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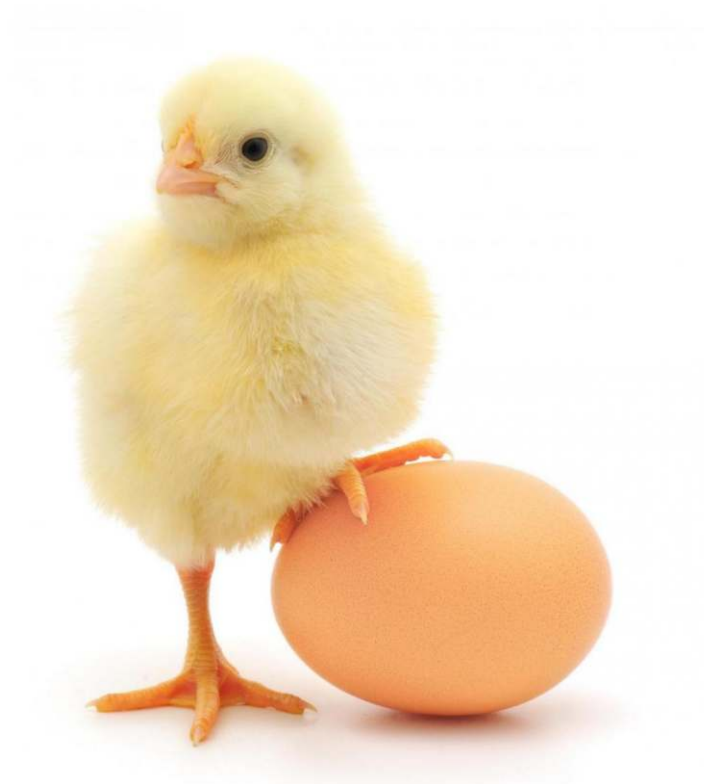

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Use of Antioxidants in Chicken Nuggets Manufactured with and Without the Use of Salt and/or Sodium Tripolyphosphate: Effects on Product Quality and Shelf-life Stability

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Abstract: Nuggets were manufactured from equal portions of breast and thigh chicken meat from chickens fed either a basal (control) or a supplemented level of α-tocopheryl acetate (vitamin E). Rosemary (0.10%) (R), sage (0.10%) (S) and tea catechins (0.01%) (TC), which were chosen from previous screening trials, were added to both control and vitamin E meat from which chicken nuggets were manufactured. The trial was repeated twice more where in addition to antioxidant addition to meat prior to nugget manufacture, 0.75% salt and 0.75% salt and 0.25% sodium tripolyphosphate (STPP) were also incorporated into both control and supplemented minced meat. Nuggets were tested for oxidative (TBARS) stability, colour (Hunter 'L, a, b' values) stability and percentage cook loss. There was a synergism between vitamin E and added antioxidants as nuggets containing vitamin E with R, S or TC had lower TBARS values than those containing vitamin E alone. Control nuggets containing R, S and TC had lower ($p<0.01$) TBARS than the control without antioxidants. R, S and TC functioned as antioxidants in the presence of salt, during refrigerated (4°C) storage for both control and vitamin E meat. The increase in TBARS numbers caused by the addition of salt was reduced by the inclusion of STPP in the chicken nugget formulation. Hunter 'a' values of nuggets formed without the use of salt or STPP were lower than those of nuggets formed with salt or salt and STPP. For nuggets containing 0.75% salt, Hunter 'a' values were highest for those manufactured from control meat without antioxidants. Nuggets containing S had lower ($p<0.05$) Hunter 'a' values than all other groups on days 3 and 6. In conclusion, the use of antioxidants reduced lipid oxidation in chicken nuggets both in the presence and absence of salt. However, when STPP was incorporated into the same product system the effect of antioxidants was reduced to a significant degree.

Key words: Chicken nuggets, sodium tripolyphosphate, poultry products

Introduction

Fresh and in particular, processed poultry meat products are very susceptible to oxidative deterioration (Higgins *et al.,* 1998b) because they contain a high proportion of polyunsaturated fatty acids (PUFA) (Higgins *et al.*, 1998a). The control of lipid oxidation in fresh and further processed meat products is a goal of food scientists and food processors (Sheldon *et al.,* 1997). The changes in quality incurred by lipid oxidation are manifested by adverse changes in colour, flavour, and nutritive value, and also by the possible production of toxic compounds (Jensen *et al.,* 1998). Adverse changes in colour are not very easily detected in chicken meat. Changes in flavour occur especially in cooked-stored chicken products. Warmed-over flavour, and overall off-flavour intensities increased in chicken patties as a result of storage for one or more days after cooking (Ang and Lyon, 1990). In addition, colour deterioration of ground chicken meat has been observed as storage time progressed (Yang and Chen, 1993), in particular, colour attributes associated with lightness/darkness and redness.

