from New Zealand White rabbits.

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