

STOCKING DENSITY – FACTOR OF PRODUCTION PERFORMANCE, QUALITY AND BROILER WELFARE

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Invited paper

Abstract: Significance of stocking density in broiler production i.e. production performance, vitality and health condition of chickens, was established at the beginning of development of industrial poultry production. However, considering intensive development of selection work and creation of more productive genotypes which, at the same time, were more demanding in regard to rearing conditions, the current importance of this research is not diminished. In favour of this statement is also the complexity of the effect of stocking density which is direct, indirect, and interacted with other factors of rearing, which eventually reflects on all aspects of broiler production: economical efficiency, quality of products and broiler welfare aspects. In the paper a review of research results is presented with general objective to define optimal stocking density in broiler production based on comparison of effects on production performances, parameters of carcass quality and indicators of broiler welfare.

Key words: broiler, stocking density, production performance, quality, welfare

Introduction

Relatively great number of research papers are focused on the effect of stocking density in broiler production and were primarily motivated by its great economical importance (*Proudfoot et al., 1979, Shanawany 1988*), also factor of carcass quality (*Edriss et al., 2003; Yadgari et al., 2006; Škrbić et al., 2006, 2007, 2008a,b,c*) and in recent period, as factor of poultry welfare (*Weeks et al., 2000; Thomas et al., 2004; Škrbić et al., 2009*).

Based on carried out research, determined ratio between produced kilograms of live mass per m² of floor surface, increase of stocking density increases production at the level of 1250 grams (*Edriss et al., 2003*), i.e. 1750 grams (*Thomas et al., 2004*) per each added bird in the box. Although in higher stocking densities the profit per chicken decreases, total production of meat per unit of floor surface increases, which results in higher profit. Higher economical

efficiency of broiler production in higher stocking densities (*Mirabito et al., 2002; Mortari et al., 2002*) with possibility to regulate environment conditions using modern equipment caused long lasting trend of its increase.

In many countries, stocking density in broiler production is not regulated, but top limiting values are determined which don't exceed 35 kg/m² (*Elwinger 1995*). In practice, applied stocking densities don't exceed the recommended values since economical optimum of broiler production is on higher stocking densities regardless of the effect on growth rate and fact that broiler welfare is progressively compromised.

Scientific basis for recommended stocking density in commercial broiler production is not unanimous.

Development of the awareness of poultry welfare, 30 years ago first in North European countries, was primarily focused on cage housing system of layer hens. Regulations were issued at national and international level which banned use of cage system of housing, and defined production systems which are based on animal friendly, human relation to animals. Welfare of farm animals contributes to perception of the quality of products by consumers which are advocating that maintenance of high welfare standards results in high quality of products (*Sundrum, 2001*).

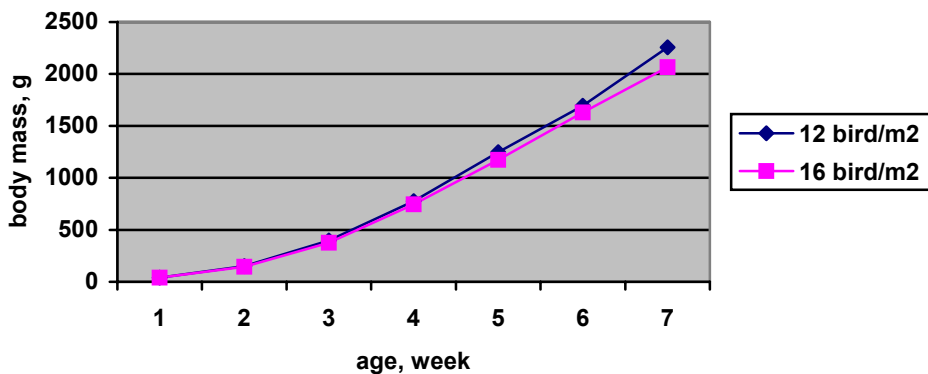
Interest in qualitative aspect of production of poultry meat is in the greater increase than interest in quantitative aspect. In spite of relatively low price of poultry meat deriving from intensive production, consumers have realized the significance of product from non-industrial systems, which beside more human rearing conditions for broilers provide also high nutrition level and health safety of the product. At the same time, such systems of production have strictly defined standards, country specific, which relate to chicken genotype, use of pasture, maximum stocking density, age of birds at slaughter, nutrition (*Fanatico et al., 2007*), which eventually limits the volume of production and satisfies the needs of one part of the market.

