OPEN ACCESS
Potravinarstvo® Scientific Journal for Food Industry
cross check Powered by iThenticate deposited

potravinárstvo®

Potravinarstvo, vol. 9, 2015, no. 1, p. 451-457
doi:10.5219/523
Received: 29 September 2015. Accepted: 3 November 2015.
Available online: 17 December 2015 at www.potravinarstvo.com

ISSN 1337-0960 (online)

OXIDATIVE STABILITY OF CHICKEN THIGH MEAT AFTER TREATMENT OF *ABIES ALBA* ESSENTIAL OIL

Adriana Pavelková, Marek Bobko, Peter Haščík, Miroslava Kačániová, Jana Tkáčová

ABSTRACT

In the present work, the effect of the *Abies alba* essential oil in two different concentrations on oxidative stability of chicken thigh muscles during chilled storage was investigated. In the experiment were chickens of hybrid combination Cobb 500 after 42 days of the fattening period slaughtered. All the broiler chickens were fed with the same feed mixtures and were kept under the same conditions. The feed mixtures were produced without any antibiotic preparations and coccidiostatics. After slaughtering was dissection obtained fresh chicken thigh with skin from left half-carcass which were divided into five groups (n = 5): C - control air-packaged group; A1 - vacuum-packaged experimental group; A2 - vacuum-packaged experimental group with ethylenediaminetetraacetic acid (EDTA) solution 1.50% w/w; A3 - vacuum-packaged experimental group with *Abies alba* oil 0.10% v/w and A4 - vacuum-packaged experimental group with *Abies alba* oil 0.20% v/w. The *Abies alba* essential oil was applicate on ground chicken things and immediately after dipping, each sample was packaged using a vacuum packaging machine and storage in refrigerate at 4 ±0.5 °C. Thiobarbituric acid (TBA) value expressed in number of malondialdehyde was measured in the process of first storage day of 1st, 4th, 8th, 12th and 16th day after slaughtering and expressed on the amount of malondialdehyde (MDA) in 1 kg sample. The treatments of chicken things with *Abies alba* essential oil show statistically significant differences between all testing groups and control group, where higher average value of MDA measured in thigh muscle of broiler chickens was in samples of control group (0.4380 mg.kg^{-1}) compared to experimental groups A1 (0.124 mg.kg^{-1}), A2 (0.086 mg.kg^{-1}), A3 (0.082 mg.kg^{-1}) and A4 (0.077 mg.kg^{-1}) after 16-day of chilled storage. Experiment results show that the treatment of chicken thigh with *Abies alba* essential oil positively influenced on the reduction of oxidative processes in thigh muscles during chilling storage and use of essential oil is one of the options increase shelf life of fresh chicken meat.

Keywords: oxidative stability; chicken meat; essential oil; *Abies alba*

INTRODUCTION

For chicken meat products, freshness, as one of the most important quality attributes, has attracted attention from producers and consumers and has a strong relationship with product sales and consumption **(Rzepka et al., 2013)**.

The production and consumption of chicken meat has become very popular worldwide owing to its desirable nutritional characteristics, such as high protein, low fat and relatively high concentrations of polyunsaturated fatty acids (PUFAs) compared to beef or pork **(Brenes and Roura, 2010)**. However, the higher level of PUFAs in muscle membranes increases the susceptibility of oxidative deterioration of lipid **(Engberg et al., 1996)**, which impairs the organoleptic characteristics and shortens the shelf-life of meat and meat products. Lipid oxidation is a major cause of meat quality deterioration, resulting in rancidity and the formation of undesirable odours and flavours, which lowers the functional, sensory and nutritive values of meat products; and therefore, consumer acceptability **(Bou et al., 2004)**. In meat, lipid peroxidation is initiated by the abstraction of hydrogen radicals from unsaturated fatty acids, induced by light **(Boselli et al., 2005)**, heat, metal ions (**Kanner et al., 1988)**, or other oxidizing agents. The reaction of oxygen with preformed free radicals results in accelerated lipid peroxidation **(Frankel, 1984)**, which leads to the formation of secondary by-products from PUFA such as MDA and the potential appearance of lower sensory scores.

The antioxidants can be of synthetic or natural origin. Synthetic antioxidants such as butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), tert-butylhydroquinone (TBHQ), and propyl gallate (PG) have been widely used in meat and poultry products **(Biswas et al., 2004; Jayathilakan et al., 2007)**. But the demand for natural antioxidants, especially of plant origin has increased in the recent years due to the growing concern among consumers about these synthetic antioxidants because of their potential toxicological effects **(Juntachote et al., 2006; Naveena et al., 2008; Nunez de Gonzalez et al., 2008)**.

One option for reducing lipid oxidation is the use of various natural plant antioxidants presented in essential oils.

Essential oils (EOs) are aromatic oily liquids obtained from plant material (flowers, buds, seeds, leaves, twigs, bark, herbs, wood, fruits and roots). They can be obtained

by expression, fermentation, enfleurage or extraction but the method of steam distillation is most commonly used for commercial production of EOs **(Van de Braak and Leijten, 1999)**. EOs obtained from various herbs are widely used in cosmetics and food manufacturing and can be used for prolonging the shelf-life of food for their antimicrobial **(Skandamis et al., 2002; Mihajilov-Krstev et al., 2009)**, and antioxidant activities **(Burt, 2004; Bobko et al., 2015a, b)**.

Studies have shown wide effective in spices to retard lipid oxidation in meat products **(Juntachote et al., 2006, 2007a, b; Chouliara et al., 2007; Mariutti et al., 2008; Sasse et al., 2009; Lee et al., 2010; Marcinčák et al., 2010; Viuda-Martos et al., 2011; Tkáčová et al., 2015)**.

