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Dietary medicinal plants enhance the chemical composition and quality of broiler chicken meat

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ABSTRACT. The use of nutritional strategies to improve the quality of meat is a relatively new approach that has emerged at the interface of animal science and food science. The effects of dietary medicinal plants (*Allium sativum* L., *Piper nigrum* L., and *Capsicum annuum* L.) addition to chicken nutrition on quality characteristics of breast and thigh with drumstick meat, as well as caloric value of chicken meat were investigated. Quality measurements included meat sensory (colour, smell, taste, softness, chewiness, juiciness and overall impression), physical (pH, colour – CIE $L^*a^*b^*$ and drip-loss) and chemical (moisture, protein, fat and ash content) characteristics. Herbs showed significant ($P < 0.05$) influence in altering most examined quality parameters of chicken meat, especially when adding red hot pepper. Caloric value of chicken meat was improved which makes garlic, black pepper and hot red pepper valuable natural feed additives in improvement of meat quality as well as a natural growth promoter. In conclusion, herbs had positive influence on chicken meat quality, however the knowledge of their mode of action is still limited and thus requires further investigation.

Keywords: Medicinal plants, nutrition, meat quality, sensory, physical characteristics

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INTRODUCTION

In last decade, consumers have become more concerned about the processed food they consume. Synthetic preservatives, which have been used in food industry, may lead to negative health consequences. The use of synthetic compounds have significant drawbacks, such as increasing cost, handling hazards, concerns about residues on food and threat to human environment. Therefore, there has been increasing interest to replace synthetic with natural, effective and nontoxic compounds (Puvača, 2018). Those, in the first place are extracts and essential oils (Giannenas et al., 2013; Puvača et al., 2019), spices (Puvača et al., 2015; Popović et al., 2018) and medicinal plants (Kostadinović et al., 2015; Puvača et al., 2018). As natural foodstuffs, spices and medicinal plants appeal to all who question safety of synthetic food additives and demand high quality products that at the same time are safe and stable. Medicinal plants have been extensively used in the therapy of some diseases for a long time. Interest in plants, plant extracts and derived phytochemicals as components of livestock feedstuffs has increased during the last years (Puvača et al., 2013). Moreover, medicinal plants and aromatic plants possess many antioxidants which are effective in preventing oxidative changes and, thus, can minimize off-odour production in meat (Najafi and Torki, 2010). The use of nutritional strategies to improve the quality of meat is a relatively new approach that has emerged at the interface of animal science and food science (Džinić et al., 2015; Puvača et al., 2016; Spasevski et al., 2018). Nutritional approaches are often more effective than direct addition of the additive to meat since the compound is preferably deposited where it is most needed (Govaris et al., 2004). As in other animal species, the physical quality of broiler meat is of major importance, since broiler chicken meat is nowadays usually consumed as cuts or as processed products rather than as whole carcasses. Physical quality refers to several meat properties, including pH and colour values. Meat quality is closely related to the decrease in muscle pH *postmortem*. Rapid *postmortem* decline in pH results in PSE (pale, soft and exudative) meat with a pale aspect and reduced water-holding capacity (Owens et al., 2000; Puvača and Stanaćev, 2011). The variations in colour of broiler breast meat fillets are significant correlated with muscle pH and extremes in colour variations (Khalafalla et al., 2011). Low ultimate pH results in "acid meat", with similar defects to those of PSE meat (Barbut, 1997), while high ultimate pH leads to DFD (dark, firm and dry) meat with dark colour and poor storage quality (Allen et al., 1997; Laudadio and Tufarelli, 2011). Beside physical meat quality, the economic importance is also related to sensory and chemical characteristics of meat which should not be forgotten. To ensure optimum quality, it is necessary to consider the entire production chain from farm to fork (Khalafalla et al., 2011). Many studies focused on the impact of many dietary supplemental components with the aim to find more efficient alternatives or combinations of different alternatives for maintaining health and improving performance of poultry and meat quality and safety, without antibiotics residues.

Therefore, the aim of this study was to investigate the influence of three different medicinal plants (garlic, black pepper and hot red pepper) in broiler diet on meat sensory, physical and chemical characteristics.