By optimalization, i.e. improvement of some of rearing conditions, primarily stocking density, it is possible even in intensive broiler production to satisfy all three aspects of poultry meat production to some extent (quantitative, qualitative and welfare aspect).

The effect of stocking density on production performances

The significance of stocking density in broiler production, i.e. production performances, vitality and health condition of broilers was established at the beginning of the development of industrial poultry production. However, considering intensive development of selection work and creation of more productive genotypes which, at the same time, were more demanding in regard to

rearing conditions, the current importance of this research is not diminished, especially if certain interactive effects of stocking density and other rearing factors are taken into consideration. Stocking density is considered as one of the most important environment factors because of the established effect on growth rate of broiler chickens. Results of previous researches confirm the effect of stocking density primarily on body mass, but also consumption and conversion of feed. At the beginning, it was not clear if the effect of stocking density on final body mass is in relation to size of feeding space, but results of Škrbić *et al.* (2006) confirmed the negative effect of high stocking densities in equal space on feeding per chicken, which excluded the effect of this factor on body mass. In favour of this, also significant effect of stocking density on intensity of chicken growth in first weeks of age of chickens was established (Škrbić 2007), when feeding space in no way can be the limiting factor.



Graph 1. Growth curve of broiler chickens under the influence of applied stocking density (Škrbić, 2007)

Results of numerous researches indicated negative effect of high stocking densities on final body mass of broiler chickens (Cravener *et al.*, 1992; Lewis *et al.*, 1997; Edriss *et al.*, 2003; Mortari *et al.*, 2002; Mendes *et al.*, 2004; Škrbić *et al.*, 2007c). Results vary depending on the applied stocking densities. Also insignificance of results in regard to final body mass of broilers in stocking densities of 10 and 13 bird/m² per floor surface was established, whereas differences between 10 and 16 bird/m² were significant (Škrbić *et al.*, 2009). Similar results are stated also by Edriss *et al.* (2003), Thomas *et al.* (2004). With the growth of broilers the effect of stocking density intensifies (Cravener *et al.* 1992; Edriss *et al.* 2003; Škrbić, 2007). In the paper by Dozier *et al.* (2005), to the age of broilers of 17 days, high stocking density had positive effect on growth rate

which can be perceived through increased creation of metabolic energy with each added chicken per box, which young chickens can use for growth. Rapid growth of broiler chickens is result of increased food consumption and metabolism which leads to increased creation of heat (*Yadgari et al., 2006*). In order to achieve adequate food consumption and intensive growth it is necessary to enable broilers uninterrupted emission of heat. Heat sensitivity increases at higher stocking densities of chickens because of increased temperature of litter and limited circulation of air around chickens. Except this direct effect, stocking density indirectly influences the creation of micro climate in the facility and forming of other environment factors. *Elwinger (1995)* defined them as factors of the farm and pointed out significant effect of season when optimal stocking density is determined in broiler production, which according to *Mendes et al. (2004)* is 16 bird/m² of floor space for winter period and 10 birds/m² for summer period. Similar results are stated by *Galobart and Moran (2005)*.

Contrary to final body mass of broilers where there is concordance between results obtained by numerous authors confirming general negative effect of high stocking densities, efficiency of food utilization in different stocking densities of broilers can be discussed. Better efficiency of food utilization in higher stocking densities was established by *Lewis et al. (1997)*, *Edriss et al. (2003)*, whereas *Andrews et al. (1990)* established higher feed conversion in conditions of higher stocking density. *Škrbić (2007)* established better feed conversion in all stages of broiler nutrition in higher stocking density, *Thomas et al. (2004)* only during starter phase, and at the end of trial, at the age of 35 days, differences were below the level of significance. Absence of the effect of stocking density on consumption of food per unit of gain of body mass was concluded also by *Mortari et al. (2002)*, *El-Deek and Al-Harhi (2004)*.