Antioxidants can slow the oxidative reactions of both lipids and pigments in meat, and much interest has been focused on natural antioxidants due to negative public perception of synthetic additives **(Cuppett et al., 1997)**. **Frankel (1996)** commented that the use of natural antioxidants has increased according to a presumption of their safety. Natural plant-derived antioxidants are primarily composed of polyphenolic compounds **(Shahidi et al., 1992)**, and antioxidants containing 2 or more phenolic hydroxyl groups have been found to be effective antioxidants **(Dziedzic and Hudson, 1984).** Plant phenolics are multi-functional antioxidants that can act as reducing agents (free radical terminators), metal chelators, and singlet O_2 quenchers. **Namiki (1990)** listed several common natural antioxidants used commercially in food, for example, tocopherols, ascorbic acid, soybean products, oat products, components of crude vegetable oils, amino acids, peptides and proteins, guaiac gum, flavonoids, spices, and herbs.

One possible use EOs from another source e.g. trees from the family *Pinaceae*, which includes many of the well-known conifers of commercial importance such as cedars, firs, hemlocks, larches, pines and spruces. Trees are rich in polyphenolic compounds, and might serve as a source of potentially useful substances, if their antimicrobial properties and safety can be established **(Välimaa et al., 2007)**. The essential oil showed antioxidative and antibacterial activities **(Yang et al., 2009)**. However, many other fir species have been recognized as rich sources of lignans, flavonoids and other phenols with antioxidant activity **(Yang et al., 2008; Li et al., 2011)**.

The essential oils isolated from *Abies alba* needles are used commercially in the cosmetic and fragrance industries; for example, silver fir needle oil is a component in air fresheners, perfumes, and household products **(Góra and Lis, 2012)**.

Wajs-Bonikowska et al. (2015) stated that in samples *Abies alba* and *Abies koreana* essential oils obtained by hydrodistillation 135 compounds were identified, constituting 98.3 – 99.9% of the total oil compositions.

Zeneli et al. (2001) have been reported that α-pinene, camphene, β-pinene, limonene and bornyl acetate were the major component in the needle oleoresin, and α-pinene, β-pinene, limonene, β-caryophyllene and germacrene D comprised the majority of cortical oleoresin of silver fir in Albania.

Data from recent scientific literature suggest an increased interest in studying the composition of the essential oil isolated from different pine species as well as biological activity. Generally, monoterpenes and sesquiterpenes are dominant components of pine needle essential oils **(Menkovic et al., 1993; Roussis et al., 1994; Dormont et al., 1998; Barnola and Cedeno, 2000; Yong-Suk and Dong-Hwa, 2005; Dob et al., 2006; Dob et al., 2007; Nikolic et al., 2007; Oluwadayo et al., 2008)**. It is important to notice that these essential oils have antimicrobial **(Sacchetti et al., 2005; Yong-Suk and Dong-Hwa, 2005; Oluwadayo et al., 2008)**, antifungal and antioxidant activity **(Gülçin et al., 2003; Pinelo et al., 2004; Sacchetti et al., 2005; Guri et al., 2006; Jerez et al., 2007a, b; Limei et al., 2008)**.

In this study we aimed to investigate the combined effect of ethylenediaminetetraacetate acid (EDTA) and plant essential oil *(Abies alba)* on the oxidative stability of fresh chicken thighs stored under vacuum packaging (VP), at 4 ±0.5 °C for a period of 16 days.

MATERIAL AND METHODOLOGY

The experiment was implemented in the local poultry station (Hydinaren a.s., Zamostie). The tested were broiler chickens of hybrid combination Cobb 500 both sexes. All the broiler chickens were fed with the same feed mixtures and were kept under the same conditions. The feed mixtures were produced without any antibiotic preparations and coccidiostatics. At the end of the fattening period (42. day) were chickens slaughtered for analysis in laboratory of Slovak University of Agriculture in Nitra. After slaughtering was dissection obtained fresh chicken thighs with skin from left half-carcass, which were divided into five groups (n = 5):

- Air-packaged (C, control group): chicken thigh fresh meat was packaging to polyethylene backs and stored aerobically in refrigerator at 4 ±0.5 °C for a period of 16 days;
- Vacuum-packaged (VP) (A1, experimental group): chicken thigh fresh meat was packaging to polyethylene backs and stored anaerobically in vacuum and in refrigerator at 4 ±0.5 °C for a period of 16 days;
- VP with EDTA solution 1.50% w/w (A2, experimental group): chicken thigh fresh meat was treated with EDTA for 1 min and packaging to polyethylene backs and stored anaerobically in vacuum and in refrigerator at 4 ±0.5 °C for a period of 16 days;
- VP with *Abies alba* oil 0.10% v/w (A3, experimental group): chicken thigh fresh meat was treated with *Abies alba* oil for 1 min and packaging to polyethylene backs and stored anaerobically in vacuum and in refrigerator at 4 ±0.5 °C for a period of 16 days;
- VP with *Abies alba* oil 0.20% v/w, (A4, experimental group): chicken thigh fresh meat was treated with *Abies alba* oil for 1 min and packaging to polyethylene backs and stored anaerobically in vacuum and in refrigerator at 4 ±0.5 °C for a period of 16 days.

Immediately after dipping, each sample was packaged using a vacuum packaging machine type VB-6 (RM Gastro, Czech Republic).

Ethylenediaminetetraacetic acid (EDTA) ($C_{10}H_{14}N_2O_8.Na_2.2H_2O$) was 99.5% purity, analytical

grade, (Invitrogen, USA). A stock solution of 500 mM concentration was prepared by diluting 186.15 $g.L^{-1}$ distilled water. A final concentration of 50 mM EDTA solution was prepared from the stock solution. The pH of the solution was adjusted to 8.0 with the addition of the appropriate quantity of NaOH solution. The amount of EDTA added to the treat chicken thighs was 0.28 $g.kg^{-1}$. Essential oil (Calendula, Nova Lubovna, Slovakia) were added to the coated chicken thigh surface (both sides) of each sample using a micropipette so as to achieve a 0.1% and 0.2% v/w final concentration of essential oils.