MATERIALS AND METHODS

Animal housing and nutrition

Biological tests were carried out under production conditions at the experimental farm "Pustara" of the Faculty of Agriculture in Novi Sad, Serbia. All experimental procedures have been approved by the competent Veterinary Authority according to the National legislation (Presidential Degree 56/2013 on harmonization of the Directive 2010/63/EU on the protection of animals used for scientific purposes) under registered number I-2015-02. At the beginning of the experiment, a total of 1200 one-day old Hubbard broilers strain, of mixed sex, were distributed into eight dietary treatments with four replicates each (Table 1).

Every dietary treatment included 150 chickens, which were divided in four pens (37-38 chicken per pen). Feeding program included three-phase diet as starter, grower and finisher, respectively. For the first 14 days, during the acclimation period, chicks were fed with starter diet, then birds were fed with grower diet for the next 21 days and then for the last 7 days of fattening period with finisher diet. During the whole trial feed and water were provided *ad libitum.* Microclimate conditions were regularly monitored. Rearing and housing condition were previously described in detail by Puvača et al. (2015), while the nutrition of the chickens were previously described in detail by Puvača et al. (2016).

Table 1. Experimental design with chickens and dietary treatments, g/100g

Experimental treatments	Additive	Concentration of additives in chicken diets		
		Starter	Grower	Finisher
		1 – 14 days	15 – 35 days	36 – 42 days
T1	Control treatment	0.0	0.0	0.0
T2	Garlic powder	0.0	0.5	0.5
T3	Garlic powder	0.0	1.0	1.0
T4	Black pepper powder	0.0	0.5	0.5
T5	Black pepper powder	0.0	1.0	1.0
T6	Hot red pepper powder	0.0	0.5	0.5
T7	Hot red pepper powder	0.0	1.0	1.0
T8	Mixture of garlic, black pepper and hot red pepper (1:1:1)	0.0	0.5	0.5

Sample collections

At the end of 42nd day of the experiment, 12 broiler chicks, six male and six female of an average body weight of each treatment group were selected for meat quality evaluations. Before slaughtering broiler chickens were starved for 12 h, and afterword slaughtered were processed by bloodletting, scalding, plucking and evisceration and chilled. Upon slaughter, dressed cold carcasses were dissected into primal cuts such as breast, thighs with drumsticks, wings, back, head, neck and legs following the method prescribed by the Regulation on Poultry Meat Quality (Official Gazette of the SFRY No. 1/81 and 51/88). After 24 hours post-mortem breast (*Musculus pectoralis*) and thigh with drumstick (*Tibialis anterior* and *Biceps femoris*) were further analysed for their sensory, physical and chemical characteristics.

Sensory analyses

Sensory assessment was conducted at the laboratory of Scientific Institute of Food Technology in Novi Sad, Serbia, equipped in accordance with the ISO standard (8589:2012) of Sensory analyse - General guidance for the design of test rooms. Five trained panellists with expertise in sensory evaluation of meat and meat products evaluated selected properties for breast (colour, smell, taste, softness, chewiness and juiciness) and thigh with drumstick (colour and smell and taste) meat. Sensory analyses were evaluated using a point system of analytical descriptive tests with a scale from 1 to 5, for the colour (1=very bad; 2=bad, 3=good; 4=very good; 5= extremely good), for the smell and taste (1=extremely unpleasant; 2=unpleasant; 3=insufficiently pleasant; 4=pleasant, good; 5=extremely pleasant, excellent), for softness (1=moderately tender; 2=tightly; 3=moderately tightly; 4=moderately soft; 5=soft), for chewiness (1=moderately toughened; 2=poor toughened; 3=chewable; 4=moderately gentle; 5=gentle), for juiciness (1=dry; 2=moderately dry; 3=moderately juicy; 4=juicy; 5=extremely juicy) and for overall impression (1=sufficient; 2=suit; 3=good; 4=very good; 5=excellent). Panellists were randomly supplied with thermally processed meat samples. Between each sample evaluation, panellists were cleaning their palate with distilled water, bread or apple. Between each repetition period of samples evaluation, 1 h was awarded to panellists for senses resting.