In addition to product composition, other factors negatively affect the quality and shelf-life stability of processed poultry products, these include; processing/storage techniques (grinding, mincing, cooking, chilling/freezing, packaging etc) and use of processing aids (processing ingredients like salt and other additives). Salt (NaCl) has multiple functions in meat products. It tenderises meat by increasing the ionic strength, enhances flavour and increases the water-holding capacity of the products. At high concentration, it can also act as a preservative by inhibiting microbial growth (Rhee and Ziprin, 2001). However, salt promotes lipid oxidation in raw and in particular, cooked meat and accelerates metmyoglobin formation and subsequent discolouration in raw meat (Rhee, 1999). Polyphosphates are used to bind water and may have the added benefit of acting as metal chelators. Nutritional value of chicken products can decrease as a result of oxidation due to a loss of PUFA's, fat soluble vitamins and pigments (Sheehy *et al.*, 1993). Therefore, there is a need to control the oxidation of lipids. Oxidation can be controlled by manipulation of packaging methods, storage conditions and the use of antioxidants. Exogenous antioxidants can be used to prolong shelf life and ensure quality of a product (Decker and Xu, 1998). The addition of antioxidants to processed meats is often carried out to counteract the negative effects that processing aids such as salt can have on shelf-life stability and overall product quality (Higgins *et al.*, 1998a; O'Neill *et al.*, 1999). However, little research has been reported on the effects of adding both salt and polyphosphates to poultry meat products with respect to oxidative stability and its control using natural forms of antioxidants.

The objectives of this study were (1) to incorporate rosemary, sage and tea catechins (the three best antioxidants determined in a previous screening trial into a chicken nugget recipe with or without the use of salt and/or STPP, in both control and vitamin E supplemented meat and (2) to investigate the effects of antioxidants, salt and STPP on the oxidative and colour stability of chicken nuggets.

Materials and Methods

Chemicals and Reagents: All Chemicals used were "AnalaR" grade obtained from Sigma Chemical Co., Steinheim, Germany; Wardle Chemicals Ltd., Green Lane, Wardle, Nr. Nantwich, Cheshire; British Drug Houses, Poole, England, Merck, Darmstadt, Germany; or Oxoid Unipath Ltd., Basingstoke, Hampshire, England.

Antioxidants: Rosemary powder (oxyless clear) was supplied by Guinness Chemicals Ltd., Portlaoise, Co. Laois, Ireland. Dried sage (freshly ground) was obtained from Natural Foods, Paul St., Cork, Ireland.

Tea catechins powders were obtained from Kingnong Natural Plant Products Company, Changsha, Hunan, China. The α-tocopheryl acetate used in the dietary supplementation trial was obtained from Roche Products Ltd., Welwyn Garden City, Hertfordshire, U.K.

Vitamin E Feeding Trial: Day-old Cobb chickens (n=300) were distributed over 6 pens (5 × 4m). Floors were bedded with sawdust on cardboard and each pen had a 250-watt infra red bulb suspended overhead. Pens were assigned to either a low or high vitamin E diet. Food and water were available *ad libitum* for six weeks. Feed was manufactured in the feed mill in Teagasc, Moorepark, Fermoy, Co. Cork. Cereals were ground through a 3 mm screen before mixing. The vitamin-trace mineral mix was premixed through 10 kg wheat before addition to the mixer. Feed was stored in pre-weighed 25 kg sacks, stamped with ID number and date of manufacture, and closed by sewing. All feed was prepared at the beginning of the trial. All bags were stored in the dark at 10-14°C for the duration of the trial.

Manufacture of Chicken Nuggets: Chicken nuggets were manufactured, based on a turkey nugget recipe by Richardson (1989). Equal quantities of chicken breast and thigh meat was minced (Mainca, C / Jaume Ferran s/n, Granollers, Barcelona, Spain) using a 20 mm plate. Rosemary, sage and tea-catechins were added at their optimum concentrations, determined from previous screening trials, to both control and vitamin E supplemented meat and compared. In subsequent trials, salt (0.75%, w/w) and/or sodium tripolyphosphate (STPP) (0.25%, w/w) were added and mixed in a Moulinex blender (Moulinex/Swan Holdings Ltd., 35 Rocky Lane, Golden Cross, Aston, Birmingham B65RQ) at top speed for 1 minute. Burgers were formed and each of these was divided into three nuggets. Nuggets were cooked without batter on a gas hotplate (Gico Spa, Vazzola (Tv), Italia) until an internal temperature of 70°C was reached. They were then over-wrapped with cling-film [6000-8000 $cm^3/m^2/24hr$ at standard temperature and pressure (STP)] and stored at 4°C in a display cabinet (Criosbanc Refrigeration, Via Montegrotto, Padova, Italia).

Colour Stability: Surface colour (Hunter L, a, b) was measured using a Minolta CR-300 colorimeter (Minolta Camera Co., Chuo-Ku, Osaka 541, Japan). For each group, four nuggets were measured in triplicate, giving 12 readings per group on days 0, 3, 6 and 9.