TBA value expressed in number of malondialdehyde (MDA) was measured in the process of first storage day of 1st, 4th, 8th, 12th and 16th day. TBA number was determined by **Marcinčák et al. (2004)**. Absorbance of samples was measured on UV-VIS spectrophotometer T80 (PG Limeted Instruments, UK) at a wavelength of 532 nm, the translation results on the amount of MDA in 1 kg samples.

Results of the experiment was evaluated with statistical program Statgraphics Plus version 5.1 (AV Trading Umex, Dresden, Germany), were calculated variation-statistical values (mean, standard deviation) and to determine the significant difference between groups was used variance analyse with subsequent Scheffe test.

RESULTS AND DISCUSSION

The results of the oxidation stability of fresh chicken thigh muscles of chicken Cobb 500 after application EDTA and plant essential oil *(Abies alba)* during 16 days storage at 4 ±0.5 °C are shown in Table 1 and Figure 1. Oxidation of lipids can occur in both fresh and cooked meats **(Min and Ahn, 2005; Jo et al., 2006)**, and can have significant impact to meat industry.

The higher average value of MDA measured in thigh muscle in 0 day of experiment was in samples of vacuum-packaged chicken thighs group with *Abies alba* oil 0.10% v/w group A3 (0.027 $mg.kg^{-1}$) compared to experimental groups A1 (0.021 $mg.kg^{-1}$), A2 (0.024 $mg.kg^{-1}$), A4 (0.026 $mg.kg^{-1}$) and air-packaged control group (0.023 $mg.kg^{-1}$). We have not found statistically significant differences between testing groups chicken thighs. During chilled storage of the thigh muscles were detected increased content of malondialdehyde in comparison to the first day of storage.

On the fourth day of storage were measured below the values of malondialdehyde in all experimental groups (0.042 $mg.kg^{-1}$ – groups A3, A4 and 0.055 $mg.kg^{-1}$ – group A1) opposite control group C (0.071 $mg.kg^{-1}$). We have found statistically significant differences ($p \leq 0.05$) between control group C and tested groups A2, A3 and A4.

A similar trend of improving the oxidation stability after eight days of refrigerate storage in the thigh muscle of hybrid combination Cobb 500 we found in the experimental groups (0053 $mg.kg^{-1}$ – A4 to 0069 $mg.kg^{-1}$ – A1) compared with control group C (0.172 $mg.kg^{-1}$).

After 12 days of thigh muscle storage was statistic significantly ($p \leq 0.05$) improved the oxidative stability of all test groups chicken things (0.066 $mg.kg^{-1}$ – A4 to 0.081 $mg.kg^{-1}$ – A1) compared to the control group C (0.246 $mg.kg^{-1}$). We have found statistically significant differences ($p \leq 0.05$) between control group C and tested groups and between tested group A1 and groups A2, A3 and A4.

During testing period of chilled storage were higher values of malondialdehyde measured in control group C compare to experimental groups. The higher average value of MDA measured in thigh muscle of broiler chickens Cobb 500 was in samples of control group C (0.438 $mg.kg^{-1}$) compared to experimental groups A1 (0.124 $mg.kg^{-1}$), A2 (0.086 $mg.kg^{-1}$), A3 (0.082 $mg.kg^{-1}$) and A4 (0.077 $mg.kg^{-1}$) after 16-day of chilled storage. At the end of the test period we have found statistically significant differences between all testing groups and control group of chicken thighs.

Table 1 Effect of *Abies alba* essential oil on the concentration of MDA ($mg.kg^{-1}$) in thigh muscle (mean ±SD) (n = 5).

Day	C	A1	A2	A3	A4
0	0.023 ±0.007	0.021 ±0.008	0.024 ±0.006	0.027 ±0.005	0.026 ±0.008
4	0.071 ± 0.012^{a}	0.055 ± 0.008^{ac}	0.049 ± 0.006^{bc}	0.042 ± 0.005^{b}	0.042 ± 0.011^{bc}
8	0.172 ± 0.017^{a}	0.069 ± 0.005^{b}	0.058 ± 0.006^{c}	0.055 ± 0.007^{c}	0.053 ± 0.010^{c}
12	0.247 ± 0.024^{a}	0.081 ± 0.008^{b}	0.072 ± 0.013^{b}	0.075 ± 0.007^{b}	0.066 ± 0.016^{b}
16	0.438 ± 0.052^{a}	0.124 ± 0.020^{b}	0.086 ± 0.013^{c}	0.082 ± 0.008^{c}	0.077 ± 0.008^{c}

Legend: C – air-packaged control group; A1 – vacuum-packaged control group; A2 – vacuum-packaged control samples with EDTA solution 1.50% w/w; A3 – vacuum-packaged experimental group with *Abies alba* oil 0.10% v/w; A4 – vacuum-packaged experimental group with *Abies alba* oil 0.20% v/w. Mean values in the same lines with different superscripts (a, b, c) are significantly different at $p \leq 0.05$ level

