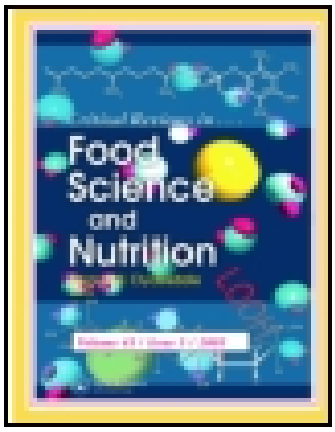

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Fruit Based Natural Antioxidants in Meat and Meat Products: A Review

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Fruit Based Natural Antioxidants in Meat and Meat Products: A Review

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ABSTRACT

Due to the potential toxic effects of synthetic antioxidants, natural antioxidant sources especially fruits are being preferred now-a-days for use in different meat products. The majority of the antioxidant capacity of a fruit is especially because of numerous phenolic compounds. Many of the phytochemicals present in fruits may help to protect cells against the oxidative damage caused by free radicals thereby reducing the risk of degenerative diseases such as cardiovascular diseases, various types of cancers and neurological diseases. Various parts of the fruit including their byproducts like skin and seeds have been used in meat products. Plum has been use as plum puree, prunes (dried plum) and plum extracts. Grape skin, seed and peel extracts, grape pomace; berries as cakes and powder extracts; pomegranate rind powder, its juice and most of the citrus fruits have proved beneficial sources of antioxidants. All these natural sources have effectively reduced the TBARS values and free radical frequency. Thus, lipid oxidation is prevented and shelf life greatly enhanced by incorporating various kinds of fruits and their byproducts in meat and meat products. There is a great scope for the use of fruits as natural sources of antioxidants in meat industry. The review is intended to provide an overview of the fruit based natural antioxidants in meat and meat products.

Keywords fruits, natural antioxidants, meat, meat products, lipid oxidation

INTRODUCTION

The increasing preference for natural foods has obliged the food industry to include natural antioxidants in various products to delay oxidative degradation of lipids, improve quality and nutritional value of foods, and replace potentially hazardous synthetic antioxidants (Fasseas *et al.*, 2007; Wojdylo *et al.*, 2007; Camo *et al.*, 2008). Including antioxidants in the diet has beneficial effects on human health because they protect the biologically important cellular components, such as DNA, proteins, and membrane lipids, from reactive oxygen species (ROS) attacks (Su *et al*., 2007). Research has shown that natural antioxidants could play a vital role in fighting diseases caused by oxidative damage and even decrease the formation and mutagenicity of heterocyclic amines (HCAs) in cooked meat (Halliwell and Gutteridge, 1992; Tsen *et al.*, 2006). Food manufacturers have also been motivated the use of natural antioxidants because studies have shown that such compounds are not only beneficial to the shelf life of food products but also in preventive medicine (Anon, 2000).

Oxidation of lipid and auto-oxidation are one of the major causes of quality deterioration and reduced shelf life of meat products. This may produce changes in meat quality parameters such as colour, flavor, odor, texture and even nutritional value (Fernandez *et al.*, 1997). Meat mincing, cooking and other processing prior to refrigerated storage disrupt muscle cell membranes facilitating the interaction of unsaturated lipids with pro-oxidant substances such as non-haem iron, accelerating lipid oxidation leading to rapid quality deterioration and development of rancidity (Tichivangana and Morrissey, 1985). Initially lipid oxidation in meat products results cardboard flavor and progresses with development of painty, rancid and oxidized flavor (Angelo *et al.*, 1990). Susceptibility of muscle tissue to lipid oxidation is also

related to the degree of lipid unsaturation, muscle type, animal diet, additives such as salt, cooking method, manner of storage and pH of the muscle (Kanner, 1994; Rhee and Ziprin, 2001).

The rate and extent of oxidative deterioration can be reduced through various means like curing, vacuum packaging, modified atmosphere packaging and most importantly adding synthetic or natural antioxidants. Although synthetic antioxidants such as butylated hydroxytoluene (BHT) and butylated hydroxyanisole (BHA) have been used extensively, recent studies have implicated them to have toxic effects (Lindenschmidt *et al.,* 1986; Shahidi *et al.,* 1992). These findings together with consumer interest in natural food additives have reinforced the need for effective antioxidants from natural sources as an alternative to prevent deterioration of meat products during processing and storage. Fruits and vegetables are rich sources of antioxidants (Phillips *et al.,* 1993; Slattery *et al.,* 2000) and can serve as a source of natural antioxidants for meat products.

Consumer's demand for natural products, as well as their concern over commonly used synthetic antioxidants, suggests that it is important to identify functional natural antioxidants to use in meat products. There has been a significant amount of research done regarding the use of fruit and other plant materials as antioxidants in meat products. The continued demand for natural products warrants a thorough review of the natural fruit based antioxidants that have been studied so far.

NATURAL ANTIOXIDANTS

Natural antioxidants are generally classified as phenolic compounds such as flavonoids and phenolic acid, vitamins, and volatile compounds found in different fruits, plants, herbs and

spices. Several types of natural plant derived antioxidants have been studied, including extracts of grape seed, sage, thyme, rice bran, white peony, red peony, sappanwood, Moutan peony, rehmania or angelica, sedge, marjoram, wild marjoram, caraway, basil extract, ginger, plum concentrates, aloe vera, mustard, tea catechins, and rosemary extract (Namiki, 1990; El-Alim *et al.*, 1999; Han and Rhee, 2004; Fiorentino *et al.*, 2008; Nunez *et al.*, 2008). The active components of natural plant-derived antioxidants are polyphenolic compounds. The most effective antioxidants are those that contain two or more phenolic hydroxyl groups (Dziedzic and Hudson, 1984; Shahidi *et al.*, 1992). Plant phenolics compounds can either act as reducing agents, free radical terminators, metal chelators, or singlet oxygen quenchers.

Recently, fruits have gathered interest from the public and the scientific community because of their health promoting properties. The benefits of fruits have been attributed to their high phenolic compound contents, which act as antioxidants (Zuo *et al.*, 2002). It is because of this high phenolic content that many fruits are a good source of natural antioxidants to use in meat products. There have been numerous studies conducted on the antioxidant potential of many fruits. A review of studies evaluating the antioxidant potential of different fruits in various meat and meat products is discussed.

