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ANTI-OXIDANTS USED IN MEAT PRODUCTS: A REVIEW

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ABSTRACT

Meat is one of the important components of non-vegetarian human diet. It is a good source of proteins, fats, vitamins and minerals. It has a high nutritional value as it contains all the essential amino acids and fatty acids making it indispensable in a balanced diet. The significance of meat and meat products in human nutrition is well documented and it is an acknowledged fact that these play a crucial role in maintenance of consumer health. As in other parts of India, the production and marketing of meat and meat products in the state of Jammu and Kashmir has been steadily growing over the years. Kashmir is well known for its traditional meat products, the cuisine collectively termed as '*Wazwan*'. These are flavorful ready-to-eat meat products which are usually freshly prepared and served hot as part of splendid meals.

KEYWORDS: Antioxidants, Lipid oxidation, Ready-to-eat meat products.

INTRODUCTION

The demand for ready-to-eat meat products including various *Wazwan* products is increasing day by day mainly due to socio-economic development and changing life styles. Besides their

immense local popularity and demand, these products also cater to the fast food requirements of a large number of domestic and foreign tourists and are relished by one and all visiting Kashmir. Thus there is great scope and need not only for their hygienic production but also for improvements over the traditional practices followed in their formulation and preparation so as to enhance their quality as well as shelf-life and thus safeguard the health of the consumers.

Two *Wazwan* products, viz. '*Rista*' & '*Goshtaba*', form the main and essential components of *Wazwan* and are thus an inalienable part of this world-famous traditional Kashmiri cuisine. *Rista* and *Goshtaba* are emulsion type meat products usually prepared from hot boned mutton after manual pounding on a stone slab with the help of a wooden hammer. Curd is invariably used in the formulation of *Goshtaba* gravy but not for *Rista* gravy.

A considerable amount of animal fat (about 20-30%) is used in the formulation of *Rista* and *Goshtaba* to achieve a stable emulsion and also to impart a special taste and flavor to these products. However, apart from these beneficial effects, the addition of fat is also responsible for certain undesirable effects in these products. The addition of fat in such amounts makes these products more susceptible to oxidative changes resulting in the development of rancidity and off-flavors and thus an overall decrease in their quality. Besides the addition of fat, there are other factors including comminution (exposure to air), addition of relatively smaller amounts of spices and condiments (depriving antioxidant effect) and use of table salt (pro-oxidant) which make these products more prone to lipid oxidative changes with consequent adverse effects on the product. Besides other undesirable effects due to oxidative changes and development of rancidity, these products cannot be kept for longer times, thus limiting their overall shelf-life and marketability. Thus, keeping in view the issues and concerns related to health, nutritional value, product quality, sensory attributes, shelf life and economics, there is a need to find an effective solution to these issues and improve the quality of these products by inhibiting or decreasing the very root cause of this problem, the lipid oxidation.

Lipid oxidation in meat and meat products can be retarded by the use of antioxidants which may be from natural sources or of synthetic origin. Synthetic antioxidants, such as butylated hydroxy anisole (BHA), butylated hydroxy toluene (BHT) and t-butyl hydro quinone (TBHQ) have been extensively used for many years in meat products. However, because of toxicological concerns of synthetic antioxidants, there has been an increasing interest in the

use of natural antioxidants including plant extracts to reduce or retard lipid oxidation in several meat products. Various plant extracts, separated from natural sources, have proven to possess strong antioxidant activity due to their high content of phenolic compounds and are permitted for use in foods to replace synthetic antioxidants. Among these plant products rosemary extract is one of the most potent and effective products with excellent antioxidant effect and is authorised as a food additive for use in foodstuffs under Directive 95/2/EC of European Commission and assigned E-392 as E-number. The antioxidant activity of rosemary extract has been associated with presence of several phenolic diterpenes. Alpha-tocopherol is one of the other natural antioxidants which have been used in meat and meat products to retard or inhibit lipid oxidation. It has been approved as a food additive in European Union with an E-number of E-307 and also enjoys GRAS status in USA.

Physico-chemical parameters

Sofi *et al.* (2010) evaluated the physico-chemical quality of *Rista* procured from high standard, medium standard and low standard outlets in Srinagar city and reported the results as: pH: 6.47±0.10, 6.39±0.10 and 6.40±0.07; moisture(%):67.17±0.97, 66.69±0.77 and 59.94±1.63; protein(%):13.54±0.28, 13.59±0.28 and 12.68±0.29; ether extract(%):14.40±0.99, 15.00±0.22 and 19.63±1.43; ash(%):2.27±0.17, 2.49±0.16 and 2.74±0.33 respectively.

Sofi *et al.* (2008) conducted a study to assess the physicochemical quality of *Goshtaba* obtained from high, medium and low standard outlets of Srinagar city and reported the respective results as: pH: 5.23±0.15, 5.10±0.10 and 4.99±0.17; moisture (%):68.90±0.81, 66.70.70±1.05 and 67.01±1.30; protein(%): 12.33±0..30, 11.94±0.21 and 12.27±0.44; ether extract(%): 14.43±0.61, 15.70±1.24 and 14.43±1.42; ash(%): 2.36±0.17, 2.50±0.20 and 2.78±0.16.

The pH and moisture, fat and protein percentages of low fat ground pork patties have been reported by Kumar and Sharma (2007) to be of the order of 6.1 ± 0.01, 56.5 ± 0.12, 18.5 ± 0.23 and 18.7 ± 0.27 respectively.

Burgers prepared from ostrich meat (alone or mixed with beef or pork) were evaluated by Fernandez *et al*. (2006) who reported the physicochemical composition of burgers made with 100% of ostrich meat as: moisture-68.67%, fat-8.58%, protein-22.43%, ash-1.95% and pH-6.07.

Szmanko *et al.* (2006) conducted physiochemical quality evaluation of processed meat products, from three different meat processing plants in different regions of Poland, in terms of protein, fat, water, NaCl, nitrate and added phosphate and reported a moisture (%) of 72.07, 52.40, 65.95 and 56.59 for cooked pork ham, Parowkowa sausages, Slaska sausage and Krakowska sausage respectively whereas, protein (%) and fat (%) was reported as: 17.55, 7.21, 11.29 and 34.70, and 15.79, 15.61, 19.51 and 20.94 respectively for these four products.

Seydim *et al.* (2006) evaluated the effect of incorporating 2% sodium lactate (SL) or 0.2% rosemary extract (RE) or their mixture (MIX) on pH of vacuum-packaged ostrich meat stored at 3 ± 1°C in the dark and found that the pH values of ostrich meat, ranging from 6.03 to 6.13, were not affected by the treatments.

Physicochemical properties of cooked chicken patties were evaluated by Kumar and Sharma (2005). The pH, moisture (%), fat (%) and protein (%) was found to be 6.18 ± 0.01, 58.87 ± 0.61, 18.98 ± 0.65 and 14.58 ± 0.34 respectively.

Yen *et al.* (2005) reported that pre-storage antioxidant dipping treatments (0.06% w/w tocopherols, propyl gallate or rosemary extract) did not have any effect on the cooking yield of frozen Australian red claw crayfish meat.

Ambrosiadis *et al.* (2004) conducted physicochemical analysis of 67 samples of fresh traditional sausages in North Greece and found the mean values as: moisture(%):49.17 ± 7.05, protein(%):17.62 ± 2.67, fat(%):29.74 ± 8.02, ash content(%):2.99 ± 0.55, pH 5.48 ± 0.49, moisture/protein ratio:2.83 ± 0.5 and water activity:0.959 ± 0.015.