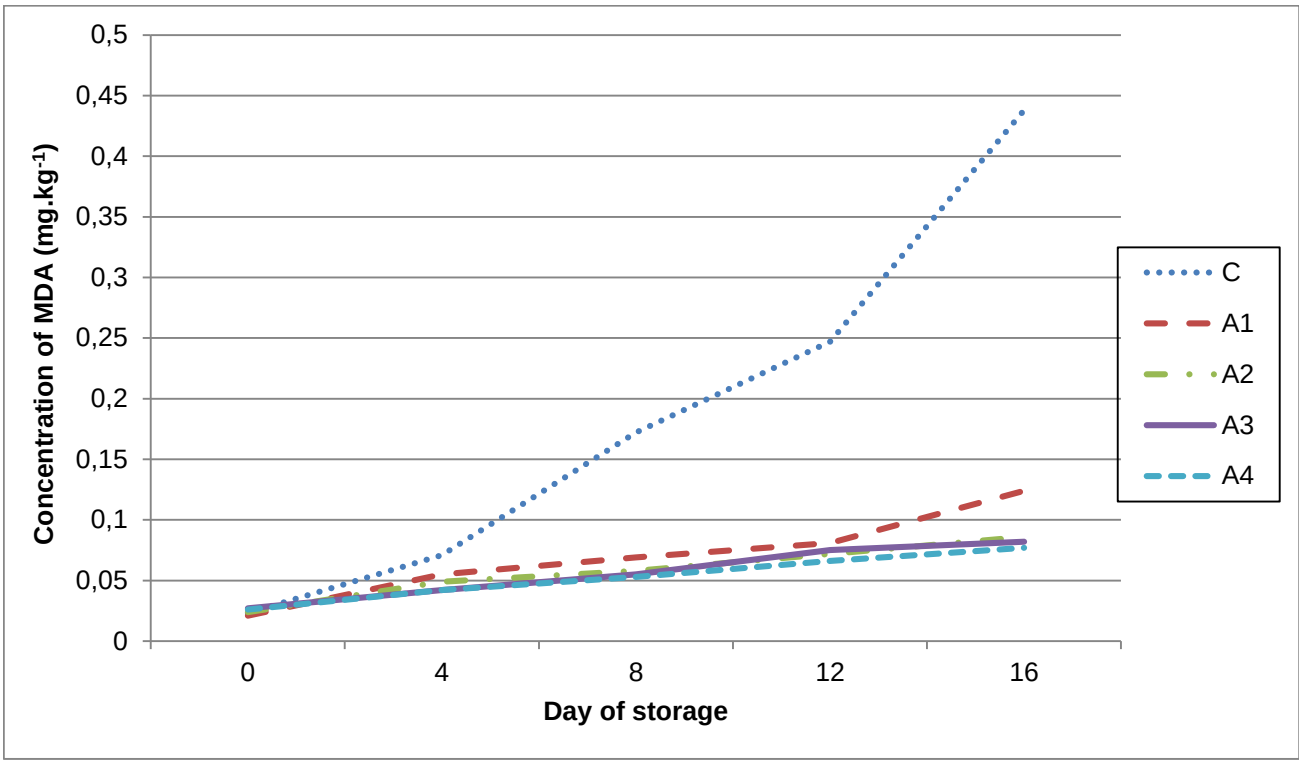

Figure 1 Concentration of MDA (mg.kg^{-1}) in thigh muscle.

Note: C – air-packaged control group; A1 – vacuum-packaged control group; A2 – vacuum-packaged control samples with EDTA solution 1.50% w/w; A3 – vacuum-packaged experimental group with *Abies alba* oil 0.10% v/w; A4 – vacuum-packaged experimental group with *Abies alba* oil 0.20% v/w.

Like plant essential oils such as oregano, thyme, sage etc. **(Economou et al., 1991; Yanishlieva and Marinova, 1995; Man and Jaswir, 2000)**, also *Abies alba* essential oil exhibits substantiating positive effect on oxidation stability of lipids in meat. **Botsoglou et al. (2007)** reported that a higher concentration of antioxidants in poultry meat has the effect of reducing lipid oxidation, i.e. there is a reduction in malondialdehyde values during chilling storage. **Sampaio et al. (2012)** examined the effect of combinations of sage, oregano and honey on lipid oxidation in cooked chicken meat (thigh and breast) during refrigeration at 4 ±0.5 °C for 96 h as measured by TBARs numbers. The analysis of variance on the TBARs data indicated that the TBARs values were significantly affected by natural antioxidants throughout refrigeration (p <0.05). Analysis their data showed that all of the three combinations of natural antioxidants tested would be beneficial for reducing the velocity of lipid oxidation in both chicken meats during storage, what are corroborated by other authors who have added honey and herbs and thereby inhibited the development of lipid oxidation in cooked meats during refrigeration time **(McKibben and Engeseth, 2002; Juntachote et al., 2007a)**.

Overall, we can state that such addition *Abies alba* essential oil as well as the packaging method (system of vacuum packing) improved the oxidative stability of chicken thigh stored cooling at 4 ±0.5 °C for a period of 16 days.

Due to consumer preferences, chicken dark meat is typically in an overabundance; thus, finding value-added options for dark chicken meat is of interest to the poultry industry. One reason ground chicken meat shelf life is limited is the rapid loss of fresh appearance.

Meat containing unsaturated fatty acids is very sensitive to lipid oxidation especially during storage, because polyunsaturated fatty acid esters are easily oxidized by molecular oxygen. This kind of oxidation is called autoxidation and proceeds by a free radical chain mechanism **(Brewer, 2011)**.

Gong et al. (2008) used TBARs values as an indicator of secondary lipid oxidation products, which were determined in minced breast and thigh muscles from chicken, turkey and duck during -4 °C storage. TBARS formation was slowest in minced chicken thigh, intermediate in duck thigh and fastest in turkey thigh (p <0.01).

Ramos Avila et al. (2013) stated that the degradation pathways of fatty substances play one of the main causes of foods deterioration and unpleasant odours. This factor is also responsible for the loss of sensory properties.

Rhee et al. (1996) observed that raw poultry meat is less prone to lipid oxidation than beef or pork meat because of its lower iron content.

CONCLUSION

The essential oil from natural sources can be used as alternatives to chemical additives which could extend the meat and meat products shelf life. Results achieved in the experiment show that the treatment of chicken thigh with *Abies alba* essential oil in concentration 0.10% v/w and

0.20% v/w with combination vacuum packaging had positive influence on the reduction of oxidative processes in thigh muscles during chilling storage at 4 ±0.5 °C in comparative with tested groups - control air-packaged group, vacuum-packaged experimental group and vacuum-packaged experimental group with EDTA solution 1.50% w/w. The use of essential oil is one of the options increase shelf life of meat.