PLUM

A plum or gage is a stone fruit tree in the genus *Prunus*, subgenus *Prunus*. Mature plum fruit may have a dusty-white coating that gives them a glaucous appearance; this is easily rubbed off. Dried plum fruits are called dried plums or prunes, although prunes are a distinct type of plum, and may have antedated the fruits now commonly known as plums. Dried plums (or prunes) are also sweet and juicy and contain several antioxidants. Plums and prunes are known

for their laxative effect. This effect has been attributed to various compounds present in the fruits, such as dietary fiber, sorbitol, and isatin. Plums have expressed antioxidant properties in a multitude of products such as precooked pork sausage, irradiated turkey and precooked roast beef (Lee and Ahn, 2005; Nunez de Gonzalez *et al.*, 2008a,b; Yildiz-Turp and Serdaroglu, 2010).

Lee and Ahn (2005) found that plum extract (obtained from the California Plum Board, Sunsweet Growers Inc., Yuba City, California) used at 3% in irradiated turkey breast rolls reduced ($p < 0.05$) lipid oxidation. Plum extract was added to samples, cooked to an internal temperature of 75°C, sliced and vacuum packaged, and irradiated at 0 and 3 kGy. In this study, TBARS value for the control product was 0.95 mg MDA/kg meat and the 3% plum extract treatment had a reduced ($p < 0.05$) TBARS value of 0.84 mg MDA/kg meat after 7 days of storage at 4°C.

Nunez de Gonzalez *et al.* (2008a) evaluated raw and cooked pork sausage patties (formulated to 32% fat) treated with 3% and 6% dried plum puree, 3% and 6% dried plum and apple puree and butylated hydroxyanisole (BHA)/butylated hydroxytoluene (BHT) at 0.02%. The precooked pork sausage patties treated with 3% and 6% dried plum puree, or 6% dried plum and apple puree showed a reduction ($p < 0.05$) in TBARS values for refrigerated patties after 28 days when compared with the control. The TBARS value of the control sample was 1.00 mg MDA/kg sample. In the sample treated with 3% dried plum puree, the TBARS value was 0.44 mg MDA/kg sample, and the 6% dried plum puree sample had a TBARS value of 0.34 mg MDA/kg sample. The 3% and 6% dried plum and apple puree samples resulted in TBARS values higher than the samples treated with dried plum puree, and the 3% dried plum and apple puree sample had a TBARS value higher than the control. The 3% and 6% dried plum puree treatments

were very similar ($p > 0.05$) to the BHA/BHT treatment, which had a TBARS value of 0.39 mg MDA/kg sample. The 3% and 6% dried plum and apple puree treatments had higher ($p < 0.05$) TBARS values than the BHA/BHT treatment. Control precooked pork sausage patties stored frozen (-20˚C) for 90 days also had a significantly higher TBARS value of 1.98 mg MDA/kg sample, compared to patties with 3% dried plum, 6% dried plum puree, and 3% dried plum and apple puree. TBARS values of these samples were 0.95, 0.46, and 1.46 mg MDA/kg sample, respectively. The BHA/BHT treatment had a TBARS value of 1.05 mg MDA/kg sample and was higher ($p < 0.05$) than the 6% dried plum treatment, but was not significantly different from the 3% dried plum treatment. The 6% dried plum and apple puree treatment did not lower ($p > 0.05$) TBARS values when compared to the control.

Nunez de Gonzalez *et al.* (2008b) found that lipid oxidation was reduced ($p < 0.05$) in precooked roast beef when treated with fresh plum juice concentrate, dried plum juice concentrate, and spray dried plum powder (all plum products obtained through California Plum Board from Sunsweet Growers, Inc., Yuba City, CA). Beef top rounds were brine injected (20% by weight of raw product) with the above plum products added at 2.5% and 5% of the brine. These products were cooked to an endpoint temperature of 62.8°C and stored at <4°C for 10 weeks. Meat treated with the 5% fresh plum juice concentrate treatment (0.16 mg MDA/kg) was found to have the lowest TBARS value of all the treatments. The TBARS value of the control was 0.62 mg MDA/kg.

Yildiz-Turp and Serdaroglu (2010) used different amounts of plum puree (5%, 10% or 15%) in low fat beef patties. TBARS values of control samples were higher than in plum puree

added samples at the end of the storage period. The addition of plum puree to the formulation significantly affected the colour of samples.

GRAPES

Grapes are a type of fruit that grow in clusters of 15 to 300, and can be crimson, black, dark blue, yellow, green, orange, and pink. Anthocyanins tend to be the main polyphenolics in purple grapes whereas flavan-3-ols (i.e. catechins) are the more abundant phenolic in white varieties. Total phenolic content, a laboratory index of antioxidant strength, is higher in purple varieties due almost entirely to anthocyanin density in purple grape skin compared to absence of anthocyanins in white grape skin (Cantos *et al.*, 2002). Grape seed extract has an antioxidant potential twenty and fifty times higher than vitamin E and vitamin C, respectively (Carpenter *et al.*, 2007).

Numerous studies conclude grape seed extract as an effective antioxidant in raw and cooked pork (Ahn *et al.*, 2002, 2007; Lau and King, 2003; Mielnik *et al.*, 2006; Carpenter *et al.*, 2007; Rojas and Brewer, 2007; Brannan, 2008). Ahn *et al.* (2002) showed that the grape seed extract ActiVin (InterHealth, Benicia, California) used at 0.05% and 0.1% in cooked ground beef (20% fat, fresh meat basis), and held for 3 days in refrigerated storage (4°C) reduced ($p < 0.05$) hexanal content when compared to a control, and was equal to samples treated with a combination of BHA/BHT at 0.02%. Over the 3 days storage period, hexanal values increased ($p < 0.05$) for all treatments with the exception of the BHA/BHT treatment. The control, rosemary and α-tocopherol treatments showed the largest increase in hexanal values. In another study by Ahn *et al.*, (2007), ActiVin used at 1.0% inhibited TBARS values by 92% in ground beef (18%

fat, fresh meat basis) when compared to the control. In this study, grape seed extract was added to ground beef, cooked to an internal temperature of 75°C, packaged in sterile plastic bags, and held for 9 days in refrigerated storage at 4°C. The TBARS value of the control sample was 9.45 ± 0.29 mg MDA/kg, and the grape seed extract treatment had a reduced ($p < 0.05$) TBARS value of 0.75 ± 0.18 mg MDA/kg.