In regard to mortality, majority of authors established no statistical dependence of this trait on stocking density, although it should not be overlooked that percentage of died broilers increases with the increase of stocking density (*Škrbić, 2007*), especially in stocking densities above 10 bird/m² (*Thomas et al., 2004*). In investigation of the effect of stocking density in production conditions of large farms, *Hall (2001)* established significant increase of mortality with the increase of stocking density. It is possible that in conditions of high stocking density mass hysterical behaviour of chickens occurs with harmful effects on their vitality, which is not occurring in experimental conditions.

The effect of stocking density of carcass quality

For long time researches were directed towards the possibility of improvement of production performances, in the field of genetics and selection as well as control of nutritive and rearing factors. Progress was obvious: broilers

realized increasingly higher body masses with lower consumption of food and production cycles were becoming shorter.

Primary goal of broiler production, i.e. production of chicken meat, is to satisfy, with minimum costs, from the quantitative and qualitative aspect, the market which is becoming more demanding. Therefore, in literature numerous definitions of quality can be found (*Pavlovski et al., 1992*) which evolve with the development of consumer awareness of certain segments of this production.

Results of research showed that carcass and meat quality properties are under significant effect of biological factors which are determined by genetic potential, sex and age of the animal (*Škrbić et al., 2007a*) and conditions of rearing and nutrition in different housing systems (*Škrbić et al., 2007b*).

Rearing conditions on farm demonstrate very significant effect on quality of carcass. In commercial broiler production high stocking density is greatly responsible for the level of increase of body mass, and in this way also for size and conformation of carcass, problems with legs, skin damages, i.e. parameters of carcass quality.

Rearing of broilers in lower stocking density provides more intensive growth and higher absolute yield of processed carcass (*Škrbić et al., 2008*), better body development, i.e. carcass conformation which represents basis for development of musculature and higher shares of carcass parts which contain more meat, especially breast (*Škrbić et al., 2009*). Response of relative indicators of carcass yield and content of abdominal fat on decrease of stocking density was not registered in the paper by *Dozier et al. (2005)*, whereas mass of processed carcass decreased linearly with the increase of stocking density.

Independence of carcass yield in regard to increase of stocking density was concluded in paper by *Mendes et al. (2004)* but with significant increase during winter season in both sexes, which indicated the conclusion on positive effect of lower stocking density in less favourable environment conditions, such as high temperatures during summer season.

Index values of conformation measures which represent the ratio of body mass and certain linear measure as comparable indicators of body composition (*Pavlovski et al., 2006*), indicate positive effect of lower stocking density on length of tubular bones, development and roundness of breast, development of hind extremities. Breast angle, although it represents genetic trait, was improved in conditions of lower stocking density (Table 1). The effect of stocking density was confirmed in both sexes, however in males it was more expressed ($p < 0.01$) compared to female sex ($p < 0.05$), which confirms the statements of *Bhardway and Mohapatra (1996)* on significant effect of sex on conformation of broiler carcass from five genotypes reared in different stocking densities. Research results obtained by *Dozier et al. (2006)* showed that increase of stocking density from 5 kg/m² to more than 25 kg/m² causes decrease of the mass of breast meat by 12 g. Similarly, *Garcia et al. (2002)* report of negative effect of increased stocking density on length, width and depth of breast.

Table 1. Index values of broiler carcass conformation measures differentiated according to sex in different stocking densities (Škrbić et al., 2009)

Conformation measures	Stocking density, bird/ m ²	
	12	16
Males (x ± Sd)		
BM/SL, g/mm	31.12 ± 2.49**	29.37 ± 2.23
BM/KL, g/mm	23.93 ± 2.25**	22.58 ± 2.08
BM/BD, g/mm	24.44 ± 1.97**	23.10 ± 1.68
Breast angle, degrees	115.60 ± 5.84	114.16 ± 8.24
BM/BG, g/mm	16.28 ± 1.26**	15.35 ± 0.93
Females (x ± Sd)		
BM/SL, g/mm	28.53 ± 2.12*	26.85 ± 2.10
BM/KL, g/mm	21.98 ± 1.79*	20.48 ± 1.89
BM/BD, g/mm	22.23 ± 1.33*	21.04 ± 1.73
Breast angle, degrees	116.31 ± 5.49	114.34 ± 4.16
BM/BG, g/mm	14.60 ± 1.02*	13.73 ± 1.08

