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REVIEW ARTICLE

An overview on applications and side effects of antioxidant food additives

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ABSTRACT

Antioxidant food additives are substances that can be added to foodstuff, in small amounts. The aim is to avoid oxidation of food products, thereby improving its durability. Authorized by the European Union Law there are more them fifty food additives with antioxidant technologic functions. On food products, two main oxidation processes prevail: (i) enzymatic oxidation of fruits, vegetables, and processed derivatives like juices, soft drinks, jellies and jams; (ii) oxidation and rancidity of spreadable fats and cooking fats and oils. Consequently, food technology uses soluble antioxidants in fats or in water, to prevent oxidation of various types of foodstuffs. Although some of these food additives are harmless when used in small quantities (e.g., the authorized amounts), the use of others might have risks to human health. Among side effects that can occur, stands out skin rashes and itching, urticarial and eczema, breathing difficulty, sneezing, gastrointestinal upsets, cholesterol in blood, hyperkinesis. This work is a synoptic review of food additives used as antioxidants authorized in the European Union, considering their characteristics, applications and side effects.

Keywords: Antioxidants; Applications of antioxidants; Food additives; Side effects of antioxidants

INTRODUCTION

Food additives are natural or synthetic substances added intentionally to food products. In small amounts, these substances increase the durability of the food product and enhance or modify its properties, including its appearance and flavor or structure, without diminishing the nutritional value (Silva and Lidon, 2016). The use of food additives is regulated by specific European Union - EU laws, considering the food where it can be applied, maximum usable quantities, chemical characterization and purity (Silva and Lidon, 2016; Commission Regulation (EU) Nº 1129/2011; Directive 95/2/EC).

According to the technological function, twenty five families of food additives have been defined. Since the oxidation of foodstuffs is an important way of degradation, one of the major families of food additives is constituted by antioxidant agents. These substances protect foodstuffs from deterioration due to oxidation processes, thereby improving them durability.

It is often necessary to use various additives simultaneously, mostly due to the characteristics of the food product, or because the additives themselves can be degraded and need to be stabilized by other(s). Also various additives can be used simultaneously to enhance a particular function (*i.e.,* synergistic effect). Some food additives can also have various technological functions, and be applied in a variety of foodstuff.

The use of antioxidant food additives is widespread in the agro-food industry in a wide variety of foodstuffs. Some antioxidants have no danger at the dosages used as food additives, but the use of other antioxidants might trigger some side effects to the health of consumers (Abdulmumeen et al., 2012).

This work is a synoptic review of food additives used as antioxidants, authorized in the EU, considering its characteristics, applications and side effects.

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USES, CHARACTERISTICS AND SIDE EFFECTS OF ANTIOXIDANT FOOD ADDITIVES

Some antioxidants are naturally occurring in food, namely ascorbic acid (also known as vitamin C, which exists in lemon juice, orange and other fruit), tocopherols (or vitamin E, that exist in vegetable oils), lactic acid (that exists, for instance, in yogurts) and citric acid (from citrus).

There are a large number of foodstuffs which are susceptible to oxidation when in contact with the air. Fats, especially unsaturated (oils and margarines), and derived from fruits (juices, canned fruit and soft drinks), are the two main groups of food, to which is necessary to add antioxidants (natural or synthetic). Indeed, this is absolutely required because during manufacturing processes, refining (fat) or storage, an alteration can develop in the antioxidants naturally occurring, or they can even be insufficient to minimize the oxidation processes.

"True" antioxidants can act by itself as antioxidants (namely, E320 butylated hydroxyanisole, butylhydroxytoluene and gallates E310 E321 to E312). Synergistic antioxidant substances are additives that are not considered "true" antioxidants, but in the presence of "true" antioxidants reinforce their action (in this context stands out the E330/citric acid). Indeed, antioxidants slow down the oxidation rates but do not prevent them entirely. After some time the antioxidant activity may be saturated. Therefore, the use of multiple antioxidants simultaneously, becomes important in order to achieve a synergic action.