Gonzalez *et al.* (2004) evaluated commercially available frankfurters purchased from various super markets in Civdad Real, Spain and reported physicochemical attributes as pH: 5.88 to 6.43, water activity (a_w):0.954 to 0.972, fat(%):10.83 to 21.92, and salt content(%):1.85 to 3.01.

Effect of incorporation of tofu at 0%, 10%, 20% and 30% level on physicochemical characteristics of cooked chicken meat patties was studied by Nayak and Tanwar (2004) and reported the results as moisture(%):64.44 ± 1.06, 65.12 ± 0.96, 65.68 ± 1.00 and 65.96 ± 1.56; protein(%):19.15 ± 0.40, 18.93 ± 0.26, 18.23 ± 0.36 and 18.06 ± 0.28; ether extract(%):8.20 ± 0.56, 8.29 ± 0.67, 8.63 ± 0.48 and 9.07 ± 0.72; ash(%):2.10 ± 0.34, 2.23 ±

0.62, 2.37 ± 0.55 and 2.55 ±0.44, and pH:6.23 ± 0.07, 6.22 ± 0.06, 6.21 ± 0.07 and 6.18 ± 0.07 respectively for the four tofu levels.

Effect of different methods of cooking (viz. pan frying, hot air oven and microwave oven) on the quality of chevon patties was investigated by Pawar *et al*. (2000) in terms of physicochemical characteristics and found that the moisture, protein and fat percentages ranged from 59.8 to 61.4, 16.9 to 17.3 and 11.4 to 12.9 respectively.

Singh and Verma (2000) analyzed chicken patties for physicochemical parameters in terms of pH, moisture (%), crude protein (%) and ether extract (%) and reported mean values as 6.53 ± 0.02, 58.02 ± 0.18, 26.16 ± 0.14 and 12.45 ± 0.08 respectively.

Sahoo and Anjaneyulu (1997b) examined the effects of addition of antioxidants (sodium ascorbate-500 ppm, alpha-tocopherol acetate-10 ppm and sodium tripolyphosphate-0.5%) on the physiochemical properties of buffalo meat nuggets during refrigerated storage (30 days at 4±1°C) and reported that treated samples had higher values of pH, moisture and protein as compared to control.

Rista, a traditional Kashmiri wazwan product was evaluated for its quality in terms of physicochemical parameters by Samoon and Sharma (1994) and reported the results as: moisture(%):64.05 ± 0.13 and 64.83 ± 0.15, protein(%):16.61 ± 0.20 and 17.42 ±0.12, fat(%): 16.52 ± 0.12 and 14.82 ± 0.12, ash(%): 2.82 ± 0.04 and 2.80 ± 0.02, pH: 6.13 ± 0.01and 5.90 ± 0.04 for *Rista* prepared from the traditionally minced and machine minced meat respectively.

Malik *et al*. (1990) evaluated the proximate composition of rabbit meat patties incorporated with hydrogenated vegetable oil and reported the moisture(%), protein(%), ether extract(%) and ash(%) as 61.586 ± 0.279, 21.493 ± 0.122, 13.500 ± 0.222 and 3.106 ± 0.048 respectively at 10% level of hydrogenated vegetable oil.

Dominquez *et al*. (1989) evaluated six brands of bologna beef pork sausages purchased in local markets of Mexico and reported the values for moisture (%) : 51.38-68.28, fat (%) : 6.63-17.13, protein (%) : 8.43-10.70, carbohydrates (%) : 11.81-27.41 and ash (%) : 2.79-4.72.

Anjaneyulu *et al*. (1989) evaluated buffalo meat patties for physiochemical properties and reported moisture (%) and pH as 58.00 and 5.52 respectively with the incorporation of 2% sodium chloride.

Samoon (1988) studied the effect of different treatments on the quality of *Goshtaba*, a traditional Kashmiri wazwan product, and reported physicochemical quality of salt treated hot boned and cold boned traditionally minced *Goshtaba* as: moisture(%):66.98 ± 0.75 and 66.45 ± 0.37, protein(%):12.01 ± 0.33 and 13.69 ± 0.74, ether extract(%):17.30 ± 0.59 and 14.64 ±_0.68, ash(%):2.51 ± 0.07 and 2.51 ± 0.07, pH:5.40 ± 0.03 and 5.20 ± 0.05 respectively.

Flores and Alvarruizo (1986) evaluated 265 samples of Spanish Chorizo sausages for physicochemical composition and reported the range of percent values for moisture as 60-77 in fresh chorizo and 55-60 percent in cured chorizo whereas the range of percent values for fat were reported as 20-45 for cured chorizo, 25-30 percent for Iberian cured chorizo and 35-40 percent for fresh chorizo.

Microbiological Quality

Sofi *et al.* (2010) evaluated the microbiological quality of *Rista* obtained from high standard, medium standard and low standard outlets in Srinagar city and reported the results for Total Viable Count (log cfu/gm) as 2.41±0.12, 2.52±0.08 and 2.57±0.17 and Coliform Count (log cfu/gm) as 1.57±0.16, 1.66±0.20 and 1.72±0.19 respectively for the samples from three types of outlets.

Sofi *et al.* (2008) conducted a study for the evaluation of microbiological quality of *Goshtaba* procured from high, medium and low standard outlets of Srinagar city and reported their Total Viable Count (logcfu/gm) as 2.18±0.13, 2.72±0.10 and 2.79±0.13 and Coliform Count (log cfu/gm) as 1.27±0.15, 1.48±0.15 and 2.02±0.25 respectively for the samples from three types of outlets.

Malik *et al.* (2007) evaluated the microbiological quality of *Rista* prepared from rabbit meat and reported TVC and Coliform Counts as 2.51±0.02 and 2.32±0.01 log cfu/gm respectively. Kumar and Sharma (2007) evaluated low fat pork patties for Total Plate Count and reported it as 1.7 ± 0.06 log cfu/g at day zero of storage.

Selvan *et al.* (2007) conducted a study on microbial quality of commercially available beef, pork, mutton and chicken products from different regions of Chennai city and reported that mutton products showed highest Total Viable Count (5.35 ± 0.03 log cfu/g) and Coliform Count (2.46 ± 0.07 log cfu/g); chicken products recorded lowest Total Viable Count (4.54 ± 0.12 log cfu/g) and anaerobic count (3.10 ± 0.01 log cfu/g). However, pork products showed lowest Coliform Count (0.66 ± 0.12 log cfu/g) among all the products studied.

Ambrosiadis *et al.* (2004) analyzed 67 samples of fresh traditional sausages in North Greece for microbiological quality and reported the values of aerobic plate count as 8.22 ± 0.5 log cfu/g, lactic acid bacteria as 7.45 ± 0.66 logcfu/g, pseudomonas as 6.88 ± 1.33 log cfu/g and yeasts as 5.39 ± 1.03 log cfu/g.

Forty samples of frozen camel meat products (10 each of burgers, Kofta, minced meat and sausages) collected from supermarkets in Cairo and Giza in Egypt were analyzed for bacteriological quality by Ouf (2004). The percent incidence rates of *E. coli*, Salmonella, *S. auerus* and *B. cereus* were reported as 30, 0, 40 and 20 for burgers, 30, 50, 50 and 30 for Kofta, 20, 0, 20 and 10 for minced meat and 40, 0, 30 and 30 for sausages respectively.