Lower concentrations of grape seed extract (0.2% and less) had no adverse effects on sensory characteristics such as color, odor and warmed over flavor (WOF) (Ahn *et al.,* 2002; Rojas and Brewer, 2007). Concentrations above 1% affected color of finished products. Ahn *et al.* (2007) found that cooked beef treated with 1% ActiVin significantly increased the a* value (9.1 ± 0.68) as compared to the control (4.55 ± 0.7), and decreased the yellow score (b*) by 20% (control 17.32 ± 0.98, treated 14.03 ± 0.97). Carpenter *et al.* (2007) showed that a concentration of 1000 μg gallic acid equivalent phenolics/g meat of grape seed extract in raw pork patties stored at 4°C for 12 days in modified atmospheric packaging increased ($p < 0.05$) a*. The control had a* value of 7.04 ± 0.49, and the treated sample was 8.19 ± 0.24. However, this color difference was not perceived as a negative by a sensory panel. Rojas and Brewer (2007) used grape seed extract (Gravinol Super, Kikkoman, Tokyo, Japan) at a concentration of 0.02% in cooked beef and pork, and found no difference ($p > 0.05$) in a* value between the treated and control samples after 8 days of refrigerated storage.

Efficiency of four concentrations of grape seed extracts (0.0, 0.4, 0.8, and 1.6 g/kg) in retarding oxidative rancidity was tested with cooked turkey breast meat by Mielnik *et al.* (2006). Development in lipid oxidation during 13 days of refrigerated storage was evaluated by means of

thiobarbituric acid-reactive substances (TBARS) and volatile compound formation. Hexanal, pentanal, octanal, 2-octenal, 1-octen-3-ol, 2-octen-1-ol, and 1-penten-3-ol showed high correlations (r>0.95) with TBARS values and could, therefore, serve as markers for the oxidation process in the cooked turkey breast meat. Supplementation of grape seed extract prior to cooking significantly improved oxidative stability of minced turkey meat during heat treatment and storage. The ability of grape seed extract to prevent lipid oxidation was concentration dependent. Vacuum packaging considerably improved oxidative stability of meat regardless of the low concentration of grape seed extract used. It appears that grape seed extract could be very effective in inhibiting lipid oxidation of cooked turkey meat during chill storage.

The effect of Isabel (IGE) and Niagara (NGE) grape seed and peel extracts on lipid oxidation, instrumental color, pH and sensory properties of raw and cooked processed chicken meat stored at −18°C for nine months was evaluated by Selani *et al.* (2011). The pH of raw and cooked samples was not affected by the addition of grape extracts. IGE and NGE were effective in inhibiting the lipid oxidation of raw and cooked chicken meat, with results comparable to synthetic antioxidants. The extracts caused alterations in color, as evidenced by the instrumental (darkening and lower intensity of red and yellow color) and sensory results of cooked samples. In the sensory evaluation of odor and flavor, IGE produced satisfactory results, which did not differ from synthetic antioxidants. These findings suggest that the IGE and NGE are effective in retarding lipid oxidation of raw and cooked chicken meat during frozen storage.

The effect on meat quality (pH, microbial spoilage, lipid oxidation and color coordinates) of two different types of red grape pomace extracts obtained by different extraction systems [(Grape pomace extract I, GPI (methanolic extraction + High-Low Instantaneous Pressure –

HLIP–GPI) and Grape pomace extract II, GPII (methanolic extraction, GPII) at 0.06 g/100 g final product concentration] in pork burgers packed under aerobic conditions (4°C) was assessed at 0, 3 and 6 days post-storage by Garrido *et al.* (2011). Based on the results the highest color stability, lipid oxidation inhibition and the best global acceptability after 6 days of storage observed in burgers added with the GPI indicate that the new extraction system (HLIP) developed could be a valid alternative to optimize the purity of the grape pomace extracts in order to use them as preservative in meat foodstuffs.

CRANBERRY

Cranberries are a group of evergreen dwarf shrubs or trailing vines in the subgenus *Oxycoccus* of the genus *Vaccinium*. The fruit is a berry that is larger than the leaves of the plant; it is initially white, but turns a deep red when fully ripe. It is edible, with an acidic taste that can overwhelm its sweetness. Raw cranberries are a source of polyphenol antioxidants, phytochemicals under active research for possible benefits to the cardiovascular system and immune system, and as anti-cancer agents (Seifried *et al.,* 2007; Halliwell, 2007). Since the early 21st century within the global functional food industry, raw cranberries have been marketed as a "superfruit" due to their nutrient content and antioxidant qualities. Cranberries have a high concentration of phenolic compounds (8.2 mg phenolics/g dry weight), which can inhibit lipid oxidation (Vinson *et al.,* 2001). Anthocyanins are the main constituent of the phenolic compounds in cranberries, which tend to accumulate during the maturation of red fruit (Kahkonen *et al.,* 2001). The potential of cranberry press cake and cranberry juice powder to be used as antioxidants in meat and poultry products has been the topic of several studies (Raghavan and Richards, 2006, 2007; Larrain *et al.,* 2008). Cranberry juice powder extract

(extracted with chloroform) was superior ($p < 0.05$) to cranberry press cake extract (extracted with either ethyl acetate or ethanol) at inhibiting lipid oxidation in vacuum-packaged mechanically separated turkey (Raghavan and Richards, 2006). Lee *et al.* (2006) examined the potential of the different polyphenolic classes found in cranberries to inhibit lipid oxidation in mechanically separated turkey and cooked ground pork. In this study, mechanically separated turkey treated with cranberry juice powder (90-MX, Ocean Spray Cranberries, Inc., Lakeville-Middleboro, MA) at 0.32% showed equal inhibition of lipid oxidation (TBARS value of 5.1 μmol/kg tissue) to rosemary extract (StabilEnhance, Naturex, Mamaroneck, NY) used at 0.04% (TBARS value 3.6 μmol/kg tissue) in samples held for 14 days at 2°C. Both treatments inhibited TBARS formation by almost 10-fold as compared to control (58.8 μmol/kg tissue). Sensory evaluation was used to detect the degree of rancid odor. Trained panelists rated the degree of rancid odor by sniffing each sample and assigning it a score between 0 and 10 (10 = highly rancid). After 14 days, control mechanically separated turkey was given a rancidity score of 5.90. The mechanically separated turkey treated with cranberry juice powder at 0.32% had a lower ($p < 0.05$) rancidity score of 1.23. However, no mention was made regarding other sensory attributes or the quality impact the cranberry juice powder had on the meat. Lee *et al., (*2006) also demonstrated that in cooked pork (30% fat before cooking), crude cranberry extract exhibited 51% inhibition on TBARS formation in samples that were held for 9 days at 2°C. Cranberry products have antioxidant properties when used in poultry and pork products. Also, cranberry juice powder is a stronger inhibitor of lipid oxidation than cranberry press cake.