Oxidative Stability: Oxidative deterioration was assessed using the 2-thiobarbituric acid distillation method of Tarladgis *et al.* (1960) as modified by Ke *et al.* (1977). For each group, four nuggets were measured in triplicate, giving 12 readings per group on days 0, 3, 6 and 9.

Cook-loss Assessment: Chicken nuggets were weighed before and after cooking. The % cook-loss was evaluated by establishing what percentage of the weight was lost during the cooking process.

Statistical Analysis: Analysis of variance (ANOVA) was conducted for each variable measured to investigate the effect of time, nugget ingredient and the interaction of both. This was a repeated measures design using a "between-subject" factor. The effect of day was measured "within-subjects". Tukey's test was used to adjust for multiple comparisons (Neter *et al.*, 1990). Tukey's test for multiple comparisons was performed using the general linear model of SPSS 10.0 for windows (SPSS, Chicago, Ill., U.S.A.) software package.

The level of statistical significance was p < 0.05.

Results

Oxidative Stability: Chicken nuggets manufactured using vitamin E supplemented meat and control meat containing TC, maintained oxidative stability throughout refrigerated storage (Fig. 1). Control meat and control plus S, had higher TBARS numbers than all other treatments on days 3, 6 and 9. The addition of TC or R to control nuggets reduced (p<0.001) TBARS numbers compared to control nuggets throughout the entire trial period. When antioxidants were added to vitamin E supplemented meat, a greater overall reduction in TBARS numbers was observed, indicating that there was a synergism between vitamin E and the added antioxidants in nuggets containing no salts (Fig. 1). On day 3 of refrigerated storage nuggets containing TC had lower (p<0.01) TBARS numbers than nuggets manufactured from vitamin E supplemented meat alone. On days 6 and 9, nuggets formed using only vitamin E supplemented meat had significantly higher TBARS values than those containing S (p<0.01), R and TC (p<0.001).

In general, the addition of salt caused an increase in TBARS numbers for all chicken nuggets (Fig. 2). Chicken nuggets containing only salt had higher TBARS values than nuggets containing salt and R or salt and S (Fig. 2). Therefore, the antioxidative effect of R and S counteracted the pro-oxidative effect of adding salt to the nuggets. Throughout the trial, nuggets manufactured from control meat containing R, S and TC had significantly (p<0.01) lower TBARS than nuggets manufactured from salted control meat without antioxidants. In nuggets manufactured from vitamin E meat, the addition of R, S and TC caused significantly (p<0.001) lower TBARS numbers compared to nuggets containing salted vitamin E meat only.

The increase in TBARS numbers caused by the addition of salt was reduced by the inclusion of STPP in the chicken nugget formulation (Fig. 3). The addition of R, S and TC reduced (p<0.001) TBARS numbers in nuggets formed using control meat, (salt and STPP) throughout the trial. The levels of TBARS numbers observed in nugget trials using both unsalted and in particular, salted meat was reduced by the inclusion of STPP in the chicken nugget formulation (Fig. 3).

Colour Stability: Colour measurements (Hunter L, a, b) were measured for all nuggets on days 0, 3, 6 and 9. There were no clear trends observed for Hunter 'b' values (data not shown).

For nuggets containing no salt, the Hunter 'L' values decreased in the order: vitamin E > control plus R > vitamin E plus R > control > vitamin E plus S > vitamin E plus TC > control plus S > control plus TC (Table 1). Nuggets containing vitamin E meat, control meat, control meat with R and vitamin E meat had significantly (p<0.05) higher Hunter 'L' values than all other samples throughout the entire trial. Hunter 'L' values were not significantly affected by adding antioxidants to the nugget formulation.

For nuggets containing 0.75% salt, the Hunter 'L' values decreased in the order: Vitamin E > control vitamin E plus R > vitamin E plus S > vitamin E plus TC > control plus R > control > control plus S (Table 2). Nuggets containing control meat with salt had significantly higher (p<0.05) Hunter 'L' values than nuggets manufactured from control meat containing antioxidants and salt. Nuggets containing vitamin E meat with salt also had significantly higher (p<0.05) Hunter 'L' values than nuggets manufactured from vitamin E meat containing antioxidants and salt. Hunter 'L' values were reduced on the addition of antioxidants to both control and vitamin E supplemented meats. Hunter 'L' values were higher (but not significantly so) for nuggets containing vitamin E supplemented meat compared to the corresponding nuggets containing control meat.

For nuggets containing salt and STPP, the Hunter 'L' values decreased in the order: control > control plus R > vitamin E plus R > vitamin E plus S > control plus S > vitamin E plus TC > vitamin E > control plus TC (Table 3). Nuggets manufactured from control meat with salt and STPP had higher (p<0.05) Hunter 'L' values than all other samples with the exception of nuggets made from control meat plus R on day 0 and day 3 of refrigerated storage. Hunter 'L' values for nuggets manufactured from control meat plus R were also higher (p<0.05) than all other groups with the exceptions of nuggets manufactured from control meat and vitamin E meat plus rosemary up to day 6 of refrigerated storage. Hunter 'L' values for the control group were higher than those of nuggets containing antioxidants. However, this trend was not observed for nuggets containing vitamin E supplemented meat.