** Significance of differences between average values at the level of $p < 0.01$

* Significance of differences between average values at the level of $p < 0.05$

Table 2. Share of major carcass parts in body mass of broilers reared in different stocking densities (Škrbić et al., 2009)

Share, % BM	Stocking density, bird/ m ²	
	12	16
Males (x ± Sd)		
Breast	20.54 ± 1.34*	19.83 ± 1.68
Thighs	9.87 ± 0.58	9.88 ± 0.71
Drumsticks	11.51 ± 0.55	11.69 ± 0.65
Females (x ± Sd)		
Breast	21.10 ± 1.13**	20.46 ± 1.19
Thighs	9.48 ± 0.51	9.35 ± 0.73
Drumsticks	11.41 ± 0.65	11.67 ± 0.53*

** Significance of differences between average values at the level of $p < 0.01$

* Significance of differences between average values at the level of $p < 0.05$

Better body development of chickens reared in lower stocking density, especially of breast part, causes significantly higher share of breast in both sexes (Table 2). However, better development of hind limbs expressed through value of thigh girth doesn't follow adequately the increase of body mass, so that the share of thighs and drumsticks would increase significantly. Similar results were obtained by *Lewis et al. (1997)*.

Quality of broiler carcass from conventional production was often diminished because of deformed and broken legs. *Gregory and Wilkins (1990)* have pointed out this problem in Great Britain where 95,5 % of broilers in supermarkets had in average 3,4 broken bones in their carcass. Weakness of legs is term used, according to *Sorensen (1999)* to describe series of sub optimal rearing conditions and it is of multi-factorial origin. Beside the effect of continuous selection of broilers on rapid growth and higher share of breast in carcass, which resulted in significant conformation changes of the present broiler type in relation to previous types (*Reddish and Lilburn, 2004*), problem is often in metabolic disbalance (*Julian, 1998*) in relation to certain specific nutritive substances necessary in conditions of rapid growth, reduced physical activity of broilers (*Lewis et al., 1997, Sorensen et al., 2000*) and mechanical injuries in high stocking densities, which are more frequent in rapid growing genotypes, considering insufficient development and maturity of the skeleton.

By providing of more floor space per chicken, it is possible to influence the level of physical activity and development and firmness of the skeleton, especially legs. Physical activity of broilers influences morphometric bone parameters, i.e. cross section of cortex and in this way improves their mechanical characteristics by better supply with blood of epiphysis of long bones and adequate mineralization (*Vitorović, 1992*). In accordance with this, strength of tibia expressed through value of breaking force is higher in chickens reared in lower stocking density (*Škrbić, 2007*). If the quality of bones is defined based on specific breaking force which eliminates the effect of body mass and primary is based on ratio between the cortex surface and medullar cavity, and not entire surface of diaphysis, significantly lower effect of stocking density can be concluded. However, majority of authors prefer breaking force to specific breaking force as quality parameter, because of established strong correlation with content and concentration of ashes in the bone (*Kim et al., 2004*).

The effect of stocking density on broiler welfare

Development of awareness of animal welfare in intensive broiler production, in the last several decades, resulted in great social pressure to provide minimum conditions in regard to welfare, where stocking density was perceived as

one of more important factors. As consequence of this, most of researches today in regard to stocking density are from the aspect of animal welfare factor.

Minimum standards in relation to broiler welfare are primary focused on area for movement of broilers as main prerequisite for development of locomotive apparatus and expression of basic forms of behaviour (*Directive 2007/43/CE*).

Trend of decrease of the growth rate in broilers registered in high stocking densities, as well as parameters of production performance, present significant indicators of welfare. Certain authors (*Sorensen et al., 2000, Dozier et al., 2006*) suggest that reduction of final body mass can be connected to decrease of food consumption because of difficult access to feeding space in conditions of high stocking density. However, in experiment carried out with the purpose to determine the effect of air circulation and air temperature, *Dozier et al. (2005a)* established reduced final body mass as a result of decreased appetite connected to worsening of environment conditions, which are characteristic for high stocking density.