BEARBERRY

Bearberries are three species of dwarf shrubs in the genus *Arctostaphylos*. The name "bearberry" for the plant derives from the edible fruit which is a favorite food of bears. The plant contains arbutin, ursolic acid, tannic acid, gallic acid, some essential oils, hydroquinones, phenolic glycosides and flavonoids (Hansel *et al.*, 1992). Bearberry is one of the lesser studied natural antioxidants as compared to other natural antioxidants obtained from fruit or plant sources. Carpenter *et al.* (2006) investigated the antioxidant activity of several plant extracts under oxidative stress in cells and found bearberry to be a strong antioxidant.

Several studies have been conducted on the antioxidant activity of bearberry at several concentrations in raw and cooked pork patties held under refrigerated conditions. Carpenter *et al.* (2007) examined the effects of bearberry (obtained from Clonminam Industrial Estate, Portlaoise, Co. Laois, Ireland) in raw and cooked pork. Cooked pork patties were heated to an internal temperature of 72°C and held for an additional 8 min at 180°C. Both cooked and raw patties were packaged in polystyrene/ethylvinylalcohol/polyethylene trays with low oxygen permeable film and then flushed with a 75% O_2: 25% CO_2 mixture. The fat content of these patties was not provided. Carpenter *et al.* (2007) found that lipid oxidation was significantly reduced when compared to the control in raw pork patties held for 12 days at 4°C. The control patties had a TBARS value of 0.91±0.01 mg MDA/kg muscle. Bearberry used at a concentration of 80 μg/g meat had a TBARS value of 0.21 ± 0.2 mg MDA/kg muscle. In the cooked pork patties stored for 4 days at 4°C, lipid oxidation was also significantly reduced. The final TBARS value for the control was 0.90 ± 0.012 mg MDA/kg muscle, and bearberry used at 80 μg/g meat had a TBARS value of 0.54 ± 0.018 mg MDA/kg muscle. These findings are in agreement with findings from Pegg *et al.* (2001) that showed bearberry used at 80 μg/g meat and 1000 μg/g meat

reduced ($p < 0.05$) lipid oxidation in cooked pork patties. Bearberry used at the 1000 μg/g meat concentration showed a 9-fold reduction in lipid oxidation in cooked pork after 4 days when stored at 4°C. Carpenter *et al.* (2007) examined the impact of bearberry on sensory and quality properties of raw and cooked pork. They found that bearberry used at 80 μg/g meat, and 1000 μg/g meat did not result in color scores that were different ($p>0.05$) from the control after 12 days storage. A trained sensory panel of 8 to 10 members was used to evaluate the samples after 0, 2, and 4 days of storage at 4°C. Samples were evaluated for color, flavor, texture, juiciness, and off-flavors on a 10-point descriptive hedonic scale (1 = extremely desirable; 10 = undesirable). They found that bearberry used at 80 μg/g meat and 1000 μg/g meat did not negatively affect these sensory attributes when compared to control.

POMEGRANATE

Pomegranate (*Punica granatum*) is native from Iran to northern India and cultivated over the whole Mediterranean region. Pomegranate fruit parts contain a high concentration of antioxidants. The peel and rind are good sources of tannins, anthocyanins and flavonoids (Naveena *et al.*, 2008a). Cam *et al.* (2009) report that juice and extract from many other common fruits show less antioxidant activity than the pomegranate. Gil *et al.* (2000) found that commercial pomegranate juice possesses an antioxidant activity three times higher than that of green tea and red wine. When pomegranate rind powder was used at 10 mg tannic acid equivalent phenolics/100 g in fresh chicken, and then prepared as cooked chicken patties, a reduction ($p < 0.05$) in TBARS values was observed when compared to control (Naveena *et al.*, 2008b). Chicken patties were treated with pomegranate, cooked to an internal temperature of 80°C, and stored in low density polyethylene pouches for 15 days at 4°C. The TBARS value for

the control was reported as 1.272 ± 0.13 mg MDA/kg meat, and the pomegranate rind powder treatment had a TBARS value of 0.203 ± 0.04 mg MDA/kg. They also reported a 68% reduction ($p < 0.05$) in TBARS values when compared to samples treated with BHT (100 mg BHT/100 g meat) for the same product held under identical storage conditions. The TBARS value for the BHT sample was 0.896 ± 0.12 mg MDA/kg meat. Pomegranate rind powder and pomegranate juice powder have little effect on sensory or quality attributes when used at concentrations of 5 to 20 mg tannic acid equivalent phenolics/100 g meat (Naveena *et al.*, 2008a,b). Naveena *et al.* (2008a) reported a decrease in L* values when compared to the control in cooked chicken patties with pomegranate rind powder at 20 mg equivalent phenolics/100g meat. The L* for the control was 63.8 ± 0.73, and the L* for the pomegranate rind powder treatment was 56.71 ± 0.74 (Naveena *et al.*, 2008a).

An 8- to 10-member semi-trained sensory panel used an 8-point descriptive scale to rate samples based on three characteristics: off-odor, sweet flavor, and chicken flavor. No significant difference ($p > 0.05$) was found between the pomegranate samples at any of the concentrations used in this study when compared to control (Naveena *et al.*, 2008a). However, there was a slight reduction in chicken flavor for the sample with 20 mg tannic acid equivalent phenolics/100 g meat. These studies demonstrate the potential of pomegranate components to be used as antioxidants in refrigerated chicken patties. Pomegranate is effective at inhibiting lipid oxidation, and does not significantly impact the overall sensory attributes of the finished product.

Effects of salt, kinnow and pomegranate fruit by-product powders on color and oxidative stability of raw ground goat meat stored at 4 ± 1°C was evaluated by Devatkal *et al.*, (2010a). Five treatments evaluated include: control (only meat), MS (meat + 2% salt), KRP (meat + 2%

salt + 2% kinnow rind powder), PRP (meat + 2% salt + 2% pomegranate rind powder) and PSP (meat + 2% salt + 2% pomegranate seed powder). Addition of salt resulted in reduction of redness scores. Lightness increased in control and unchanged in others during storage. Redness scores declined and yellowness showed inconsistent changes during storage. Thiobarbituric acid reactive substances (TBARS) values were higher ($P < 0.05$) in MS followed by control and KRP samples compared to PRP and PSP samples throughout storage. The PSP treated samples showed lowest TBARS values than others. Percent reduction of TBARS values was highest in PSP (443%) followed by PRP (227%) and KRP (123%). Salt accelerated the TBARS formation and by-products of kinnow and pomegranate fruits counteracted this effect. The overall antioxidant effect was in the order of PSP > PRP > KRP > control > MS. Therefore, these powders have potential to be used as natural antioxidants to minimize the auto-oxidation and salt induced lipid oxidation in raw ground goat meat.

