VETERINARSKI ARHIV 85 (6), 591-600, 2015

Technological properties and chemical composition of the meat of sheep fed with *Agaricus bisporus* supplement

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ABSTRACT

The aim of this study was to determine technological properties and basic chemical composition of sheep meat. In this study a total of 50 sheep carcasses were used. The dietary groups were controlled, one group was fed a basal diet and the other group with diets containing 1.5 % dry supplement of *Agaricus bisporus*, during the 6 months of the winter feeding period. The meat pH, EC, color and chemical composition were measured 24 h post-mortem in the m. longissimus dorsi. Sheep fed with the addition of *Agaricus bisporus* had a significantly lower proportion of nutrients (fat and protein) and a significantly higher proportion of water compared with the control group of animals ($P<0.001$). In selected adult animals fed with a supplement of *Agaricus bisporus* the muscular region was darker (L*) with a higher degree of redness (a*) and a lower degree of yellowness (b*) in relation to the same muscular region of the control group. There were no significant differences in fatty acid composition between the groups.

Key words: sheep, meat quality, dry supplement, *Agaricus bisporus*

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ISSN 0372-5480
Printed in Croatia

Introduction

In the Republic of Croatia there are around 600,000 sheep, of which about 100,000 are kept on the islands, where nearly 90 % of sheep are indigenous breeds (VNUČEC et al., 2012). The quality of lamb and sheep meat is defined by tissue composition, physical and chemical properties, chemical composition, nutritive value and sensory characteristics (LAMBE et al., 2009; KAIĆ et al., 2012; KRVAVICA, 2012). From the viewpoint of consumers, the color of meat is the most important factor in quality. Equally important is the smell of meat. Consumers also attach great attention to the texture and tenderness of the meat (PURCHAS, 1990; MARTINEZ-CEREZO, 2005).

The white button mushroom (*Agaricus bisporus*) is one of the most widely cultivated mushrooms in the world. The good nutritional characteristics of white button mushrooms, their low-fat and high values of protein and carbohydrates, among which dietary fiber are predominant, make them a very acceptable food, not only for humans but also for domestic animals intended for human consumption. In today's modern conditions of breeding, use of white button mushroom supplement as an applicable substitute for antibiotic growth promoters in animal food, as well as positive effects on production traits and the health status of the animals, also acts very favorably on the nutritional value and nutritional properties of the meat (MRŠIĆ et al., 2013). Specifically, in accordance with Article 17 of Regulation (EC) No. 1831/2003 on additives for use in animal nutrition, the Commission has determined a Register of feed additives, under which it recommends the natural feed additive CoE 543, an extract of *Agaricus bisporus*. Thus, GIANNENAS et al. (2010a,b) on a model of broilers fed with an *Agaricus bisporus* supplement, or isolated preparations from it, described significant antioxidant, antibacterial and immune stimulatory effects, and its impact on the reduced occurrence of stress in farm housed chickens. Also, the results of research in the farm housed sheep breed Lika Pramenka, fed with the addition of button mushroom supplement, showed its antiparasitic and antifungal activity and its positive effects on the health status and production traits of animals (ŠPIRANEC et al., 2013; KOZAČINSKI et al., 2014; ŠPOLJARIĆ et al., 2015).

The objective of this experiment was to evaluate the technological properties and chemical composition of sheep muscles treated with a dry supplement of *Agaricus bisporus,* to determine its possible effects on the quality of sheep meat.

Materials and methods

Experimental animals. Fifty, one-year-old sheep, of the Lika Pramenka breed were used in this experiment. The dietary groups were controlled, one group was fed with a basal diet (C) and the other group with diets containing 1.5 % dry supplement of *Agaricus bisporus* (A), during the 6 months of the winter feeding period. Upon completion of the experiment, after slaughter, muscle tissues were obtained from each experimental

group, from the m. longissimus dorsi. The study was conducted within the framework of the VIP project (2012-11-17, with co-financing by Podravka d. d., Koprivnica) on the OPG Živkovic, Kvatre, Perusić farms. All procedures used in this research were in compliance with the European guidelines for the care and use of animals in research (Directive 2010/63/EC).

Technological properties of sheep meat. The color of the meat was determined according to the CIE standard (Comission Internationale de l'Eclairage, 1986), with a Minolta Kroma Metro CR-410 device (Minolta Co., Ltd., Japan) with a 50 mm diameter area measuring range of color L*, a* and b*. The color spectrum was determined with standard illumination (lighting) D65. Before each measurement, the device was calibrated with calibration plate No. 21433027. The concentration of hydrogen ions (pH) was determined with a Eutech instrument CyberScan pH 310. Electrical conductivity was determined with a LF-Control system device (Würthinger, Pettenbach, Austria) in milliSiemens/cm (mS/cm). Monitored parameters were measured on a cross section of samples of m. longissimus dorsi, 24 h post mortem, after the stabilization of the meat color (20 minute exposure of surface of m. longissimus dorsi to the air, so-called bloom time). Final color values were determined as the mean value of three measured values.

