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QUALITY OF POULTRY MEAT FROM NATIVE CHICKEN BREEDS – A REVIEW

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Abstract

The objective of the paper was to demonstrate the possibilities of using Polish native breeds of chickens for the production of meat for its specific quality features in the light of worldwide researches. The object of the analysis was the quality of meat from slow-growing chickens raised in varied housing systems, including capons and poulards. The findings of studies on the quality of poultry meat from native breeds obtained from post-production cockerels and from hens in their post egg-laying stage have shown that there are chances for their use in meat production. Native breed hens can also be used as foundation material for the production of capons, poulards or international mixed breeds for purposes of extensive farming. The body weight of native breed hens, including their muscle build depend on the bird's genotype, feeding, length of exploitation and farming system. Meat from native breed hens, raised in free-range systems has less fat, but with higher polyunsaturated fatty acids in their meat muscles as well as a healthier ratio of *n-6/n-3* PUFA acids. Outdoor free-range access influences the meat colour, i.e., bright coloured breast muscle (L*) as well as increased intensity of red coloration of leg muscles (b*). Caponisation of hens enhances intensified body weight gains along with increased fattening of meat. In comparison with cockerel meat, the meat of capons is more juicy, tender and of better taste, while poulard meat has distinctively favourable sensory values in comparison with broiler chicken meat.

Key words: biodiversity, chickens, capon, poulard, meat, quality

Considering the plentiful supply of food products in the world today, the concept of quality is of particular importance. Being a complex concept, poultry meat quality is understood in various ways and thus it is difficult to define conclusively. Poultry meat quality is made up of its safety, nutritive value and sensory characteristics. Meat safety is determined by the degree of microbiological and chemical contamina-

tion. The nutritional quality of poultry meat depends on the content of high-value protein, unsaturated fatty acids, vitamins, macro- and micronutrients, cholesterol and other biologically active compounds. Meat colour, aroma and flavour are essential sensory traits. Simply put, it can be stated that poultry meat is of good quality if it fully meets consumer expectations. Modern consumers seek meat that is low in fat, tender, juicy, with good flavour and aroma (Magdelaine et al., 2008; Dyubele et al., 2010; Loo et al., 2010; Walley et al., 2015).

Meat quality characteristics are affected, among others, by genetic factors such as appropriate choice of breed/line or commercial hybrid (Berri et al., 2005; Bianchi et al., 2006; Dal Bosco et al., 2012; Jaturasitha et al., 2008 a, b; Riedel et al., 2013; Umaya, 2014; Zhao et al., 2012) and the sex of birds (López et al., 2011). Poultry meat quality is also influenced by the rearing system (Fanatico et al., 2006; Husak et al., 2008; Araújo et al., 2011; Mikulski et al., 2011; Zhao et al., 2012; Chen et al., 2013; Moujahed and Haddad, 2013; Tong et al., 2012, 2014, 2015; Wang et al., 2009 a, b). Another important determinant of meat quality is the slaughter age of birds (Díaz et al., 2012; Tougan et al., 2013).

The objective of the paper was to demonstrate the possibilities of using Polish native breeds of chickens for the production of meat for its specific quality features in the light of worldwide researches. The object of the analysis was the quality of meat from slow-growing chickens raised in varied housing systems, including capons and poulards.

Quality of meat from native chicken breeds compared to broiler meat

The world production of poultry meat is based on raising fast-growing broiler chickens, i.e. commercial hybrids intended solely for meat production (Yang and Jiang, 2005). The intensive breeding work together with optimised feeding and housing conditions have considerably shortened the rearing period of fast-growing chickens, but a problem has arisen with the maturity of meat and its sensory and technological quality (Bianchi et al., 2006; Kijowski and Kupińska, 2013). The development of single-purpose production of chickens has marginalised dual-purpose production, thus supplanting native chicken breeds. Today, with the growing demand for poultry products from extensive systems, an opportunity arises to increase the importance of raising native chicken breeds, which are particularly suitable for free-range and organic farming because of their good adaptation to the local conditions. This is confirmed by the experience of many countries, in which native breeds of slow-growing chickens provide good-quality meat, which is in increasing demand (Fanatico et al., 2005 a, b; Youssao et al., 2009; Smith et al., 2012; Yin et al., 2013; Choo et al., 2014; Walley et al., 2015).

In practical production, meat under extensive systems was initially produced using native chicken breeds almost exclusively (Yang and Jiang, 2005). For example, in Spain use was made of native meat-type chickens, which at 10 months of age reach a body weight of about 4–5 kg and a dressing percentage in excess of 80% (Franco et al., 2012). Today, meat from extensive farming is mainly obtained from hybrids of native breeds and fast-growing lines (Youssao et al., 2009; Miguel et al., 2011; Sarica et al., 2014). Compared to the native breeds, such hybrids

are characterised by higher rate of growth, better feed conversion and greater dressing percentage while being still well adapted to the local environment, which is of particular importance in free-range systems. Consumer interest in flavoursome meat from slow-growing chickens is increasing in many countries of the world despite its relatively high price. One example is the production of "Three Yellow" chickens in Asia or "Label Rouge" chickens in France (Berri et al., 2005; Smith et al., 2012; Guan et al., 2013). According to Tang et al. (2009), production of the native chicken breeds in China is estimated to increase by 5–10% each year.