Devatkal *et al.,* (2010b) evaluated the antioxidant effect of extracts of fruit by-products viz., kinnow rind powder (KRP), pomegranate rind powder (PRP) and pomegranate seed powder (PSP) in goat meat patties. Total phenolics content, DPPH radical scavenging activity and effect of these extracts on instrumental color, sensory attributes and TBARS values during storage (4 ± 1°C) of goat meat patties were evaluated. Results showed that these extracts are rich sources of phenolic compounds having free radical scavenging activity. Hunter Lab *L* value significantly ($P < 0.05$) lowered in PRP followed by PSP and KRP patties. Sensory evaluation indicated no significant differences among patties. Further, a significant ($P < 0.5$) reduction in TBARS values (lipid oxidation) during storage of goat meat patties was observed in PRP, PSP and KRP as compared to control patties. Average TBARS values (mg/kg meat) during refrigerated storage

(4 ± 1°C) were significantly lower in PRP, followed by PSP and KRP as compared to control. The overall anti-oxidant effect was in the order of PRP > PSP > KRP. It was concluded that extracts of above fruits by-product powders have potential to be used as natural antioxidants in meat products.

Vaithiyanathan *et al.* (2011) evaluated the effect of dipping in pomegranate fruit juice phenolics (PFJP) solution on the shelf life of chicken meat held under refrigerated storage at 4°C. Breast muscle obtained from spent hens was dipped (1:2 w/v; muscle: liquid) in sterile water or in sterile water with 0.02% (v/v) PFJP, packed, stored at 4°C for 28 days and samples were analyzed on 2 days of intervals. Thiobarbituric acid reactive substance values were lower in samples treated with PFJP. Total sulfhydryl and protein bound sulfhydryl content values were higher in samples treated with PFJP. Microbial quality evaluation showed that aerobic and psychrotrophic counts were higher in samples treated without PFJP. Sensory evaluation revealed that acceptability level of samples treated without PFJP decreased on 12^{th} day of storage. It is concluded that spent hen breast meat samples dipped in 0.02% PFJP reduced protein oxidation and inhibited microbial growth and sensorily acceptable up to 12 days of refrigerated storage at 4°C.

GOLDEN APPLE (BAEL)

Aegle marmelos commonly known as bael is a plant indigenous to India. Since antiquity, the ripe fruits of bael have been used as a dietary source in the Indian subcontinent. Suvimol *et al.* (2008) reported that the bael fruit pulp contains important bioactive compounds such as carotenoids, phenolics, alkaloids, pectins, tannins, coumarins, flavonoids and terpenoids which were attributed to protect against chronic diseases. In addition, Purohit and Vyas (2005) and

Rathore (2009) reported that it also contains many vitamins and minerals including vitamin C, vitamin A, thiamine, riboflavin, niacin, calcium, and phosphorus. Therefore, bael fruit may indicate that it is one of the important plants used for indigenous traditional medicine. Kamalakkannan and Prince (2003a,b) reported that the aqueous extract of the bael fruit pulp possesses potent antioxidant effects. Additionally, Abdullakasim *et al.* (2007) also reported that the bael fruit drink was found to possess high quantities of total phenolic compounds (83.89/37.6 mg gallic acid equivalents/100 ml) and was also a good antioxidant in both DPPH (1,1 diphenyl-2-picryl hydrazyl) and PCL (photochemiluminescence) assays. With regard to the in vitro studies on bael, Venkatesh (2006) reported hydroalcoholic extract of bael at the concentrations of 25-500 μg/ml caused a concentration dependent inhibition of Fe_2SO_4-induced LPx in rat brain homogenate. Jagetia *et al.* (2004) observed similar findings in animal studies where the intraperitoneal administration of the hydroalcoholic extract of the fruit pulp (20 mg/kg body weight) for five consecutive days before exposure to different doses of γ-radiation (6 to 9 Gy) prevented radiation-induced LPx in the liver, kidney, intestine and spleen of mice. Raja *et al.* (2009) reported that in the serial dilution assay, the aqueous extract of the bael pulp caused a concentration-dependent inhibitory effect on the enterotoxigenic *E. coli.*

CITRUS FRUITS

Citrus fruits are abundant in the Indian subcontinent. Lemon, lime, pomelo, sweet lime, orange etc. are cultivated in abundance in different regions of India. The citrus juice and wine making industries produce large amounts of residues and waste that are rich in phenolic compounds. Baker (1994) found that citrus peels are rich in pectin which is known to possess blood sugar lowering and cholesterol lowering properties. Bocco *et al.* (1998) reported that peel

and seeds from the citrus industry can account for up to 50% of total fruit weight. Adding value to this, Gorinstein *et al.* (2001) reported that the total phenolic content of lemon, orange and grapefruit peel is 15% higher than that of peeled fruits. Other than these, Manthey *et al.* (2001) and Xu *et al.* (2006) found that carotenoids and hydroxycinnamic acids are also abundant in citrus peels.

Fernandez-Lopez *et al.* (2004) investigated the antioxidant and antibacterial effect of rosemary, orange and lemon extracts in cooked Swedish-style meatballs, reported that activity in a lard system was established for all the extracts and further determination of the development of rancidity as thiobarbituric acid reactive substances consistently showed that about 50% of the rancidity can be controlled by the citrus preparations. Fernández-López *et al.* (2005) also investigated the antioxidant and antibacterial effect of rosemary, orange and lemon extracts in cooked Swedish-style meatballs. Activity in a lard system was established for all the extracts and further determination of the development of rancidity as thiobarbituric acid reactive substances consistently showed that about 50% of the rancidity can be controlled by the citrus preparations. Two of the rosemary extracts (water soluble and oil soluble) were more effective with practically complete elimination of rancidity (TBA values) after a period of 12 days. Rosemary extract activity against lactic acid bacteria and *Listeria* but not *Brochothrix thermosphacta* was demonstrated in an agar diffusion test, but in the product only lactic acid bacteria counts were slightly reduced. Sensory analysis results, particularly aroma and acceptability scores, indicated the significant advantages in using rosemary and citrus extracts in rancidity-susceptible meat products.