Dessi *et al.* (2001) analyzed 605 samples of minced meat processed products (including hamburgers and sausages) produced by wholesale trade companies in Sardinia for aerobic mesophilic count and presence of *E.coli, S.aureus and* Salmonella and observed that microbial count was unsatisfactory in 5 samples and 7 samples had aerobic mesophillic count above permissible level but were not regarded as unsafe.

Malik and Keshri (2001) evaluated rabbit meat patties for various microbiological quality parameters during refrigerated storage and reported the Total Plate Count values for freshly prepared product as 4.468 ± 0.223 logcfu/g.

A total of 100 samples of ground meat and hamburgers obtained from large scale retail trade outlets and butcher shops were analyzed for counts of total mesophillic, faecal colifoms, sulphide reducing clostridia and faecal streptococci by Pizzin *et al.* (1998). Results showed that the values were well within permissible limits indicating that overall level of hygiene was satisfactory.

Sahoo *et al.* (1998) studied the effect of addition of several natural antioxidants (500 ppm sodium ascorbate, 10 ppm alpha-tocopherol acetate and 0.5% sodium tripolyphosphate) on

the microbiological quality of ground buffalo meat mince during frozen storage and reported that treatment did not cause noticeable differences in growth of various microorganisms present in the meat and meat quality decreased as the storage period increased.

Aerobic plate count was reported to be 4.16 ± 0.21 and 4.08 ± 0.18 log cfu/g respectively for hot boned traditionally minced and machine minced salt treated *Rista* by Samoon and Sharma (1994) while for cold boned salt treated and phosphate treated *Rista* the reported results were 4.22 ± 0.19 and 3.97 ± 0.09 logcfu/g respectively.

Dominquez *et al.* (1989) evaluated the microbiological quality of six brands of bologna beef pork sausages purchased in local markets of Mexico and reported a mesophilic count of 5.6 x 10^4 to 2.8 x10^6 and Most Probable Number coliform count as 3 to 406/gm. No Salmonella was found in any sample while as *S. aureus* was found only in one sample.

Total aerobic plate count of freshly prepared salt treated and phosphate treated *Goshtaba* was assessed by Samoon (1988) and reported it to be 3.60 ± 0.16 and 3.51 ± 0.17 logcfu/g respectively in the two treatments. Darwish *et al.* (1986) analyzed 20 samples of several meat products (minced meat, kofta, kofta pane, rice kofta and beef burgers) from Cairo supermarkets for total colony count, enterobacteriacae, Salmonella *and E.coli*. Results showed that *E.coli* was present in all samples while *Salmonella typhi* was detected in 5% of minced meat, 5% of beef burgers, 10% of kofta pane and 10% of rice kofta samples.

Rayman *et al.* (1986) collected samples of a variety of frozen meat pies in Canada and evaluated them for aerobic colony count, coliform count, Salmonella, *C. perfringens, S. auerus*, yeast and mould. Salmonella was not found in any of the pie samples where as low number of *C. perfringens* and *S. auerus* was found. Degree of contamination regarding aerobic plate count, coliform count, yeast and mould was not alarmingly high to warrant establishment of microbiological standards.

Sensory parametres

Sofi *et al.* (2010) studied the sensory parameters of *Rista* obtained from high, medium and low standard outlets of Srinagar city and reported the values of scores for appearance as 6.57±0.13, 6.44±0.14 and 5.94±0.14, for flavour as 6.33±0.13, 5.94±0.15 and 5.74±0.15, for texture as 6.59±0.13, 6.31±0.13 and 5.85±0.14, for juiciness as 6.44±0.13, 6.15±0.13 and 5.87±0.16, for mouth coating as 6.43±0.14, 6.22±0.16 and 6.00±0.16, for saltiness as

6.80±0.11, 6.56±0.16 and 6.22±0.16 and for overall acceptability as 6.57±0.12, 6.22±0.12 and 5.81±0.15 respectively on an 8-point descriptive scale (where 8= extremely palatable, 1=extremely unpalatable).

The sensory quality of *Goshtaba* procured from high, medium and low standard outlets of Srinagar city was evaluated by Sofi *et al.* (2008) and the results of sensory scores reported were as follows: appearance: 6.85±0.10, 6.48±0.10 and 6.02±0.12, flavour: 6.70±0.13, 5.89±0.15 and 5.61±0.12, texture: 6.57±0.10, 5.89±0.12 and 5.56±0.16, juiciness: 6.62±0.13, 5.91±0.14 and 5.89±0.13, mouth coating: 6.49±0.14, 6.13±0.17 and 6.00±0.17, saltiness: 6.70±0.13, 6.09±0.15 and 6.08±0.14 and overall acceptability: 6.81±0.11, 5.91±0.14 and 5.61±0.15 respectively on an 8-point descriptive scale (where 8= extremely palatable, 1=extremely unpalatable).

The scores for various sensory attributes like appearance, flavour, juiciness, texture and overall acceptability for low fat ground pork patties were evaluated by Kumar and Sharma (2007) and reported their mean scores as 7.2 ± 0.11, 7.2 ± 0.07, 7.0 ± 0.09, 7.0 ± 0.10 and 7.1 ± 0.09 respectively on an 8-point descriptive scale (where 8= extremely desirable and 1= extremely poor).

Fernandez *et al.* (2006) conducted quality evaluation of burgers made from ostrich meat in terms of sensory parameters like saltiness, fattiness, rancid flavor, residual taste, colour intensity, hue, juiciness, shine, firmness and found overall acceptability score of 8.05 ± 0.22 on 10-point scale (where 10 = highly acceptable and 1 = not acceptable).

The sensory quality of processed meat products produced in three different meat processing plants situated in different regions of Poland was assessed by Szmanko *et al.* (2006) for taste, smell, juiciness and texture and reported the overall quality scores as 4.68, 4.54, 4.56 and 4.68 for cooked pork ham, Parowkowa sausages, Slaska sausage and Krakowska sausage respectively on a 5-point scale (where 5 = maximum and 1 = minimum points).

Kumar and Sharma (2005) studied sensory attributes of cooked chicken patties at 0, 5, 10 and 15% levels of pressed rice flour extender. Overall acceptability was reported as 7.04±0.10, 6.80±0.12, 6.64±0.10 and 6.38±0.14 respectively on an 8-point descriptive scale (where 8= extremely desirable, 1=extremely undesirable).

Serdaroglu *et al.* (2005) investigated sensory quality of meat balls after using legume meals as extenders and found that sensory acceptability was high ($\geq$ 6.8). Results suggested that legume meal can be used as meat ball extender. Yilmaz (2005) assessed physico-chemical properties of low fat veal meat balls containing different levels of wheat bran (5, 10, 15, 20%) and compared with control samples (10% fat) for sensory properties and reported that acceptability scores differed significantly between various samples with best scores noted for control.

Ambrosiadis *et al.* (2004) evaluated sensory quality of 67 samples of fresh traditional sausages purchased from butchers shops and supermarket in North Greece and reported mean sensory scores on a 5 point hedonic scale as 4.46 ± 0.63 for appearance, 4.14 ± 0.63 for firmness, 3.80 ± 0.97 for flavour and 4.12 ± 0.52 for overall quality.

Girish *et al.* (2004) investigated quality and storage stability of patties prepared from spent chicken meat and chicken byproducts by adding sodium caseinate, whey protein concentrate, skim milk powder and milk co-precipitate at different levels and found that sensory scores for flavour, juiciness and overall acceptability were highest in chicken patties containing 2% whey protein concentrate.