Compared to fast-growing broilers, native chicken breeds and their hybrids show lower weight gain and a smaller proportion of breast muscle in the carcass compared to fast-growing broilers, but their meat has many quality characteristics valued by modern consumers (Table 1).

Table 1. Results of selected studies comparing the meat quality traits of slow-growing native chicken breeds and fast-growing broilers

Line/ breed	Results	References
1	2	3
Sudanese native chicken ecotypes Bare-neck (BN), Large Beladi (LB), Betwil (BT) and commercial broilers (Hybro and Hubbard).	The highest levels of protein and ether extract recorded for the exotic meat strain, Hybro and the lowest recorded for the native chicken BN. Hubbard being the highest and LB and BT being the lowest for shank weight and shank length respectively.	Yousif et al. (2014)
Slow growing chickens (produced by using two heavy egg type parents BARII and RIRII and fast growing ROSS parents) were compared with commercial broilers and pure parents.	Breast muscle pH values were found higher in some crossbred groups. Breast and leg meat of ROSS genotype had higher L* values (paleness) than did those of RIRII and BARII genotypes, whereas crossbred genotypes had the lowest L* values. Breast and leg meat of ROSS genotype had the lowest a* value (redness) while crossbred genotypes had the highest b* (yellowness) values were found highest in ROSS genotype's breast and leg meats.	Sarica et al. (2014)
Thai Indigenous chicken breed: Baetong (BT), Black-boned (BB) and Praduhangdum (PD) chickens.	BB chickens and PD chickens had more edible portion and wing yield than B chickens. BB chickens and B chickens had more leg yield than PD chickens. BB breast meat had greater shear force and shear energy than B breast meat and PD breast meat. BB breast meat and skin was darker than B and PD breast meat and skin. BB breast meat had higher drip loss and lower cooking loss than the others.	Pripwai et al. (2014)

Table 1 – contd.

1	2	3
Taiwan game hens (cage, floor-pen and free-range).	The free-range group had the lowest fat content in breast and thigh meat, and the lowest calorie content in thigh meat. The crude protein and total collagen contents in thigh meat and total collagen content in breast meat of the free-range group were significantly higher than those of the cage. The meat sensory scores of flavor, chewiness and overall acceptability of both thigh and breast meat of the free-range group were significantly better than those of the other groups. Free-range displayed well-received meat quality, with higher scores for flavor, chewiness and overall acceptability for greater sensory satisfaction in both breast and thigh meat.	Lin et al. (2014)
Chinese indigenous chicken breeds (Ninghai, frizzle, Ninghai xiang, and Zhenning loquat chicken) and commercial broilers (Arbor Acres).	Better meat quality, i.e. lower shear force, shorter fibre diameter, lower drip loss, in indigenous breeds in comparison with commercial broilers.	Guan et al. (2013)
Korean native chicken (Hanhyup, KNC) and commercial broilers. KNC aged 12 wk (KNL) and 7 wk (KNS), and commercial broilers aged 5 wk (BL) and 3 wk (BS).	KNL and KNS had higher protein but lower fat content than BL and BS. The L* values of breast and thigh meat, were different between KNS and BS, whereas significant differences in both values were observed between KNL and BL. Compared to the other three types of chickens, KNS contained the highest total and insoluble collagen content.	Jayasena et al. (2013)
Ross 708 chickens were reared under standard conditions, and JA657 chickens were reared under Label Rouge conditions.	The nutritional quality of raw and cured-cooked meat was improved, whereas the technological quality of the and sensory quality of the processed products were not or only slightly affected. Lower breast yield, lower lipid content in the breast meat and a higher slaughter age – Label Rouge chickens seemed to be less efficient for *n-3* FA deposition in breast muscles than the standard chickens.	Baeza et al. (2013)
Genetic stock typical of a Label Rouge-type broiler and a conventional strain.	Much lower weight of breast muscle and slightly lower weight of leg muscle, darker colour of raw and cooked leg muscles, and lighter colour of breast muscle, higher redness (a*) and lower yellowness (b*), lower or comparable sensory score of meat.	Smith et al. (2012)
Fayoumi, Rhode Island Red (RIR), RIR × Fayoumi (RIFI) and Fayoumi × RIR (FIRI).	The breast and thigh meat composition had non-significant difference among pure and crossbred chickens. Crossbred chickens gained better body weight than Fayoumi and moderate than RIR chickens with lower mortality.	Khawaja et al. (2012)

Table 1 – contd.