The oxidation of food involves the addition of an oxygen atom, or follows from the removal of a hydrogen atom, from molecules constituting the foodstuff. Accordingly, there are two main types of oxidation: autoxidation of unsaturated fatty acids and oxidation catalyzed by oxidative enzymes. The autoxidation of unsaturated fatty acids involves the reaction between molecular oxygen (O_2) and the double C = C bonds. These reactions synthetizes free radicals, and highly reactive oxygen species, that produce compounds responsible for bad odor and the rancidity of food. Antioxidants, that minimize the oxidation rates, react with free radicals and, thus, reduce the self-oxidation rate. Amongst the antioxidants that act in this manner, stands out tocopherols (E306 to E309 - which are natural antioxidants) and artificial antioxidants (butylated hydroxyanisole - E320, and butylhydroxytoluene - E321). The oxidation of food can also be caused by enzymatic reactions with high specificity for each type of substrate. For instance, when cutting an apple or banana, some fenolases quickly catalyze the oxidation of certain molecules (*e.g.,* tyrosine), leaving the surface exposed to the air, which therefore become with a dark hue. This "enzyme tanning" leads to the formation of pigments, namely melanin. Antioxidants that inhibit this type of oxidation include agents that bind to free oxygen, such as ascorbic acid (E 300), or agents that inhibit enzymatic activity, such as citric acid (E 330).

Tocopherols

Different types of tocopherols, which differ by the number and position of methyl groups on the benzene ring, are well known (Figs. 1-4).

Among tocopherols, α-tocopherol has the highest biological activity, due to its antioxidant properties, which attenuate the lipid peroxidation rate. Although this vitamin E exists naturally in many foods, in particular in vegetable fats (especially wheat germ fat), α-tocopherol may be considered a food additive (E 307), since the refining process of oils from food cause the loss of this vitamin, being necessary its addition and other antioxidants to fats, to prevent their oxidation (rancidity). Nevertheless, besides α-tocopherol, others are used as antioxidant tocopherols (Table 1.).

An extract rich in tocopherols (E 306) displays oily and viscous characteristics, with limpid aspect of red or brownish, distinctive odor and flavor, and may be

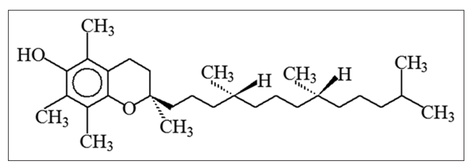

Fig 1. α-Tocopherol (E307) structure.

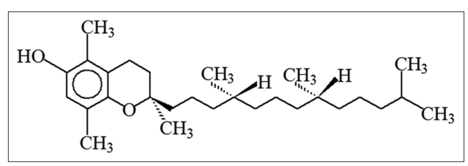

Fig 2. β-Tocopherol structure, one of the E306 constituents.

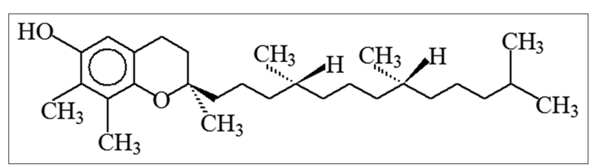

Fig 3. γ-Tocopherol (E308) structure.

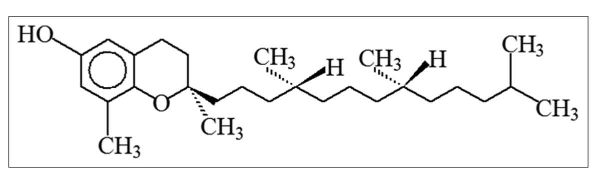

Fig 4. δ-Tocopherol (E309) structure.

obtained by distillation of vegetable oils. The extract rich in tocopherols is partially comprised of tocotrienols and concentrate tocopherols (*i.e.,* natural vitamin E), which include α-tocopherol, the β-tocopherol, the γ-tocopherol and δ-tocopherol. Tocotrienols (α, β, γ and δ), existing in the rich stratum in tocopherols, are products with a chemical structure that is similar to tocopherols, but the aliphatic chain has three double bonds in positions 3,7,11 (Fig. 5).