REFERENCES

Barnola, L. F., Cedeno, A. 2000. Inter-population differences in the essential oils of *Pinus caribaea* needles. *Biochemical Systematics and Ecology*, vol. 28, no. 10, p. 923-931. http://dx.doi.org/10.1016/s0305-1978(00)00036-3

Biswas, A. K., Keshri, R. C., Bisht, G. S. 2004. Effect of enrobing and antioxidants on quality characteristics of precooked pork patties under chilled and frozen storage conditions. *Meat Science*, vol. 66, no. 3, p. 733-741. http://dx.doi.org/10.1016/j.meatsci.2003.07.006

Bobko, M., Kročko, M., Haščík, P., Bobková, A. 2015a. Oxidative stability of chicken meat after propolis extract application in their diets. *Potravinarstvo*, vol. 9, no. 1, p. 48-52. http://dx.doi.org/10.5219/427

Bobko, M., Haščík, P., Bobková, A., Pavelková, A., Tkáčová, J., Trembecká, L. 2015b. Lipid oxidation in chicken meat after application of bee pollen extract, propolis extract and probiotic in their diets. *Potravinarstvo*, vol. 9, no. 1, p. 342-346. http://dx.doi.org/10.5219/495

Boselli, E., Caboni, M. F., Rodriguez-Estrada, M. T., Toschi, T. G., Daniel, M., Lercker, G. 2005. Photooxidation of cholesterol and lipids of turkey meat during storage under commercial retail conditions. *Food Chemistry*, vol. 91, no. 4, p. 705-713. http://dx.doi.org/10.1016/j.foodchem.2004.06.043

Botsoglou, N. A., Govaris, A., Giannenas, I., Botsoglou, E., Papapageorgiou, G. 2007. The incorporation of dehydrated rosemary leaves in therations of turkeys and their impact on the oxidative stability of the produced raw and cooked meat. *International Journal of Food Science and Technology*, vol. 58, no. 4, p. 312-320. http://dx.doi.org/10.1080/09637480701228583

Bou, R., Guardiola, F., Tres, A., Barroeta, A. C., Codony, R. 2004. Effect of dietary fish oil, a-tocopheryl acetate, and zinc supplementation on the composition and consumer acceptability of chicken meat. *Poultry Science*, vol. 83, no. 2, p. 282-292. http://dx.doi.org/10.1093/ps/83.2.282

Brenes, A., Roura, E. 2010. Essential oils in poultry nutrition: Main effects and modes of action. *Animal Feed Science and Technology*, vol. 158, no. 1-2, p. 1-14. http://dx.doi.org/10.1016/j.anifeedsci.2010.03.007

Brewer, M. S. 2011. Natural antioxidants: Sources, compounds,mechanisms of action, and potential applications. *Comprehensive Reviews in Food Science and Food Safety*, vol. 10, no. 4, p. 221-247. http://dx.doi.org/10.1111/j.1541-4337.2011.00156.x

Burt, S. 2004. Essential oils: their antibacterial properties and potential applications in foods-a review. *International Journal of Food Microbiology*, vol. 94, no. 3, 223-253. http://dx.doi.org/10.1016/j.ijfoodmicro.2004.03.022

Chouliara, E., Karatapanis, A., Savvaidis, I. N., Kontominas, M. G. 2007. Combined effect of oregano essential oil and modified atmosphere packaging on shelf-life extension of fresh chicken breast meat, stored at 4 °C. Food Microbiology, vol. 24, no. 6, p. 607-617. http://dx.doi.org/10.1016/j.fm.2006.12.005

Cuppett, C., M. Schnepf C. Hall III. 1997. Natural antioxidants - Are they a reality? Natural Antioxidants. *F. Shahidi, ed. AOCS Press, Champaign, IL.* p. 12-24.

Dob, T., Berramdane, T., Chelghoum, C. 2006. Analysis of essential oil from the needles of *Pinus pinaster* growing in Algeria. *Chemistry of Natural Compounds*, vol. 41, no. 5, p. 545-548. http://dx.doi.org/10.1007/s10600-005-0202-z

Dob, T., Berramdane, T., Chelgoum, C. 2007. Essential oil composition of *Pinus halepensis* Mill. from three different regions of Algeria. *Journal of Essential Oil Research*, vol. 19, no. 1, p. 40-43. http://dx.doi.org/10.1080/10412905.2007.9699226

Dormont, L., Roques, A., Malosse, C. 1998. Cone and foliage volatiles emitted by *Pinus cembra* and some related conifer species. *Phytochemistry*, vol. 49, no. 5, p. 1269-1277. http://dx.doi.org/10.1016/s0031-9422(98)00105-8

Dziedzic, S. Z., Hudson, B. J. F. 1984. Phenolic acids and related compounds as antioxidants for edible oils. *Food Chemistry*, vol. 14, no. 1, p. 45-51. http://dx.doi.org/10.1016/0308-8146(84)90017-7

Economou, K. D., Oreopoulou, V., Thomopouls, C. D. 1991. Antioxidant properties of some plant extract of the labiatae family. *JOACS*, vol. 68, no. 2, p. 109-113.

Engberg, R. M., Lauridsen, C., Jensen, S. K., Jakobsen, K. 1996. Inclusion of oxidised vegetable oil in broiler diets. Its influence on nutrient balance and on antioxidative status of broilers. *Poultry Science*, vol. 75, no. 8, p. 1003-1011. http://dx.doi.org/10.3382/ps.0751003

Frankel, E. N. 1984. Lipid oxidation: Mechanisms, products, and biological significance. *Journal of the American Oil Chemists' Society*, vol. 61, no. 12, p. 1908-1917. http://dx.doi.org/10.1007/bf02540830

Frankel, E. N. 1996. Antioxidants in lipid foods and their impact on food quality. *Food Chemistry*, vol. 57, no. 1, p. 51-55. http://dx.doi.org/10.1016/0308-8146(96)00067-2

Góra, J., Lis, A. 2012. Essential Oils of Great Value., Lodz University of Technology Press, Lodz.