Physical analyses

The pH values of breast meat and thigh with drumstick were measured using the portable pH meter (Consort C931, Turnhout, Belgium) equipped with an insertion glass combination electrode (Mettler Toledo Greifensee, Switzerland). Means of twelve measurements were presented. Colour measurements of breast and thigh with drumstick meat were carried out using photo-colorimeter Minolta Chroma Meter CR-400 (Minolta Co., Ltd., Osaka, Japan). Colour characteristics are given in the CIE $L^*a^*b^*$ system (L^* = lightness; a^* = redness and b^* = yellowness). Two measurements were taken on surfaces and cut places of meat samples for each treatment. Data presented are means of 24 measurements. For drip-loss of heat processing determination, samples of meat were measured before heat processing and after the treatment samples were cooled at room temperature for 1 h, and measured in order to determine the loss.

Chemical analyses and meat caloric value

Meat chemical characteristics were determined according to the ISO recommended standards for moisture, protein, fat and ash contents. Data presented are means of twelve measurements.

The caloric value of 100 g of white and dark meat by influence of dietary spice plants addition to chicken daily nutrition was calculated according to the following equation:

Caloric value (kcal) = (protein (g/100g) × 4 kcal) + (fat (g/100g) × 9 kcal)

Statistical analyses

Statistical analyses were conducted using statistical software program Statistica 13 for Windows, to determine if variables differed between treatments. Significant effects were further evaluated using analysis of variance (ANOVA), least square means (LSM) and standard errors of least square means (SE_{LSM}). Fisher's LSD *post-hoc* multiple range test with Bonferroni corrections were used to ascertain differences among treatments. A significance level of $P<0.05$ was used.

RESULTS AND DISCUSSION

Results in this paper are presented in a form of tables with the least square means and standard errors of least square means, while in available literature there is no sufficient data on meat quality regarding the medicinal plants we used, which makes this investigation a novelty in field of chicken meat quality. Therefore, discussion will go in way of presenting of our findings compared with published works regarding the sensory, physical and chemical quality of broiler meat.

Sensory characteristics

Results for sensory characteristics (colour, smell, taste, softness, chewiness, juiciness and overall impression) of breast and thigh with drumstick meat of broiler chickens fed with different dietary spice addition are presented in Table 2. Supplementing medicinal plants in broiler ration such as garlic, black pepper and hot red pepper and their combined mixture led to significant differences ($P < 0.05$) in meat quality characteristics. The T1 muscles of breast meat had the significantly ($P < 0.05$) lowest visual colour score compared to the other experimental treatments. The highest visual colour score of thigh with drumstick meat was recorded in treatment with 1.0 g/100g (T7, 4.9) of hot red pepper with significant ($P < 0.05$) differences compared to treatments T2, T4 (4.5) and T5, T6 (4.6), respectively. When it comes to the scores of breast meat smell, significant differences ($P > 0.05$) were absent, but the highest score of 4.9 was recorded in thigh with drumstick meat in treatment T5 followed by 4.8 (T3, T7, T8), 4.7 (T1), 4.6 (T4), 4.4 (T2) and 4.3 (T6), respectively. Similar tendency was observed in breast meat taste. As it was the case with the breast meat smell, the same highest score of meat softness was observed with the addition of 1.0 g/100g of hot red pepper in treatment T7, which get the score of soft meat. The lowest score of softness was recorded in breast meat of chickens fed 1.0 g/100g of garlic powder, but again higher then score point of 3, resulting as moderately soft which is very acceptable by consumers. Gentle and moderately gentle scores of breast meat was recorded in control treatment (T1), 1.0 g/100g hot red pepper (T7), 0.5 g/100g black pepper and hot red pepper (T4, T6) with significant ($P < 0.05$) differences compared to treatments T2 and T8, respectively. Hot red pepper at both concentrations have positively influenced on the breast meat juiciness with the highest scores of 4.5 and 4.4, respectively. When it comes to overall impression, dietary of hot red pepper showed the highest scores of sensory meat quality, while the lowest was observed in garlic treatment groups with an average score of 4.3.