1	2	3
The Korean native chickens (Woorimotdak TM, KNC) and commercial broilers (Ross, CB).	A total of 16 protein spots were differentially expressed in the breast and thigh meat between the two breeds. A total of seven protein spots were represented by different levels between the KNC and CB for breast meat. Among them three protein spots showed increases in their expressions in the KNC, while four other protein spots showed increases in the CB. All nine protein spots that were represented by different levels between the KNC and CB for thigh meat showed increases in their expression in the KNC.	Liu et al. (2012)
Savannah and Forest ecotype chicken of Benin, using Label Rouge (T55 ×SA51) as a control genotype.	The meat of the Label Rouge chickens was similar to that of the local chickens.	Youssao et al. (2012)
Castellana Negra (CN) chickens and F1 crossbred chickens (CNPN) from improved Castellana Negra hens and improved Penedesenca Negra cocks.	The protein content of the meat was similar; heavier birds (CNPN) had more fat than those slaughtered at lower weights (CNPN and CN). Adults had a higher saturated fatty acid content and the young CNPN chickens had more monounsaturated fatty acids than the CN chickens. In the CNPN adults, less water was lost during cooking.	Miguel et al. (2011)
Broiler strains: Paraíso Pedrês (PP) and Máster gris plumé – Super Pesadão (SP), utilized for semi-intensive rearing; Cobb® (C), utilized in intensive rearing systems.	C breast presented higher yellowness (b*) and redness (a*) means. PP had lower shear force values. Higher pH and shear force values were found in the meat of SP birds. Both PP and SP strains presented physicochemical and proximate composition characteristics similar to those of the C strain in the breast and thigh cuts.	Souza et al. (2011)
Chinese local chicken breed (Beijing-you; BJY) and a genetically improved broiler line (Arbor Acres; AA).	The phospholipid and essential fatty acid contents in BJY chickens were significantly higher than those in AA chickens. No differences between the breeds in the contents of polyunsaturated fatty acids, unsaturated fatty acids, protein. Breast muscle fibre diameter was significantly smaller and fibre density was higher in BJY chickens than in AA chickens. Breast muscle from 120-d-old BJY chickens was judged to have better quality of phospholipids and essential fatty acid contents and muscle fibre characteristics than breast muscle from 42-d-old AA chickens.	Zhao et al. (2011)
Italy local purebred Ancona (A) and Cornish × Ancona (CA) crossbred chickens.	The chemical composition of the breast was affected by strain only for lipid content. pH and colour were affected by crossing. The fatty acid profile of the breast did not show significant variations. TBARS (thiobarbituric acid reactive substances) values were higher in the CA.	Dal Bosco et al. (2011)

Table 1 – contd.

1	2	3
Korean native chicken WoorimatdagTM, (WM) and a commercial broiler (Ross, CB).	The crude fat contents of WM thigh meat were lower than those of CB. WM thigh meat contained higher stearic and arachidonic acid contents but lower palmitoleic and oleic acid contents compared to those of CB. The thigh meat colour CIE L* – and CIE b*– values of WM were lower. WM thigh meat showed higher collagen content, hardness, springiness, gumminess, and chewiness than CB. In a sensory evaluation, odour, taste and overall acceptance were higher, while colour was lower in WM.	Jung et al. (2011)
Broiler breeds: JA757 and New Hampshire (NH).	JA757 did best for most smell and flavour attributes, whereas NH did best for texture attributes. The flavours 'neck of pork' and 'umami' were significantly improved when JA757 was fed on the broiler feed and when the NH was given the grower feed. Meat was significantly harder and stringier when JA757 was fed on the grower feed. This was not the case for the NH.	Horsted et al. (2010)
Géline de Touraine' (GT), experimental crossbreed (EC) and 'Label rouge' (LR).	GT chickens compared with LR and EC chickens were characterised by increased carcass fatness and an increased lipid level in the thigh meat. In both breast and thigh meat the percentage of monounsaturated fatty acids was increased and the percentage of polyunsaturated fatty acids was decreased.	Baeza et al. (2010)
North Korean native chickens (NKNC), South Korean native chickens (SKNC, Woorimotdak) and commercial broilers (CB).	Chicken breast and thigh meat had a higher crude protein content than CB. The breasts of the NKNC and CB had higher pH values than that of the SKNC, but the cooking loss was higher in NKNC. The surface colour of the breast and thigh meat of the NKNC was darker and redder than that of the SKNC and CB. The total collagen content of the breast and thigh muscles was the highest in the NKNC, followed by the SKNC and CB. A similar trend occurred with breast meat hardness. Sensory evaluation did not show any differences among the three different strains of chicken except for the meat colour.	Jeon et al. (2010
Korean native chicken (KNC) and commercial broiler (CB).	The KNC thigh muscle had a lower content of crude fat and higher crude ash than the CB thigh. In regards to the fatty acid composition, the KNC breast muscle had a higher content of arachidonic acid (C20:4) than the CB.	Choe et al. (2010)

Table 1 – contd.