Gülçin, I., Büyükokuroğlu, M. E., Oktay, M., Küfrevioğlu, Ö.İ. 2003. Antioxidant and analgesic activities of turpentine of *Pinus nigra* Arn. subsp. *pallasiana* (Lamb.) Holmboe. *Journal of Ethnopharmacology*, vol. 86, no. 1, p. 51-58. http://dx.doi.org/10.1016/s0378-8741(03)00036-9

Guri, A., Kefalas, P., Roussis, V. 2006. Antioxidant potential of six pine species. *Phytotherapy Research*, vol. 20, no. 4, p. 263-266. http://dx.doi.org/10.1002/ptr.1848

Jayathilakan, K., Sharma, G. K., Radhakrishna, K., Bawa, A. S. 2007. Antioxidant potential of synthetic and natural antioxidants and its effect on warmed-over-flavour in different species of meat. *Food Chemistry*, vol. 105, no. 3, p. 908-916. http://dx.doi.org/10.1016/j.foodchem.2007.04.068

Jerez, M., Tourino, S., Sineiro, J., Torres, J. L., Nunez, M. J. 2007a. Procyanidins from pine bark: Relationships between structure, composition and antiradical activity. *Food Chemistry*, vol. 104, no. 2, p. 518-527. http://dx.doi.org/10.1016/j.foodchem.2006.11.071

Jerez, M., Selga, A., Sineiro, J., Torres, J. L., Nunez, M. J. 2007b. A comparison between bark extracts from *Pinus pinaster* and *Pinus radiate*: Antioxidant activity and procyanidin composition. *Food Chemistry*, vol. 100, no. 2, p. 439-444. http://dx.doi.org/10.1016/j.foodchem.2005.09.064

Jo, S., Nam, K., Min, B., Ahn, D., Cho, S., Park, W. 2006. Antioxidant activity of *Prunus mume* extract in cooked chicken breast meat. *International Journal of Food Science*

and Technology, vol. 41, no. s1, p. 15-19. http://dx.doi.org/10.1111/j.1365-2621.2006.01234.x

Juntachote, T., Berghofer, E., Siebenhandl, S., Bauer, F. 2006. The antioxidative properties of Holy basil and Galangal in cooked ground pork. *Meat Science*, vol. 72, no. 3, p. 446-456. http://dx.doi.org/10.1016/j.meatsci.2005.08.009

Juntachote, T., Berghofer, E., Siebenhandl, S., Bauer, F. 2007a. Antioxidative effect of added dried Holy basil and its ethanolic extracts on susceptibility of cooked ground pork to lipid oxidation. *Food Chemistry*, vol. 100, no. 1, p. 129-135. http://dx.doi.org/10.1016/j.foodchem.2005.09.033

Juntachote, T., Berghofer, E., Siebenhandl, S., Bauer, F. 2007b. The effect of dried galangal powder and its ethanolic extracts on oxidative stability in cooked ground pork. *LWT - Food Science and Technology*, vol. 40, no. 2, p. 324-330. http://dx.doi.org/10.1016/j.lwt.2005.08.008

Kanner, J., Hazan, B., Doll, L. 1988. Catalytic "free" iron ions in muscle foods. *Journal of Agricultural and Food Chemistry*, vol. 36, no. 3, p. 412-415. http://dx.doi.org/10.1021/jf00081a002

Lee, M.-A., Choi, J.-H., Choi, Y.-S., Han, D.-J., Kim, H.-Y., Shim, S.-Y., Chung, H.-K., Kim, Ch.-J. 2010. The antioxidative properties of mustard leaf (*Brassica juncea*) kimchi extracts on refrigerated raw ground pork meat against lipid oxidation. *Meat Science*, vol. 84, no. 3, p. 498-504.http://dx.doi.org/10.1016/j.meatsci.2009.10.004

Li, Y.-L., Wu, L., Ouyang, D.-W., Yu, P., Xia, J.-H., Pan, Y.-X., Yang, X. W., Zeng, H. W., Cheng, X. R., Jin, H. Z., Zhang, W. D. 2011. Phenolic compounds of *Abies nephrolepis* and their NO production inhibitory activities. *Chemistry & Biodiversity*. vol. 8, no. 12, p. 2299-2309. http://dx.doi.org/10.1002/cbdv.201000373

Limei, Y., Zhao, M., Wang, J. S., Cui, C., Yang, B., Jiang, Y., Zhao, Q. 2008. Antioxidant, immunomodulatory and antibreast cancer activities of phenolic extracts from pine (*Pinus massoniana* Lamb.) bark. *Innovative Food Science and Emerging Technologies*, vol. 9, no. 1, p. 122-128. http://dx.doi.org/10.1016/j.ifset.2007.06.006

Man, Y., Jaswir, I. 2000. Effect of rosemary and sage extracts on frying performance of refind, bleached and deodorized plam olein during deep-fat frying. *Food Chemistry*, vol. 69, no. 3, p. 301-307. http://dx.doi.org/10.1016/s0308-8146(99)00270-8

Marcinčák, S., Sokol, J., Bystrický, P., Popelka, P., Turek, P., Máté, D. 2004. Determination of lipid oxidation level in broiler meat by liquid chromatography. *Journal of AOAC International*, vol. 87, p. 1148-1152.