Table 2. Effect of garlic, black pepper and hot red pepper dietary supplementation on sensory quality of broiler chicken breast and thigh with drumstick (Least squares means)

Experimental treatments		Quality parameters of breast meat							Quality parameters of thigh with drumstick	
		Colour	Smell	Taste	Softness	Chewiness	Juiciness	Overall impression	Colour	Smell and taste
T1	LSM	4.9^{b}	4.8^{a}	4.7^{a}	4.5^{abc}	4.5^{a}	4.3^{ab}	4.5^{ab}	4.7^{abc}	4.7^{abc}
T2	LSM	5.0^{a}	4.7^{a}	4.5^{ab}	4.4^{abcd}	4.2^{ab}	4.0^{bd}	4.3^{b}	4.5^{bc}	4.4^{cd}
T3	LSM	5.0^{a}	4.8^{a}	4.6^{ab}	4.1^{d}	4.2^{ab}	3.8^{d}	4.3^{ab}	4.7^{ac}	4.8^{ab}
T4	LSM	5.0^{a}	4.9^{a}	4.8^{a}	4.5^{abc}	4.4^{ab}	4.2^{abc}	4.5^{ab}	4.5^{c}	4.6^{bcd}
T5	LSM	5.0^{a}	4.7^{a}	4.5^{ab}	4.3^{bcd}	4.3^{ab}	4.3^{ab}	4.4^{ab}	4.6^{bc}	4.9^{a}
T6	LSM	5.0^{a}	4.7^{a}	4.5^{ab}	4.6^{ab}	4.4^{ab}	4.5^{a}	4.6^{a}	4.6^{bc}	4.3^{d}
T7	LSM	5.0^{a}	4.8^{a}	4.7^{ab}	4.7^{a}	4.5^{a}	4.4^{a}	4.6^{ab}	4.9^{a}	4.8^{ab}
T8	LSM	5.0^{a}	4.7^{a}	4.4^{b}	4.2^{cd}	4.0^{b}	3.9^{cd}	4.3^{ab}	4.8^{ab}	4.8^{ab}
Pooled SE_{LSM}		0.01	0.11	0.11	0.12	0.14	0.14	0.10	0.1	0.08

Means in the same column with a common superscript letter are not significantly different ($P < 0.05$)

Sensory analysis is one of the oldest means of meat quality control which also allowing manufacturers to identify, understand and respond to consumer preferences more effectively (Saha et al., 2009), helping manufacturers to increase competition on the market (Ponte et al., 2004). In our experiment, the sensory quality of meat shows very high scores for smell, juiciness and overall impression, which leads to conclusion that the addition of medicinal plants didn't have adverse effect on meat quality and that the amount of added plants in chicken diet was adequate. Contrary to our results, investigation of Džinić et al. (2015) evaluated the sensory quality of breast chicken meat with the addition of 2.0% of garlic powder showing characteristic taste and pungent smell of garlic from broiler feed which was transferred to meat. This characteristic flavour can be both non-beneficial and beneficial depending of consumers affinities and demands. In the same investigation, the addition of garlic led to excellent meat quality regarding the juiciness and tenderness of breast meat, in accordance with our study. Similar results were obtain by Popović et al. (2016) using selected essential oils in broiler diet on sensory meat quality, which reviled significant influence of this phytobiotic in altering of taste, juiciness and tenderness of chicken meat. Addition of 30 mg/kg of *Macleaya cordata* (Zdunczyk et al., 2010) which is from same alkaloid family as black pepper shows overall intensive smell for breast meat without any atypical smell. As for the breast meat, similar results were obtained for the thigh meat sensory evaluation. According to our findings, also the study of Waskar et al. (2011) reported that supplementation of polyherbal feed supplement in basal diet was effective in improving overall meat quality attributes such as fillet and tender yield, sensory meat characteristics, organoleptic cooked meat parameters, overall palatability and acceptability of meat. The natural products such as garlic, black pepper and hot red pepper did not have any residual or adverse effect on eating and cooking quality of meat, and hence resulted safe for usage. This study have confirmed that the direct influence on meat quality have nutrition of chickens what is in accordance with previous mentioned findings.

Physical characteristic

Results for meat physical characteristics (pH value, colour – CIE $L^*a^*b^*$ values and drip-loss of heat treatment) of all eight dietary treatments are presented in Tables 3 and 4, respectively.