1	2	3
	The sensory acceptance was not significantly different between the breast and thigh of the KNC and CB. The KNC had higher cohesiveness, chewiness and gumminess than the CB, which are indicative of a unique texture property.	
Traditional English strains and commercial broiler.	Lower carcass fatness (40%), darker muscle colour, higher muscle redness (a*) and yellowness (b*).	Sandercock et al. (2009)
Local breed chickens: Chinese native breeds (Wenchang and Xianju), commercial broiler (Avian), commercial layer (Hy-Line Brown), and Chinese commercial broiler (Lingnanhuang).	Higher carcass fatness, lower thermal loss, more MUFA but less PUFA, higher inosine-5′-monophosphate content.	Tang et al. (2009)
Commercial male chickens: White mini broilers (WMB), Ross broilers (R) and Hy-Line Brown (HLB).	The rate of breast meat of the HLB was significantly lower than those of the WMB and R broilers. However, the Hy-Line brown cockerels showed higher leg meat than the others. The breast meats of the WMB presented the highest lightness value. The yellowness of the breast and redness of the leg meat of the WMB and R broilers was significantly higher than that of the HLB cockerels. The meat colour in the WMB was significantly higher than that of the HLB cockerels.	Ahn et al. (2009)
Native (White Lueyang) and modern commercial broiler strain (Arbor Acres).	There were significant differences in carcass and meat characteristics.	Liu and Niu (2008)
Thai indigenous chicken breeds: Southern Thai native, Naked-neck, Kai Dang, Blackboned and the Northern Thai native compared to commercial broiler chickens.	The indigenous chicken meat tends to have a longer time of rigor onset, with lower ultimate pH compared to broiler meat resulting in lower water holding capacity. The high content of intramuscular collagen, but which is low in myofibrillar protein content. The indigenous chicken meat has a high glutamic acid content but low fat and cholesterol contents. Indigenous chicken muscle structure has very thick perimysium connective tissue.	Wattanachant (2008)
Thai native (TH), crossbred (Thai native × Barred Plymouth Rock; THB), Barred Plymouth Rock (BPR) and Shanghai (SH) chickens.	Thigh muscle fibre of the TH had higher type I and lower type IIB whereas they were similar in breast muscle fibre. Cholesterol and triglyceride contents as well as n-3 fatty acid and the ratio of n-6/n-3 of the Thai indigenous male strain was more favourable compared to those all genotypes. Breast and thigh muscle were higher in shear force value and collagen content but the sensory evaluation was not significantly different.	Jaturasitha et al. (2008 a)

Table 1 – contd.

1	2	3
Chinese indigenous chicken breeds (Beijing fatty chicken and Jingxing 100 cross-bred chicken) and commercial broilers (Arbor Acres).	Fine-fibred muscles of small diameter and high density, which improves the sensory attributes of the meat.	Chen et al. (2007)
Local slow-growing species (Beijing You chicken, BJY). Male chickens from and commercially fast-growing strain (Arbor Acres, AA).	The impact of heat stress was breed dependent and BJY chickens showed a higher resistance to high ambient temperature, which could be related to their increased feed efficiency and deposition of abdominal fat under heat exposure.	Lu et al. (2007)
Organic laying hens; Italian dual-purpose breeds (Ermellinata di Rovigo; ER and Robusta Maculata; RM) as well as hybrid genotypes (Hy-Line White 36; HLW and Hy-Line Brown; HLB).	Local breeds presented higher live body weight and dressing percentage compared with hybrids. The RM and ER carcasses had the highest breast and leg percentage, respectively. The ER breast presented the highest lightness value and the lowest final pH value compared with the other 3 groups. The breast meat significantly differed according to genotype for almost all the studied sensorial parameters (adhesivity, fibrousness, chewiness, solubility, juiciness, tenderness, shear resistance), with the exception of aroma and odour intensity. In the thigh, genotype affected aroma, adhesiveness, fibrousness, solubility, tenderness and shear resistance.	Rizzi et al. (2007)
Autochthonous chicken breeds: Modenese (MOD) and Romagnolo (ROM) and commercial Hy Line W36.	Carcass yield was higher in MOD than in Hy-Line W36, as ROM were intermediate. Breast yield was not significantly different among breeds, as thigh + drumstick yield was higher in MOD than in ROM and Hy-Line W36. Breast meat colour showed lower b* and hue values in ROM than in MOD and Hy-Line W36 and Hy-Line. Breast meat showed higher moisture and ash content in Hy-Line W36 than in MOD, and ROM content was higher in the two local breeds than in Hy-Line W36.	Sabbioni et al. (2006)
Thai indigenous chickens and commercial broilers (CP707).	Cooking losses of indigenous chicken muscles increased markedly in the temperature range 80–100ºC and were significantly higher than those of the broilers.	Wattanachant et al. (2005 a)
Thai indigenous chickens and broiler chicken (commercial line *CP707*).	Perimysium thicknesses were 14.2 μm for biceps femoris muscle and 7.10 μm for pectoralis muscle of indigenous chicken muscles, thicker than those of broiler muscles, which were 9.93 μm for biceps femoris muscle and 3.87 μm for pectoralis muscle.	Wattanachant et al. (2005 b)
Thai indigenous chickens and commercial broilers (CP707).	Indigenous chicken muscles contained higher protein contents but lower fat and ash contents compared to broiler muscle.	Wattanachant et al. (2004)

Table 1 – contd.

1	2	3
	The indigenous chicken muscles contained more saturated and less polyunsaturated fatty acids than the broiler muscles. The total collagen contents of indigenous pectoralis and biceps femoris muscles were higher than those found in broiler pectoralis and biceps femoris muscles. The CIE system values of lightness (L*), redness (a*), and yellowness (b*) of indigenous chicken muscles were higher than those of broiler muscles. The shear values of indigenous chicken muscles either raw or cooked were higher than those of broiler muscles.	

Possibility of dual-purpose use of hens covered by gene pool protection programmes in Poland

Poland has 19 breeds/lines of laying hens undergoing conservation, which can and should be used as a source of meat (capons, poulards) or as foundation material for developing hybrids of slow-growing broiler chickens, following the "Label Rouge" example. Each of the lines covered by gene pool protection in Poland is a distinct genotype, which determines the occurrence of unique quantitative and qualitative traits which are not found in breeds selected for high productivity (Krawczyk et al., 2012).

