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Dietary Administration of Animal Diets with Aromatic and Medicinal Plants: Influence on Meat Quality

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<http://dx.doi.org/10.5772/67038>

Abstract

Aromatic plants are gaining importance in recent years as potential sources of natural food preservatives due to the growing interest in the development of safe and effective natural food preservation. The use of vegetal substances with antimicrobial and antioxidant properties to increase the shelf life in meat and meat products is a promising technology. Taking into account that the diet with antioxidant may be absorbed and prevent lipid oxidation and colour deterioration, the possibility of feeding animal diets contains aromatic and medicinal plant (as thyme leaf, rosemary and sage) as natural antioxidants and antimicrobials represent a very interesting opportunity to replace synthetic antioxidants. In this sense, herbs of the Labiatae family, such as rosemary and sage, have been extensively studied for antioxidant and antimicrobial activities in a variety of systems. This review gives an overview of the current knowledge and recent trends in the use of plant-derived compounds from aromatic and medicinal as antimicrobials and antioxidant in animal diet and its effect on meat quality, their potentials and challenges.

Keywords: aromatic plants, meat, animal diet, antioxidant, antimicrobial, meat quality

1. Introduction

Animal scientists have been interested in improving meat quality and product composition through the modification of the diet of animals. The possible use of nutritional strategies to improve quality of food products from livestock is a new approach that emerges at the interface of food science and animal science. These strategies have emphasized in the improvement of the oxidative stability, such as supplementation of animal with natural antioxidants to minimize pigment and lipid oxidation in meat or the alteration of nutritional profile, increasing the content of polyunsaturated fatty acid (PUFA). The consumption of meat (rich in saturated fatty acid)

is related with diseases such as some types of cancers and cardiovascular diseases (especially in developed countries).

In this sense, in recent years, consumers' pressure to reduce the composition and quality of fat in meat has led to attempts to modify meat by dietary strategies [1]. The modification of fatty acid profile of meat is to decrease saturated fatty acid and increase the ratio n-3: n-6 and PUFA: SFA (>4).

Between the strategies used, meat can be modified by external addition in the elaboration of meat or by the addition in the animal diet of ingredients considered beneficial for health, where these ingredients are able to eliminate or reduce components that are considered harmful. In this sense, several studies have shown that animal diet can strongly influence the quality of the meat.

For example, the stability of muscle foods further improves after the addition of food ingredients in diet of animals than the direct addition to the meat products, because the antioxidants are deposited where it is most needed. In order to alter the oxidative stability of intact muscle foods, the only technology available is the use of food ingredients in the diet. In these products, where natural antioxidants are added to the diet producing a nutritional alteration of muscle composition, no additive declarations are required and are more label-friendly.

Taking into account all these considerations, recent changes in legislation controlling the use of animal feed additives and the increasing demand of consumers for healthier meat products, if possible free of chemical additives, have stimulated interest in bioactive secondary metabolites as alternative performance enhancers.

2. Production of functional meat products

2.1. Functional meat products

Meat and meat products are essential for a balanced diet, although it must also be remembered that they are susceptible to modifications to give them a 'healthier' appearance. Numerous studies have demonstrated the possibility of changing the image of meat and meat products from the traditionally accepted image to one of healthy living thanks to the modification of animal diet, addition (vegetables, extracts, fibres, herbs, spices, etc.), elimination (fats) and reduction (saturated fatty acid, additives) of different ingredients. The object of including functional ingredients in the case of meat is not only concerned with providing it with certain desirable properties but also an attempt to change its image in these health-conscious days.

However, meat has beneficial health effects, for example, regarding obesity, and it also has satiating properties. This aspect is very important in the development of tasty and satiating functional meat products.

Therefore, in meat, the modifications to which it may be subjected to confer functional properties on it are based on modifications to the feed an animal receives or on postmortem manipulation

of the carcass. Therefore, through the modification of animal diet, the lipid, fatty acid, and vitamin E content can be changed [2].

In the market of functional food, rapid progress has been made in the development of this kind of food, based on the results of studies on food components providing positive health benefits over and above normal nutritional benefits. Although many books and reviews on functional foods have been published, few of them have emphasized in the functional properties of meat and meat products (examples of functional properties of foods are anticarcinogenicity, antimutagenicity, antioxidative activity and antiaging activity). By modification of animal diet with the introduction of bioactive compounds, it should be possible to develop new meat products with potential health benefits. Such meat products would open up a new market in the meat industry.

2.2. Dietary supplementation of functional ingredients

2.2.1. Natural antioxidants

Fresh meat is mainly packed unprocessed and refrigerated. Currently the most widely used method in the marketing of fresh meat is packaging under modified atmosphere, both in the form of vacuum packaging and gas mixtures of known composition. The short shelf life of packed fresh meat is one of the principal concerns for its marketing. Lipid composition is a major determinant in the susceptibility of meat to oxidative changes and rancidity, leading to warmed-over flavours [3]. The quality attributes of meat products deteriorate due to the lipid oxidation during processing and storage. Lipid oxidation is responsible for development of primary and secondary oxidation products (short-chain aldehydes and ketones), reduction in nutritional quality, as well as changes in flavour, which can precipitate economic losses in terms of inferior product quality. The compounds formed after oxidation may adversely affect the overall quality and acceptability of meat and meat products (changes in flavour, texture and nutritional value).

In addition, the oxidative stability also affects the meat proteins. Specifically, the oxidation of indispensable amino acid reduces their digestibility and availability, and the tenderness of meat [4]. In addition, the oxidizable components of meat need to be protected from damages caused by the reactive oxygen species (ROS). The protection could be provided naturally through the deposition of antioxidant compounds derived from the feeds into the animal tissues.

Regarding meat storage stability can be extended with opportune packaging systems, by the exogenous addition of antioxidants or by adopting feeding systems able to improve the antioxidant status of muscle [4].

The rate of lipid oxidation can be effectively retarded by restricting the access to oxygen during storage vacuum-packaging and by the use of antioxidants that can be synthetic or natural: synthetic antioxidants were widely used in the meat industry, but consumer concerns over safety and toxicity pressed the food industry to find natural sources [5].

As alternative, synthetic antioxidants can be used natural extract from plant as grape, olives, sesame seed, tea, soybean, rosemary, thyme, etc with antioxidant properties [6]. Phenolic-rich

plant materials or extracts used as dietary supplement or added to meat products exerted antioxidant properties by inhibiting lipid and protein oxidation in meat [7–9]. Studies reported that dietary antioxidant prevents colour deterioration and lipid oxidation [10–11].