Health of legs and walking ability are reliable indicators of total welfare in poultry (*Sanotra et al., 2001, 2002*). Gait scores is parameter used to evaluate the walking ability (*Kestin et al., 1992*) and it decreases with the increase of stocking density. Especially, number of chickens scored 4 and 5, which indicates seriously compromised walking ability, is significantly higher when space is less than $0.0625\text{m}^2/\text{bird}$ (*Sorensen et al., 2000*). In the paper by *Škrbić et al. (2009)* in general, no problems with walking ability of chickens in investigated stocking densities were observed (10, 13, 16 bird/m²). However, in such situation, frequency of certain scores in groups indicates certain influence of stocking density, as well as of age which reflects the effect of body mass of chickens on walking ability. Chickens at the age of 3 weeks in groups of lower stocking density weren't scored higher than 2, which indicates walk i.e. movement without serious problems in regard to manoeuvre ability and speed. However, in group with higher stocking density, in 2.78 % of evaluated chickens significant disturbance in walk was observed. In the same group, but at the age of 6 weeks, 4% of evaluated chickens were not able to walk. Main cause of this can be lack of physical activity of chickens as consequence of lack of space in higher stocking density and genetic predisposition to reach high final body masses which are in disbalance with the development of locomotive apparatus (*Sanotra et al., 2001; Petersen, 2004*).

Also, broilers in high stocking densities have higher frequency of foot pad lesions and hock burns, and both parameters are in correlation with poor gait score (*Sorensen et al., 2000*).

With the increase of stocking density quality of litter diminishes significantly (*Thomas et al., 2004*), expressed through content of dry matter and temperature, which is known as factor of leg health. Broilers spend during day approx. 76-86 % of total time lying on the litter. In conditions of high stocking

density, as well as with the age, i.e. increase of body mass, this percentage reaches the top limit (*Weeks et al., 2000*).

At the same time with the increase of temperature and moisture content, physical and microbiological characteristics of litter change, which are significant for incidence of contact dermatitis caused by bacterial infections, especially *Staphylococcus aureus* and *Escherichia coli* (*Butterworth, 1999*). However, correlation between moisture content of litter and incidence of serious foot-pad dermatitis was not significant in the research of *Eichner et al. (2007)*, which indicates that for the incidence of foot pad dermatitis other factors are important, such as type of litter, nutrition factors, growth dynamics (*Petersen, 2004*).

Table 3. Average temperature and humidity content of litter in investigated broiler stocking densities (*Škrbić et al., 2009*)

Stocking density, birds/m ²	Average temp., °C		Average content of humidity (%) in 6 week
	3 weeks	6 weeks	
10	21.75	29.66	42.49
13	22.50	30.83	49.59
16	22.67	31.83	54.76

Conclusion

In conclusion, the extreme complexity of the effect of stocking density in broiler production is evident. Results of numerous papers clearly indicate negative effects of high stocking densities not only on production performances and parameters of quality, but also on parameters which are considered reliable indicators of broiler health and welfare. However, for the purpose of defining optimal stocking density it is necessary to realize differences in effects depending on the broiler genotype, environment conditions, duration of production cycle (final body masses), season, management conditions. At the same time, stocking density directly influences the economical efficiency of broiler production, which imposes the need to find compromise, considering the suggestions of majority of authors on top limits at the level of 30-35 kg/m².

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Gustina naseljenosti – faktor proizvodnosti, kvaliteta i dobrobiti brojlera

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Rezime

Značaj gustine naseljenosti za brojlersku proizvodnju, odnosno za proizvodne performanse, vitalnost i zdravstveno stanje pilića, utvrđen je još s početka razvoja industrijskog živinarstva. Međutim, s obzirom na intenzivan razvoj selekcijskog rada i stvaranje sve produktivnijih genotipova, koji su istovremeno zahtevniji u odnosu na uslove gajenja, ne umanjuje se aktuelnost ovih istraživanja. U prilog tome je kompleksnost dejstva gustine naseljenosti koji su direktni, indirektni, povezani interakcijskim vezama sa drugim faktorima gajenja, što se u krajnjem ishodu odražava na sve aspekte brojlerske proizvodnje: ekonomičnost, kvalitet proizvoda i aspekte dobrobiti brojlera.

U radu je dat prikaz rezultata pojedinih istraživanja sa generalnim ciljem definisanja optimalne gustine naseljenosti brojlera, na osnovu izvršene komparacije efekata na proizvodne performanse, parametre kvaliteta trupa i indikatore dobrobiti brojlera.