Slightly small numerical average values of breast meat pH with significant ($P < 0.05$) differences (ranged from 5.5 to 5.7) which are smaller than 0.3 can be explained as a possible statistical error (Table 3). One of the basic tenets of meat science is that accelerated or extended *postmortem* glycolysis may cause the development of PSE. There are implicit interrelationships between temperature and pH because glycolysis is exothermic, and the effects of pH are severe when a carcass is still near body temperature. Meat with a low pH appears pale because it scatters more light back to the observer than meat with a high pH which appears dark because it transmits more light into its depth than meat with a low pH. In this experiment the lowest pH of 5.5 was recorded in breast meat of chicken in dietary treatment T4 fed 0.5 g/100g of black pepper powder, while the highest pH (5.7) was observed in treatments T2 and T6 with dietary addition of 0.5 g/100g of garlic and hot red pepper powder.

Table 3. Effect of garlic, black pepper and hot red pepper dietary supplementation on physical parameters of breast meat (Least squares means)

Experimental treatments		Physical parameters of breast meat				
		pH	Colour values			Drip-loss
			L*	a*	b*	
T1	LSM	5.6^{ab}	57.4^{a}	2.5^{a}	5.8^{a}	22.9^{cd}
T2	LSM	5.7^{ab}	57.0^{ab}	2.5^{a}	5.4^{a}	31.4^{a}
T3	LSM	5.6^{ab}	54.3^{ab}	2.9^{a}	6.3^{a}	29.9^{a}
T4	LSM	5.5^{b}	56.5^{ab}	2.0^{a}	4.2^{a}	26.1^{b}
T5	LSM	5.6^{ab}	53.4^{ab}	2.3^{a}	4.3^{a}	23.1^{cd}
T6	LSM	5.7^{a}	53.1^{b}	2.3^{a}	3.9^{a}	20.5^{d}
T7	LSM	5.6^{ab}	57.1^{ab}	2.4^{a}	6.3^{a}	24.3^{bc}
T8	LSM	5.6^{ab}	55.6^{ab}	2.4^{a}	4.4^{a}	31.1^{a}
Pooled SE_{LSM}		0.04	1.38	0.49	0.87	0.93

Means in the same column with a common superscript letter are not significantly different ($P < 0.05$)

When it comes to a CIE $L^*a^*b^*$ colour values, from the results given in Table 3, it can be observed that the differences in a^* (redness) and b^* (yellowness) colour system is present between dietary treatments (a^*: 2.0-2.9; b^*: 3.9-6.3) but without significant differences ($P > 0.05$). Colour values for L^* (lightness) show significant differences ($P < 0.05$) among dietary treatments. The lowest value for lightness was observed in breast meat of chickens on dietary treatment including 0.5 g/100g of hot red pepper, while the highest value for the lightness of breast meat was observed in control treatment. Based on the results of pH and colour values, breast meat could be classified as PSE, but if we take in account the scores of sensory analyses of meat, and that the white meat is in question it could be classified as meat of normal quality, with the significant influence of dietary spice plants addition.

Heat processing of meat had a significant influence on meat drip-loss ($P < 0.05$). Hot red pepper in treatment T6 showed the highest positive influence, where the lowest drip-loss of meat after heat treatment was observed (20.5%). In the other experimental dietary treatments meat drip-loss ranged from 23.1 to 31.1%, with the highest value observed in treatment with the addition of 0.5 g/100g of garlic powder.

Data on physical quality of chicken red meat (thigh with drumstick) are shown in Table 4. From our findings it can be noticed a very small average differences in pH values, but with significant differences ($P < 0.05$), as it was case with breast meat. Values of pH ranged from 5.9 to 6.0, so the thigh with drumstick can be classified as a normal quality meat. The highest value of redness (a^*) was observed in treatment with the addition of 1.0 g/100g of hot red pepper with significant ($P < 0.05$) differences compared to other experimental dietary treatments. The lowest a^* value was recorded in treatment T4 with the addition of black pepper powder. Contrary to white meat, significant differences ($P < 0.05$) were observed and in b^* colour values of thigh and drumstick meat, which ranged from 4.2 (T3) to 6.2 (T2), respectively. The highest lightness (61.0) combined with high redness (3.6) was observed in meat of control treatment ($P < 0.05$) and it could be classified as reddish, soft and exudative (RSE) meat, while the addition of spices especially hot red pepper had positive influence of red meat, which could be classified as normal.

Dietary addition of hot red pepper also shows its positive influence on meat drip-loss after heat treatment. Experimental treatment T7 recorded lowest drip-loss value (27.3%).