Antioxidant compounds are usually added at a moderate dosage level since high level of inclusion may mechanistically cause adverse effects through pro-oxidative action [12].

Several studies have indicated that the modification of animal diet alters the oxidation of the meat (e.g. studies with lambs). The value of lambs lies in their ability to use low-quality feeds, in a sense upgrading low-quality inputs to high-quality outputs [13]. Santé-Lhoutellier et al. [14] studied the influence of diet on lamb meat oxidation and founds that the oxidative stability of lamb meat clearly depends on diet.

Scerra et al. [15] compared ewe's diet with pasture or concentrated and showed an increase in the PUFA content in intramuscular fat lamb fed with pastures. Nieto et al. [16] showed an increase in PUFA content of lamb meat fed with thyme compared with control diets. Elmore et al. [17] reported the same increase of PUFA in lamb meat after inclusion of diet fish in the diet. Similarly, Bas et al. [18] and Ponnampalam et al. [19] reported increases in the content of long-chain n-3 fatty acids in lamb meat with the diet of linseed or fish oil, respectively.

Including herb distillates into livestock diets can have positive effects. Moñino and others [13] reported that inclusion of herb distillates (distilled rosemary leaves) into pregnant ewes diet increased carbonic acid, carnosol and rosmarinic acid in the lamb meat. Fresh lamb meat from distilled rosemary diet presented lower DPPH values and higher total ferric reducing antioxidant power, indicating that rosemary reduced lipid oxidation. Another studies in pigs reported similar results [20].

In addition, Simitzis et al. [21] found that meat from lambs fed a feed that had been sprayed with oregano essential oil (1 mL/kg) was much more stable to lipid oxidation during both refrigerated and frozen storage than that from controls. Boler et al. [22] found that feeding vitamin E to pigs increased pork stability during storage. Gobert et al. [23] reported a synergism effect in the combination of plant extract rich in polyphenols and vitamin E.

2.2.2. Conjugated linoleic acid

Interests in conjugated linoleic acid (CLA) have increased in the last decades as a result of its potential effects on human health-related benefits and animal production, as a result of the effects of dietary CLA to increase the animal performance, improve meat quality and provide meat products with high amounts of CLA.

Inconsistent results have been reported about the effects of dietary CLA on the growth, body composition and meat quality. Different animal species, different breeds, age, duration and levels of CLA, husbandry conditions and the composition of feed could explain these conflicting results [24].

Conjugated linoleic acid has been studied in many animal models to determine its effects on lipid metabolism, as *trans*-10, *cis*-12 is known to reduce adipose deposition. In the mouse model, CLA in the diet has been found to increase metabolic rate and fatty acid oxidation

while reducing fatty acid synthesis, lipoprotein lipase activity and division and differentiation of adipocytes [25]. Study by Wynn et al. [26] found a 36-fold increase in muscle trans-10, cis-12 CLA when a source of CLA (containing similar amounts of cis-9, trans-11 and trans-10, cis-12 isomers) was fed to growing lambs at 100 g/kg DM (approximately 50 g/kg DM of each isomer). They also found a 2- to 5-fold increase in cis-9, trans-11 CLA and a 3- to 20-fold increase of trans-10, cis-12 CLA in liver and adipose tissues.

It is generally accepted that dietary CLA can improve the body composition through reducing fat deposition and backfat thickness. In pigs, the fat deposition was reduced and the ratio of lean to fat increased linearly as the dietary CLA increased [27]. Dietary CLA not only reduced fat deposition but also altered the fatty acid composition of tissue lipids. In the study of Szymczyk et al. [28], the proportion of saturated fatty acids such as palmitic and stearic acids increased significantly, while that of monounsaturated and polyunsaturated fatty acids including palmitoleic, oleic, linoleic and arachidonic acid in broiler chickens decreased significantly.

In addition, other studies have shown that dietary CLA could increase the concentration of CLA in muscle and adipose tissues of chicken. Du and Ahn [29] reported that the amount of total CLA increased from 0 to 10.51 and 17.75 mg/g lipids in broiler breast muscle after 5 weeks of feeding 2 and 3% CLA. Therefore, feed nonruminant animal with synthesized CLA changes the fatty profile. These studies show that supplementation of CLA in the diet could be a strategy for developing a value-added meat product.

2.2.3. Vitamin E

Supplementation with vitamin E in animal diet improves meat quality by limiting lipid and protein oxidation [30–32]. Guidera et al. [32] reported an improvement in colour stability in lambs receiving with 1000 mg α -tocopherol/kg feed compared with non-supplemented feeds.

Rowe et al. [33] showed that dietary vitamin E decreased the levels of protein oxidation and its influence on beef tenderization. Other study about texture of meat reported that the diet supplementation with 1000 IU vitamin E caused lower shear force in beef steaks from longissimus dorsi after 14 day of postmortem storage [34].

In addition, the effects of dietary vitamin E on drip loss were inconsistent: in poultry, dietary vitamin E inhibited the development of PSE conditions induced by heat stress resulting in improved meat quality [35].

Some studies have indicated a possible role for high doses of vitamin E in preventing shifts in PUFA biohydrogenation pathways [36, 37], thus minimizing any negative effect of plant oil on milk production, milk fat yield and/or milk fatty acid composition. Vitamin E could act either as an inhibitor of bacteria producing trans-10 C18:1 [37] or affect the accumulation of biohydrogenation intermediates in rumen fluid and CLA content [38].

The supplementation of ewes and lamb diet with Vitamin E [39, 40] is usually carried out by using a synthetic source of α -tocopherol (all-rac- α -tocopheryl-acetate), due to its stability and lower cost in animal feeds [41]. Another vitamin E source is RRR- α -tocopheryl-acetate, which is a derivate from vegetable oils and exhibits higher biological activity than synthetic vitamin

E [42]. Recent studies in dairy cows have estimated that the relative bioavailability of vitamin E from natural sources is 1.36 times greater than that of synthetic vitamin E [43].

2.2.4. Omega-3 (ω 3) fatty acids

Omega-3 PUFA consumption reduces the risk of cardiovascular disease [44] and inhibits the growth of mammary and prostate gland tumours [45]. It also delays the loss of immunological functions and is required for the normal foetal development of the brain [46].

PUFA is essential constituents for the development and growth of animal. In this group, docosahexaenoic acid (DHA, 22:6), docosapentaenoic acid (DPA, 22:5) and eicosapentaenoic acid (EPA, 20:5) are included.

It is possible to obtain enhanced n-3 PUFA meat, including the diet different raw materials such as linseed, chia (*Salvia hispanica*) or its oils and fish meal or other sea products [47].