Citrus limetta Risso is a species of citrus. Common names for varieties of this species include sweet limetta, Mediterranean sweet lemon, sweet lemon, and sweet lime. In India, it is commonly called sathukudi, mousambi, mosambi, or musambi. Nogata *et al.* (2006) reported that flavonoids hespiridin and naringin were found to be present in the peel and inner part of the fruit of *Citrus limetta* which are attributed to anti-tumour, anti-inflammatory and antioxidant properties. H´erent *et al.* (2007) isolated the essential oils with α-pinene, β-pinene, sabinene, β-myrcene, p-cymene, limonene, γ-terpinene, neryl acetate, β-bisabolene, α-bergamotene from the zests of *Citrus limetta* Risso.

Viuda-Martos *et al.* (2009) reported that the addition of citrus waste water (5-10%) obtained as co-product during the extraction of dietary fibre and oregano or thyme essential oils (0.02%) to the bologna samples reduced the residual nitrite levels and the degree of lipid oxidation. The flavonoids hesperidin and narirutin were detected in all the samples.

Viuda-Martos *et al.* (2010) studied the effect of adding orange dietary fibre (1%), rosemary essential oil (0.02%) or thyme essential oil (0.02%) and the storage conditions on the quality characteristics and the shelf-life of *mortadella*, a bologna-type sausage. The moisture, fat, ash content and colour coordinates lightness ($L*$) and yellowness ($b*$) were affected by the fibre content. The treatments analysed lowered the levels of residual nitrite (57.56% and 57.61%) and the extent of lipid oxidation, while analysis of the samples revealed the presence of the flavonoids, hesperidin and narirutin. No *enterobacteria* or psychotropic bacteria were found in any of the treatments.

The extracts from kinnow peel, kinnow seeds, litchi pericarp, litchi seeds, grape seeds, and banana peel were screened for total phenolic content (TPC), trolox equivalent antioxidant

capacity (TEAC), 1,1 diphenyl-2-picryl hydrazyl (DPPH) radical scavenging activity, as well as reducing power by Babbar *et al.* (2011). Kinnow peel extract exhibited the highest reducing power, TEAC, and DPPH free radical scavenging activity, whereas, the phenolic content of 37.4 mg GAE/g-dw was highest for grape seed extract. Banana peel extract with a low TPC showed the lowest reducing power, TEAC as well as DPPH free radical scavenging activity among the fruit residue extracts examined in the present study. Correlation analysis between the reducing power and DPPH radical scavenging ability; reducing power and ABTS (2,2'-azino-bis (3-ethylbenzthiazoline-6-sulphonic acid) radical scavenging activity; and ABTS and DPPH radical scavenging abilities showed a high degree of correlation (r^2 = 0.85–0.91). However, r^2 of 0.36, 0.66, and 0.49 between TPC and DPPH radical scavenging activity; TPC and reducing power; and TPC and ABTS radical scavenging ability, respectively, indicated that some non-phenolic compounds also contributed to the total antioxidant activity in fruit residue extracts examined in this study.

Contini *et al.* (2012) investigated the potential antioxidant activity of a natural citrus extract used as an ingredient for the production of active food packaging. The extract, in methanol, was sprayed onto the surface of polyethylene terephthalate (PET) trays. For comparison, a second set of trays were prepared using α-tocopherol as the coating. The effectiveness of the two types of packaging in delaying lipid oxidation in cooked turkey meat slices, stored at 4°C over 4 days, was compared using 2-thiobarbituric acid-reactive substances (TBARS) and hexanal assays. TBARS and hexanal values, for meat stored on the Citrus extract coated trays, were significantly lower ($P < 0.01$) than those of meat stored on uncoated (control) trays while α-tocopherol coated trays exhibited no significant effect compared to control trays

($P > 0.05$). The effectiveness of the Citrus extract coating, compared to the α-tocopherol coating, was attributed to its higher surface roughness, demonstrated by optical profilometry, and the higher level of release (solubility) of the antioxidant in water.

Phyllanthus emblica, (syn. *Emblica officinalis* Gaertn), genus *Phyllanthus* (Euphorbiaceae) is widely distributed in most tropical and subtropical countries. *Emblica officinalis is also* known as Emblic myrobalan and Indian gooseberry in English, Yeowkan in Chinese, Phylontha emblic in French and Amla in Hindi. Barthakur *et al.* (1991) analyzed amla as potential food source and reported it to have considerably higher concentrations of most minerals, protein and amino acids like Glutamic acid, proline, aspartic acid, alanine, cystine and lysine. Reddy *et al.* (2005) evaluated antioxidant activity of amla in biscuits reported that amla at 1% level in biscuits was very effective in preventing oxidation and increasing shelf-life without affecting organoleptic qualities and Scartezzini *et al.* (2006) reported that fruits of *E. officinalis* contains higher amount of vitamin C. Mishra *et al.* (2011) developed ready to eat amla (*Emblica officinalis*) chutney and reported that the fruits of amla are used in many medicinal preparations of ayurvedic and unani systems of medicine as well as food supplement.

Ghosal *et al.* (1996) has established by comprehensive chromatographic, spectroscopic and crucial chemical analysis of fresh juice and extractive that the antioxidant effect of amla is not due to its rich vitamin C content but the activity is located in the low molecular weight hydrolysable tannins. Tannins like embelicanin-A, emblicanin-B, punigluconin, pedunculagin have been found to provide protection against oxygen radical induced haemolysis of rat peripheral blood erythrocytes. The mechanism of action of antioxidant activity has been suggested to be due to recycling of sugar reductone moiety and conversion of the polyphenol in

to medium and high molecular weight tannins. Naik *et al.* (2005) found that the aqueous extract of *E. officinalis* to be a potent inhibitor of lipid peroxide formation and scavenger of hydroxyl and superoxide radicals *in vitro*.

Kumar *et al.* (2006) investigated the antioxidant activity of free and bound phenolics of *E. officinalis* and turmeric. Higher level of antioxidant activity in *Embelica officinalis* has been attributed to the phenolic content (12.9%, w/w) in them. Gallic acid and tannic acid were identified as the major antioxidant components in phenolic fractions of *Embelica officinalis*. The antioxidant properties of *E. officinalis* extracts and their effects on the oxidative stress in streptozotocin-induced diabetes were examined in rats. Amla showed strong inhibition of the production of advanced glycosylated end products which is a glycosylated protein that is an indicator of oxidative stress. Furthermore, thiobarbituric acid-reactive substances levels were significantly reduced with amla, indicating a reduction in lipid peroxidation.