In general, Hunter 'L' values were highest in nuggets containing no salt and lowest in nuggets containing salt and STPP with the exceptions of nuggets manufactured from control meat with S, control meat with TC and vitamin E meat (data not shown).

Hunter 'a' values of chicken nuggets manufactured without the use of salt or STPP decreased over time for all treatment groups (Table 4). Nuggets manufactured from vitamin E meat only had the highest Hunter 'a' values in the absence of salt and STPP on day 0. However, by day 6 and 9 of refrigerated display, the highest Hunter 'a' values were observed in nuggets manufactured from vitamin E meat with R.

For nuggets manufactured using 0.75% salt, the Hunter 'a' values of all treatment groups decreased over time with the exception of those containing vitamin E meat with R which remained stable after day 6 and those

Table 1: Hunter 'L' Values of Chicken Nuggets Containing Natural Antioxidants

Sample	Day 0	Day 3	Day 6	Day 9
Control	65.00±1.3	64.51±2.3	64.98±1.5	65.03±1.2
Control + R	66.82±2.5	63.98±1.7	67.27±2.3	66.11±0.7
Control + S	58.49±0.7	59.53±1.3	59.68±2.0	62.27±1.8
Control + TC	57.62±1.6	59.71±1.5	52.23±1.5	56.23±0.7
Vitamin E	63.89±2.9	64.84±2.2	65.41±2.0	67.83±1.6
Vitamin E + R	63.99±0.4	66.25±0.5	66.11±2.7	65.20±1.9
Vitamin E + S	63.41±0.7	63.67±0.4	62.60±0.6	61.95±1.7
Vitamin E + TC	64.24±1.4	62.98±2.5	58.55±1.2	61.55±1.0

Table 2: Hunter 'L' Values of Chicken Nuggets Containing Natural Antioxidants and 0.75% Salt

Sample	Day 0	Day 3	Day 6	Day 9
Control	63.67±1.0	64.54±0.9	65.20±0.5	64.37±0.9
Control + R	60.35±1.8	61.32±0.9	61.10±1.0	61.40±1.2
Control + S	60.94±0.8	57.51±1.3	60.71±0.8	59.81±1.0
Control + TC	61.20±1.7	61.97±1.2	61.82±1.3	61.86±2.1
Vitamin E	66.67±0.9	67.32±1.0	66.40±0.8	65.73±1.0
Vitamin E + R	62.69±0.4	63.41±1.1	63.85±2.1	63.07±2.3
Vitamin E + S	61.10±0.7	63.39±1.5	62.75±3.4	64.88±1.4
Vitamin E + TC	62.40±0.8	61.83±1.8	66.10±0.7	61.24±0.7

Table 3: Hunter 'L' Values of Chicken Nuggets Containing Natural Antioxidants, 0.75% Salt and 0.25% STPP

Sample	Day 0	Day 3	Day 6	Day 9
Control	60.19±0.2	61.32±0.9	61.74±0.7	62.49±1.1
Control + R	58.97±2.2	60.65±0.3	59.12±1.5	59.88±1.3
Control + S	56.02±0.6	58.36±1.2	55.56±1.1	56.46±1.8
Control + TC	55.13±0.3	56.85±0.5	54.63±0.4	56.58±0.5
Vitamin E	57.23±2.0	56.75±1.2	55.65±2.3	58.44±1.6
Vitamin E + R	58.25±0.8	58.18±0.7	58.74±0.7	59.81±0.6
Vitamin E + S	56.88±2.1	58.51±3.1	56.42±0.5	57.93±1.1
Vitamin E + TC	58.65±1.3	56.29±0.4	56.83±1.8	58.43±1.7

Table 4: Hunter 'a' Values of Chicken Nuggets Containing Natural Antioxidants

Sample	Day 0	Day 3	Day 6	Day 9
Control	1.71±0.1	1.19±0.6	-0.17±0.1	-0.11±0.1
Control + R	2.71±0.1	2.39±0.1	1.14±0.4	1.10±0.1
Control + S	2.60±0.6	1.23±0.5	0.81±0.3	0.27±0.3
Control + TC	2.63±0.4	1.82±0.3	1.60±0.1	1.18±0.1
Vitamin E	2.81±0.5	2.34±0.3	1.88±0.4	1.24±0.3
Vitamin E + R	2.49±0.1	2.25±0.3	2.10±0.3	1.59±0.2
Vitamin E + S	1.23±0.0	1.06±0.1	0.37±0.1	0.25±0.1
Vitamin E + TC	1.76±0.1	1.54±0.3	1.28±0.3	0.74±0.1

Table 5: Hunter 'a' Values of Chicken Nuggets Containing Natural Antioxidants and 0.75% Salt