One of the most important strategies in nonruminants is the inclusion of marine sources of n-3 PUFA and the study of product quality. For example, fed pigs or poultry with cereal-based diet increase n-3 PUFA and n-6 PUFA.

Coates et al. [48] reported that regular consumption of ω 3 fatty acid-enriched pork can decrease the content of serum triglycerides and increase the production of serum thromboxane, and thus, it can reduce cardiovascular diseases. There are many other alternative food sources rich in long-chain PUFA available, and they include meat, milk and eggs from animals fed with ω 3-enriched diets [49].

Crespo and Esteve-García [50] studied the inclusion of 10% olive oil, sunflower oil and linseed oil in broiler chickens for 20 days before slaughter. They showed highest n-3 PUFA and more favourable n-6:n-3 ratio in broilers fed with linseed oil, highest C18:1 in chicken fed with olive oil and highest proportion of linoleic acid in chicken fed with sunflower oil. Therefore, poultry diet with plant oils reported significant changes in the SFA, PUFA and MUFA content of abdominal fat of chicken. Similarly, Lu et al. [51] reported significant increase in C18:2 and C18:3 content in meat from pigs fed with soybean oil and linseed oil, respectively.

In addition, duration of feeding and time influences in the transfer of n-3 long-chain polyunsaturated fatty acids were found to be influenced by time and duration of feeding and the presence of other oil supplements. Haak et al. [52] studied the effect of inclusion of linseed or fish oil into the diet of pigs and concluded that a direct dietary source of DHA was required to increase DHA in animal muscle and that levels in pork could not be substantially influenced by dietary supply of precursors.

In addition, Lopez-Ferrer et al. [53] demonstrated that inclusion of rapeseed oil and linseed oil into the diet increased linoleic acid (used to synthesize w-3 PUFA).

Few studies have demonstrated that the oxidation of muscle from animal-derived enriched in n-3 PUFA is higher: for example, studies are made in rabbit meat [54–57], lamb meat [58], poultry [59] and pigs [60].

In order to avoid the higher tendency to oxidation in meat rich-PUFA, is recommended adding antioxidant in animal diet [61]. Therefore, the incorporation of the natural ingredients with antioxidant properties into the feed could be an interesting strategy to prevent oxidation of the meat [62–67].

2.2.5. Selenium

In many countries, there is a deficiency of selenium intake. The recommendations for selenium (60 and 75 $\mu\text{g}/\text{day}$ for adult female and male in UK) are not covered by diet. Thus, the strategies to improve human selenium intake are the production of selenium-rich foods (eggs, milk and meat) with selenium supplementation in the animal diet or intake of selenium supplement capsular form.

Particular interest in selenium has been generated as a result of clinical studies showing that dietary supplementation with organic selenium, in the form of yeast grown on a media enriched with this trace element, decreased cancer mortality twofold [68]. Selenium is an essential trace mineral for human and animal because it is involved in regulating various physiological functions as an integral part of selenoproteins. Additionally, inadequate selenium consumption is associated with decreased fertility, genetic defects and poor health [69].

Various types of meat are important natural sources of selenium in human nutrition [70]. The selenium concentration in meats depends of selenium supplements used and geographical origin [71, 72]. Indeed, it is well established that selenite or selenate dietary supplementation is not effective in increasing selenium concentration in the meat. The main form of selenium in muscles of animals fed on grain-based diet is Se-Met, animals cannot produce this form of selenium Se-Met, and it must be in the diet. The form of selenium found in breast and muscle of chicken fed with high doses of selenium yeast is Se-Met. Therefore, only the organic selenium (in the form Se-Met) in cattle, pigs or chicken can increase the selenium concentration in the meat.

Pork: Producing selenium-enriched pork is reported in several studies. Kim and Mahan [73] compared the effects of supplementation dietary of inorganic and organic selenium in pork. These authors shown that selenium concentration in loin increased from 0.154 to 3.375 mg/kg with organic selenium supplementation. In addition, to increased selenium level, good colour, low drip loss, reduced pig odour, chewy and tender improved in final meat [74]. This selenium pork is available in Korea and Canada.

Beef: It is considered the major source of dietary selenium. However, there is a variation of concentration depending on country. For example, in USA, the selenium content in beef is higher than in Europe. This content of selenium can be increased with the addition of organic form into the diet of cattle [75].

Lamb: It can also be enriched with organic selenium into the diet. In this sense, Bierla et al. [76] reported that 100 g of selenium lamb reported 50% of recommendation of selenium per day.

Chicken: As in the case of beef and pork, the inclusion of selenite increases moderately the selenium level. Therefore, the use of organic selenium into the diet is necessary in order to

increase the levels in meat [77]. There is a commercial option of chicken-enriched selenium called 'Selen Chicken' in Korea. In Ukraine, a combination of selenium and Vitamin E is added to commercial chicken meat [78] in order to produce selenium-enriched meat and improves meat quality during storage.

Turkey: The option of producing selenium-enriched turkey meat is available in USA where the high levels (around 34 g/100 g) are obtained by using organic selenium in the diet and the soil rich in selenium [79].

These increased selenium contents in meat products can be an excellent way to improve selenium status and safe for people living in selenium-deficient areas.

2.2.6. *Plants, fruits, herbs and spices*

As alternative, synthetic antioxidants can be used for plants, fruit, herbs or spices as carob, citrus pulp, algae, grape, olives, sesame seed, tea, soybean, rosemary, thyme, etc. Phenolic-rich plant materials or extracts are used as dietary supplement or added to meat products exerted antimicrobial and antioxidant properties.

Carob: Gravador et al. [80] studied the modification of fatty acids and oxidative stability of meat from lambs fed carob-containing diets. Previous studies showed that growth performance in lamb is compromised when a level of carob higher than 45% is administered into the animal diet [81]. Therefore, in this study, either 24 or 35% carob pulp was used in the diets in the current study in order to assure similar lamb growth performances compared to a conventional barley-based diet.

Citrus pulp: Several studies have reported an improvement of meat oxidative stability in response to the administration of citrus-pulp diets. Taking into accounts that citrus fruits can be processed to obtain juices, a substantial amount of by-products originates. Among these, the dried citrus pulp is widely used for ruminant feeding, and for its favourable nutrient composition, it can replace high proportions of cereal concentrates in the diet with no detrimental effects on animal productivity. Citrus fruits contain high levels of bioactive compounds, including polyphenols, terpenes, carotenoids and ascorbic acid, which exhibit antioxidant properties [82]. Therefore, the study of Inserra et al. [7] studied the effect of inclusion dried citrus pulp in the diet of lamb on the meat oxidative stability. These authors concluded that including high levels of dried citrus pulp in diets for intensively reared lambs might represent a feasible strategy to decrease the amount of cereal concentrates without compromising animal performances and to naturally improve meat oxidative stability.