The other additives (E307 to E309) are of synthetic origin, can occur as viscous clear oil, with colors ranging from pale yellow, or amber and orange, and may undergo oxidation and darken on exposure to air and light. All tocopherols, used as food additives, are insoluble in water and soluble in ethanol (Commission Regulation (EU) Nº 231/2012; FAO, 2006).

The high solubility of tocopherols in fats facilitates their homogenization. Thus, these antioxidants become particularly important in the prevention of fat oxidation. These antioxidants can be used in most foodstuffs, namely in oils and emulsified fats, or in foods for infants and children (Commission Regulation (EU) Nº 1129/2011; Directive 95/2/EC), due to their lack of toxicity.

It has long been reported that tocopherols do not exhibit any harmful effect on health (Scientific Opinion, 2015; Tomassi and Silano, 1986). Besides, vitamin E is essential to life, protecting the cells of the human body against oxidation and helps the assimilation of vitamin K. Moreover, although the selenium can enhance the antioxidant activity of the tocopherols (itself is an antioxidant), is not used in agro-food processing and transformation due to its high toxicity and carcinogenic characteristics. Alternatively, other innocuous synergist chemical entities are used.

Table 1: Tocopherols used as antioxidants

Additive code	Designation	Chemical Formula
E 306	Rich extract of tocopherols	------ a)
E 307	α- Tocopherol	$C_{29}H_{50}O_2$
E 308	γ- Tocopherol	$C_{28}H_{48}O_2$
E 309	δ- Tocopherol	$C_{27}H_{46}O_2$

a) Is a mixture of several tocopherols and tocotrienols

Table 2: BHA, BHT and TBHQ used as antioxidants

Additive code	Designation	Chemical formula
E319	t-Butylhydroquinone (TBHQ)	$C_{10}H_{14}O_2$
E320	t-Butyl-4-methoxyphenol, butylated hydroxyanisole (BHA)	$C_{11}H_{16}O_2$
E321	2,6-Di-t-butyl-4-methylphenol, butylated hydroxytoluene (BHT)	$C_{15}H_{24}O$

BHA, BHT and TBHQ

Derivatives of phenol, namely t-butyl-4-methoxyphenol (also known as butylated hydroxyanisole - BHA) and 2,6-di-t-butyl-4-methylphenol (further known as butylhydroxytoluene - BHT), have been widely used, as food additives (E320 and E321 respectively), to inhibit oxidation reactions in some foods (Figs. 6 and 7; Table 2). More recently it was authorized the use of another food additive, the t-butylhydroquinone (TBHQ, with the E-code E319) (Commission Regulation (EU) Nº 231/2012; Commission Regulation (EU) Nº 1129/2011). The food additive BHA is a mixture of two structural isomers (Race, 2009).

BHA and BHT are artificial antioxidants, with white or slightly yellow crystals, having a faint characteristic odor, being insoluble in water and freely soluble in ethanol. TBHQ, also has an artificial origin, being a white solid crystalline with a characteristic odor; practically insoluble in water and soluble in ethanol (Commission Regulation EU) Nº 231/2012; FAO, 2006). BHA and BHT may be applied isolated (Race, 2009), or in combination with gallates, in particular, propyl gallate (E310), octyl gallate (E311), and dodecyl gallate (E312).

E319, E320 and E321 are antioxidants that prevent the oxidation of fats and oils, being used in oils and fats (in professional manufacture or preparation of foodstuffs subjected to thermal treatments). They can also be used in oils or fat for frying (excluding olive pomace oil), lard and other animal fats, cake mixes, dehydrated soups, dried meat products, dehydrated potatoes, cereal-based snack foods, some food supplements and processed nuts and other products (Commission Regulation (EU) Nº 1129/2011).