Marcinčák, S., Popelka, P., Šimková, J., Marcinčáková, D., Martonová, M. 2010. Oxidative stability of chilled chicken meat after feeding of selected plants. *Potravinarstvo*, vol. 4, no. 3, p. 46-49. http://dx.doi.org/10.5219/38

Mariutti, L. R. B., Orlien, V., Bragagnolo, N., Skibsted, L. H. 2008. Effect of sage and garlic on lipid oxidation in high-pressure processed chicken meat. *European Food Research and Technology*, vol. 227, no. 2, p. 337-344. http://dx.doi.org/10.1007/s00217-007-0726-5

McKibben, J., Engeseth, N. J. 2002. Honey as a protective agent against lipid oxidation in ground turkey. *Journal of Agricultural and Food Chemistry*, vol. 50, no. 3, p. 592-595. http://dx.doi.org/10.1021/jf010820a

Menkovic, N. R., Ristic, M. S., Samardzic, Z. J., Kovacevic, N. N., Tasic, S. R. 1993. Investigations of relic *Pinus* species. II. The essential oil of *Pinus heldreichii*. ISHS *Acta Horticulturae*, vol. 344, p. 578-581. http://dx.doi.org/10.17660/actahortic.1993.344.68

Mihajilov-Krstev, T., Radnović, D., Kitić, D., Zlatković, B., Ristić, M., Branković, S. 2009. Chemical composition and antimicrobial activity of *Satureja hortensis* L. essential oil. *Open Life Sciences*, vol. 4, no. 3, p. 411-416. http://dx.doi.org/10.2478/s11535-009-0027-z

Min, B., Ahn, D. U. 2005. Mechanism of lipid peroxidation in meat and meat products - A review. *Food Science and Biotechnology*, vol. 14, no. 1, p. 152-163.

Namiki, M. 1990. Antioxidants/antimutagens in food. *Critical Reviews in Food Science and Nutrition*, vol. 29, no. 4, p. 273-300. http://dx.doi.org/10.1080/10408399009527528

Naveena, B. M., Sen, A. R., Vaithiyanathan, S., Babji, Y., Kondaiah, N. 2008. Comparative efficacy of pomegranate juice, pomegranate rind powder extract and BHT as antioxidants in cooked chicken patties. *Meat Science*, vol. 80, no. 4, p. 304-308. http://dx.doi.org/10.1016/j.meatsci.2008.06.005

Nikolic, B., Ristic, M., Bojovic, S., Marin, P. D. 2007. Variability of the needle essential oils of *Pinus heldreichii* from different populations in Montenegro and Serbia. *Chemistry and Biodiversity*, vol. 4, no. 5, p. 905-916. http://dx.doi.org/10.1002/cbdv.200790079

Nunez de Gonzalez, M. T., Hafley, B.S., Boleman, R. M., Miller, R. K., Rhee, K. S., Keeton, J. T. 2008. Antioxidant properties of plum concentrates and powder in precooked roast beef to reduce lipid oxidation. *Meat Science*, vol. 80, no. 4, p. 997-1004. http://dx.doi.org/10.1016/j.meatsci.2008.04.014

Oluwadayo Sonibare, O., Olakunle, K. 2008. Chemical composition and antibacterial activity of the essential oil of *Pinus caribaea* from Nigeria. *African Journal of Biotechnology*, vol. 7, no. 14, p. 2462-2464. [cit. 2015-09-28] Available at: http://www.ajol.info/index.php/ajb/article/viewFile/59026/47339

Pinelo, M., Rubilar, M., Sineiro, J., Nunez, M. J. 2004. Extraction of antioxidant phenolics from almond hulls (*Prunus amygdalus*) and pine sawdust (*Pinus pinaster*). *Food Chemistry*, vol. 85, no. 2, p. 267-273. http://dx.doi.org/10.1016/j.foodchem.2003.06.020

Ramos Avila, F., Pro-Martínez, A., Sosa-Montes. E., Cuca-García, J. M., Becerril-Pérez, C., Figueroa-Velasco, J. L., Ruiz-Feria, C. A., Hernández-Cázares, A. S., Narciso-Gaytán, C. 2013. Dietary supplemented and meat-added antioxidants effect on the lipid oxidative stability of refrigerated and frozen cooked chicken meat. *Poultry Science*, vol. 92, no. 1, p. 243-249. http://dx.doi.org/10.3382/ps.2012-02409

Rhee K. S., Anderson L. M., Sams A. R. 1996. Lipid oxidation potential of beef chicken, and pork. *Journal of Food Scince*, vol. 61, no. 1, p. 8-12. http://dx.doi.org/10.1111/j.1365-2621.1996.tb14714.x

Roussis, V., Petracis, P. V., Ortiz, A., Mazomenos, B. E. 1994. Volatile constituents of needles of five *Pinus* species grown in Greece. *Phytochemistry*, vol. 39, no. 2, p. 357-361. http://dx.doi.org/10.1016/0031-9422(94)00885-w

Rzepka, M., Ozogul, F., Surowka, K., Michalczyk, M. 2013. Freshness and quality attributes of cold stored Atlantic bonito (*Sarda sarda*) gravad. *International Journal of Food Science and Technology*, vol. 48, no. 6, p. 1318-1326. http://dx.doi.org/10.1111/ijfs.12094

Sacchetti, G., Maietti, S., Muzzoli, M., Scaglianti, M., Manfredini, S., Radice, M., Bruni, R. 2005. Comparative evaluation of 11 essential oils of different origin as functional

antioxidants, antiradicals and antimicrobials in foods. *Food Chemistry*, vol. 91, no. 4, p. 621-632. http://dx.doi.org/10.1016/j.foodchem.2004.06.031

Sampaio, G. R., Saldanha, T., Soares, R. A. M., Torres, E. A. F. S. 2012. Effect of natural antioxidant combinations on lipid oxidation in cooked chicken meat during refrigerated storage. *Food Chemistry*, vol. 135, no. 3, p. 1383-1390. http://dx.doi.org/10.1016/j.foodchem.2012.05.103