The bioactive compounds (phenolic compounds) originating from the citrus fruits may cause the protective effects of dietary citrus pulp, against oxidation of lipid and meat proteins. Gladine et al. [83] showed that, after the dietary administration of a citrus extract to sheep, naringenin was detected in plasma and was able to increase its resistance to lipid peroxidation. Therefore, some of bioactive compounds in citrus are bioavailable in ruminants. Citrus pulp, which otherwise is just an agricultural waste, could find a valuable application in small ruminant feeding as a natural and cheap alternative to cereal concentrate feedstuffs with an ultimate positive impact on meat protein oxidative stability.

Algae are the original sources of DHA [84]. Several studies reported the inclusion of algae in animal feed in order to improve DHA content in eggs [85, 86] and chicken meat [87].

In this sense, the study of Delles et al. [88] investigated the influence of dietary algae and selenium (organic or inorganic) on quality of chicken meat. The results indicate that feeding diets with high-oxidized oil increased the vulnerability of lipids and proteins to oxidation and reduced the activities of tissue antioxidant defence enzymes. However, the dietary supplementation with an algae-based Se yeast and organic mineral antioxidant blend negated these effects. Furthermore, dietary antioxidant supplementation imparted a protective barrier against oxidation of broiler breast meat under HiOx, PVC, and SK packaging conditions throughout retail display. The improved oxidative stability appears to be associated with enhanced cellular antioxidant enzymatic activity and reduced ROS propagation *in vivo*. A more limited number of studies have looked into the effects of dietary supplementation with DHA-rich marine algae on the fatty acid composition of muscle tissue of pigs [89, 90].

Herbs and spices: Some herbs of the *Labiatae* family, particularly rosemary and sage, have been extensively studied for their antioxidative and antimicrobial activity. The vegetation in Southeast Spain is richer in aromatic plants than any other place in Europe. The province of Murcia is a major importer and processor of medicinal herbs. Rosemary and thyme are the most exploited, and their use mainly being the extraction of essential oils, a process that generates an excess of distilled leaves. These products are currently under-used but could be used as potential sources of natural antioxidants and antimicrobials in the food industry.

Rosemary is the only spice commercially available for use as an antioxidant in Europe and the United States. Its extract contains antioxidant compounds, the most active being phenolic diterpenes such as carnosic acid, carnosol, rosmanol, epirosmanol, isorosmanol, methylcarnosate and rosmarinic acid [91]. These compounds have been shown to help prevent oxidation.

Thyme essential oil (*EO*) contains more than 60 ingredients, most of which possess important beneficial effects, for example, antiseptic, carminative, antioxidant and antimicrobial properties. The most important compounds of thyme *EO* are the phenols thymol (68.1%) and carvacrol (3.5%), which constitute the major and most active constituents, as well as the monoterpene hydrocarbons *p*-cymene (11.2%) and γ -terpinene (4.8%), which are known to have antioxidant properties and slow antimicrobial activity. The antibacterial properties of these compounds are in part associated with their lipophilic character, leading to their accumulation in membranes and to subsequent membrane-associated events such as energy depletion. Moreover, the (poly)phenolic compounds are characterized by having redox properties, which allow them to act as reducing agents, hydrogen donors, singlet oxygen quenchers and also as metal chelators.

Essential oil and extracts from *Labiatae* herbs have been successfully used in a wide variety of foods with good results as far as oxidative deterioration is concerned: for example, in turkey products [92], beef [93], pork [94], chicken [95], hens [96], lamb [13, 97–99] and in

vitro system [100]. In contrast, unsatisfactory results have been obtained in others cases. For example, Galobart et al. [101] and O'Grady et al. [102] concluded that a diet supplemented with rosemary did not affect the lipid stability of eggs or fresh meat.

3. Current status on the consumers acceptance and market for functional meat products

Regarding diversity in enriched poultry products, it is interesting to note that selenium-enriched eggs are already commonly seen on supermarket shelves in the Ukraine and Belarus. Selenium enrichment of eggs, meat and milk may be viewed as merely production of naturally designed food ingredients.

Indeed, production and commercialization of functional meat products have already opened a new era in supplementation of animals and have provided a real chance for producers to differentiate and add value to meat poultry products and to meet the increasingly diverse requirements of consumers.

There is a lack of studies on the effect on human health and safety of these meats. By that reason, the European food authorities are reluctant to promote the consumption of functional foods. However, the consumers have been accepted the link between health and food, and the responsibility of researcher and food authorities is to ensure that new functional meat products and products are healthy and safe. Promoted studies in this sense could lead to the development of differentiated meat products and meat with potential human health benefits, for example, promote the use of antioxidants that are components with nutraceutical and maintain the product safety of foods.

4. Conclusion and future prospects

The possibility to produce new animal-derived products with specific nutrients that promote health and improve the diet of consumers is a real target.

These animal-derived products are development with the same sensory characteristics that the only difference is the amount of specific nutrients. No modifications of traditions or eating habits of poblations are produced, and these foods are cooked and consumed as usual. Therefore, without any modification of consumer's habits, problem related with deficit of various nutrients (e.g. selenium) can be solved.

The main difficulties in the market of functional meat products are consumer's idea that consumption of meat is unhealthy. However, consumers of many countries accept other animal-derived products as healthy food (e.g. milk and dairy products). Thus, more studies are necessary to demonstrate and afterwards inform consumers the functional value of meat.