Sample	Day 0	Day 3	Day 6	Day 9
Control	3.91±0.1	3.21±0.0	2.08±0.1	1.59±0.2
Control + R	3.08±0.3	2.24±0.2	1.36±0.1	0.79±0.2
Control + S	1.97±0.0	1.38±0.3	0.38±0.1	0.23±0.2
Control + TC	2.09±0.0	1.80±0.2	1.58±0.1	1.07±0.1
Vitamin E	2.22±0.1	2.05±0.2	1.68±0.1	1.65±0.3
Vitamin E + R	2.27±0.1	2.27±0.1	1.70±0.1	1.70±0.2
Vitamin E + S	2.19±0.2	1.26±0.1	0.69±0.0	0.51±0.1
Vitamin E + TC	1.94±0.1	1.70±0.2	1.56±0.4	1.79±0.5

Table 6: Hunter 'a' Values of Chicken Nuggets Containing Natural Antioxidants, 0.75% Salt and 0.25% STPP

Sample	Day 0	Day 3	Day 6	Day 9
Control	3.70±0.4	2.46±0.5	1.41±0.3	1.15±0.2
Control + R	2.91±0.5	2.37±0.2	1.49±0.4	1.55±0.5
Control + S	1.90±0.2	0.77±0.4	0.70±0.6	0.03±0.4
Control + TC	2.21±0.2	1.05±0.2	0.83±0.2	0.66±0.2
Vitamin E	3.83±0.2	3.26±0.1	2.43±0.7	2.22±0.3
Vitamin E + R	2.40±0.1	2.20±0.3	1.11±0.1	1.03±0.4
Vitamin E + S	2.53±0.4	2.10±0.5	1.30±0.1	0.84±0.2
Vitamin E + TC	2.02±0.2	2.01±0.3	1.61±0.2	0.93±0.3

Table 7: Effect of antioxidants and meat type on percentage cook loss of chicken nuggets formed using breast and thigh control and vitamin E supplemented meat and cooked on a gas hotplate to an internal temperature of 70°C

Sample	Antioxidant Used	No Salt or Phosphates	0.75% Salt	0.75% Salt and 0.25% STPP
Control	None	28.1	10.7	8.1
	Rosemary	17.6	17.1	10.9
	Sage	21.4	10.9	12.2
	Tea catechins	31.1	12.4	13.0
Vitamin E	None	21.1	13.9	14.1
	Rosemary	19.1	17.2	17.9
	Sage	25.6	10.5	11.8
	Tea catechins	25.2	9.5	14.1

containing vitamin E meat with TC which increased again after day 6 of refrigerated display (Table 5). Nuggets manufactured from control meat and 0.75% salt had the highest Hunter 'a' values on days 0, 3 and 6 of refrigerated display. Nuggets manufactured from vitamin E meat with TC and 0.75% salt had the highest Hunter 'a' values at the end of the display period. However, this group had the lowest initial Hunter 'a' values.

For nuggets manufactured using 0.75% salt and 0.25% STPP, the Hunter 'a' values of all treatment groups decreased over time with the exception of those containing vitamin E meat with R which increased again after day 6 of refrigerated display (Table 6). Nuggets containing vitamin E meat, salt and STPP had the highest Hunter 'a' values on all sampling days with the exception of those manufactured from vitamin E meat with R.

Cook Loss: Cook loss values were highest in nuggets without salt or STPP (Table 7). The addition of salt decreased cook losses of nuggets for all treatment groups. Cook loss was further reduced ($p<0.001$) by the addition of STPP for nuggets containing control meat and control meat with R. All nuggets containing salt and STPP had lower cook loss percentages than those manufactured without salt or STPP. For nuggets formed without salt, cook losses decreased in the order: control with TC > control > vitamin E with S > vitamin E with TC > control with S > vitamin E > vitamin E with R > control with R. For nuggets containing salt or salt and STPP, the highest cook loss percentage was observed in those manufactured from vitamin E meat with R. Overall, there were no significant differences observed between the percentage cook loss for control and vitamin E nuggets in any experimental trial conducted. There were also no trends observed in cook losses from nuggets as a result of adding antioxidants to the formulation.

Discussion

Oxidative Stability: The results obtained from experimental trials suggest a synergistic relationship between vitamin E and each of the antioxidants added to the product formulation. In contrast, to the data presented here, no synergistic effect between vitamin E and rosemary was reported when they were both added to chicken and pork frankfurters (Resurreccion and Reynolds, 1990). The same was found for both sage and rosemary added with vitamin E to a cooked beef homogenate (Wong *et al.,* 1995). However, one fundamental difference between this current study and others is that vitamin E was fed to chickens in the present study as opposed to processing vitamin E into meat products, thereby, allowing vitamin E to function more effectively due to integrated placement within the muscle structure. Due to its greater ability to function as an antioxidant in meat systems when offered to meat producing animals, vitamin E can interact with other components within the muscle system in question. When vitamin E was fed in the diet, a synergistic relationship between rosemary and α-tocopherol on