Table 4. Effect of garlic, black pepper and hot red pepper dietary supplementation on physical parameters of thigh with drumstick (Least squares means)

Experimental treatments		Physical parameters of thigh with drumstick				
		pH	Colour values			Drip-loss
			L*	a*	b*	
T1	LSM	6.0^{ab}	61.0^{a}	3.6^{ab}	5.4^{ab}	30.2^{ab}
T2	LSM	6.0^{ab}	60.7^{ab}	2.9^{bc}	6.2^{a}	31.2^{a}
T3	LSM	6.0^{ab}	57.2^{bc}	2.4^{bc}	4.2^{ab}	31.6^{a}
T4	LSM	5.9^{b}	60.3^{abc}	2.3^{c}	4.4^{ab}	32.6^{a}
T5	LSM	6.0^{ab}	57.0^{c}	2.4^{bc}	4.5^{ab}	31.1^{a}
T6	LSM	6.0^{a}	58.9^{abc}	2.9^{bc}	3.6^{b}	33.7^{a}
T7	LSM	5.9^{ab}	58.2^{abc}	4.2^{a}	5.5^{ab}	27.3^{b}
T8	LSM	5.9^{ab}	59.0^{abc}	3.2^{abc}	5.3^{ab}	31.9^{a}
Pooled SE_{LSM}		0.04	1.21	0.44	0.74	1.2

Means in the same column with a common superscript letter are not significantly different ($P < 0.05$)

Considering the glycolytic process, initial pH value provides best information for physiological meat quality. Highly accelerated as well as accelerated pH decline are related to a light meat colour and poor juice retention, which in the majority of cases is the same for pH values ranging from 5.8 to 6.0 concerning exudative meat composition. Besides pH value many other sensory, instrumental and biophysical methods are involved in determination of chicken meat quality (Damez and Clerjon, 2008). During recent years, deviations in meat quality which did not show typical characteristics of PSE and DFD were repeatedly reported. There was acceptable colour and increased wateriness (RSE) as well as pale colour and good juice retention (PFN). Of especially interest is RSE meat, as drip-loss means a loss in weight and therefore economic losses. In our experiment, pH value of chickens breast meat ranged from 5.5 to 5.7 and in thigh and drumstick between 5.9 and 6.0 with observed significant ($P < 0.05$) differences, while the Qiao et al. (2001) in their investigation reported pH values of the lighter than-normal, normal and darker-than-normal groups with 5.81, 5.96, and 6.23, respectively, which were significantly different from each other. Stanaćev et al. (2011) recorded pH value of 5.6 in meat from chickens fed 2% of garlic powder. According to Karunanayaka et al. (2016), meat with the pH higher than 5.8 is classified as normal meat quality. Several researchers have demonstrated a significant relationship between raw meat colour and raw meat pH (Allen et al., 1997, 1998; Fletcher, 1999). Barbut (1993) reported that lightness (L^*) had the highest correlation of the L^*, a^*, b^* colour values with PSE conditions. In our experiment, the dietary addition of garlic, black pepper and hot red pepper had influence on broiler chicken meat colour. The relationship between muscle pH, colour, and meat quality in red meat species is well established. As noted earlier, the relationship between poultry meat colour and pH has also been well documented, but the relative influence on poultry meat quality is not as well established as in the extremes of PSE and DFD conditions in pork and beef (Qiao et al., 2001). Positive influence of medicinal plants addition in broiler chicken diet on meat quality was also observed by Savković et al. (2008) using a mixture of different spice and aromatic herbs. Hot red pepper in the current experiment showed the highest positive influence with the lowest drip-loss of breast meat after heat treatment (20.5%), while the higher addition of same spice (T7) in thigh with drumstick also showed positive influence and lowest drip-loss of 27.3%. Allen et al. (1998) reported that initial and tumbled L^* values are correlated positively with drip-loss and cook-loss of chicken meat. Their results were in agreement with the previous findings of Barbut (1993), who observed a high correlation between L^* and cooking loss, whereas the Allen *et al.* (1998) found no correlation between raw meat pH and drip-loss or cook-loss. In our trial, the highest drip-loss of breast meat was observed in treatment T2 with L^* of 57.0 and in treatment T6 with L^* of 58.9 of red meat, which is in agreement with earlier findings.