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References

- [1] Wood, JD., Richardson, RI., Nute, GR., Fisher, AV., Campo, MM., Kasapidou, E., Sheard, PR., Enser, M. (2003). Effects of fatty acids on meat quality: A review. *Meat Sci.* 66, 21–32.
- [2] Jiménez-Colmenero, F., Carballo, J., Cofrades, S. (2001). Healthier meat and meat products: their role as functional foods. *Meat Sci.* 59, 5–13.
- [3] Jeremiah, LE. (2001). Packaging alternatives to deliver fresh meats using short- or long-term distribution. *Food Res Int*, 34, 749–772.
- [4] Descalzo, AM., Sancho, AM. (2008). A review of natural antioxidant and their effects on oxidative status, odor and quality of fresh beef produced in Argentina. *Meat Sci*, 79, 423–436.
- [5] Coronado, SA., Trout, GT., Dunshea, FR., Shah, NP. (2002). Antioxidant effects of rosemary extract and whey powder on the oxidative stability of wiener sausages during 10 months frozen storage. *Meat Sci*, 62, 217–24.
- [6] Tang, S., Kerry, JP., Sheehan, D., Joe Bukley, D., Morrissey, PA. (2001). Antioxidative effect of added tea catechins on susceptibility of cooked red meat, poultry and fish patties to lipid oxidation. *Food Res Int*, 34, 651–7.
- [7] Inserra, L., Priolo, A., Biondi, L., Lanza, M., Bognanno, M., Gravador, RS., Luciano, G. (2014). Dietary citrus pulp reduces lipid oxidation in lamb meat. *Meat Sci.* 96(4), 1489–1493.
- [8] Gravador, RS., Jongberg, S., Andersen, ML., Luciano, G., Priolo, A. Marianne N. Lund, MN. (2014). Dietary citrus pulp improves protein stability in lamb meat stored under aerobic conditions. *Meat Sci.* 97(2), 231–236.
- [9] Nieto, G., Díaz, P., Bañon, S., Garrido, MD. (2010). Dietary administration of ewe diets with a distillate from rosemary leaves (*Rosmarinus officinalis* L.): influence on lamb meat quality. *Meat Sci.* 84, 23–29.
- [10] Botsoglou, NA., Govaris, A., Giannenas, I., Botsoglou, E., Papageorgiou, G. (2007). The incorporation of dehydrated rosemary leaves in the rations of turkeys and their impact

- on the oxidative stability of the produced raw and cooked meat. *Int J Food Sci Nutr.* 58(4), 312–320.
- [11] Luciano, G., Monahan, FJ., Vasta, V., Pennisi, P., Bella, M., Priolo, A. (2009). Lipid and colour stability of meat from lambs fed fresh herbage or concentrate. *Meat Sci.* 82(2), 193–199.
- [12] Moyo, B., Oyedemi, S., Masika, PJ., Muchenje, V. (2012). Polyphenolic content and antioxidant properties of *Moringa oleifera* leaf extracts and enzymatic activity of liver from goats supplemented with *Moringa oleifera* leaves/sunflower seed cake. *Meat Sci.* 91, 441–447.
- [13] Moñino, I., Martinez, C., Sotomayor, JA., Lafuente, A., Jordan, MJ. (2008). Polyphenolic transmission to Segureño lamb meat from ewes' diets supplemented with the distillate from rosemary (*Rosmarinus officinalis*) leaves. *J Agric Food Chem.* 56(9), 3363–7.
- [14] Santé-Lhoutellier, V., Engel, E., Gatellier, Ph. (2008). Assessment of the influence of diet on lamb meat oxidation. *Food Chem.* 109(3), 573–579.
- [15] Scerra, M., Caparra, P., Foti, F., Galofaro, V., Sinatra, MC., Scerra, V. (2007). Influence of ewe feeding systems on fatty acid composition of suckling lambs. *Meat Sci.* 76, 390–394.
- [16] Nieto, G., Bañon, S., Garrido, MD. (2012a). Incorporation of thyme leaves in the diet of pregnant and lactating ewes: Effect on the fatty acid profile of lamb. *Small Ruminant Res.* 105, 140–147.
- [17] Elmore, JS., Cooper, SL., Enser, M., Mottram, DS., Sinclair, LA., Wilkinson, RG., Wood, JD. (2005). Dietary manipulation of fatty acid composition in lamb meat and its effect on the volatile aroma compounds of grilled lamb. *Meat Sci.* 69, 233–242.
- [18] Bas, P., Berthelot, E., Pottier, E., Normand, J. (2007). Effect of level of linseed on fatty acid composition of muscles and adipose tissues of lambs with emphasis on trans fatty acids. *Meat Sci.* 77, 678–688.
- [19] Ponnampalam, EN., Trout, GR., Sinclair, AJ., Egan, AR., Leury, BJ. (2001). Comparison of the color stability and lipid oxidative stability of fresh and vacuum packaged lamb muscle containing elevated omega-3 and omega-6 fatty acid levels from dietary manipulation. *Meat Sci.* 58, 151–161.
- [20] McCarthy, TL., Kerry, JP., Kerry, JF., Lynch, PB., Buckley, DJ. (2001). Evaluation of the antioxidant potential of natural food/plant extracts as compared with synthetic antioxidants and vitamin E in raw and cooked pork patties. *Meat Sci.* 58(1), 45–52.
- [21] Simitzis, PE., Deligeorgis, SG., Bizelis, JA., Dardamani, A., Theodosiou, I., Fegeros, K. (2008). Effect of dietary oregano oil supplementation on lamb meat characteristics. *Meat Sci.* 79(2), 217–23.
- [22] Boler, DD., Gabriel, SR., Yang, H., Balsbaugh, R., Mahan, DC., Brewer, MS., McKeith, FK., Killefer, J. (2009). Effect of different dietary levels of natural-source vitamin E in grow-finish pigs on pork quality and shelf life. *Meat Sci.* 83(4), 723–30.