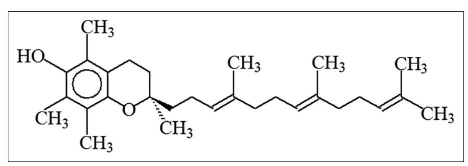

Fig 5. α-Tocotrienol structure, one of the E306 constituents.

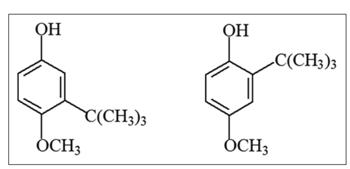

Fig 6. Structure of 2-t-butyl-4-methoxyphenol and 3-t-butyl-4-methoxyphenol, BHA constituents of the additive (E 320).

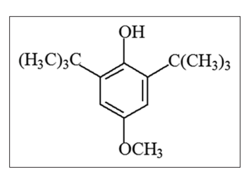

Fig 7. 2,6-Di-t-butyl-4-methylphenol (BHT) (E321) structure.

Although it has been reported that BHA and BHT have prophylactic against cancer, some carcinogenic properties also have been pointed (Inetianbor et al., 2015; Race, 2009; Voss, 2002). It has been found that E320 is tumor-producing when fed to rats (Tuormaa, 1994). In addition there are also other side effects, namely increased synthesis of digestive enzymes in the liver that may lead to an increased catabolism rate of some substances (such as vitamins A and D). Besides, the risk of allergy manifested by rash, urticarial, angioedema and eczema, increased levels of cholesterol and lipids in blood, the risk of accumulation in adipose tissue and some are suspected of hyperkinesis (Voss, 2002; Goodman et al., 1990) have further been reported. Accordingly, none of these antioxidants can be used in food for infants and children. Prolonged exposure to very high doses of TBHQ may also be carcinogenic (Gharavi and Kadi, 2005). However, the European Food Safety Agency (EFSA) reported that TBHQ is a safe food additive if only authorized doses are applied to foodstuff (Scientific Opinion, 2004, 2016; Race, 2009).

Gallates

Gallates are excellent antioxidants to fats, and can be used as "true" antioxidants or as synergistic antioxidants (Table 3) with BHA (E320) and tocopherols (E306 to E309). However, their use is not without health risks, being banned in foods for infants and children, due to the risk of methemoglobinemia (Garrido et al., 2012; Voss, 2002).

The three gallates (Figs. 8-10) used as antioxidants are of synthetic origin and have been chemically characterized. E310, E311 and E312 are white or creamy-white, crystalline odorless solids, and are insoluble or slightly soluble in water, and freely soluble in ethanol and ether (Garrido et al., 2012).

E310, E311 and E312 can be used in lard, oils and fats for frying, fish oils and fat sheep, poultry and beef, sauces, soups and broths dehydrated, pre-cooked cereals, spices and condiments, dehydrated granulated potatoes, chewing gum and snacks, and other foodstuff (Commission Regulation (EU) Nº 1129/2011; Directive 95/2/EC). Yet, its use is not without health hazards, being recognized some side effects such as allergic reactions (eczema, hives and stomach upset), especially in asthmatics and people who do not tolerate acetylsalicylic acid (Garrido et al., 2012). Besides, gallates can have possible residues of organochlorines. The safety of E311 and E312 is also under discussion (Garrido et al., 2012; Voss, 2002), being consider to have a high degree of danger for infants and children, being prohibited their use in specific foods for infants and children.