Konieczny *et al*. (2004) studied sensory properties of dried beef snacks (beef jerky with original taste, sweet and hot beef jerky) and found that general assessment score was 3.92 out of 5 for beef jerky snacks with original taste and 3.62 out of 5 for sweet and hot beef jerky snacks indicating that snacks were acceptable and had good sensory quality. Sensory analysis of commercial Salami was carried out by Vittorio *et al.* (2004) for various sensory attributes and reported the scores of 2.5 ± 1.1, 3.7 ± 0.9, 4.75 ± 1.3, 3.25 ± 1.3, 3.05 ± 0.9, 4.47 ± 1.5 and 3.4 ± 1 for colour intensity, flavour, firmness, saltiness, hardness, cohesiveness and overall acceptability respectively on a 6-point scale (where 1 = very low and 6= very high).

Various sensory attributes of freshly prepared rabbit meat patties were evaluated by Malik and Keshri (2001) and reported sensory scores for appearance, flavour, juiciness, texture and overall acceptability as 7.38±0.13, 7.33±0.13, 7.38±0.13, 7.38±0.15 and 7.48±0.11 respectively on an 8-point descriptive scale (where 8 = extremely palatable and 1 = extremely unpalatable).

Singh and Verma (2000) evaluated chicken patties, formulated with 0, 10, 15 and 20% soya, for overall acceptability and reported scores of 6.6±0.31, 6.8±0.26, 5.6±0.32 and 4.8±0.26 respectively on a 7-point descriptive scale (where 7=extremely palatable, 1=extremely unpalatable).

Goshtaba prepared from hot boned traditionally minced and hot boned machine minced salt treated mutton was evaluated for sensory quality in terms of appearance, flavour, juiciness, texture and overall acceptability by Samoon (1988). The sensory scores obtained were 7.19 ± 0.15 and 6.67 ± 0.16, 6.57 ± 0.13 and 6.71 ± 0.16, 6.86 ± 0.14 and 6.42 ± 0.16, 7.05 ± 0.18 and 5.95 ± 0.14, and 6.67 ± 0.19 and 6.28 ± 0.15 respectively for the two types of products on an 8-point descriptive scale (where 8=extremely palatable, 1=extremely unpalatable).

Fresh *Rista* prepared from hot boned as well as cold boned traditionally minced mutton was evaluated for sensory quality by Samoon (1988) in terms of appearance, flavour, juiciness, texture and overall acceptability. The scores obtained for the two types of the product were: 7.52±0.13 and 6.81±0.16, 7.24±0.15 and 6.48±0.19, 6.95±0.15 and 6.48±0.15, 6.95±0.15 and 6.43±0.19, and 7.00±0.14 and 6.29±0.18 respectively. He further reported the sensory scores for machine minced *Rista* as 7.14 ± 0.14, 7.00±0.14, 6.81±0.13, 6.67±0.13 and 6.57±0.13 for the said parameters respectively on an 8-point descriptive scale (where 8= extremely palatable, 1=extremely unpalatable).

Rosemary as an antioxidant

Trindade *et al.* (2010) investigated the effect of BHT/BHA blend and rosemary and oregano extracts, added individually or in combination, on lipid oxidation and fatty acid composition in irradiated frozen beef burgers (-20^{o}C, 90 days) and found rosemary extract applied alone or in combination with BHA/BHT or oregano extract, was more effective in preventing oxidation compared to oregano extract or oregano extract + BHA/BHT.

Bragagnolo *et al.* (2007) investigated the potential of rosemary (*Rosmarinus officinalis,* L.) to inhibit lipid oxidation in minced chicken breast and thigh muscle processed at 600 MPa for 10 min during subsequent heat treatment using electron spin resonance (ESR) spectroscopy and electrochemical detection of oxygen consumption and concluded that rosemary was effective in retarding lipid oxidation since the pressurized, minced chicken breast and thigh with rosemary added showed lower rate of oxygen consumption and lower tendency of free radical formation following heat treatment than the samples without rosemary.

Georgantelis *et al*. (2007a) investigated the effect of rosemary extract, chitosan and α-tocopherol, added individually and in combination, on lipid oxidation and colour stability of frozen (-18^{0}C) beef burgers stored for 180 days and found that chitosan alone or in combination with α-tocopherol or rosemary had the best antioxidative effect and retention of red colour in the product, with chitosan+rosemary extract showing best results.

Georgantelis *et al.* (2007b) investigated the effect of rosemary extract, chitosan and alpha-tocopherol, added individually or in combination on lipid oxidation of fresh pork sausages stored for 20 days at 4°C and found that chitosan and its combination with rosemary showed the most intense antioxidative effect of all other combinations. Lund *et al.* (2007) investigated the effect of rosemary extract and ascorbate/citrate (1:1) in combination with modified atmosphere packaging (100% N_2, 80% O_2/20% N_2) on protein and lipid oxidation in minced beef patties during storage in the dark for up to 6 days at 4°C and reported that both antioxidant systems tested were found to inhibit lipid oxidation but not protein oxidation. In addition, rosemary extract was found to regenerate or protect alpha-tocopherol.

Nam *et al.* (2007) reported that rosemary and alpha-tocopherol combination at 0.05 and 0.02% of meat weight, respectively, showed the most potent antioxidant effects in reducing both TBARS values and the amounts of volatile aldehydes in irradiated raw and cooked pork patties.

Balentine *et al.* (2006) investigated the pre- and post-grinding application of rosemary and its effects on lipid oxidation and colour during storage (4^{o}C, 144 hrs) of beef (trim, cube, coarse and fine ground) and found that pre-grinding treatments of beef (trim and cube) showed highest redness values and oxymyoglobin content and lowest Thiobarbituric acid reactive substances (TBARS) values. Also rosemary treated samples (both inoculated @ 10^7 cfu/g *E.coli* and uninoculated) showed lower TBARS values and remained redder longer than their untreated counterparts.

Estevez and Cava (2006) studied the effect of increasing levels (150, 300 and 600ppm) of rosemary essential oil on lipid and protein oxidation and the increase of non-heme iron content during refrigeration (+4°C/60 days) of frankfurters produced with tissues from Iberian pigs (IF) or white pigs (WF). It was found that the rosemary essential oil successfully inhibited the development of lipid and protein oxidation in IF with that antioxidant effect being more intense at higher concentrations of essential oil. However, in WF, 150ppm

rosemary essential oil showed an antioxidant effect, significantly reducing the generation of lipid and protein oxidation products but at higher levels (300 and 600ppm) the essential oil had, in general, no effect on lipid oxidation while significantly enhanced the oxidation of proteins and the release of iron from myoglobin.

Estevez *et al.* (2006) found that rosemary essential oil significantly reduced hardness in porcine liver pates stored at 4^{o}C for 90 days, with rosemary oil exhibiting similar antioxidant properties to BHT denoting its suitability as alternative to synthetic antioxidants.

Lee *et al.* (2006a) observed that antioxidant combination of rosemary, citrate and erythorbate stabilized meat colour and inhibited TBARS and hydroperoxide formation in n-3 fortified fresh ground turkey and fresh pork sausage stored at 4^{o}C or -18^{o}C.

Lee *et al*. (2006b) studied the antioxidant effectiveness of ginger extract in fresh, frozen and precooked pork patties and found that their shelf life, as determined by TBA value, was improved. Seydim *et al.* (2006) found that the addition of 0.2% rosemary extract to ostrich mince patties inhibited lipid oxidation during storage at 3±1°C.