- [23] Gobert, M., Gruffat, D., Habeanu, M., Parafita, E., Bauchart, D., Durand, D. (2010). Plant extracts combined with vitamin E in PUFA-rich diets of cull cows protect processed beef against lipid oxidation. *Meat Sci.* 85(4), 676–83.
- [24] Zhang, W., Xiao, S., Samaraweera, H., Lee, E.J., Ahn, D.U. (2010). Improving functional value of meat products. *Meat Sci.* 86(1), 15–31.
- [25] Wahle, K.W.J., Stevens, S.D., Rotondo, D. (2004). Conjugated linoleic acids: are they beneficial or detrimental to health? *Prog Lipid Res.* 43, 553–87.
- [26] Wynn, R.J., Daniel, ZCTR., Flux, C.L., Craigon, J., Salter, A.M., Buttery, P.J. (2006). Effect of feeding rumen-protected conjugated linoleic acid on carcass characteristics and fatty acid composition of sheep tissues. *J Anim Sci.* 84, 3440–50.
- [27] Ostrowska, E., Muralitharan, M., Cross, R.F., Bauman, D.E., Dunshea, F.R. (1999). Dietary conjugated linoleic acids increase lean tissue and decrease fat deposition in growing pigs. *J Nutr.* 129, 2037–2042.
- [28] Szymczyk, B., Pisulewski, P.M., Szczurek, W., Hanczakowski, P. (2001). Effects of conjugated linoleic acid on growth performance, feed conversion and subsequent carcass quality in broiler chickens. *Br J Nutr.* 85, 465–473.
- [29] Du, M., Ahn, D.U. (2002). Effect of dietary conjugated linoleic acid on the growth rate of live birds and on the abdominal fat content and quality of broiler meat. *Poultry Sci.* 81, 428–433.
- [30] Chan, W.K.M., Hakkarainen, K., Faustman, C., Schaefer, D.M., Scheller, K.K., Liu, Q. (1996). Dietary vitamin E effect on color stability and sensory assessment of spoilage in three beef muscles. *Meat Sci.* 42, 387–399.
- [31] Lanari, M.C., Schaefer, D.M., Scheller, K.K. (1995). Dietary vitamin E supplementation and discoloration of pork bone and muscle following modified atmosphere packaging. *Meat Sci.* 41, 237–250.
- [32] Guidera, J., Kerry, J.P., Buckley, D.J., Lynch, P.B., Morrissey, P.A. (1997). The effect of dietary vitamin E supplementation on the quality of fresh and frozen lamb meat. *Meat Sci.* 45, 33–43.
- [33] Rowe, L.J., Maddock, K.R., Lonergan, S.M., Huff-Lonergan, E. (2004). Oxidation environments decrease tenderization of beef steaks through inactivation of μ -calpain. *J Anim Sci.* 82, 3254–3266.
- [34] Carnagey, K.M., Huff-Lonergan, E.J., Trenkle, A., Wertz-Lutz, A.E., Horst, R.L., Beitz, D.C. (2008). Use of 25-hydroxyvitamin D₃ and vitamin E to improve tenderness of beef from longissimus dorsi of heifers. *J Anim Sci.* 86, 1649–1657.
- [35] Olivo, R., Soares, A.L., Ida, E.I., Shimokomaki, M. (2001). Dietary vitamin E inhibits poultry PSE and improves meat functional properties. *J Muscle Food.* 25, 271–283.
- [36] Juárez, M., Dugan, M.E.R., Aalhus, J.L., Aldai, N., Basarab, J.A., Baron, V.S., McAllister, T.A. (2011). Effects of vitamin E and flaxseed on rumen-derived fatty acid intermediates in beef intramuscular fat. *Meat Sci.* 88, 434–440.

- [37] Pottier, J., Focant, M., Debier, C., De Buysser, G., Goffe, C., Mignolet, E., Froidmont, E., Larondelle, Y. (2006). Effect of dietary vitamin E on rumen biohydrogenation pathways and milk fat depression in dairy cows fed high-fat diets. *J Dairy Sci.* 89, 685–692.
- [38] Hou, J., Wang, F., Wang, Y., Liu, F. (2013). Effects of vitamin E on the concentration of conjugated linoleic acids and accumulation of intermediates of ruminal biohydrogenation in vitro. *Small Rumin Res.* 111, 63–70.
- [39] Capper, J.L., Wilkinson, R.G., Kasapidou, E., Pattinson, S.E., Mackenzie, A.M., Sinclair, L.A. (2005). The effect of dietary vitamin E and fatty acid supplementation of pregnant and lactating ewes on placental and mammary transfer of vitamin E to the lamb. *Br J Nutr.* 93, 549–557.
- [40] Kasapidou, E., Wood, J.D., Richardson, R.I., Sinclair, L.A., Wilkinson, R.G., Enser, M. (2012). Effect of vitamin E supplementation and diet on fatty acid composition and on meat colour and lipid oxidation of lamb leg steaks displayed in modified atmosphere packs. *Meat Sci.* 90, 908–916.
- [41] Vagni, S., Saccone, F., Pinotti, L., Baldi, A. (2011). Vitamin E bioavailability: past and present insights. *Food Nutr Sci.* 2, 1088–1096.
- [42] Lauridsen, C., Engel, H., Craig, A.M., Traber, M.G. (2002). Relative bioactivity of dietary RRR- and all-rac-alpha-tocopheryl acetates in swine assessed with deuterium-labeled vitamin E. *J Anim Sci.* 80, 702–707.
- [43] Weiss, W.P., Hogan, J.S., Wyatt, D.J. (2009). Relative bioavailability of all-rac and RRR vitamin E based on neutrophil function and total α -tocopherol and isomer concentration in periparturient dairy cows and their calves. *J Dairy Sci.* 92, 720–731.
- [44] Temple, N.J. (1996). Dietary fats and coronary heart disease. *Biomed Pharmacother.* 50(6–7), 261–268.
- [45] Rose, D.P. (1997). Dietary fatty acids and prevention of hormone-responsive cancer. *Proc Soc Exp Biol Med.* 216(2), 224–233.
- [46] Leung, I.Y.F., Sandstrom, M.M., Zucker, C.L., Neuringer, M., Max Snodderly, D. (2005). Nutritional manipulation of primate retinas. IV. Effects of n-3 fatty acids, lutein, and zeaxanthin on S-cones and rods in the foveal region. *Exp Eye Res.* 81(5), 513–529.
- [47] Ayerza, R., Coates, W., Lauria, M. (2002). Chia seed (*Salvia hispanica* L.) as an omega-3 fatty acid source for broilers: Influence on fatty acid composition, cholesterol and fat content of white and dark meats, growth performance, and sensory characteristics. *Poult Sci.* 81(6), 826–837.
- [48] Coates, A.M., Sioutis, S., Buckley, J.D., Howe, P.R.C. (2009). Regular consumption of n-3 fatty acid-enriched pork modifies cardiovascular risk factors. *Br J Nutr.* 101, 592–597.
- [49] Simopoulos, A.P. (1999). New products from the agri-food industry: The return of n-3 fatty acids into the food supply. *Lipids* 34, 297–301.