The body weight as well as the muscling of laying and multipurpose hens differ from those of broiler chickens; they are closer to those in slow-growing chickens and depend on bird genotype, feeding system and length of productive life (Murawska et al., 2005; Murawska and Bochno, 2007). In the breast muscles of native chicken breeds the level of crude protein (over 24%) was higher than in young broilers (Wattanachant et al., 2004) but similar to that in the Spanish indigenous breed Mos.

Połtowicz (2007) and Połtowicz and Doktor (2012), who studied meatiness in hybrids resulting from the crossing of 4 lines of native chickens with Hubbard male broilers, concluded that in hybrids aged 12 weeks, the body weight varied from 2126 to 2968 g and dressing percentage was in the 70.66–76.26% range. Meat from the hybrids was juicy and tender, and the proportion of abdominal fat did not exceed 3% of carcass weight. Another type of poultry meat is that from slow-growing chickens reared for an extended period of 12–15 weeks, which have a higher proportion of breast muscle and a lower proportion of leg muscle and abdominal fat in the carcass (Połtowicz et al., 2003; Fanatico et al., 2005 a, b).

Cockerels of some conservation breeds and the hybrids of these breeds with meat-type cockerels produce meat with a good taste and dietetic qualities (Połtowicz et al., 2003). Special consideration should be given to the native strains of laying hens, namely Greenleg Partridge, Yellowleg Partridge, Polbar and heavier breeds

Sussex, Rhode Island Red, Barred Rock and New Hampshire, which can provide starting material for producing multipurpose hens for organic farms, where both laying performance and dressing percentage is valued. Puchała et al. (2014), who evaluated the quality of meat from one-year-old chickens of four conserved populations found that heavier layers, such as Barred Rock (WJ-44), New Hampshire (N-11) and Rhode Island Red (R-11), which show good muscling and dressing percentage similar to that of broilers, but have a higher fat content, are most suitable to be used for meat. Compared to the other strains, the meat of light chickens of the native Greenleg Partridge breed (Z-11) contains less fat and cholesterol, and its dark colour suggests potential culinary use in a similar way to game meat. The meat of WJ-44, N-11 and R-11 chickens was characterised by a better sensory score compared to the meat and broth from Z-11 chicken carcasses.

Due to the poor solubility of collagen fibres, the meat of intensively reared broiler chickens is not a good base for traditional broth. A study by Puchała et al. (2014, 2015) suggests that meat from one-year-old multipurpose chickens can be used to make broth that receives a high score in sensory evaluation. Gornowicz and Lewko (2010) note that meat from organically raised Yellowleg Partridge (Ż-33) and Rhode Island Red (R-11) chickens crossed with a free-range Ross meat-type cockerel is tasty and less fatty.

As already noted, world poultry meat production is dominated by white-feathered broilers owing to their rapid growth and high feed efficiency. However, interest in colour-feathered chickens is increasing with the development of organic farming and use of chickens in agritourist farms. Because of their high body weight and coloured plumage, recently there has been an increased interest in heavy strains of multipurpose hens undergoing conservation in Poland, such as the New Hampshire (N-11) and Barred Rock (lines P-11, D-11, WJ-44), which were used for backyard farming (Krawczyk et al., 2012). The appearance (plumage colour, type of comb), meat flavour and meat texture, as well as the fat content of their meat are the main attributes that attract owners of agritourism farms to purchase these type of hens. These birds are not only attractive for rural tourism but, when slaughtered at a proper age, they are a source of quality meat used for making traditional Polish dishes. The WJ-44 × N-11 hybrids were studied by Koreleski et al. (2008), who found 12 weeks of age to be the optimal period for rearing them as broilers, because at this age they have a comparable body weight and dressing percentage to those of young broiler chickens.

Capon and poulard production

Today in different regions of the world there is a growing interest in poulard and capon meat from native breed chickens or their hybrids (Lin and Hsu, 2002; Durán, 2004; Chen et al., 2006 a, b; Rikimaru et al., 2009 a, b; Díaz et al., 2010; Calik et al., 2015). The effect of breed on the quality of capon meat (Díaz et al., 2010) enables different breeds to be used for producing capons with breed-specific characteristics. Caponisation improves the quality of meat and allows local cockerel breeds to be used for meat production (Table 2).

Table 2. Results of selected studies comparing the meat quality traits of capons and uncaponised birds.