Riznar *et al.* (2006) investigated the antioxidant and antimicrobial effects of 2 commercially available oil-soluble rosemary extracts, VivOX 20 and VivOX 4, in vacuum-packed chicken frankfurters and compared them against a commercially available preservative, Robin LI LS. It was found that in chicken frankfurters with added VivOX 20 and VivOX 4, higher oxidative stability was exhibited at all storage temperatures as in frankfurters with Robin LI LS. Salminen *et al.* (2006) found that rapeseed meal and camelina meal alone and in combination with rosemary extract proved effective antioxidants in cooked pork meat patties whereas soy meal and flour were effective only in combination with rosemary extract.

Balev *et al.* (2005) compared the effect of some antioxidants on lipid and pigment oxidation in Bulgarian dry-fermented sausages (Lukanka sausages). The antioxidants used included, a commercial mix of antioxidants, Grindox 1021 (GR), rosemary (RS), rutine (RT), sodium erythrobate (SE) or L-ascorbic acid (AA). It was found that Grindox 1021 (GR), restricted the development of peroxidation processes in dry-fermented sausages to a greater extent than the individual action of either rosemary (RS), rutine (RT), sodium erythrobate (SE) or L-ascorbic acid (AA), when applied at the same concn. They further concluded that the addition of RS or GR (1 g/kg) had the greatest effects on suppressing hydroperoxides, the primary derivatives

of lipid peroxidation.

Montero *et al.* (2005) investigated the effects of quercetin and rosemary extracts on lipid and protein oxidation in minced fish flesh during thermal and high-pressure gelation and found that rosemary gave higher protection against lipid oxidation, while as quercetin was more effective against protein oxidation.

Bragagnolo *et al.* (2005) studied the protective effect of rosemary against lipid oxidation and tocopherol degradation in pressure-processed chicken breast mince with 0.5% added salt during chilled storage (5°C) for 9 days, with or without subsequent heat treatment. It was found that the addition of rosemary significantly decreased secondary lipid oxidation products in chicken mince after high-pressure processing at 600 MPa for 10 min and subsequent chilled storage. Besides, it gave a protective effect to tocopherol.

Estevez *et al.* (2005) investigated the effects of addition of rosemary essential oil at 3 different concentrations (150, 300 and 600 ppm) on the protein oxidative stability of frankfurters during refrigerated storage (+4°C/60 days). It was found that the addition of rosemary essential oil at concentrations of 300 and 600 ppm gave successful protection against protein oxidation, protected the heme molecule from degradation and significantly inhibited the increase of nonheme iron in refrigerated stored frankfurters, offered colour stability as well as enhanced the texture characteristics of frankfurters by reducing hardness, adhesiveness, gumminess and chewiness and controlling the loss of elasticity during refrigeration.

Fernandez-Lopez *et al.* (2005) investigated the antioxidative effect of rosemary, orange and lemon extracts in cooked meat balls stored at 8^{o} C for 12 days and found that 50% of the rancidity could be controlled by citrus preparations while as rosemary extracts (both oil and water soluble) resulted in complete elimination rancidity.

Han and Rhee (2005) investigated the effects of addition of various herb extracts like angelica, rehmania, moutan peony, sappanwood, red peony, white peony and rosemary on the oxidative stability of goat meat mince and beef patties stored at a refrigeration temperature for 0-6 days. They found that all of the tested herb extracts, apart from angelica, significantly reduced lipid oxidation in goat meat, while as, 0.25% of all herb extracts, apart from rehmania and angelica, reduced lipid oxidation to a minimum in raw and cooked, salted and

unsalted beef samples. Lee *et al.* (2005) investigated the ability of sodium tri-polyphosphate, sodium citrate, sodium erythorbate, BHA, mixed tocopherols and rosemary extracts in various combinations on the colour stability and lipid oxidation of beef patties fortified with n-3 fatty acids and found sodium citrate/sodium erythorbate and rosemary extract as the most effective combination.

Yen *et al.* (2005) investigated the effects of pre-storage antioxidant (0.06% w/w tocopherol, propyl gallate or rosemary extract) dipping treatments on the shelf life of Australian red claw crayfish tail meat during frozen storage (20°C) for 1-6 months and found that the antioxidant treatments significantly lowered TBARS generation in the samples.

Ahn *et al.* (2004) investigated the inhibition of *E. coli* O157:H7, *S. typhimurium* and *L. monocytogenes* by commercially available grape seed (GS), pine bark (PB) extracts and rosemary oleoresin together with the effects of various natural extracts on the oxidative stability of raw beef mince and concluded that these natural extracts have the potential to be used with other preservative methods to reduce pathogenic numbers, lipid oxidation and colour degradation in beef mince.

Estevez *et al.* (2004) studied the effect of addition of 2 natural antioxidant extracts (sage and rosemary essential oils) and 1 synthetic antioxidant (BHT) on generation of volatile compounds in liver pates from Iberian and white pigs and found that the addition of BHT successfully reduced the amount of volatiles derived from PUFA oxidation while as added essential oils showed different effects on the generation of volatiles when added in pates from Iberian or white pigs because they inhibited lipid oxidation in the former and enhanced oxidative instability in the latter. Gimenez *et al.* (2004) investigated the effects of natural antioxidants (rosemary extract or ascorbic acid) and different lighting conditions on the shelf life of gilt-head sea bream fillets and found that both antioxidants delayed lipid oxidation and improved sensory properties.

Korczak *et al.* (2004) studied the influence of fat oxidation on the stability of lysine and protein digestibility in meat products made with minced meat with added antioxidants (rosemary extracts, soy protein hydrolysate, BHT) during frozen storage and found that the use of antioxidants in the meat products slowed the rate of lipid oxidation markedly thus concluding that the use of antioxidants in meat products extended storage stability and protected protein value.

Kyung *et al.* (2004) studied the quality of hamburger made from pork, beef and pork fat, treated with rosemary powder (200-500 ppm), irradiated (5-20 kGy) and stored at 5°C for 3 months and found that the TBARS content of irradiated hamburgers was highest for control burgers without addition of rosemary powder and lowest for those treated with 500 ppm rosemary extract.

Nissen *et al.* (2004) evaluated the antioxidative activity of plant extracts (rosemary, green tea, coffee and grape skin) in precooked pork patties stored under retail conditions (4°C in air for 10 days) and found that the incorporation of extracts resulted in lower levels of secondary oxidation products and higher levels of vitamin E in the patties prior to storage, suggesting that the extracts inhibited lipid oxidation during processing of the pork. Also rosemary extract demonstrated best antioxidative activity followed by grape skin, green tea and lastly coffee.

Racanicci *et al.* (2004) compared the antioxidative activity of dried leaves of dittany with that of Rosemary in pre-cooked meat balls during cold storage for less than or equal to 10 days and found rosemary extract as being the most efficient antioxidant than dittany. Serdaroglu and Yildiz (2004) studied the effects of using ascorbic acid (AA), rosemary extract and alpha-tocopherol/ascorbic acid (T+AA) on some quality characteristics of chicken patties stored at -20°C for 6 months and found that at the end of the storage period, patties with T+AA had the lowest TBA values.

Xuetong *et al.* (2004) investigated the effect of antioxidants, viz. rosemary extract, sodium erythorbate and sodium nitrite, on Turkey bologna and found that rosemary extract and sodium nitrite inhibited oxidation while erythorbate increased TBARS values.