References

- ANDREWS L.D., WHITING T.S., STAMPS L. (1990): Performance and carcass quality of broilers grown on raised flooring and litter. *Poultry Science*, 69, 1644-1652.
- BHARDWAY J.K., MOHAPATRA S.C. (1996): Influence of sex, genotype, density and their interactions on broiler performance traits. XX World's Poultry Congress, New Delhi, September. *Proceedings*, IV, 103.
- BUTTERWORTH A. (1999): Infectious components of broiler lameness: A review. *World's Poultry Science Journal*, 55, 327-352.
- CRAVENER T.L., ROUSH W.B., MASHALY M.M. (1992): Broiler production under varying population densities. *Poultry Science*, 71, 427-433.
- DIRECTIVE 2007/43/CE. DIRECTIVE 2007/43/CE).
http://ec.europa.eu/food/animal/welfare/farm/broilers_en.htm
- DOZIER W.A., THAXTON J.P., BRANTON S.L., MORGAN G.W., MILES D.M., ROUSH W.B., LOTT B.D., VIZZIER-THAXTON Y. (2005): Stocking Density on Growth Performance and Processing Yields of Heavy Broilers. *Poultry Science* 84, 1332-1338.

- DOZIER W.A., LOTT B.D., BRANTON S.L. (2005a): Live performance of male broilers subjected to constant or increasing air velocities at moderate temperatures with a high dew point. *Poultry Science* 84, 1328-1331.
- DOZIER W.A., THAXTON J.P., PURSWELL J.L., OLANREWAJU H.A., BRANTON S.L., ROUSH W.B. (2006): Stocking Density Effects on Male Broilers Grown to 1,8 Kilograms of Body Mass. *Poultry Science*, 85, 344-351.
- EDRISS M.A., DAVOODVANDI S., POURREZA J. (2003): The Effect of stock density on the production of performance and carcass traits in broiler chickens. *Proceedings XVIth European Symposium on the Quality of Poultry Meat*, September 2003., Saint-Brienc, France, 695-700.
- EICHNER G., VIEIRA S.L., TORRES C.A., CONEGLIAN J.L.B., FREITAS D.M., OYARZABAL O.A. (2007): Litter Moisture and Footpad dermatitis as affected by Diets Formulated on an All-Vegetable Basis or Having the Inclusion of Poultry By-Product. *Journal of Applied Poultry Research*, 16, 344-350.
- EL-DEEK, A.A., AL-HARTHI, M.A. (2004): Responses of Modern Broiler to Stocking Density, Green Tea, Commercial Multi Enzymes and Their Interactions on Productive Performance, Carcass Characteristics, Liver Composition and Plasma Constituents. *International Journal of Poultry Science* 3, 10, 635-645.
- ELWINGER K. (1995): Broiler production under varying population densities-A field study. *Archiv für Geflügelkunde*, 59, 4, 209-215.
- FANATICO A.C., PILLAI P.B., EMMERT J.L., OWENS C.M. (2007): Meat Quality of Slow- and Fast-Growing Chicken Genotypes Fed Low-Nutrient or Standard Diets and Raised Indoors or with Outdoor Acces. *Poultry Science*, 86, 2245-2255.
- GALOBART J., MORAN E.T. (2005): Influence of Stcking Density and Feed Pellet Quality on Heat Stressed Broilers from 6 to 8 Weeks of Age. *International Journal of Poultry Science*, 4, 2, 55-59.
- GARCIA R.G., MENDES A.A., GARCIA E.A., NÄÄS I.A., MUREIRA J., ALMEIDA I.C.L., TAKITA T.S. (2002): Effect of Stocking Density and Sex on Feathering, Body Injury and Breast Meat Quality of Broiler Chickens. *Revista Brasileira de Ciência Avícola*, 40, 1.
- GREGORY N.G., WILKINS L.J. (1990): Broken bones in chickens: Effect of stunning and processing in broilers. *British Poultry Science*, 31, 53-58.
- HALL A.L. (2001): The effect of stocking density on the welfare and behaviour of broiler chickens reared commercially. *Animal Welfare*, 10, 23-40.
- JULIAN R.J. (1998): Rapid Growth Problems: Ascites and Skeletal Deformities in Broilers. *Poultry Science*, 77: 1773-1780.
- KESTIN S.C., KNOWLES T.G, TINCH A.E., GREGORY N.G. (1992): Prevalence of leg weakness in broiler chickens and relationship with genotype. *Veterinary Record*, 131, 190-194.