Line/ breed	Results	References
1	2	3
Lohmann Silver chickens caponised at 45 of age and slaughtered at the 26, 30 and 34 weeks of age.	Capons had a heavier breast and lighter leg than intact males. Lipid accumulation was enhanced by the caponisation and fat was stored mainly at the fat pad and the skin. The Pectoralis major muscle of capons had higher intramuscular fat content, lightness (L*) and yellowness (b*) values and lower redness values (a*).	Symeon et al. (2012)
Hinai-jidori chickens caponised at 2, 4, and 8 weeks of age and slaughtered at 26 weeks of age.	Early caponisation decreased in the daily weight gain after caponisation, thereby enabling efficient capon production from slow-growing meat-type chickens at early stages of development.	Rikimaru et al. (2011)
Layer-type Slovenian hybrid Prelux-G chickens caponised at the age of 52 days and slaughtered at the age of 185 days.	The capons had more abdominal fat. Meat physico-chemical characteristics (pH, drip loss) were similar in both groups, except for the colour. Capons had lighter and a less red colour of meat as cocks. There was no difference between the capons and cocks in the content of muscle proteins, water and intramuscular fat.	Volk et al. (2011)
Mos (Spanish indigenous breed), Sasso T-44 and X-44 (commercial strains). Caponisation at 48 days of age for the T-44 and X-44 strains and at 60 days of age for the Mos chickens; slaughtered at 5, 6, 7 and 8 months.	In breast meat, the Mos capon showed lower water holding capacity, higher drip loss and was lighter than the other breeds. In drumstick meat, the Mos capon showed lower lipid content, lower water holding capacity and was lighter and less red than the other breeds. Chemical composition, pH, water holding capacity, drip loss, colour and texture of the meat were significantly influenced by the age of the capons. The meat of the youngest birds showed higher ash content, higher pH, lower water holding capacity, higher drip loss, higher lightness and lower shear test values than that of the older ones.	Díaz et al. (2010)
Redbro broilers caponised at 3 weeks of age and slaughtered at 18 or 24 weeks of age.	Capons had heavier livers than intact males. Caponisation resulted in increased skin-fat weights of the thigh and the breast. Caponisation had no effect on pH 24 h post-mortem and cooking loss. Capons' breasts had lower shear values and displayed lighter, more yellow, and less red meat than that of intact males.	Symeon et al. (2010)
Hinai-jidori chickens (cross between a Hinai-dori sire and Rhode Island Red dam) caponised at 8 weeks of age and slaughtered at 26 weeks.	Caponisation caused its meat to be fattier and decreased its redness as compared with males. Caponisation resulted in a change of the fatty acid profile of the thigh meat, which was similar to the meat from females. Capon meat became tenderer when compared with an uncaponised bird and similar in tenderness to the female. Capons had less connective tissue and thin endomysium as compared with males.	Rikimaru et al. (2009 a)

Table 1 – contd.

1	2	3
Hinai-jidori chickens (cross between a Hinai-dori sire and Rhode Island Red dam) caponised at 8 weeks of age and slaughtered at 22, 26, 30 weeks of age.	In the carcass traits, the capons showed a higher proportion of whole leg and total meat than the females at 26 and 30 weeks of age. The capons had heavier abdominal fat weight than the male at 26 weeks of age.	Rikimaru et al. (2009 b)
Tibetan Chicken caponised or sham-operated at either 6 weeks of age (early) or 18 weeks of age (late) and slaughtered at 24 weeks of age.	The caponised group showed significant increases in terms of intermuscular fat deposits, subcutaneous fat thickness, liver weight, triacylglycerol concentration and abdominal fat weight at 24 weeks of age compared with the intact and sham groups. Later caponisation resulted in a significant increase in liver weight, abdominal fat weight, total cholesterol and triacylglycerol concentrations. In both trials the capons exhibited lower leg muscle weight than did the intact. There were no significant effects on breast muscle weight of either the early or late caponisation.	Shao et al. (2009)
Hubbard (meat-type strain) × Golden Comet (egg-type strain) caponised at the age of 45 days and slaughtered at the age of 26 weeks of age.	Capons exhibited the highest values of breast and thigh meat lightness and yellowness as well as the lowest values of redness compared with cocks. Capons and slips presented lower Allo Kramer shear values of cooked breast meat in comparison with cocks. Capons showed a higher content of total lipid, cholesterol and ash in both breast and thigh meat. Capons exhibited a significantly higher content of linoleic and linolenic acids and lower content of arachidonic, eicosapentaenoic, docosapentaenoic and docosahexaenoic acids in respect to slips and cocks.	Sirri et al. (2009)
Castellana Negra chickens caponised at 8 weeks of age and slaughtered at 29 weeks of age.	Caponisation did not result in weight improvements. Heavier pectoral muscles in capon than in uncastrated birds, but no differences in thigh and drumstick weight and length. Capon meat showed a higher fat content than that of the cocks, making it juicier and less fibrous. No differences were found in fatty acid content (C 14:0, C 18:0, C 18:1, C 18:2). No differences in colour measurements, pH or water loss from the meat.	Miguel et al. (2008)
Single Comb White Leghorn caponised at 3 and 12 weeks of age and slaughtered at 16 and 26 weeks.	Caponisation significantly increased the protein content of the pectoral major muscle, but decreased the ash content. Early caponisation (3-weeks-old) only increased the weight and protein content of the pectoral major muscle with decreased ash content in 16-week-old capons. Late caponisation (12-weeks-old) showed no effects on pectoral major muscle quantity.	Chen et al. (2007)
Taiwan country chicken caponised at 8 weeks of age and slaughtered at 26 weeks of age.	The weight of the slips was between that of the capons and intact males, but was heavier than that of the capon. The live-weight, carcass weight and shank perimeter in the capons were higher.	Chen et al. (2006 a)

Table 1 – contd.