Djenane *et al.* (2003) evaluated the effects of rosemary extracts and Vitamin-C combination on the shelf life of beef steaks packaged under modified atmospheric packaging and found them to significantly extend the chilled shelf life of the product from around 10 to 20 days by inhibiting metmyoglobin formation, microbial growth and lipid oxidation as also increasing the intensity of red colouration. Fernandez-Lopez *et al.* (2003) evaluated the effect of rosemary and hyssop extracts in cooked pork stored for 8 days at 4°C and found that rosemary and hyssop extracts inhibited lipid oxidation, metmyoglobin formation and stabilized red colour of the meat.

Nassu *et al.* (2003) compared the antioxidant effectiveness of two different levels (0.05% and 0.025%) of rosemary in fermented goat meat sausage stored for 90 days at 30^{o}C and found that 0.05% formulation showed better oxidative stability, greater overall acceptability, greater colour values and lower oxidized aroma and flavour than 0.025% formulation. Sanchez-Escalante *et al.* (2003) evaluated the effects of rosemary, oregano, ascorbic acid and borage on the oxidative stability of beef patties during modified atmosphere storage at 2±1°C for 24 days and reported that all antioxidants, except ascorbic acid, significantly reduced TBARS formation, myoglobin oxidation and colour fading. Sensory analysis of beef patties revealed that rosemary, borage and oregano extended the shelf life of beef patties from 8 to 12 days, whereas a combination of rosemary and ascorbic acid prolonged shelf life for a further 4 days.

Arneth and Muench (2002) found that formation of cholesterol oxides in heated meat products can be decreased or slowed by presence of nitrite, ascorbate, rosemary or modified atmospheric packaging/vacuum packaging. Armitage *et al.* (2002) studied the effect of egg albumin coatings containing natural antioxidants, viz. fenugreek, rosemary and vitamin-E, on the oxidative stability of raw and cooked poultry meat and found that coatings containing rosemary and vitamin-E improved the oxidative stability of raw samples.

Yu *et al.* (2002) reported that 250 and 500 ppm water-soluble rosemary extracts (WSRE) significantly decreased TBARS formation in cooked turkey rolls prepared from fresh, ground turkey breast during storage at 4°C. Carthy *et al.* (2001) evaluated the antioxidant activities of aloevera, fenugreek, ginseng, mustard, rosemary, sage, soya protein, tea catechins and whey protein concentrate in pork patties prepared from both fresh and previously frozen (-20^{o}) pork and reported tea catechins, rosemary and sage as being the most effective antioxidants with the potency order as tea catechins > rosemary > sage.

Formanek *et al.* (2001) found that the oxidative stability of alpha-tocopheryl acetate supplemented beef patties was improved by addition of commercial rosemary extracts to samples stored under aerobic packaging conditions or modified atmospheres with elevated oxygen levels, during refrigerated storage. Sanchez-Escalante *et al.* (2001) reported that rosemary powder with or without ascorbic acid were the most effective antioxidants in inhibition of oxidation of lipids and myoglobin and in extending shelf life of packaged beef patties stored at 2°C in the dark for up to 20 days. Kim *et al.* (2000) investigated the effects of water extracts of 22 different spices (WES) on the sensory quality of kimchi and reported

that all WES improved kimchi flavour, but that basil, celery and rosemary had the greatest flavour-enhancing effect. It was also reported that the addition of 1% (w/v) basil, celery and rosemary to kimchi stored at 10°C for 28 days resulted in increased pH after 21 days.

Karpinska *et al.* (2000) found that the addition of rosemary extract delayed the oxidation of fried meat balls (made from poultry mince) during 5 months of frozen storage. Karpinska *et al.* (2000) investigated the influence of addition of rosemary extracts at 1 or 1.5% on the sensory quality of fried meat balls (made from poultry mince) during 5 months of frozen storage and found that the products containing rosemary extract were less susceptible to development of sour and rancid taste and aroma. Chang and Chen (1998) studied the factors affecting the hotness stability of chicken hot-wing products and concluded that application of antioxidants, viz. BHA, BHT or sodium nitrite and rosemary oleoresin, reduced the rate of rancidity development and loss of hotness during refrigerated storage.

Langourieux and Escher (1998) studied the effect of addition of citric acid and de-aromatized rosemary extract on the development of strong sulfurous off flavour in heat sterilized pork and concluded that rosemary extract as a primary antioxidant lessened both H_2S and ethane formation for a limited storage period. Vareltzis *et al.* (1997) found that the natural antioxidant properties of rosemary retarded oxidation of filleted and minced frozen (-18°C) fish samples throughout storage period of 120 days with rosemary treated samples containing significantly less malonaldehyde compared with controls.

Lee *et al.* (1997) investigated the effect of rosemary powder and rosemary extract on the sensory quality of chicken sausage stored at 4±1°C for 10 days and -20±1°C for 6 months and found that flavour intensity, texture, and colour were maintained for all treatments, and no significant off-flavours were detected through 8 days and 6 month storage.

Ho *et al.* (1995) evaluated the effects of various antioxidants and packaging systems on the storage stability and sensory properties of reduced-fat fresh pork sausage products during frozen storage and found rosemary extract to be equally effective as BHT/Propyl gallate/citric acid in antioxidant properties.

Guentensperger (1995) reported that the addition of rosemary extract before or after precooking inhibited oxidative changes over a longer period of storage at 20 or 37°C in retorted pork. Ma-Edmonds *et al.* (1995) found that use of rosemary oleoresin (0.2%)

controlled warmed-over flavour in precooked beef patties during 9 days storage period. Pizzocaro *et al.* (1994) reported that the addition of ground fresh leaves of rosemary (0.3% by wt.) or rosemary + sage (0.3% by wt. each) have a considerable antioxidative action in beef hamburgers stored for up to 10 months at -20°C. It was also reported that the freshness retention as well as the sensory quality of the beef hamburgers was improved during storage. Huisman *et al.* (1994) found that the combination of decreased O_2 atmosphere in the packs and addition of rosemary (0.05%) resulted in a significantly lower amount of TBARS and a significantly better sensory score in cooked meat balls (minced pork) during chill storage (5°C).

Boyd *et al.* (1993) investigated the antioxidant properties of TBHQ (0.5 g/kg + 20 g/kg ascorbic acid - TBHQ-AS) and an extract of rosemary (2.5 g/kg) alone and in combination in cooked fish flakes stored at -20°C and reported the order of effectiveness in inhibiting oxidation as TBHQ-AS > combination > rosemary > untreated control -70°C > untreated control -20°C. Butler and Larick (1993) found that the use of antioxidant treatments, viz. rosemary oleoresins, sodium nitrite, or sodium nitrite + rosemary oleoresin improved the sensory characteristics and oxidative stability of aseptically processed beef gels at 3^{o}C. Iriarte *et al.* (1992) compared the effects of two antioxidants, viz. a commercial antioxidant and rosemary extract, in cured pork fat and found rosemary extract to be more effective than the commercial antioxidant in preventing oxidation in cured pork-fat.

Stoick *et al.* (1989) studied the antioxidative effects of oleoresin rosemary (OR) on restructured beef steaks and breaded chicken nuggets during chilled storage (4°C, 8 days) and frozen (-20°C, 6 months) storage and reported that OR in combination with sodium tripolyphosphate inhibited lipid oxidation during storage at both temperatures.