- KIM W.K., DONALSON L.M., HERRERA P., WOODWARD C.L., KUBENA L.F., NISBET D.J., RICKE S.C. (2004): Effects of Different Bone Preparation Methods (Fresh, Dry, and Fat-Free Dry) on Bone Parameters and the Correlations Between Bone Breaking Strength and the Other Bone Parameters. *Poultry Science*, 83, 1663-1666.
- LEWIS P.D., PERRY G.C., FARMER L.J., PATTERSON R.L.S. (1997): Responses of Two Genotypes of Chicken to the Diets and Stocking Densities Typical of UK and "Label Rouge" Production Systems: 1. Performance, Behaviour and Carcass Composition. *Meat Science*, 45, 4, 501-516.
- MENDES A.A., GARCIA R.G., IMEIDA I.C.L.A., MOREIRA J. (2004): Effect of stocking densities and season on performance, environmental and thermoregulatory parameters and carcass yield of broiler chickens. XXII World's Poultry Congress, Istanbul-Turkey, 8-13 June 2004, Book of abstracts, 417 (CD Fulltext).
- MIRABITO L., BERTHELOT A., BARON F., BOUVAREL I., AUBERT C., BOCQUIER C., DALIBARD F., SANTE V., LE POTTIER G. (2002): Influence of reducing the stocking density on the performance, behaviour and physical integrity of meat turkeys. *Archiv für geflügelkunde*. 11-th European Poultry Conference, Bremen 2002., Abstr., 354.
- MORTARI A.C., ROSA A.P., ZANELLA I., NETO C.B., VISENTIN P.R., BRITES L.B.P. (2002): Performance of broilers reared in different population density, in winter, in South Brazil. *Ciência Rural*, 32, 3.
- PAVLOVSKI Z., LUKIĆ M., CMILJANIĆ R., ŠKRBIĆ Z. (2006): Konformacija trupova pilića. *Biotechnology in Animal Husbandry*, 3-4, 83-97.
- PAVLOVSKI Z., VLAHOVIĆ M., MAŠIĆ B. (1992): Kvalitet živinskih proizvoda i zahtevi potrošača danas i sutra. *Biotechnology in Animal Husbandry*, 8, 5-6, 167-174.
- PETERSON J.S. (2004): Management and housing systems for broilers – Effects on welfare and production. XXII World's Poultry Congress, Istanbul-Turkey, 8-13 June 2004, Book of abstracts, 325 (CD Fulltext).
- PROUDFOOT F.G., HULAN H.W. (1979): The effect of four stocking densities on broiler carcass grade, the incidence of breast blisters and other performance traits. *Poultry Science*, 58, 791-795.
- REDDISH J.M., LILBURN M.S. (2004): A Comparison of Growth and Development Patterns in Diverse Genotypes of Broilers. 1. Male Broiler Growth. *Poultry Science* 83, 1067-1071.
- SANOTRA G.S., LUND J.D., ERSBOLI A.K., PETERSEN J.S., VESTERGAARD K.S. (2001): Monitoring leg problems in broilers: A survey of commercial broiler production in Denmark. *World Poultry Science Journal*, 57, 55-69.
- SANOTRA G.S., LUND J.D., VESTERGAARD K.S. (2002): Influence of light-dark schedules and stocking density on behaviour, risk of leg problems and occurrence of chronic fear in broilers. *British Poultry Science*, 43, 3, 344-354.