Chemical characteristics and caloric characteristic of chicken meat

From the results given in Table 5, it can be observed no significant (P > 0.05) differences in moisture content in both breast and thigh with drumstick meat. Moisture in white meat ranged from 71.8 to 73.9 g/100g and 72.5 to 74.8 g/100g in red meat, respectively. The highest content of protein (24.0 g/100g) was observed in treatment T5 with significant (P < 0.05) differences compared to treatments T2 (22.3), T1 (22.1) and T8 (21.8 g/100g), respectively. The lowest amount of fat was observed in treatment T5 (0.16 g/100g) what was expected because of the negative correlations between the content of protein and fat. The highest fat content was recorded in control treatment T1 (0.55 g/100g) with significant (P < 0.05) differences compared to the other treatments. Significant differences between the groups (P < 0.05) were found in for the ash content of both breast meat and thigh with drumstick meat. The highest content of protein (20.6 g/100g) in thighs with drumsticks was observed in dietary treatment with addition of hot red pepper (T7). Interesting is that the same treatment also contains highest content of fat (3.86 g/100g). This could be explained by the influence of capsaicin as the active compound in hot red pepper on the metabolism of fat and the highest utilisation from the feed which is incorporated in the body. The lowest content of protein in meat, as in the breast meat was observed in control treatment (18.6 g/100g) with the fat content of 2.59 g/100g, which could be a sign of positive influence of dietary medicinal plants addition to alteration of chicken meat nutritive quality.

Table 5. Effect of garlic, black pepper and hot red pepper dietary supplementation on chemical characteristic of breast meat and thigh with drumstick (Least squares means)

Experimental treatments		Quality parameters of breast meat				Quality parameters of thigh with drumstick			
		Moisture	Protein	Fat	Ash	Moisture	Protein	Fat	Ash
T1	LSM	73.8^{a}	22.1^{b}	0.55^{a}	1.12^{bc}	74.7^{a}	18.6^{b}	2.59^{e}	1.00^{b}
T2	LSM	73.4^{a}	22.3^{b}	0.48^{b}	1.19^{ab}	74.3^{a}	18.7^{b}	3.74^{a}	1.06^{a}
T3	LSM	73.9^{a}	22.6^{ab}	0.30^{c}	1.18^{ab}	72.7^{a}	19.8^{ab}	2.79^{d}	1.09^{a}
T4	LSM	73.3^{a}	22.6^{ab}	0.28^{c}	1.16^{abc}	74.2^{a}	19.4^{ab}	2.99^{c}	1.00^{b}
T5	LSM	72.3^{a}	24.0^{a}	0.16^{d}	1.24^{a}	72.5^{a}	20.0^{a}	2.26^{f}	1.07^{a}
T6	LSM	71.8^{a}	22.7^{ab}	0.49^{b}	1.17^{ab}	74.3^{a}	19.5^{ab}	3.24^{b}	1.08^{a}
T7	LSM	72.6^{a}	21.8^{b}	0.18^{d}	1.06^{c}	73.3^{a}	20.6^{a}	3.68^{a}	1.06^{a}
T8	LSM	72.4^{a}	22.5^{ab}	0.27^{c}	1.17^{ab}	74.8^{a}	19.7^{ab}	2.13^{f}	1.08^{a}
Pooled SE_{LSM}		0.81	0.53	0.02	0.02	0.81	0.44	0.04	0.02

Means in the same column with a common superscript letter are not significantly different (P < 0.05)