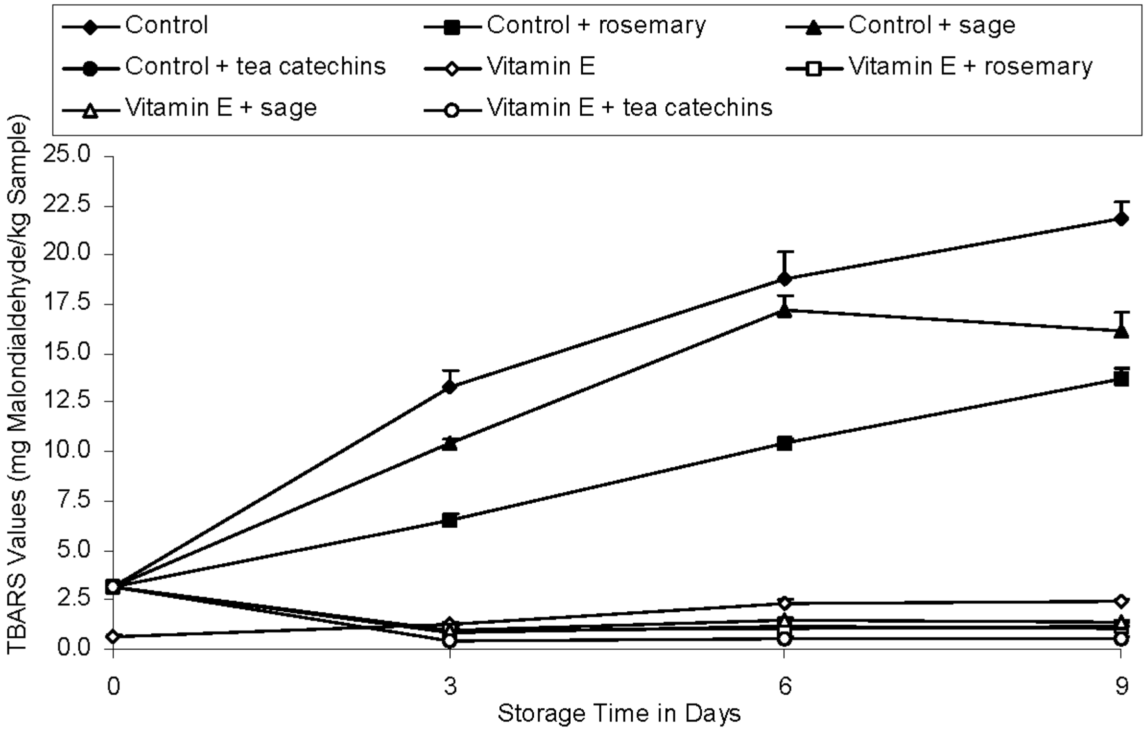

Fig. 1: Effect of antioxidants on oxidative stability of chicken nuggets, formed from control and vitamin E supplemented breast and thigh meat held under refrigerated display (4°C) for 9 days.