Chemical composition and fatty acids profile. The amount of water (method according to ISO 1442 standard), fat (method according to ISO 1443 standard), protein (method ISO 937 standard) and ash (method according to ISO 936 standard) were determined. Fatty acid composition was determined by separation and quantification of fatty acids by gas chromatography (Perkin Elmer Autosystem; FID detector, 300 °C) by comparison with internal standards (Commission Regulation 796/2002 of the EU).

Statistical analyses The results of the monitored chemical composition of muscle and qualitative indicators of sheep meat were processed by statistical software (SAS Institute, 1999). The results of differently treated groups of sheep was analyzed by a simple t-test.

Results

Technological properties of sheep meat. Table 1 presents the average values of pH, electrical conductivity (EC) and indicators of meat color (L*, a* and b*) in the total studied sample. Results for all indicators were mostly within the boundaries of standard quality.

Chemical composition. The significance of the impact of nutrition on chemical composition (water, fat, protein and ash) of the m. longissimus dorsi of Lika Pramenka sheep breed and qualitative indicators of sheep meat (pH, EC, L*, a* and b*) are shown in Table 2.

Fatty acids profile. Table 3 shows the effect of nutrition on the fatty acid composition of the m. longissimus dorsi of the Lika pramenka sheep breed.

Table 1. The indicator values to the total studied sample (n = 50)

Parameter	$\bar{x}$	SD	s $\bar{x}$	Min.	Max.	Cv
Water %	76.94	0.49	0.13	76.05	77.65	0.63
Fat %	1.34	0.20	0.05	1.13	1.74	14.68
Protein %	19.45	1.33	0.36	17.62	20.99	6.84
Ash %	1.10	0.06	0.02	0.95	1.20	5.84
pH	5.58	0.08	0.02	5.47	5.69	1.49
EC	3.71	0.09	0.03	3.60	3.90	2.56
L*	41.85	1.74	0.47	29.89	43.67	4.16
a*	27.98	1.07	0.29	26.65	29.78	3.84
b*	8.84	0.76	0.20	8.02	9.92	8.59

Table 2. The statistical significance of the parameters under different treatment groups

Parameter	A	C	s $\bar{x}$	The level of significance
Water %	77.32[a]	76.56[b]	0.11	***
Fat %	1.18[a]	1.51[b]	0.04	***
Protein %	18.24[a]	20.65[b]	0.18	***
Ash %	1.05[a]	1.14[b]	0.02	**
pH	5.66[a]	5.50[b]	0.01	***
EC	3.66[a]	3.77[b]	0.03	*
L*	40.18[a]	43.25[b]	0.06	***
a*	28.91[a]	27.05[b]	0.19	***
b*	8.13[a]	9.54[b]	0.08	***

a,b Values in the same row of the table marked with different letters differ significantly *P<0.05; **P<0.01; *** P<0.001

Table 3. Fatty acid composition of m. longissimus dorsi Lika Pramenka

Fatty acids (% of total fatty acids)	A	C
Caprinic acid; C10:0	0.05	0.04
Lauric acid; C12:0	0.04	0.04
Myristic acid; C14:0	0.80	1.07
Pentadecylic acid; C15:0	0.26	0.35
Palmitic acid; C16:0	15.08	13.91
Margaric acid; C17:0	0.83	0.62
Stearic acid; C18:0	19.89	14.11
Arachidic acid; C20:0	0.13	0.09
Behenic acid; C22:0	0.10	0.13
Lignoceric acid; C24:0	0.08	0.08
Myristoleic acid; C14:1	0.03	0.04
Palmitooleic acid; C16:1	0.79	0.91
Heptadecenoic acid ; C17:1	0.43	0.51
Oleic acid; C18:1n9	33.64	31.75
Gondoic acid; C20:1n9	0.13	0.10
Linoleic acid; C18:2n6	15.41	17.72
α-Linolenic acid; C18:3n3	2.12	3.72
γ-Linolenic acid; C18:3n6	0.05	0.09
Eicosadienoic acid; C20:2	0.02	0.01
Eicosatrienoic acid; C20:3n3	0.02	0.02
Dihomo-γ-linolenic acid; C20:3n6	0.40	0.58
Arachidonic acid; C20:4n6	4.90	6.26
Eicosapentaenoic acid (EPA); C20:5n3	1.66	3.45
Docosapentaenoic acid; C22:5n3	2.65	3.89
Docosahexaenoic acid (DHA); C22:6n3	0.48	0.50
Summarized fatty acid profile[1]		
SFA	37.25	30.45
MUFA	35.02	33.31
PUFA	27.72	36.24
PUFA:SFA	0.744	1.190

[1]SFA = saturated fatty acids; MUFA = monounsaturated fatty acids; PUFA = polyunsaturated fatty acids

Discussion

The pH of the muscle is the main indicator used to measure meat quality at a commercial level. The pH at 24 h ranged from 5.47 to 5.69, indicating that the animals were not stressed at the time of slaughter. The results of this research support the assumption that the sheep are not very susceptible to stress and rapid falls in pH in the muscles after slaughter are not characteristic for this animal species (KAIĆ et al., 2012).