1	2	3
	The abdominal fat weight of the capons and females were heavier than that for intact males; the slips were between the capons and intact males. The percentage of low-density lipoprotein (LDL) was lower than that in intact male chickens.	
Taiwan country chickens caponised at 8 weeks of age and slaughtered at 26 weeks of age.	The abdominal fat and relative abdominal fat weights of capon were significantly heavier than intact and sham while the tibia weight and relative weight were the lightest.	Chen et al. (2006 b)
Extremeña Azul chickens caponised at 60–64 days of age, and slaughtered at 32 weeks of age.	Capon body weight was significantly lower than that of roosters. No significant differences in the corresponding percentages of abdominal fat and eviscerated carcass. No significant differences were detected in capon and rooster meat organoleptic characteristics.	Durán (2004)
Nara chickens caponised at 4 weeks of age and slaughtered at 16 weeks of age.	The weight gain was significantly increased in caponised birds compared to non-caponised birds. Caponisation is the most suitable technique to have maximum meat from the chicken.	Rahman et al. (2004)
Taiwan country chicken caponised at 10 weeks of age and slaughtered at 28 weeks of age.	The capons had greater tenderness in the breast and thigh muscles. No differences were associated with cooking loss, muscle chewiness, and elasticity. The capons had a significantly smaller fibre diameter in the Pectoralis major, but were not significantly different in the fibre diameter of the Gastrocnemius pars externa.	Lin and Hsu (2002)

It also appears that in Poland, some strains of hens involved in the conservation programme could be used for producing capons and poulards. Their meat, which has high sensory attributes, was considered an exclusive delicacy in traditional Polish cuisine, as confirmed by the multitude of recipes in old cookbooks and culinary guides. The use of the native chickens breeds Greenleg Partridge and Yellowleg Partridge for capon production has been the subject of research (Calik et al., 2015; Calik, 2015; Kwiecień et al., 2015). Capons increased their rate of weight gain but at the same time their meat became fattier and its nutritive value was no higher than in cockerels. However, capon meat received high scores for juiciness, tenderness and taste compared to cockerel meat (Calik et al., 2015).

Poulards are raised in several European countries (including France, Spain and Italy) and poulard dishes are served at both restaurants and agritourist farms, where they are a major attraction for gourmets. In these countries the chickens used for poulard production are native breeds with a relatively high body weight (3–5 kg). There is no literature on the production results and meat quality of poulards, and limited information regarding production technology appears in a few guides for Spanish breeders. Studies on poulard production from native breeds chickens have also been started in Poland (Obrzut et al., 2014). In the first stage, it was evaluated if

pure, native breeds of multipurpose hens with a high body weight can be used for this purpose, because no native meat breeds are available in Poland. The sensory evaluation of this meat has confirmed its unique flavour and delicacy, and the taste panel unanimously agreed that poulard meat has more favourable sensory characteristics than broiler meat.

Effect of free-range production of native breed chickens on meat quality

The quality of poultry carcasses and meat can be also influenced by the production system (Fanatico et al., 2005 a; Husak et al., 2008; Gornowicz and Lewko, 2010; Dal Bosco et al., 2012; Bogosavljević-Bošković et al., 2012). The intensive rearing system has drastically reduced not only the number of native breed chickens, but also the diversity of poultry products offered to consumers. One way to increase the variety of poultry products for the modern consumer is to develop extensive production systems, in particular free-range and organic farming. From the nutritional standpoint, the meat of slow-growing birds is healthier (less fat and higher content of *n-3* PUFA) and thus might better fit with the consumer's expectations of organic products (Sirri et al., 2011). Legal regulations on organic poultry production cover many areas including chicken feeding principles and rearing conditions, obliging poultry producers to provide free outdoor access and to reduce stocking density. Adherence to strict organic production requirements ensures that the meat is free of substances detrimental to health and has a beneficial effect on meat quality. Organically-raised poultry meat is low in fat, has the colour, flavour and aroma desired by the consumers, and is characterised by an *n-6/n-3* PUFA ratio that is good for human health (Gornowicz and Lewko, 2010; Dal Bosco et al., 2012; Smith et al., 2012), which additionally reduces the profitability of rearing and makes this product less accessible to lower-income consumers.

Cheaper products can be obtained from birds kept in environmentally-friendly systems, in which housing and feeding requirements are less rigorous than in organic systems, and birds have free access to outdoor space, which improves the quality of the products obtained. A special form of free-range husbandry in Polish conditions is backyard farming, which had been common until the 1950s but gradually declined in importance later on. Today, backyard farming of laying hens is of minor importance in global poultry production because the products are mainly used for self-supply of agricultural farms. The birds recommended for backyard farming are mainly native breed chickens and their hybrids which quickly adapt to extensive husbandry conditions and are willing to use grass areas (Krawczyk et al., 2012). Increased locomotor activity of the birds in outdoor areas generally reduces their body weight and fatness (Gornowicz and Lewko, 2010; Smith et al., 2012; Puchała et al., 2015), because free-range birds more often peck grass and less often consume feed and rest compared to birds without outdoor access.