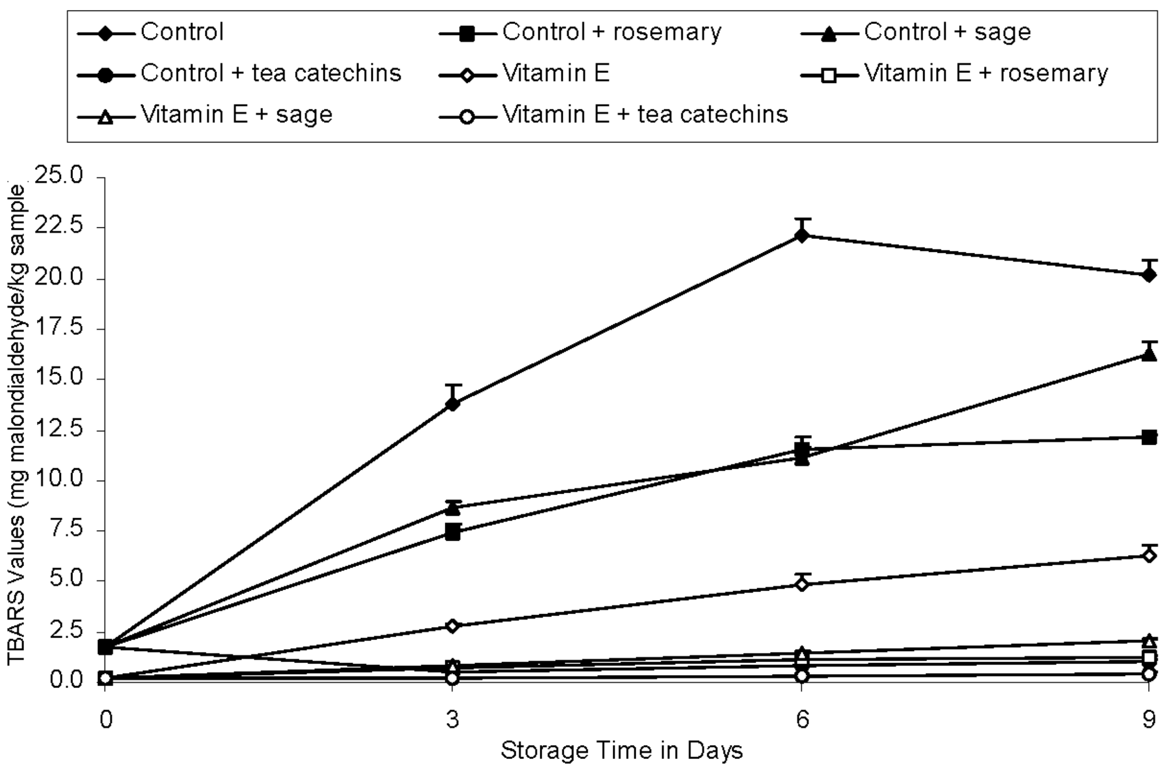

Fig. 2: Effect of antioxidants on oxidative stability of chicken nuggets, formed from control and vitamin E supplemented breast and thigh meat in the presence of salt held under refrigerated display (4°C) for 9 days

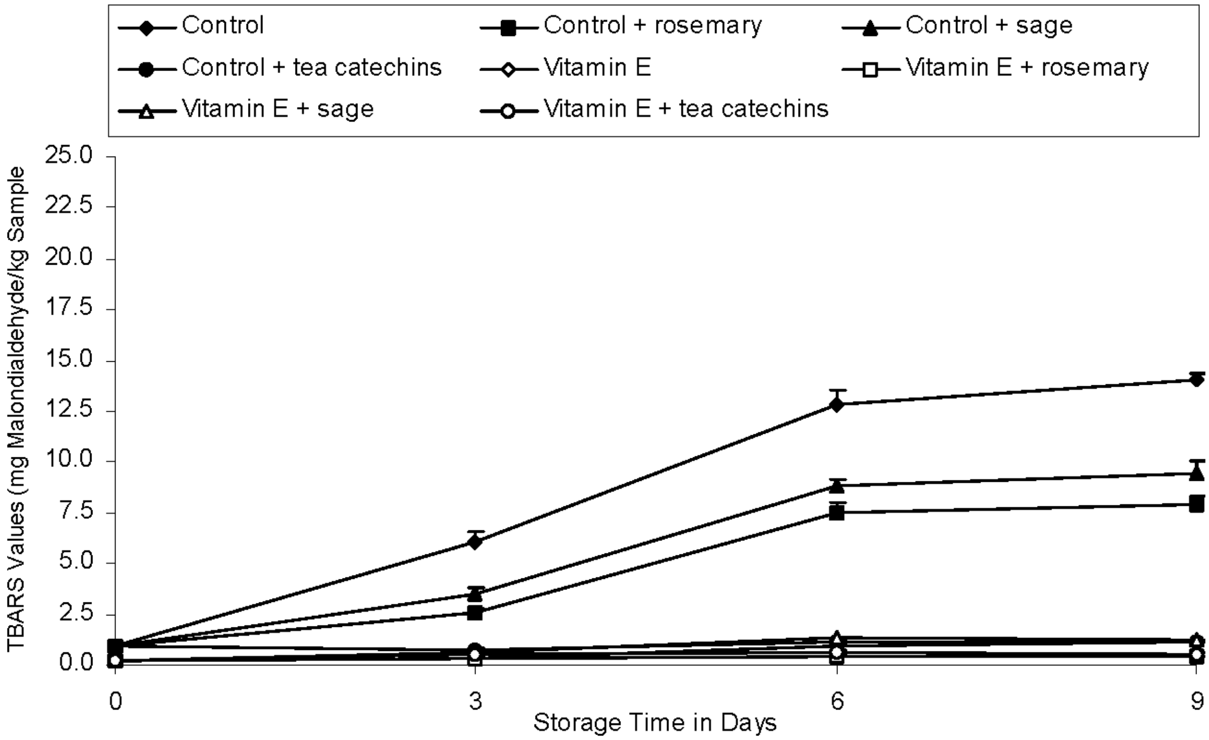

Fig. 3: Effect of antioxidants on the oxidative stability of chicken nuggets formed using control and vitamin E supplemented breast and thigh meat, in the presence of salt and STPP, stored under retail display conditions (4°C) for 9 days

lipid stability was observed in minced beef (Formanek *et al.*, 2001), in rainbow trout (Akhtar *et al.,* 1996) and in sardine oil and frozen-crushed fish meat systems (Wada and Fang, 1992). Thus, our results are in agreement with other studies which showed that dietary vitamin E and added rosemary had a synergistic effect on the oxidative stability of meat products.