Table 3: Gallates authorized as antioxidants

Additive code	Designation	Chemical formula
E310	Propyl gallate	$C_{10}H_{12}O_5$
E311	Octyl gallate	$C_{15}H_{22}O_5$
E312	Dodecyl gallate	$C_{19}H_{30}O_5$

Ascorbic acid and derivatives

Some additives have multiple functions. This is the case of vitamin C (*i.e.,* L-ascorbic acid). Vitamin C (Fig. 11), which also is a nutritional agent, is being used in the agro-food industry as an antioxidant (E 300).

The use of some ascorbates as food additives is also allowed (Table 4).

The ascorbic acid and the ascorbates (Figs. 12 and 13) are white to slightly yellow, odorless crystalline powders (Commission Regulation (EU) Nº 231/2012; FAO, 2006). Like L-ascorbic acid, ascorbates also are excellent antioxidants that can be used in general foodstuffs, due to the absence of side effects. Ascorbic acid or ascorbate derivates have high water solubility, which allows their use in non-lipid foodstuffs. Thus, stands out the use on fresh minced meat, charcuterie and salted products, fish, shellfish and mollusk unprocessed; fruit and horticultural products unprocessed frozen or chilled, some types of bread, fresh pasta (Lidon et al., 2014; Scotter and Castle, 2004), foie gras, beer, peeled potatoes and some foods for infants and children (Commission Regulation (EU) Nº 1129/2011; Directive 95/2/EC).

The fatty acid esters of ascorbic acid, E304i and E304ii (Figs. 14 and 15), are white or yellowish-whit solid, with a citrus-like odor, very slightly soluble or insoluble in water (FAO, 2006; Commission Regulation (EU) Nº 231, 2012). Thus, although these food additives (E304i and E304ii) can be used in most food products, they are especially applied in sausages, partly dehydrated milk, not emulsified oils and fats, and foods for children and babies.

Erythorbic acid, also named isoascorbic acid, and its sodium derivative, are also used as antioxidants (Table 5).

Isoascorbic acid (Fig. 16) is an isomer of L-ascorbic acid, being obtained by chemical synthesis.

E315 and E316 are white crystalline solids, which darkens gradually on exposure to light, freely soluble in water and soluble in ethanol. Although the side effects of E315 and E316 are poorly studied, these additives are thought to inhibit the absorption of natural vitamin C. These antioxidants are only used in semi-preserved and preserved meat and fish products (Commission Regulation (EU) Nº 1129/2011; Directive 95/2/EC).

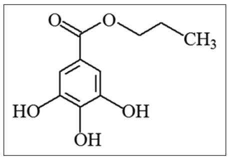

Fig 8. Propyl gallate (E310) structure.

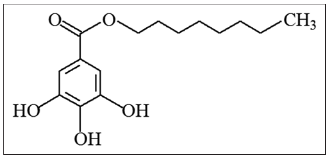

Fig 9. Octyl gallate (E311) structure.

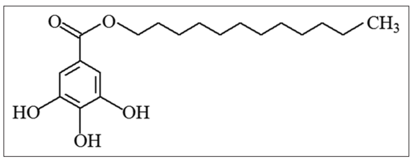

Fig 10. Dodecyl gallate (E312) structure.

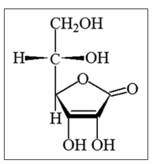

Fig 11. L-ascorbic acid (E300) structure.

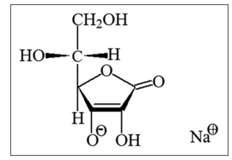

Fig 12. Sodium ascorbate (E 301) structure.

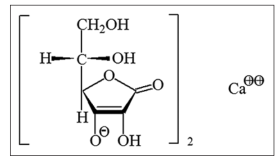

Fig 13. Calcium ascorbate (E302) structure.

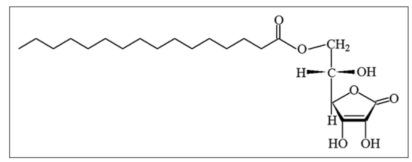

Fig 14. Palmitate L-ascorbyl (E304i) structure.