The color is a very important criterion in determining the quality of meat and is used as a parameter for meat quality categorization in classes as PSE, desirable and TST meat. HOPKINS (1996) claim that fresh lamb meat with L* values between 34 and 35 is most suitable for the consumer. KHLIJI et al. (2010) suggest that sheep meat with L* ≥34 or a ≥9.5 and * can be considered as "normal." Although, according to these authors randomly selected consumers with 95 % certainty will choose meat with far higher values (L* = 44, a* = 14.4). According to this, our samples can be considered as normal meat. With such conflicting results, in assessing the quality of lamb meat other characteristics should be taken into account that affect the overall impression of consumers, as well as the amount of body fat, the amount of drip loss, tenderness and the flavor of the meat.

The m. longissimus dorsi of Lika Pramenka sheep breed contains an average of 76.94 % water, 1.34 % fat, 19.45 % protein and 1.10 % ash. All analyzed parameters were characterized by low variability, indicating the high uniformity of lamb carcasses from which muscle tissues were sampled for analysis.

Sheep fed with the addition of white button mushrooms (A) had a significantly lower proportion of nutrients (fat and protein) and a significantly higher proportion of water compared to the control group of animals (C, $P<0.001$). Namely, ŠPIRANEC et al. (2013) described that in sheep fed with the supplement of white button mushroom there was a strong excessive immunostimulatory effect, which is in accordance with the research by VERDONCK et al. (2008). This research also indicates that the establishment of a stronger and prolonged immune response could cause a reduction in the proportion of protein in sheep meat fed with the addition of white button mushrooms. In the sheep from group C a significantly lower total quantity of minerals (ash) was found, but the level of significance between the groups was slightly lower ($P<0.01$).

With respect to the qualitative parameters of sheep meat, pH, EC and color (L*, a* and b*) there were also significant differences between the experimental and control groups of animals. The lowest level of significance with qualitative indicators of meat between the groups was found for parameter EC, where a significantly higher amount of extracellular water (higher EC value) was found in the meat of the control group ($P<0.05$, Table 2). PAGE et al. (2001) reported that carcasses with higher fat content have higher EC, L* and b* values and lower pH and a* value. The present study shows that sheep fed with a supplement of *Agaricus bisporus* (C) had a significantly lower fat content, and it

is assumed that this is the reason for the appearance of significantly darker meat (lower L* value), significantly lower b* values (yellowness) and significantly higher pH values a* (redness), compared to the control group of animals ($P<0.001$). Our results are in accordance with WULF et al. (1997) and PAGE et al. (2001), who also report that carcasses with higher fat content, due to differences in glycolytic metabolism, had a lower pH value, brighter (higher L* value) and softer meat.

The composition and proportion of fatty acids in sheep meat directly depend on the type of food consumed. Nowadays consumers, especially in developed countries, pay more attention not only to the total amount of fat in meat, but also to its quality or the presence of saturated and unsaturated fatty acids. Fat in lamb carcasses of the Dalmatian Pramenka breed is composed predominantly of saturated fatty acids (SFA; 37.25 %) and monounsaturated fatty acids (MUFA; 35.02 %), while the proportion of polyunsaturated fatty acids (PUFAs; 27.72 %) is significantly lower. Among the saturated fatty acids in the muscle tissue of the Dalmatian Pramenka lambs the most common were palmitic (16:0) and stearic (18:0) acids; the highest amount of monounsaturated fatty acids was oleic (18:1n-9c), while in the group of polyunsaturated fatty acids the most prevalent was linoleic (18:2n-6), arachidonic acid (20:4n-6) and docosapentaenoic acid (C22:5n-3), which is consistent with the literature data (WOOD et al., 2008). No significant differences in fatty acid composition were found between the two groups.

The amount of palmitic acid was lower (15.08 %) in animals fed with the addition of *Agaricus bisporus* than in the control group of animals (13.91 %). Oleic acid (18: 1 n-9c) is the most important fatty acids of all types of meat, it accounts for more than 30 % of the total fatty acids in meat and has broad biological functions. According to our results it is possible to see that the amount of oleic acid increased in the animals fed with the addition of white button mushroom. The amount of linoleic acid was lower in the meat from animals fed with the addition of white button mushrooms than in the control group (Table 3). As the essential linoleic acid is derived exclusively from food, this can be explained by the fact that animals regularly consumed corn, which is known to be rich in linoleic acid.