- [50] Crespo, N., Esteve-García, E. (2002). Nutrient and fatty acid deposition in broilers fed different dietary fatty acid profiles. *Poult Sci.* 81, 1533–1542.
- [51] Lu, P., Zhang, LY., Yin, JD., Everts, AKR., Li, DF. (2008). Effects of soybean oil and linseed oil on fatty acid compositions of muscle lipids and cooked pork flavour. *Meat Sci.* 80, 910–918.
- [52] Haak, L., De Smeet, A., Fremaut, D., Van Walleggem, K., Raes, K. (2008). Fatty acid profile and oxidative stability of pork influence by duration and time of dietary linseed or fish oil supplementation. *J Anim Sci.* 86, 1418–1425.
- [53] Lopez-Ferrer, S., Baucells, MD., Barroeta, AC., Grashorn, MA. (2001). n-3 Enrichment of chicken meat. 1. Use of very long-chain fatty acids in chicken diets and their influence on meat quality: Fish oil. *Poult Sci.* 80, 741–752.
- [54] Kouba, M., Benatmane, F., Blochet, JE., Mourot, J. (2008). Effect of a linseed diet on lipid oxidation, fatty acid composition of muscle, perirenal fat, and raw and cooked rabbit meat. *Meat Sci.* 77(80), 829–834.
- [55] Castellini, C., Dal Bosco, A., Bernardini, M., Cyril, HW. (1998). Effect of dietary vitamin E on the oxidative stability of raw and cooked rabbit meat. *Meat Sci.* 50, 153–161.
- [56] Dal Bosco, A., Castellini, C., Bianchi, L., Mugnai, C. (2004). Effect of dietary alinolenic acid and vitamin E on the fatty acid composition, storage stability and sensory traits of rabbit meat. *Meat Sci.* 66, 407–413.
- [57] Oriani, G., Salvatori, G., Pastorelli, G., Pantaelo, L., Ritieni, A., Corino, C. (2001). Oxidative status of plasma and muscle in rabbits supplemented with dietary vitamin E. *J. Nutr Biochem.* 12, 138–143.
- [58] Berthelot, V., Bas, P., Pottier, E., Normand, J. (2012). The effect of maternal linseed supplementation and/or lamb linseed supplementation on muscle and subcutaneous adipose tissue fatty acid composition of indoor lambs. *Meat Sci.* 90, 548–557.
- [59] Lin, CF., Asghar, A., Gray, JI., Buckley, DJ., Booren, AM., Crackel, RL., et al. (1989). Effects of oxidised dietary oil and antioxidant supplementation on broiler growth and meat stability. *Br Poult Sci.* 30, 855–864.
- [60] Monahan, FJ., Buckley, DJ., Morrissey, PA., Lynch, PB., Gray, JI. (1992). Influence of dietary fat and a-tocopherol supplementation on lipid oxidation in pork. *Meat Sci.* 31, 229–241.
- [61] Díaz, MT., Cañeque, V., Sánchez, S., Lauzurica, C., Pérez, C., Fernández, C., Álvarez, I., De la Fuente, J. (2011). Nutritional and sensory aspects of light lamb meat enriched in n-3 fatty acids during refrigerated storage. *Food Chem.* 124, 147–155.
- [62] Joo, ST., Lee, JI., Ha, YL., Park, GB. (2002). Effects of dietary conjugated linoleic acid on fatty acid composition, lipid oxidation, color, and water-holding capacity of pork loin. *J Anim Sci.* 80, 108–112.

- [63] You, KM., Jong, HG., Kim, HP. (1999). Inhibition of cyclooxygenase/lipoxygenase from human platelets by polyhydroxylated/methoxylated flavonoids isolated from medicinal plants. *Arch Pharm Res.* 22(1), 18–24.
- [64] Vasta, V., Pennisi, M., Lanza, D., Barbagallo, M., Bella, A., Priolo, A. (2007). Intramuscular fatty acid composition of lambs given a tanniniferous diet with or without polyethylene glycol supplementation. *Meat Sci.* 76, 739–745.
- [65] Youdim, KA., Deans, SG. (2000). Effect of thyme oil and thymol dietary supplementation on the antioxidant status and fatty acid composition of the ageing rat brain. *Br J Nutr.* 83, 878.
- [66] Lee, KW., Everts, H., Kappert, HJ., Frehner, M., Losa, R., Beynen, AC. (2003). Effects of dietary essential oil components on growth performance, digestive enzymes and lipid metabolism in female broiler chickens. *Br Poult Sci.* 44, 450.
- [67] Govaris, A., Botsoglou, E., Florou-Paneri, P., Moulas, A., Papageorgiou, G. (2005). Dietary supplementation of oregano essential oil and α -tocopheryl acetate on microbial growth and lipid oxidation of turkey breast fillets during storage. *Int J Poult Sci.* 4, 969.
- [68] Clark, LC., Combs, GF. Jr, Turnbull, BW., Slate, EH., Chalker, DK., Chow, J., Davis, LS., Glover, RA., Graham, GF., Gross, EG, Krongrad, A., Lesher, JL. Jr, Park, HK., Sanders, BB. Jr, Smith, CL., Taylor, JR. (1996). Effects of selenium supplementation for cancer prevention in patients with carcinoma of the skin. A randomized controlled trial. Nutritional Prevention of Cancer Study Group. *J Am Med Assoc.* 276, 1957–1963.
- [69] Surai, PF., Karadas, F., Pappas, AC., Sparks, NH. (2006). Effect of organic selenium in quail diet on its accumulation in tissues and transfer to the progeny. *Br Poult Sci.* 47, 65–72.
- [70] Lawler, TL., Taylor, JB, Finley, JW., Caton, JS. (2004). Effect of supranutritional and organically bound selenium on performance, carcass characteristics, and selenium distribution in finishing beef steers. *J Anim Sci.* 82, 1488–1493.
- [71] McNaughton, SA., Marks, GC. (2002). Selenium content of Australian foods: a review of literature values. *J Food Compos Anal.* 15, 169–182.
- [72] Daun, C., Johansson, M., Onning, G., Akesson, B. (2001). Glutathione peroxidase activity, tissue and soluble selenium content in beef and pork in relation to meat ageing and pig RN phenotype. *Food Chem.* 73, 313–319.
- [73] Kim, YY., Mahan, DC. (2001). Comparative effects of high dietary levels of organic and inorganic selenium on selenium toxicity of growing–finishing pigs. *J Anim Sci.* 79, 942–948.
- [74] Cole, DJA. (2000). Selenium, the pig and the human diet. In: T.P. Lyons and D.J.A. Cole (Eds.), *Conc. Pig Sci. 2000*. Nottingham University Press, Nottingham, pp. 149–158.
- [75] Simek, J., Chladek, G., Koutnik, V., Steinhäuser, L. (2002). Selenium content of beef and its effect on drip and fluid losses. *Anim Sci Pap Rep.* 20(Suppl. 1), 49–53.