Consumers believe that poultry meat from extensive systems is flavourful because the diet of hens contains many additional nutrients that birds consume on the free range, which has a positive effect on the flavour, aroma as well as colour of the meat. Colour is an important attribute by which consumers judge the carcass. Yellowleg Partridge, Rhode Island Red and New Hampshire are chickens with

a genetically determined yellow colour of the skin, which consumers associate with the carcasses of free-range chickens (Puchała et al., 2014). Tong et al. (2015) showed that, in local breed chickens, increasing outdoor access days advantageously affects body weight gain, breast yield as well as the lightness (L*) of breast meat and the redness (a*) of leg meat. In a study by Puchała et al. (2015), the free-range production system allowed native chickens to eat vegetation containing xanthophylls which were deposited in subcutaneous fat; this increased the colour intensity of carcasses and of the broth cooked from these carcasses, making them more yellow as desired by the consumers. Also Fanatico et al. (2005 a) found skin colour intensity to increase in slow-growing birds having access to the free range. What is more, Puchała et al. (2015) showed that the free-range production system of Greenleg Partridge and Rhode Island Red chickens reduced carcass fatness and increased the proportion of both *n-6* and *n-3* polyunsaturated fatty acids (PUFA) in breast and leg muscles, without causing any significant changes in the content of saturated fatty acids. Among PUFA, the meat of free-range chickens was found to contain relatively high amounts of linoleic acid $C_{18:2n-6}$, which were higher than in native Spanish chicken breeds (Franco et al., 2012) but similar to the level in three out of six different varieties of organically-raised broiler chickens, as reported by Dal Bosco et al. (2012).

Many research findings indicate that initial muscle pH determines some physicochemical traits such as water holding capacity, colour, cooking loss or tenderness of heat-treated meat (Jakubowska et al., 2004). However, the results of studies concerning the pH of meat in different production systems are inconsistent. Puchała et al. (2015) and Michalczuk et al. (2014) reported no effect of the rearing system on pH, whereas Gornowicz and Lewko (2010) found lower pH values in free-range chickens.

A similar situation exists for water holding capacity, which in the meat of one-year-old free-range chickens was small (Puchała et al., 2015) and much lower than in broiler chickens (Bogosavljević-Bošković et al., 2012). Neither Puchała et al. (2015) nor Michalczuk et al. (2014) found any effect of breed and rearing system on the water holding capacity of breast and leg muscles, whereas Gornowicz and Lewko (2010) and Mikulski et al. (2011) noted a decrease in the water holding capacity of leg muscles from broiler chickens having access to the free range.

In the meat of one-year-old native breed chickens, higher cooking loss was found for leg muscles than breast muscles (Puchała et al., 2015), and these findings conform with the results of studies with broilers (Gornowicz, 2008) and slow-growing chickens (Połtowicz and Doktor, 2012).

Shear force, which reflects meat tenderness, is correlated directly with bird age, which is why the results obtained by Puchała et al. (2014) with one-year-old chickens are considerably higher than for the meat from young broiler chickens (Fanatico et al., 2005 b; Połtowicz and Doktor, 2012). Michalczuk et al. (2014) suggest that the shear force of broiler meat increases under the organic production system and this tendency was also observed for the meat of one-year-old chickens (Puchała et al., 2015).

An environmentally-friendly production system, which shares some characteristics with the Polish backyard farming system, is ‘Label Rouge’; typical of French ag-

riculture, it is impressively organised with continually increasing sales (Magdelaine et al., 2008). The originality of this method consists in combining the elements of traditional poultry farming with special procedural care for quality of the end product (Raynaud and Valceschini, 1997; Westgren, 1999). Products can be labelled as Label Rouge and sold at a higher price if they meet the minimum requirements specified by the French Ministry of Agriculture (Farmer et al., 1997; Lewis et al., 1997). Label Rouge involves farming slow-growing chickens, which are fed high amounts of grains and reared at low stocking density with access to the outdoor area until 81 days of age (Lewis et al., 1997). The Label Rouge system produces poultry meat which has better flavour compared to meat from conventional broiler production (Duclos et al., 2007; Fanatico et al., 2007). The meat from Label Rouge chickens is less fatty, contains more intramuscular collagen and has the flavour, aroma and colour desired by consumers. It is estimated that, in France, half of the poultry carcasses sold come from the "Label Rouge" system.

The meat of native breed chickens raised under the extensive system with access to outdoor runs covered with vegetation may be a good raw material for making regional products, which are very popular among consumers (Grashorn, 2007; Fanatico et al., 2006).

Conclusions

The practical use of native breed chickens at risk of extinction is an efficient method of their protection. These chickens not only provide good quality eggs but are also a source of good quality meat, especially when raised under extensive conditions with outdoor access. Moreover, the use of native breed chickens in extensive (outdoor and organic) production systems increases the diversity and attractiveness of poultry products on the food market. The body weight of native breed hens, including their muscle build depend on the bird's genotype, feeding, length of exploitation and farming system. Meat from native breed hens, raised in free-range systems has less fat, but with higher polyunsaturated fatty acids in their meat muscles. Outdoor free-range access influences the meat colour. Native breed chickens could be used as a foundation material for producing capons, poulards or interstrain hybrids for extensive rearing. Caponisation of hens enhances intensified body weight gains along with increased fattening of meat. In comparison with cockerel meat, the meat of capons is more juicy, tender and of better taste, while poulard meat has distinctively favourable sensory values in comparison with broiler chicken meat.

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