The fatty acid composition of ruminant meat is considerably more complex than monogastric meat, there are more trans fatty acids, fatty acids with an odd number of carbon atoms as a result of the enzyme activity of microorganisms in the rumen of ruminants that break down the structural components of plants and fatty acids of food, resulting in numerous products of which some are absorbed into the small intestine, and are incorporated in the animal's tissue lipids. Optimizing nutrition as a source of fatty acids can affect the fatty acid profile of the meat. The aim is to reduce the proportion of linoleic acid (omega-6), and increase the proportion of α-linolenic acid (omega-3) and long-chain and polyunsaturated fatty acids. So far it has been confirmed that in monogastric animals it is much easier to achieve changes in the composition of fatty

acids in the tissue compared to ruminants (WOOD et al., 2008; KRVAVICA et al., 2013). Our results indicated a reduction in the proportion of linoleic acid in sheep meat, which can be regarded as a positive result from the addition of white button mushrooms to the food of the experimental animals (ENSER et al., 1996).

Generally, the meat of ruminants had a lower and unfavorable ratio of polyunsaturated to saturated fatty acids, due to the biohydrogenization of fat, in relation to monogastric animals. Numerous studies confirm that the total amount of saturated fatty acids depends on the tissue sampling, the weight of the animals, feeding, and the age and sex of the animals. These parameters also depend on the amount of unsaturated fatty acids, especially oleic, linoleic and linolenic (ČORBO, 2007; EL SHAHAT et al., 1988; HANSEN and CZOCHANSKA, 1988). Finally it should be emphasized that our research confirms the previous finding that the effects of genotype and feeding is less important for fatty acid profile than the impact of the total amount of adipose tissue in the trunk and muscles, and the age and slaughter weight (WOOD et al., 2008).

Conclusion

Sheep fed with the addition of white button mushrooms had a significantly lower proportion of nutrients (fat and protein) and a significantly higher proportion of water than the control group of animals ($P<0.001$). The muscular region of the selected adult animals, fed with a supplement of white button mushrooms, was darker (L*) with a higher degree of redness (a*) and a lower degree of yellowness (b*) in relation to the same muscle region of the control group. No significant differences between the fatty acid compositions of both groups were found. Based on the above mentioned results we may conclude that feeding with a supplement of *Agaricus bisporus* has no influence on the technological properties and chemical composition of sheep meat. Given this fact we believe that research should continue in order to determine the amount of addition of *Agaricus bisporus* which will positively influence the technological properties of the meat and retain the desirable sensory characteristics in terms of color and softness, while providing a positive immune response.

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Received: 13 October 2014
Accepted: 9 June 2015

CVRTILA FLECK, Ž., L. KOZAČINSKI, B. NJARI, D. MARENČIĆ, G. MRŠIĆ, K. ŠPIRANEC, D. ŠPOLJARIĆ, M. J. ČOP, M. ŽIVKOVIĆ, M. POPOVIĆ: Tehnološka svojstva i kemijski sastav mesa ovaca hranjenih pripravkom plemenite pečurke *Agaricus bisporus*. Vet. arhiv 85, 591-600, 2015.

SAŽETAK

Cilj ovog istraživanja bio je utvrditi tehnološka svojstva te osnovni kemijski sastav mesa ovaca. U istraživanju je bilo obuhvaćeno ukupno 50 klaonički obrađenih ovčjih trupova. Pokusne životinje bile su podijeljene u dvije skupine pri čemu je kontrolnoj skupini (C) hranidba prilagođena samo za održavanje osnovnih životnih potreba, a drugoj (pokusnoj, A) skupini u hranu je dodavano 1,5 % osušenog pripravka plemenite pečurke *Agaricus bisporus*, tijekom 6 tjedana zimskog perioda. Boja, električna provodljivost, pH i kemijski sastav mesa određivani su 24 sata nakon klanja na m. longissimus dorsi. Ovce hranjene dodatkom plemenite pečurke imale su značajno manji udio hranjivih tvari (masti i bjelančevina) i značajno veći udio vode u odnosu na kontrolnu skupinu (P<0,001). Mišićna regija odabranih odraslih grla hranjenih pripravkom plemenite pečurke bila je tamnija (L*) s višim stupnjem crvenila (a*) i nižim stupnjem žutila (b*) u odnosu na mišićnu regiju kontrolne skupine. Nije bilo značajnih razlika masnokiselinskog sastava obiju skupina.

Ključne riječi: ovca, kakvoća mesa, plemenita pečurka, *Agaricus bisporus*