CAROB FRUIT

Ceratonia siliqua, commonly known as the carob tree and St John's-bread, is native to the Mediterranean region including Southern Europe, Northern Africa, the larger Mediterranean islands; to the Levat and Middle-East of Western Asia into Iran; and to the Canary Islands and Macaronesia. Carob fiber contains a large amount of phenolic antioxidants. Phenolic antioxidants help protect the body from diseases which are a result of cell oxidation caused by free radicals.

Bastida *et al.* (2009) evaluated the effect of adding condensed tannins in the form of non-purified (Liposterine®) or purified (Exxenterol®) extracts obtained from carob fruit to

prevent lipid cooked pork meat systems from oxidizing during chilling and frozen storage. The antioxidant activity of these extracts was compared with that of α-tocopherol. Meat lipid alteration was evaluated as thiobarbituric acid reactive substances content (TBARS) and polar material-related triglyceride compounds followed by high-performance size-exclusion chromatography (HPSEC). TBARS levels were lower ($P < 0.05$) in samples containing Liposterine (LM), Exxenterol (EM), and α-tocopherol (TM) than in control sample (CM) under chilled storage. TBARS formation was similar ($P > 0.05$) for LM and EM but lower ($P < 0.05$) than for TM. Polar material increased several times in all samples, but significantly less in TM and EM than in LM. Thermal oxidation compounds determined by HPSEC were lower ($P < 0.05$) in EM than in LM or TM. The changes in polar material were proportionally smaller after six months frozen storage than after chilled storage, with Exxenterol displaying the highest antioxidant protection. Therefore, carob fruit extracts can be successfully used to reduce fat alteration in cooked pork meat at chilled and frozen temperatures.

OTHER FRUITS

There are certain other fruit sources which have been tried as antioxidant sources in meat products. Peschel *et al.* (2006) screened eleven fruit and vegetable byproducts and two minor crops for industrial polyphenol exploitation potential by determination of their extraction yield, total phenolic content (TPC, Folin–Ciocalteu), and antioxidant activity (NTZ/hypoxanthine superoxide assay, ferric thiocyanate method). Extracts with the highest activity, economic justification and phenolic content were obtained from apple (TPC maximum 48.6 ± 0.9 mg Gallic acid equivalents g^{-1} dry extract), pear (60.7 ± 0.9 mg GAE g^{-1}), tomato (61.0 ± 3.0 mg GAE g^{-1}), golden rod (251.4 ± 7.0 mg GAE g^{-1}) and artichoke (514.2 ± 14.9 mg GAE g^{-1}).

Apple, golden rod and artichoke byproducts were extracted at pilot plant scale and their antioxidant activity was confirmed by determination of their free radical scavenging activity (DPPH) and the inhibition of stimulated linoleic acid peroxidation (TBA and Rancimat® methods). The preservative effect of the three extracts (determination of the peroxide value in test crème formulations with 0.1–1.0% extract concentrations) was similar to the established antioxidants Oxynex® 0.1%, Controx® KS 0.15%, and butylated hydroxytoluene (BHT) 0.01%. This study demonstrates the possibility of recovering high amounts of phenolics with antioxidant properties from fruit and vegetable residuals not only for food but also cosmetic applications.

Jayaprakasha *et al.* (2007) extracted the dried fruits of cinnamon with ethyl acetate, acetone, methanol and water using a Soxhlet extractor. The total phenolics content of the extracts as determined by Folin–Ciocalteu method were found to be the highest in water extract (44.5%) and the lowest in ethyl acetate (14.4%). The antioxidant activity (AA) of the extracts was evaluated through in vitro model systems such as *β*-carotene-linoleate, and 1,1-diphenyl-2-picryl hydrazyl (DPPH); the antimutagenicity of these extracts was also assayed against the mutagenicity of sodium azide by Ames test using tester strain of *Salmonella typhimurium* (TA100) at different concentrations. In both the model systems, the AA of the extracts was found in the order of water>methanol>acetone>ethyl acetate. All the extracts decreased sodium azide mutagenicity in *S. typhimurium* strain (TA100). At 5000 μg/plate all the extracts showed strong antimutagenicity. The antimutagenicity of water extract was followed by acetone, methanol and ethyl acetate. The results of the present study indicate that under-utilized

and unconventional part of cinnamon is a good source of antioxidant and antimutagenic phenolics.

Seventy two male *Bianca Italiana* rabbits were used to study the effects of the inclusion (0%, 0.5%, and 1.0%) of a natural extract of chestnut wood (Silvafeed ENC) in the diet on productive traits, carcass characteristics, meat quality, lipid oxidation and fatty acid composition of rabbit meat by Liu *et al.* (2009). Results showed ENC had no significant effect on live weight, productive traits, hot carcass weight, dressing percentage, skin weight, pH, cooking losses, shear force and colour. The iron content was higher in *Longissimus thoracis et lumborum* (LTL) muscle of rabbit fed the ENC 1.0% diet than the control group. TBARS average values in the group ENC 0.5% were significantly lower ($P < 0.05$) than in the control and ENC 1.0% groups. Myristic acid (C14:0; $P < 0.01$), palmitoleic acid (C16:1 *cis*-9; $P < 0.05$) and pentadecanoic acid (C15:0; $P < 0.01$) contents were lower in LTL muscle of rabbits fed the ENC 1.0% diet, whereas the palmitic acid (C16:0) content was higher ($P < 0.05$) in the rabbits of this group. Moreover, the rabbits fed with the ENC 0.5% diet had lower ($P < 0.01$) levels of *trans*-vaccenic acid (C18:1 *trans*-11) compared to rabbits fed with the control diet. No significant differences were observed in saturated (SFA), monounsaturated (MUFA), polyunsaturated (PUFA) fatty acids, as well as in PUFA/SFA and *n* - 6/*n* - 3 ratios among the groups.