- [76] Bierla, K., Dernovics, M., Vacchina, V., Szpunar, J., Bertin, G., Lobinski, R. (2008). Determination of selenocysteine and selenomethionine in edible animal tissues by 2D size-exclusion reversed-phase HPLC-ICP MS following carbamidomethylation and proteolytic extraction. *Analyt Bioanalyt Chem.* 390, 1789–1798.
- [77] Arnold, RL., Olson, OE., Carlson, CW. (1973). Dietary selenium and arsenic additions and their effects on tissue and egg selenium. *Poult Sci.* 52, 847–854.
- [78] Yaroshenko, FO., Surai, PF., Yaroshenko, YF., Karadas, F., Sparks, NHC. (2004). Theoretical background and commercial application of production of Se-enriched chicken. *Proceedings of the XXII World's Poultry Congress, Turkey*, p. 410.
- [79] Schubert, A., Holden, JM., Wolf, WR., (1987). Selenium content of a core group of foods based on a critical evaluation of published analytical data. *J Am Dietetic Assoc.* 87, 285–299.
- [80] Gravador, RS., Luciano, G., Jongberg, S., Bognanno, M., Scerra, M., Andersen, ML., Marianne, N., Lund, MN., Priolo, A. (2015). Fatty acids and oxidative stability of meat from lambs fed carob-containing diets. *Food Chem.* 182(1), 27–34.
- [81] Vasta, V., Pennisi, P., Lanza, M., Barbagallo, D., Bella, M., Priolo, A. (2007). Intramuscular fatty acid composition of lambs given a tanniniferous diet with or without polyethylene glycol supplementation. *Meat Sci.* 76, 739–745.
- [82] Abeysinghe, DC., Li, X., Sun, CD., Zhang, W., Zhou, C., Chen, K. (2007). Bioactive compounds and antioxidant capacities in different edible tissues of citrus fruit of four species. *Food Chem.* 104, 1338–1344.
- [83] Gladine, C., Rock, E., Morand, C., Bauchart, D., Durand, D. (2007). Bioavailability and antioxidant capacity of plant extracts rich in polyphenols, given as a single acute dose, in sheep made highly susceptible to lipoperoxidation. *Br J Nutr.* 98, 691–701.
- [84] Abril, R., Garret, J., Zeller, SG., Sande, WJ., Mast, RW. (2003). Safety assessment of DHA-rich microalgae from *Schizochytrium* sp.: Part V. Target animal safety/toxicity in growing swine. *Regul Toxicol Pharmacol.* 37,73–82.
- [85] Van Elswyk, ME. (1997). Comparison of n-3 fatty acid sources in laying hen rations for improvement of whole egg nutritional quality. A review. *Br J Nutr.* 78(Suppl. 1), 61–69.
- [86] Meluzzi, A., Sirri, F., Tallarico, N., Franchini, A. (2001). Effect of different vegetable lipid sources on the fatty acid composition of egg yolk and on hen performance. *Arch Geflugelkd.* 65, 207–213.
- [87] Sirri, F., Minelli, G., Iaffaldano, N., Tallarico, N., Franchini, A. (2003). Oxidative stability and quality traits of n-3 PUFA enriched chicken meat. *Italian J Anim Sci.* 2(1), 450–452.
- [88] Delles, RM., Xiong, YL., True, AD., Ao, T., Dawson, KA. (2014). Dietary antioxidant supplementation enhances lipid and protein oxidative stability of chicken broiler meat. *Poult Sci.* 93, 1561–1570.
- [89] Marriott, NG., Garret, JE., Sims, MD., Abrul, JR. (2002). Composition of pigs fed a diet with docosahexaenoic acid. *J Muscle Foods.* 13, 265–277.

- [90] Sardi, L., Martelli, G., Lambertini, L., Parisini, P., Mordenti, A. (2006). Effects of a dietary supplement of DHA-rich marine algae on Italian heavy pig production parameters. *Livest Sci.* 103, 95–103.
- [91] Cuvelier, ME., Richard, H., Berset, C. (1996). Antioxidative activity and phenolic composition of pilot-plant and commercial extracts of sage and rosemary. *J Am Oil Chem Sci.* 73, 645–652.
- [92] Govaris, A., Florou-Paneri, P., Botsoglou, E., Giannenas, I., Amvrosiadis, I., Botsoglou, N. (2007). The inhibitory potential of feed supplementation with rosemary and/or α -tocopheryl acetate on microbial growth and lipid oxidation of turkey breast during refrigerated storage. *Food Sci Technol, LWT*, 40, 331–337.
- [93] Djenane, D., Sánchez-Escalante, A., Beltrán, JA., Roncalés, P. (2002). Ability of α -tocopherol, taurine and rosemary, in combination with vitamin C, to increase the oxidative stability of beef steaks displayed in modified atmosphere. *Food Chem.* 76, 407–415.
- [94] Janz, JAM., Morel, PCH., Wilkinson, BHP., Purchas, RH. (2007). Preliminary investigation of the effects of low-level dietary inclusion of fragrant essential oils and oleoresins on pig performance and pork quality. *Meat Sci.* 75, 360–365.
- [95] López-Bote, CJ., Gray, JL., Gomaa, EA., Flegal, CJ. (1998). Effect of dietary administration of oil extracts from rosemary and sage on lipid oxidation in broiler meat. *Br Poult Sci.* 39, 235–240.
- [96] Parpinello, GP., Meluzzi, A., Sirri, F., Tallarico, N., Versari, A. (2006). Sensory evaluation of egg products and eggs laid from hens fed diets with different fatty acid composition and supplemented with antioxidants. *Food Res Int.* 39, 47–52.
- [97] Nieto, G., Estrada, M., Jordán, M.J., Garrido, M.D., Bañon, S. (2011). Effects in ewe diet of rosemary by-product on lipid oxidation and the eating of cooked lamb under retail display conditions. *Food Chem.* 124, 1423–1429.
- [98] Nieto, G., Bañon, S., Garrido, MD. (2011b). Administration of distillate Thyme leaves into the diet of Segureña ewes: effect on lamb meat quality. *Anim J.* 6(12), 2048–56.
- [99] Nieto, G. (2013). Incorporation of by-products of rosemary and thyme in the diet of ewes: effect on the fatty acid profile of lamb. *Eur Food Res Technol.* 236, 379–389.
- [100] Nieto, G., Huvaere, K., Skibsted, LH. (2011). Antioxidant activity of rosemary and thyme by-products and synergism with added antioxidant in a liposome system. *Eur Food Res Technol.* 233, 11–18.
- [101] Galobart, J., Barroeta, AC., Baucells, MD., Codony, RM., Ternes, W. (2001). Effect of dietary supplementation with rosemary extract and α -tocopheryl acetate on lipid oxidation in eggs enriched with ω -3-fatty acids. *Poult Sci.* 80, 460–467.
- [102] O’Grady, MN., Maher, M., Troy, DJ., Moloney, AP., Kerry, JP. (2006). An assessment of dietary supplementation with tea catechins and rosemary extract on the quality of fresh beef. *Meat Sci.* 73, 132–143.