Sasse, A., Colindres, P., Brewer, M. S. 2009. Effect of natural and synthetic antioxidants on the oxidative stability of cooked, frozen pork patties. *Journal of Food Science*, vol. 74, no. 1, S30-S35. http://dx.doi.org/10.1111/j.1750-3841.2008.00979.x

Shahidi, F., Janitha, P. K., Wanasundara, P. D. 1992. Phenolic antioxidants. *Critical Reviews in Food Science and Nutrition.* vol. 32, no. 1, p. 67-103. http://dx.doi.org/10.1080/10408399209527581

Skandamis, P., Tsigarida, E., Nychas, G.-J. E. 2002. The effect of oregano essential oil on survival/death of *Salmonella* typhimuriumin meat stored at 5 °C under aerobic, VP/MAP conditions. *Food Microbiology*, vol. 19, no. 1, p. 97-103. http://dx.doi.org/10.1006/fmic.2001.0447

Tkáčová, J., Angelovičová, M., Haščík, P., Bobko, M. 2015. Oxidative stability of chicken meat during storage influenced by the feeding of alfalfa meal. *Potravinarstvo*, vol. 9, no. 1, p. 106-111. http://dx.doi.org/10.5219/444

Välimaa, A.-L., Honkalampi-Hämäläinen, U., Pietarinen, S., Willför, S., Holmbom, B., von Wright, A. 2007. Antimicrobial and cytotoxic knotwood extracts and related pure compounds and their effects on food-associated microorganisms. *International Journal of Food Microbiology*, vol. 115, no. 2, p. 235-243. http://dx.doi.org/10.1016/j.ijfoodmicro.2006.10.031

Van de Braak, S. A. A. J, Leijten, G. C. J. J. 1999. Essential Oils and Oleoresins: A survey in the Netherlands and other major Markets in the European Union. CBI, Centre for the Promotion of Imports from Developing Countries, Rotterdam. p. 116.

Viuda-Martos, M., Mohamady, M. A., Fernández-López, J., Abd ElRazik, K. A., Omer, E. A., Pérez-Alvarez, J. A., Sendra, E. 2011. *In vitro* antioxidant and antibacterial activities of essentials oils obtained from Egyptian aromatic plants. *Food Control*, vol. 22, no. 11, p. 1715-1722. http://dx.doi.org/10.1016/j.foodcont.2011.04.003

Wajs-Bonikowska, A., Sienkiewicz, M., Stobiecka, A., Maciąg, A., Szoka, Ł., Karna, E. 2015. Chemical Composition and Biological Activity of Abies alba and A. koreana Seed and Cone Essential Oils and Characterization of Their Seed Hydrolates.*Chemistry & Biodiversity*, vol. 12, no. 3, p. 407-418. http://dx.doi.org/10.1002/cbdv.201400167

Yang, S.-A., Jeon, S.-K., Lee, E.-J., Im, N.-K., Jhee, K.-H., Lee, S.-P., Lee, I. S. 2009. Radical scavenging activity of the essential oil of silver fir (*Abies alba*). *Journal of Clinical Biochemistry and Nutrition*, vol. 44, no. 3, p. 253-259. http://dx.doi.org/10.3164/jcbn.08-240

Yang, X.-W., Li, S.-M., Shen, Y.-H., Zhang, W.-D. 2008. Phytochemical and biologicalstudies of *Abies* species. *Chemistry & Biodiversity*. vol. 5, no. 1, p. 56-81. http://dx.doi.org/10.1002/cbdv.200890015

Yanishhlieva, V., Marinova, M. 1995. Antioxidant activity of selected species of the family Lamiaceae grown in Bulgaria. *Food / Nahrung*, vol. 39, no. 5-6, p. 458-463. http://dx.doi.org/10.1002/food.19950390510

Youg-Suk, K., Dong-Hwa, Sh. 2005. Volatile components and antibacterial effects of pine needle (*Pinus densiflora* S. and Z.) extracts. *Food Microbiology*, vol. 22, no. 1, p. 37-45. http://dx.doi.org/10.1016/j.fm.2004.05.002

Zeneli, G., Tsitsimpikou, C., Petrakis, P. V., Naxakis, G., Habili, D., Roussis, V. 2001. Foliar and cortex oleoresin variability of silver fir (*Abies alba* Mill.) in Albania. *Zeitschrift für Naturforschung* C, vol. 56, no. 7-8. http://dx.doi.org/10.1515/znc-2001-7-810

Ack nowledgments:
This work was supported by grant VEGA 1/0129/13.

Contact address:
Adriana Pavelková, Slovak University of Agriculture in Nitra, Faculty of Biotechnology and Food Sciences, Department of Evaluation and Processing of Animal Products, Tr. A. Hlinku 2, 949 76 Nitra, Slovakia, E-mail: adriana.pavelkova@uniag.sk

Marek Bobko, Slovak University of Agriculture in Nitra, Faculty of Biotechnology and Food Sciences, Department of Evaluation and Processing of Animal Products, Tr. A. Hlinku 2, 949 76 Nitra, Slovakia, E-mail: marek.bobko@uniag.sk.

Peter Haščík, Slovak University of Agriculture in Nitra, Faculty of Biotechnology and Food Sciences, Department of Evaluation and Processing of Animal Products, Tr. A. Hlinku 2, 949 76 Nitra, Slovakia, E-mail: peter.hascik@uniag.sk.

Miroslava Kačániová, Slovak University of Agriculture in Nitra, Faculty of Biotechnology and Food Sciences, Department of Microbiology, Tr. A. Hlinku 2, 949 76 Nitra, Slovakia, E-mail: miroslava.kacaniova@uniag.sk.

Jana Tkáčová, Slovak University of Agriculture in Nitra, Faculty of Biotechnology and Food Sciences, Department of Evaluation and Processing of Animal Products, Tr. A. Hlinku 2, 949 76 Nitra, Slovakia, E-mail: jana.tkacova@uniag.sk.