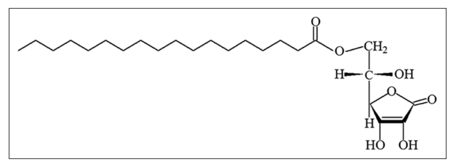

Fig 15. L-ascorbyl stearate (E304ii) structure.

Table 4: L-ascorbic acid and L-ascorbates used as antioxidants

Additive code	Designation	Chemical formula
E 300	L-Ascorbic acid (vitamin C)	$C_6H_8O_6$
E 301	Sodium ascorbate, soium L-ascorbate	$C_6H_7O_6Na$
E 302	Calcium ascorbate, calcium ascorbate dihydrate	$C_{12}H_{14}O_{12}Ca.2H_2O$
E304	Fatty acid esters of ascorbic acid:	
(i) E304	L-ascorbyl palmitate	$C_{22}H_{38}O_7$
(ii) E304	L-ascorbyl stearate	$C_{24}H_{42}O_7$

Table 5: Isoascorbic acid and isoascorbate

Additive code	Designation	Chemical formula
E 315	Erythorbic acid or acid isoascorbic	$C_6H_8O_6$
E 316	Erythorbate sodium or sodium isoascorbate	$C_6H_7O_6Na.H_2O$

Citric acid and citrates

Citric acid (pK1 = 3.09, pK2 = 4.74 and pK3 = 5.41) is often used as an additive (E 330) in numerous food products. Citric acid (Fig. 17) are commonly used in caramels, fruit juices, nectars and soft drinks, ice cream, marmalades, fruit jams, jellies, fruit preserves and vegetables, dairy products (processed cheese, some butter, margarine and other spreadable fats), oils and fats, fish and shellfish unprocessed, peeled potatoes, sausages, frozen fish products and baby food (Commission Regulation (EU) Nº 1129/2011; Directive 95/2/EC). The low pH of this acid, determines a large amount of technological applications, being an important acidifying, acidity regulator, antioxidant and can also act as synergist of other antioxidants.

Citric acid is widely used as a food additive and shows no side effects (Inetianbor et al., 2015; Lidon et al., 2014). Citrates are also applied in the agrofood industry (Table 6).

Citrates are derived from citric acid salts (Table 6 and Figs. 18-22) and can also act as antioxidants. Citrates used as food additives are synthetically produced.

Citric acid and citrates have diverse technological functions (Table 7) (FAO, 2006). Besides, like citric acid, citrates also do not seem to exhibit any side effect on human health (Voss, 2002; Lawrence, 1998).

Tartaric acid and tartrates

Tartaric acid, as well as sodium and potassium tartrate, at the feeding level has several technological functions due to their antioxidant properties. Tartaric acid (Fig. 23) occurs

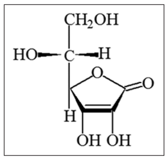

Fig 16. Isoascorbic acid (E315) structure.

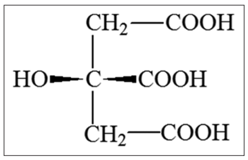

Fig 17. Citric acid (E 330) structure.

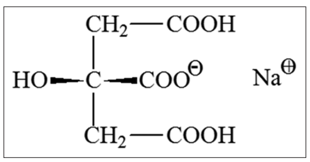

Fig 18. Monosodium citrate (E 331i) structure.

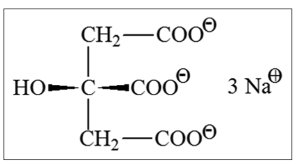

Fig 19. Trisodium citrate (E 331iii) structure.