Rosemary as antimicrobial

Celiktas *et al.* (2007) tested the antimicrobial activity of the essential oils and methanolic extracts of *R. officinalis* against *S.aureus, Proteus vulgaris, Pseudomonas aeruginosa, Klebsiella pneumonia, Enterococcus feacalis, E. coli, Staphylococcus epidermidis, Bacillus subtilis* and *Candida albicans* and reported that the tested bacteria were sensitive to the essential oils and partially to methanolic extracts.

Georgantelis *et al.* (2007b) investigated the effect of rosemary extract, chitosan and alpha-tocopherol, added individually or in combination on the microbiological quality

(Enterobacteriaceae, Pseudomonas spp., total viable count, yeasts and moulds, and lactic acid bacteria) of fresh pork sausages stored for 20 days at 4°C and reported that the lowest microbial counts were obtained in the samples containing both chitosan and rosemary extract.

Cervenka *et al.* (2006) studied the effect of different herbal extracts on antimicrobial activity against *Arcobacter* spp (*A.butzleri, A.cryaerophilus* and *A.skirrowii*) and found that rosemary was one of the extracts which showed the strongest antimicrobial activity against the Arcobacter strains examined.

Khaddor *et al.* (2006) evaluated the effect of rosemary essential oil on the mycelial growth of *Penicillium aurantiogriseum* and *P. viridicatum* and found a significant decrease in mycelial dry weight obtained with the addition of 0.05-2.5% of rosemary essential oil in yeast extract sucrose broth. Omar *et al.* (2006) investigated the impact of various herb extracts on growth, sporulation and enterotoxin production by *Cl. perfringens* in meat mince and found sage, rosemary, oregano, garlic and onion extracts to be the most effective, with aqueous extracts causing the greatest inhibition.

Riznar *et al.* (2006) reported that the addition of commercially available oil-soluble rosemary extracts to chicken frankfurters stored at 4 or 12°C significantly reduced aerobic plate counts compared to controls. Lopez *et al.* (2005) evaluated the antimicrobial activity of essential oils of cinnamon, clove, basil, rosemary, dill and ginger against *S.aureus, B.cereus, E.faecalis* and *L. monocytogenes, E.coli, Yersinia enterocolitica, Salmonella choleraesuis* and *P.aeruginosa, C.albicans, P.islandicum* and *A.flavus* and reported that cinnamon and clove gave the strongest inhibition, followed by basil and rosemary, with dill and ginger giving the weakest inhibition.

Santoyo *et al.* (2005) investigated the antimicrobial activity of essential oil-rich fractions of rosemary against 6 microbial species, including Gram positive bacteria (*S.aureus* and *B.subtilis*), Gram negative bacteria (*E.coli* and *P.aeruginosa*), a yeast (*C.albicans*) and a fungus (*A.niger*) and reported that all of the essential oil-rich fractions showed antimicrobial activity against all of the microorganisms tested. Fernandez-Lopez *et al.* (2005) investigated the antibacterial effect of rosemary, extract in cooked meat balls and reported that it reduced the lactic acid bacterial counts in the product. Oh *et al.* (2004) studied the effects of combined gamma-irradiation and treatment with rosemary extract powder on the microbiological quality and shelf life of hamburgers made of pork, beef and pork back fat stored at 5°C for 4

months or at 30°C for 3 wk and found that the addition of rosemary extract increased the shelf life of burgers irradiated at 5 or 10 kGy by 14 days when stored at 5°C.

Sanchez-Escalante *et al.* (2003) found that the mean microbial counts in beef patties containing rosemary, oregano and borage were significantly lower on days 8 and 12 of storage under modified atmosphere package at 2 ± 1°C, but at other times, insignificant differences were observed between treated and untreated samples. Pintore *et al.* (2002) investigated the inhibition of *S.aureus* ATCC 25923 and *S. epidermidis* (Gram positive bacteria), and *E.coli* ATCC 25922 and *P.aeruginosa* ATCC 27853 (Gram negative bacteria) by the rosemary oils and found the Gram positive bacteria to be more susceptible to the rosemary essential oils than the Gram negative bacteria. Djenane *et al.* (2002) reported that beef steaks treated with vitamin C + rosemary extract (500 ppm) had significantly lower levels of psychotropic aerobic flora than other samples after 22 days of storage at 1°C.

Kim *et al.* (2000) reported that the addition of 1% (w/v) basil, celery and rosemary to kimchi stored at 10°C for 28 days resulted in significant reduction in the levels of total microbes and lactic acid bacteria after 7 days. Baratta *et al.* (1998) reported that rosemary essential oils showed significant activity against food poisoning organisms such as *S. aureus, S. pullorum* and *Y. enterocolitica*, food spoilage organisms such as *B. subtilis, P. aeruginosa* and *L. plantarum*, organisms of faecal origin such as *Alcaligenes faecalis, E. coli* and *S. faecalis* and against the spoilage fungus *A. niger*.

Vitamin-E (α-Tocopheryl acetate) as an antioxidant

Lee and Ahn (2003) investigated the effect of antioxidant combinations on the oxidative changes and off-odour production in irradiated turkey breast meat and homogenates and reported that sesamol, sesamol + tocopherol, and gallate + tocopherol were among the most effective antioxidants in reducing TBARS, volatile compound production and off-odour intensity in turkey breast homogenates. Lee *et al.* (2003) studied the consumer acceptance of irradiated raw and cooked turkey breast meat with added antioxidants and found that addition of sesamol + tocopherol or gallate + tocopherol was effective in reducing TBARS values and aldehydes, especially under aerobic conditions.

Mielnik *et al.* (2003) found that Trolox C (Vitamin E) had best antioxidative effect, followed by Biolox HT-W (Rosemary extract), Vitamin C and other commercial rosemary extaracts in mechanically deboned turkey meat (MDTM) during 7 months of frozen storage. Furthermore,

the antioxidative activity was dose-dependent. Nam *et al.* (2003) found that the addition of ascorbic acid or sesamol + alpha-tocopherol to beef mince before irradiation effectively reduced lipid oxidation and S-volatiles. Nam and Ahn (2003a) determined the effects of antioxidants (sesamol + alpha-tocopherol or gallate + alpha-tocopherol) and double packaging combinations on lipid oxidation and volatile compounds production in irradiated raw and cooked turkey breast patties and found that the antioxidants had a beneficial effect on lipid oxidation and reduced the levels of off-odour volatile compounds.

Nam and Ahn (2003b) reported that the antioxidant treatments (gallate, alpha-tocopherol, Trolox, sesamol or carnosine) were effective in reducing both off odour formation and TBARS of irradiated pork homogenates and patties. Djenane *et al.* (2002) reported that different antioxidant combinations, viz. vitamin C (500 ppm) either alone or in combination with taurine (50mM), alpha-tocopherol (100 ppm) or rosemary extract (500 ppm), significantly reduced the TBARS formation in beef steaks stored at 1°C for 6-29 days.

Nam *et al.* (2002) studied the effect of added antioxidants (gallate + tocopherol or sesamol + tocopherol) on oxidative stability of irradiated pork patties and reported that no lipid oxidation (determined by reaction with TBARS) was observed, even in aerobically packaged irradiated pork patties. Furthermore, it was found that the added antioxidants had little effect on the sensory characteristics and consumer acceptance of irradiated pork patties which were found acceptable to the consumers.