Many studies have shown that the addition of salt to meat and meat products results in an increase in the TBARS numbers (Higgins *et al.,* 1998a; O'Neill *et al.*, 1999; Rhee and Ziprin, 2001). However, O'Neill *et al.* (1999) reported that salted patties from chickens fed a supplemental level (200mg kg^{-1}) of α-tocopheryl acetate had lower TBARS numbers than salted patties from chickens fed a basal level (30mg kg^{-1}) of α-tocopheryl acetate. A similar trend was observed in this study for chicken nuggets containing salt and rosemary or salt and sage (Fig. 2). Nuggets containing salt and tea catechins had lower TBARS values than other control groups, so the effect of adding vitamin E to the formulation was less dramatic (Fig. 2). Therefore, the results of this study show that rosemary, sage and tea catechins still function as antioxidants in the presence of salt, during refrigerated (4°C) storage. This was true for both control and vitamin E supplemented meat.

The increase in TBARS numbers caused by the addition of salt was reduced by the inclusion of STPP in the nugget formulation. This is in agreement with several authors who reported that adding phosphates to chicken nuggets (Adcox *et al.,* 1996) and chicken nugget batter (Lai *et al.,* 1991) reduced TBARS numbers. Ang and Young (1989) reported that the concentration of STPP added to broiler breast patties was an important factor in controlling the TBARS numbers during cooking and subsequent storage. In this study, the addition of rosemary, sage and tea catechins significantly reduced TBARS numbers compared to the control containing salt and STPP. However, when vitamin E supplemented meat was used in the formulation, TBARS numbers were not significantly reduced by the addition of antioxidants (Fig. 3).

Colour Stability: Hunter 'L' values were higher in nuggets containing no salts and lowest in nuggets containing salt and STPP with the exceptions of nuggets manufactured from control meat with S, control meat with TC and vitamin E meat. This is in agreement with Swatland and Barbut (1999) who reported that increasing the salt content from 0 to 2% in comminuted samples of chicken breast decreased the Hunter "L" values before and after cooking. However, our results disagree with the findings of Young *et al.* (1996) who found that in cooked chicken breast muscles, CIE "L" values were elevated by STPP treatment.

Hunter 'a' values tended to be higher for nuggets containing both salt and STPP for vitamin E supplemented groups with the exception of those manufactured from vitamin E meat with R. This was contrary to the findings of Young *et al.* (1996) who noticed decreased "a" values in cooked chicken breast after addition of STPP. Kim and Marshall (1999) reported that chicken legs dipped in 5% trisodium phosphate for 10 min had similar colour and odour to fresh controls while chicken legs dipped in 10% trisodium phosphate had lower Hunter "a" and "b" values than controls. Therefore, the level of STPP added in this study (0.25%) may have been too low to cause a decrease in Hunter "a" values of the chicken nuggets, yet strong enough to produce a desired antioxidant effect with respect to pigment and lipid oxidation. The addition of antioxidants to control meat resulted in higher Hunter 'a' values in the absence of salt or STPP. However, adding antioxidants to control meat in the presence of salt and salt with STPP resulted in lower Hunter 'a' values. Thus, the effect of adding salt or salt and STPP to control meat reduced the negative influence of antioxidants on the Hunter 'a' values because salt and STPP were found to increase the redness of all nuggets.

Cook Loss Assessment: Cook loss decreased when salt was added to the nugget formulation, for all treatment groups. This is in agreement with Swatland and Barbut (1999) who reported that cooking losses in comminuted chicken breast decreased as the salt concentration was increased from 0 to 2%. All nuggets containing salt and STPP had lower cook loss percentages than those manufactured without salt or STPP. These findings are in agreement with those of McGee *et al.* (2003) who reported that beef injected with sodium lactate, STPP or NaCl had lower cooking loss percentages than control beef. However, Cheng and Ockerman (2003) found that the cooking yield of roast beef was dependent on the level of phosphate added. The presence or addition of antioxidants did not affect the cook yield of nugget formulations.

Conclusions: Addition of salt increased lipid oxidation (TBARS) in chicken nuggets. Nuggets formed using control meat with TC, vitamin E meat with R, vitamin E meat with S and vitamin E meat with TC, were oxidatively stable even after the addition of salt. In the absence of salt a synergism was seen between α-tocopherol and R and α-tocopherol and S. Addition of salt and STPP to the nugget formulation reduced TBARS compared to adding salt alone. Addition of R, S and TC to nuggets containing control meat further reduced TBARS numbers.

In the absence of salt and STPP, Hunter 'L' values were higher for nuggets containing control meat compared to the corresponding nuggets containing vitamin E supplemented meat. There were no effects of vitamin E supplementation or addition of antioxidants on the Hunter 'L' values in the presence of salt or salt and STPP. Hunter 'a' values tended to be higher in the presence of salt or salt and STPP than in the absence of salt.

Cooking yields were highest in the presence of salt for all treatment groups with the exceptions of control and control plus R which had highest cook yields in the presence of salt and STPP. In the presence of salt, cook yields for nuggets containing control meat were increased by adding antioxidants but this was not the case when R was added to vitamin E supplemented meat. R, TC and S showed potential for use as antioxidants in processed chicken products containing salt and STPP. Antioxidant activity decreased in the order TC > R > S. TC was shown to be as effective as dietary vitamin E in controlling lipid oxidation in the chicken nugget system employed in this study.

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