Table 6: Citric acid and citrates used as antioxidants

Additive code	Designation	Chemical formula
E 330	Citric acid	$C_6H_8O_7$ (anhydrous) $C_6H_8O_7.H_2O$ (monohydrate)
E 331	Sodium citrates:	
(i) E 331	Monosodium citrate	$C_6H_7O_7Na$ (anhydrous) $C_6H_7O_7Na.H_2O$ (monohydrate)
(ii) E 331	Disodium citrate	$C_6H_6O_7Na_2.1,5H_2O$
(iii) E 331	Trisodium citrate	$C_6H_5O_7Na_3$ (anhydrous) $C_6H_5O_7Na_3.nH_2O$ (n=2 or 5) (hydrated)
E 332	Potassium citrates:	
(i) E 332	Monopotassium citrate	$C_6H_7O_7K$
(ii) E 332	Tripotassium citrate	$C_6H_5O_7K_3.H_2O$
E 333	Calcium citrates:	
(i) E 333	Monocalcium citrate	$(C_6H_7O_7)2Ca.H_2O$
(ii) E 333	Dicalcium Citrate	$(C_6H_7O_7)2Ca_2.H_2O$
(iii) E 333	Tricalcium citrate	$(C_6H_6O_7)2Ca_3.4H_2O$

naturally in grapes and can be obtained as a byproduct of the wine industry, or through chemical processes (Bastos et al., 2009; Ayora-Cañada et al., 2000).

Substituting one or two H + for sodium ions (Na^+) or potassium (K^+) various tartrates can be obtained (Table 8).

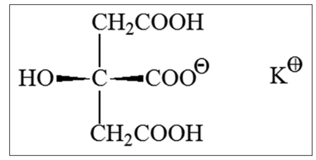

Fig 20. Monopotassium citrate (E 332i) structure.

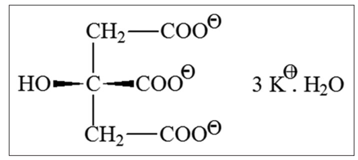

Fig 21. Tripotassium citrate (E 332ii) structure.

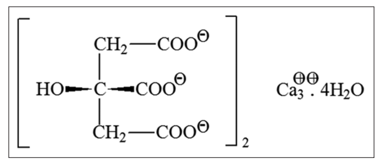

Fig 22. Tricalcium citrate (E 333iii) structure.

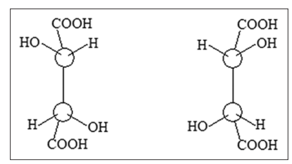

Fig 23. Acids tartaric-D (-) and tartaric-L (+) structures.

These tartrates might have a natural occurrence but can also be chemically synthesized.

L-tartaric acid, sodium and potassium tartrates (Table 8; Figs. 24 and 25) are colorless or transparent crystals, with a high solubility in water. Tartaric acid is freely soluble in ethanol but the tartrates derivatives are insoluble in ethanol (Commission Regulation (EU) Nº 231/2012; FAO, 2006).

L-tartaric acid (E334), besides being an antioxidant that can also act as a synergist for other antioxidants, is also an acidity regulator and a sequestrant. It can be used in most food products, including fresh pasta (Lidon et al., 2014), fruits and vegetables canned, cafeteria products, preserves, jams and jellies, gelatins, sugarless gum and food for children and babies (Commission Regulation (EU) Nº 1129/2011; Directive 95/2/EC). In moderate doses, it seems that E334 does not have side effects; however, high doses may have a laxative effect, and/or cause gastroenteritis and decreases calcium absorption in the human body (Voss, 2002).

Tartrates also have antioxidant properties but can also have a synergist function for other antioxidants. Additionally, they can act as stabilizers, emulsifiers, acidity regulators and sequestrants. Additives E335 and E336 may be used in the majority of food products, particularly fruit and vegetables, canned, preserves, jams and jellies, confectionery, soft drinks and food for children and babies (Commission Regulation (EU) Nº 1129/2011; Directive 95/2/EC). E337 additive can be used in most food products, including fruits and vegetables, canned products based on cheese, meat products and wines. It's long been known the laxative effect of tartrates when consumed in high doses (Voss, 2002).