Vara-Ubol and Bowers (2002) studied the effectiveness of alpha-tocopherol as a possible replacement for sodium tripolyphosphate (STP) in preventing lipid oxidation and off flavour development in cooked meat patties and found that the a combination of 0.3% alpha-tocopherol with 0.3% STP was nearly as effective as 0.5% STP in preventing lipid oxidation throughout refrigerated storage (4 days). Cheah and Gan (2000) compared the effect of galangal *(Alpinia galanga)* extract (0.02, 0.05 and 0.10% w/w) and galangal extract (0.05 w/w) + alpha-tocopherol (0.02% w/w) on the oxidative stability and microbiological quality of raw beef mince at 4 ± 1°C for 7 days and reported that addition of alpha-tocopherol to galangal extract had an additive protective effect on the oxidative, but not the microbial, stability of beef mince. Verma and Sahoo (2000) studied the effect of tocopherol acetate (ATA) preblending on the quality of ground chevon during refrigerated storage and found that shelf life of refrigerated ground chevon could be extended by up to 7 days using 10 ppm ATA. O'Grady *et al.* (2000) investigated the effects of exogenous vitamin E (alpha-

tocopherol) on the colour stability and susceptibility of beef mince to oxymyoglobin and lipid oxidation and reported that oxidation was lower in samples containing exogenous alpha-tocopherol, although colour deterioration was unaffected. Yang and Park (1999) investigated the combined effects of rosemary extract and alpha-tocopherol treatment and vacuum packaging on shelf life of herring *(Clupea pallasi)* fillet during cold (4°C) and frozen storage (-20°C) and found shelf life to be more than 3 days at 4°C and 90 days at -20°C.

Bandarra *et al*. (1999) studied the antioxidant synergy of alpha-tocopherol and phospholipids and found that alpha-tocopherol and phosphatidylethanolamine (PE) showed the highest synergistic effect and proposed that the high degree synergy between PE and tocopherol is probably due to a simultaneous antioxidant mechanism involving Maillard compounds. Lee *et al*. (1999) reported that 200 ppm alpha-tocopherol successfully inhibited lipid oxidation in beef patties following storage at 10°C for a period of 30 days.

Lampi *et al*. (1999) found that both alpha and gamma tocopherols significantly inhibited the oxidation of rapeseed oil triacylglycerols. However, at low levels, alpha-tocopherol was more stable and a more effective antioxidant than gamma-tocopherol. Staruch and Belej (1998) investigated the effect of added tocopherol on the colour stabilization of fermented sausages and found significant positive contribution of antioxidant addition to the intended colour of the products.

Yin *et al*. (1998) studied the effect of application of alpha-tocopherol in dry Chinese pork/chicken sausages on the physicochemical properties and reported that alpha-tocopherol addition had no influence on the pH value or cooking loss but delayed lipid and oxymyoglobin oxidation.

Sahoo *et al.* (1998) studied the effect of addition of several natural antioxidants (500 ppm sodium ascorbate, 10 ppm alpha-tocopherol acetate and 0.5% sodium tripolyphosphate) on the lipid oxidation and shelf life stability of ground buffalo meat mince during frozen storage. These authors further reported that the preblended samples had significantly lower TBARS and metmyoglobin values and greater shelf life during frozen storage.

Sahoo *et al.* (1998) studied the effect of addition of several natural antioxidants (500 ppm sodium ascorbate, 10 ppm alpha-tocopherol acetate and 0.5% sodium tripolyphosphate) on the sensory attributes of buffalo meat mince and found that preblended samples had

significantly better sensory scores for meat colour and odour. Kanatt *et al*. (1998) reported that the addition of tocopherol resulted in retardation of oxidative rancidity in irradiated chicken mince during chilled storage.

Wang and Lin (1997) reported that lipid oxidation in fresh fried chicken legs and those stored for 1 week at 4°C was inhibited significantly by treatment with 180 or 300 ppm tocopherol. Sahoo and Anjaneyulu (1997a) reported that the shelf life of ground buffalo meat preblended with 10 ppm tocopherol acetate could be extended to 8 days without any undesirable changes in colour, odour or microbial load, compared to a storage life of 6 days for control samples. Sahoo and Anjaneyulu (1997b) reported that natural antioxidants (sodium ascorbate-500 ppm, alpha-tocopherol acetate-10 ppm and sodium tripolyphosphate-0.5%) increased the refrigerated shelf life of buffalo meat nuggets upto 30 days as compared to control nuggets (10 days).The treated nuggets showed lower contents of free fatty acids even after 25 days of storage and exhibited better flavour and acceptability scores than the control nuggets during the 30 days storage period. Li and King (1996) found that exogenously added alpha-tocopherol reduced lipid oxidation and decreased myosin denaturation during heating in hand ground dark chicken meat.

Bruun-Jensen *et al*. (1996) compared the antioxidant activity of RRR-alpha-tocopherol and RRR-delta-tocopherol (100 or 200 ppm) alone or in combination with ascorbyl palmitate (200 ppm) in turkey meat balls during chilled storage (5°C for up to 9 days) and reported that alpha-tocopherol (200 ppm) in combination with ascorbyl palmitate was the most efficient inhibitor of lipid oxidation. Nedeljkovic *et al.* (1995) reported that the addition of 0.3% vitamin E or 0.02% rosemary extract significantly reduced intensity of oxidative changes in mechanically separated poultry meat stored at 4°C.

Wong *et al.* (1995) studied the effects of potential antioxidants viz., vitamin-E, rosemary and sage extracts on lipid peroxidaion of cooked beef homogenate and found that vitamin-E inhibited lipid peroxidation in concentration dependent manner, while as rosemary and sage extracts effectively inhibited lipid peroxidation.

Wada and Fang (1994) studied the synergistic antioxidant effects of rosemary and alpha-tocopherol mixture (0.035% of each extract) on oxidation of dried sardine (*Sardinops melanostica*) meat stored at 5°C for 5 days and found that sardine meat treated with combined antioxidants had a lower peroxide value than all other samples. Fang and Wada

(1993) studied the effect of mixture of α-tocopherol and rosemary extract (0.035% + 0.035%) in sardine fish oil and found that it showed a significantly stronger antioxidant effect than α-tocopherol or rosemary extract alone and also increased the effective lifetime of α-tocopherol for 10 days more than in samples treated with α-tocopherol alone even if the amount of α-tocopherol in latter cases was twice more. Wada and Fang (1992) evaluated the synergistic antioxidant effect of α-tocopherol and rosemary mixture in sardine oil model system and frozen-crushed fish meat and found that the antioxidant combination delayed the onset of oxidation 5 days longer than either α-tocopherol or rosemary extract alone and its antioxidant activity was comparable to BHA.

Wada and Fang (1992) studied the synergistic antioxidant effects of rosemary and alpha-tocopherol mixture (0.02 + 0.05%) in sardine oil model system and frozen crushed fish meat and reported that it delayed the onset of oxidation 5 days longer than either alpha-tocopherol or rosemary extract alone, and its antioxidant activity was comparable to that of BHA. Resurreccion and Reynolds (1990) reported that natural tocopherols provided significantly more protection from oxidation in frankfurters containing chicken and pork than controls containing no antioxidant, and were as affective as BHA/BHT in retarding oxidation. Timmermann and Adams (1989) found that a distinct antioxidant action was obtained by addition of >50 ppm tocopherol. This effect increased sharply as tocopherol concentration approached 500 ppm, remained relatively constant to about 2500 ppm and decreased above this concentration.

CONCLUSION

Several workers abroad have explored the use of rosemary extract and α-tocopherol in tackling the problem of lipid oxidation in some meat products. However, while limited work has been done on the use of α-Tocopherol in meat and meat products in India, there are no such reports on the use of Rosemary extract.

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