- SHANAWANY M.M. (1988): Broiler performance under high stocking densities. *British Poultry Science*, 29, 29-43
- ŠKRBIĆ Z. (2007): Efekti gustine naseljenosti i svetlosnog programa na proizvodne i klanične osobine brojlerskih pilića različitog genotipa. Doktorska disertacija. Poljoprivredni fakultet, Beograd.
- ŠKRBIĆ Z., PAVLOVSKI Z., LUKIĆ M. (2006): Possibility of improvement of certain slaughter traits by reducing the density of housing of broiler chickens. XII European Poultry Conference, Verona, Italy, 10-14 sept. *World's Poultry Science Journal*. Book of abstracts, 62, 273 (full text in CD).
- ŠKRBIĆ Z., PAVLOVSKI Z., LUKIĆ M. (2007a): Uticaj dužine tova u različitim sistemima gajenja na klanične osobine brojlerskih pilića genotipa Redbro. *Biotehnologija u stočarstvu* 23, 3-4, 67-74.
- ŠKRBIĆ Z., PAVLOVSKI Z., LUKIĆ M. (2007b): Slaughter traits of slow growing broiler hybrids in different rearing systems. *Proceedings XVIII European Symposium on the Quality of Poultry Meat and XII European Symposium on the Quality of Eggs and Egg Products*, Prague, 323-325.
- ŠKRBIĆ Z., PAVLOVSKI Z., LUKIĆ M. (2007c): Body mass and dynamics of growth of broiler chickens of different genotype in improved rearing conditions. 2nd International Congress on Animal Husbandry "New Perspectives and Challenges of Sustainable Livestock Farming", Belgrade, October 3-5. *Biotechnology in Animal Husbandry*, 23, 5-6, Book 2, 347-357.
- ŠKRBIĆ Z., PAVLOVSKI Z., LUKIĆ M. (2008b): Efekat gustine naseljenosti na pojedine klanične osobine brojlera genotipa Cobb. *Biotechnology in Animal Husbandry*, 24, 1-2, 51-58.
- ŠKRBIĆ Z., PAVLOVSKI Z., LUKIĆ M., BLAGOJEVIĆ M. (2008a): Carcass quality of broilers reared in lower stocking density and in conditions of discontinuous light program. 1st Mediterranean Summit of WPSA "Advances and Challenges in Poultry Science", 7-10. May 2008., Porto Carras, Greece. *Book of Proceedings*, 1028-1032.
- ŠKRBIĆ Z., PAVLOVSKI Z., LUKIĆ M., BLAGOJEVIĆ M. (2008c): Kvalitet trupa brojlera gajenih u manjoj gustini naseljenosti i u uslovima diskontinuiranog svetlosnog programa. *Živinarstvo*, 10, 3-9.
- ŠKRBIĆ Z., PAVLOVSKI Z., LUKIĆ M., PERIĆ L., MILOŠEVIĆ N. (2009): The Effect Of Stocking Density On Certain Broiler Welfare Parameters. *Biotechnology in Animal Husbandry*, 25, 1-2, 11-21.
- ŠKRBIĆ Z., PAVLOVSKI Z., LUKIĆ M., VITOROVIĆ D., BLAGOJEVIĆ M. (2009): Effect of stocking density and lighting program on broiler growth, carcass conformation and tibia quality. *Acta Veterinaria*, 59, (in print).
- SORENSEN P., SU G., KESTIN S. C. (2000): Effects of Age and Stocking Density on Leg Weakness in Broiler Chickens. *Poultry Science* 79: 864-870.

-
- SORENSEN P., SU G., KESTIN S.C. (1999): The Effect of Photoperiod : Scotoperiod on Leg Weakness in Broiler Chickens. *Poultry Science* 78, 336-342.
- SUNDRUM A. (2001): Organic livestock farming – a critical review. *Livestock Production Science*, 67, 3,207 – 215.
- THOMAS D.G., RAVINDRAN V., THOMAS D.V., CAMDEN B.J., COTTAM Y.H., MOREL P.C.H., COOK C.J. (2004): Influence of stocking density on the performance, carcass characteristics and selected welfare indicators of broiler chickens. *New Zealand Veterinary Journal*, 52, 76-81.
- VITOROVIĆ D. (1992): Anatomske karakteristike kostiju i mišića pilića lakog i teškog tipa gajenih na podu i u kavezima. Doktorska disertacija. Veterinarski fakultet, Beograd.
- WEEKS C.A., DANBURY T.D., DAVIES H.C., HUNT P., KESTIN S.C. (2000): The behaviour of broiler chickens and its modification by lameness. *Applied animal Behaviour Science*, 67, 111-125.
- YADGARI L., KINREICH R., DRUYAN S., CAHANER A. (2006): The effects stocking density in hot conditions on growth, meat yield and meat quality of featherless and feathered broilers. XII European Conference, Verona, Italy. *World's Poultry Science Journal. Book of abstracts*, 62, 603.

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