Moisture content of white and red meat was almost equal among dietary groups. Similarly, research reported that broiler chickens feed supplementation with Echinacea (*Echinacea purpurea*), garlic (*Allium sativum*) and ginger (*Zingiber officinale*) resulted in no effect on meat moisture content. In our experiment, the highest protein content of breast (24.0 g/100g) and thigh with drumstick (20.6 g/100g) meat was observed in treatments T5 and T6, respectively. From this fact, it can be noticed that the dietary addition of black pepper and hot red pepper to chicken ration led to significant improvement of meat quality. In a previous research of Stanaćev et al. (2011), dietary garlic powder addition to chickens diet at level of 2.0 g/100g, resulted in significant differences in protein content (22.9 g/100g) in breast meat compared to control diet (21.8 g/100g). The lowest protein content of 18.6 g/100g was observed in red meat from control treatment. Souza et al. (2011) reported that protein content of chicken breast meat ranged from 22.48 to 22.61 g/100g without significant differences. Content of protein in chicken breast meat in range from 20.7 to 32.1% was reported by Mohammed (2013) with energy value between 160.0 and 212.0 kcal. In our experiment, the energetic value of breast meat was influenced by dietary medicinal plants addition and it ranged from 92.5 kcal (T8) to 97.5 kcal (T5). Onibi et al. (2009) reported significant influence of spice and herbs in broiler nutrition on fat content, where the thigh muscle had the highest fat content (82.9 g/kg), followed by drumstick muscle (66.9 g/kg) and lowest for breast muscle (49.1 g/kg). Lowest fat content of breast meat in the current experiment was recorded when birds fed 1.0 g/100g of black pepper powder (0.16 g/100g) and 2.13 g/100g in red meat of chicken fed with mixture of garlic, black pepper and hot red pepper powder at 0.5 g/100g. Similarly, fat deposition has been reported to be higher in red meat than in breast meat (Onibi, 2006). Breast meat fat content was affected by the interaction between sex and genetic strain, with males presenting the highest values as found by Souza et al. (2011). On the other hand, Lonergan et al. (2003) reported higher fat content values in females as influenced by the interaction between sex and genetic group fed with the same dietary mixtures. Addition of black pepper powder had high influence on mineral content of breast meat in our experiment. Significantly higher ash content of chicken meat was reported by Mohammed (2013) who is in accordance with our results.

Addition of medicinal plants to broiler chickens diet resulted in significant ($P < 0.05$) differences in meat caloric value (Table 6). Chickens fed with 1.0 g/100g of black pepper had the highest energetic value (97.7 kcal), while the chickens fed with the same amount of hot red pepper showed the lowest energetic value (88.9 kcal) of breast meat ($P < 0.05$). Small differences between the other treatments were observed ($P > 0.05$). When it comes to caloric value of red meat, conversely to white meat, the addition of hot red pepper (T7) influenced in high energetic value (115.5 kcal) of meat with statistically significant ($P < 0.05$) differences compared to all other treatments. The lowest energetic value of red meat was recorded in treatments T5 and T8, while the high energetic value (108.5 kcal) was recorded in red meat of chickens fed with dietary addition of garlic at the level of 0.5 g/100g.

When it's come to energetic value of chicken meat, it can be observed that the addition of spices to chicken nutrition had significant influence on altering caloric value of meat.

Table 6. Effect of garlic, black pepper and hot red pepper dietary supplementation on caloric values of chickens breast meat and thigh with drumstick (Least squares means)

Type of meat		Dietary treatments							
		T1	T2	T3	T4	T5	T6	T7	T8
White meat	LSM	93.5^{ab}	93.8^{ab}	93.4^{ab}	93.2^{ab}	97.7^{a}	95.4^{ab}	88.9^{b}	92.5^{ab}
	SE_{LSM}	2.26	2.26	2.26	2.26	2.26	2.26	2.26	2.26
Red meat	LSM	98.0^{c}	108.5^{b}	104.5^{bc}	104.5^{bc}	100.6^{cd}	107.1^{bd}	115.5^{a}	98.2^{c}
	SE_{LSM}	2.23	2.23	2.23	2.23	2.23	2.23	2.23	2.23

Means in the same row with a common superscript letter are not significantly different ($P < 0.05$)

CONCLUSIONS

Based on our findings, it can be concluded that the dietary addition of garlic, black pepper and hot red pepper to broiler diet showed significant influence in improvement of sensory, physical and chemical characteristics of meat. It is important that meat from chicken fed with medicinal plants resulted in higher energetic value which is of practical importance for human nutrition. Moreover, it can be concluded that administrative and technological as well as nutritional and sensory quality of chicken meat can only be reached with proven feed supplements, because of not all of the additives may have beneficial effects on meat quality, but can have the opposite tendency. From this trial, the used medicinal plants showed significant effect on chicken meat quality, but the knowledge of their use is still limited, and thus further investigation is still necessary.

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CONFLICT OF INTEREST STATEMENT

The authors declare that they have no conflicts of interest.

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