The influence of protein oxidation, as measured by the dinitrophenylhydrazine (DNPH) method, on colour and texture changes during chill storage (2°C, 12 days) of cooked burger patties was studied by Ganhão *et al*. (2010). Extracts from arbutus-berries (*Arbutus unedo*., AU), common hawthorns (*Crataegus monogyna*., CM), dog roses (*Rosa canina*., RC) and elm-leaf blackberries (*Rubus ulmifolius Schott*., RU) were prepared, added to burger patties (3% of total

weight) and evaluated as inhibitors of protein oxidation and colour and texture changes. Negative (no added extract, C) and positive control (added quercetin; 230 mg/kg, Q) groups were also considered. The significant increase of protein carbonyls during chill storage of control burger patties reflects the intense oxidative degradation of the muscle proteins. Concomitantly, an intense loss of redness and increase of hardness was found to take place in burger patties throughout refrigerated storage. Most fruit extracts as well as Q significantly reduced the formation of protein carbonyls and inhibited colour and texture deterioration during chill storage. Likely mechanisms through which protein oxidation could play a major role on colour and texture changes during chill storage of burger patties are discussed. Amongst the extracts, RC was most suitable for use as a functional ingredient in processed meats since it enhanced oxidative stability, colour and texture properties of burger patties with no apparent drawbacks.

The extraction conditions of procyanidins (PC) from the Chinese hawthorn (*Crataegus pinnatifida*) fruits were optimized by response surface methodology (RSM) by Liu *et al.* (2010). Results showed that 93.4 ± 0.21% of the PC could be recovered. The crude extract was then purified by using a LSA-10 resin column, which showed excellent adsorption and desorption properties for PC purification. A fraction with PC content above 83.2% and mainly consisting of EC, a singly-charged dimer and trimer as identified by HPLC/MS, was obtained by isolation on LSA-10 resin. The antioxidant activity of hawthorn PC was tested *in vitro* with different systems. In solution systems, the $^{\bullet}OH$ and $O_2^{-\bullet}$ scavenging ability of hawthorn PC were higher than vitamin C. In a liposome peroxidation system, hawthorn PC exhibited much higher antioxidant activity than vitamin E. In addition, hawthorn PC (0.02% w/v) was efficient to inhibit lipid peroxidation during enzymatic hydrolysis of porcine meat at 50°C for 24 hours.

Thirty eight types of fruits commonly consumed in Singapore were systematically analyzed for their hydrophilic oxygen radical absorbance capacity (H-ORAC), total phenolic content (TPC), ascorbic acid (AA) and various lipophilic antioxidants by Isabelle *et al.* (2010). Antioxidant composition and concentration varied widely across different fruits. Many of the tropical fruits tested were high in antioxidants. Amongst all fruits tested, sapodilla (*Manilkara zapota*) had the highest H-ORAC and TPC whilst guava had the highest AA per gram fresh weight. Papaya, red watermelon and cantaloupe had the highest β-cryptoxanthin, lycopene and β-carotene per gram fresh weight, respectively. On the other hand, durian and mangosteen were high in tocopherols and tocotrienols, respectively.

Berasategi *et al.* (2011) developed a new formulation of bologna-type sausage enriched in ω-3 polyunsaturated fatty acids (PUFA) (8.75% linseed oil), using a lyophilized aqueous-ethanolic extract of *Melissa officinalis.* A comparison with the effectiveness of butyl hydroxyanisole (BHA) synthetic antioxidant to decrease the oxidation of PUFAs was performed. The formulation increased the ω-3 PUFAs content, especially α-linolenic acid, decreasing significantly the ω-6/ω-3 ratio from 17.3 to 1.9, and also the Atherogenic Index and Thrombogenic Index (0.38–0.31 and 1.03–0.54, respectively). Modified sausages with BHA and *Melissa* extract showed significantly lower peroxides value (2.62 and 6.11 meqO_2/kg) and thiobarbituric acid value (0.26 and 0.27 mg malondialdehyde/kg) and higher antioxidant capacity (hydrophilic fraction ABTS: 0.45 and 0.74 meq Trolox/g product; lipofilic fraction ABTS: 0.44 and 0.37 meq Trolox/g product) than those without these ingredients (16.49 meq O_2/kg, 2.08 mg malondialdehyde /kg, 0.26 and 0.27 meq Trolox/g product, respectively). Sensorial tests showed that acceptability of the new formulations was similar to control products.

Jia *et al.* (2012) assessed the antioxidant efficacy of black currant (*Ribes nigrum* L.) extract (BCE) in raw pork patties during chilled storage. The extracting conditions of frozen BCE including ethanol concentrations (0–100%) and extracting times (0.25–12 hours) were studied. BCE extracted with 40% ethanol for 2 hours had the highest anthocyanin content, the strongest radical scavenging activities as well as the second strongest reducing power. BCE was condensed and added to pork patties at 5, 10 or 20 g/kg. Compared with the control, BCE treatments significantly decreased the thiobarbituric acid-reactive substance values and carbonyls formation and reduced the sulfhydryl loss of pork patties in a dose-dependent manner ($P < 0.05$), which showed that the BCE significantly inhibited lipid and protein oxidation. The BCE-treated patties showed significantly higher redness ($P < 0.05$) than the control. The findings demonstrated strong potential for BCE as a natural antioxidant in meat and meat products.

CONCLUSIONS

Meat products during storage are highly liable to quality deterioration in terms of color and flavor through lipid oxidation. Particle-size reduction and subsequent exposure to various microbial contaminants during processing of meat products, combined with the pro-oxidant effect of salt, cause these products to have a relatively short shelf life. The oxidized or rancid flavor that develops rapidly during refrigeration or frozen storage of cooked meat causes the warmed-over flavor. Quality loss may be prevented or minimized by a range of techniques, including the use of additives, in particular to interfere with oxidative chemical reactions and to prevent or delay microbial growth. Synthetic antioxidants have fallen under scrutiny due to their potential toxic nature.

Natural antioxidants (NANT's) derived from plants are becoming increasingly popular as functional food and feed ingredients. It is proposed that such compounds are involved in direct ROS scavenging processes in plants, in food and in the gastrointestinal tract, counteracting oxidative stress and preventing pathogen outbreaks and the development of ROS-related diseases such as colon diseases and cardiovascular diseases. By varying NANT ratios in individual diets, one can specifically manipulate the microbiome of an individual with a specific genotype.

Consumer's preference for natural products has compelled the meat industry to seek natural solutions to minimize oxidative rancidity and increase the shelf-life of the products. Due to their high content of phenolic compounds, fruits and other plant materials are a good source of natural antioxidants and provide a good alternative to currently used conventional antioxidants. Various fruits and their byproducts in the form of powders, juices and extracts have proved potential antioxidant sources. There is a great scope for further exploration of various fruits to be used as functional ingredients at commercial level.

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