Lactic acid and lactate

Lactic acid (Fig. 26) is a food additive (E270) with various technological functions, including antioxidant and synergistic action on other antioxidants, preservatives, acidity regulator and acidifying (Costa and Conte-Junior, 2015).

Lactic acid can be synthesized by bacteria from starch and can be used in most food products, including juices and nectars, compotes, jams and jellies, spreadable fats, oils and non-emulsified fats, processed cheese, sauces, olives, bread and food for infant and young children (Commission Regulation (EU) Nº 1129/2011; Directive 95/2/EC). Lactates are also used as antioxidants and synergistic of other antioxidants (Table 9). Besides, sodium lactate also has functions of humectant and bodying agent, whereas calcium lactate is used as acidity regulator and yeast food (FAO, 2006).

Sodium and potassium lactates (Figs. 27 and 28) are usually marketed in the form of colorless and transparent solutions with a slight characteristic odor, while calcium lactate (Fig. 29) is marketed in the form of crystalline powder or granules of white pearl color.

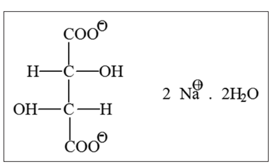

Fig 24. Disodium L-tartrate (E335ii) structure.

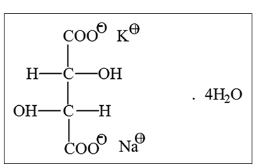

Fig 25. Potassium sodium L(+)-tartrate (E337) structure.

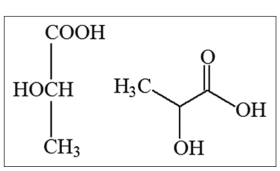

Fig 26. Lactic acid (E270) structure.

Lactates are used in most food products, namely in fruits and pickled vegetables, bread and pastries, sterilized, pasteurized and UHT cream, low-calorie cream and pasteurized low-fat cream, cheese and infant and young children food (Commission Regulation (EU) Nº 1129/2011; Directive 95/2/EC).

Phosphoric acid and phosphates

Phosphoric acid occurs in most fruits but it can also be obtained in the chemical industry. Phosphoric acid is marketed as a viscous clear, colorless, odorless liquid.

Phosphates are derived from phosphoric acid (Table 10) and can be used as food additives with different technological functions, but also including the antioxidant function (Commission Regulation (EU) No. 231/2012; Directive 2000/63/CE).

Phosphoric acid (E338) acts as an antioxidant synergist and acidity regulator, namely in non-alcoholic flavored drinks (UHT pasteurized, sterilized and powder), some

Table 7: Technological functions of citric acid and citrate

Additive code	Designation	Technological functions
E 330	Citric acid	Antioxidant, acidifying, acidity regulator, sequestering and synergist for other antioxidants
E 331	Sodium citrates:	Antioxidants and synergists of other antioxidants, acidity regulators, stabilizers, emulsifiers, sequestrants, melting salts in some types of cheese (milk) and carriers
(i) E 331	Monosodium citrate	
(ii) E 331	Disodium citrate	
(iii) E 331	Trisodium citrate	
E 332	Potassium citrates:	Antioxidants, synergists of other antioxidants, stabilizers, transport agents, sequestering and acidity regulators
(i) E 332	Monopotassium citrate	
(ii) E 332	Tripotassium citrate	
E 333	Calcium citrates:	Antioxidants, sequestering agents, synergists, other antioxidants, acidity regulators
(i) E 333	Monocalcium citrate	
(ii) E 333	Dicalcium citrate	
(iii) E 333	Tricalcium citrate	

Table 8: Tartrates and tartaric acid used as antioxidants

Additive code	Designation	Chemical formula
E 334	L (+) – Tartaric acid	C_4H_6O
E 335	Sodium tartrates:	
(i) E 335	L-Monosodium tartrate, sodium hydrogen tartrate	$C_4H_5O_6Na.H_2O$
(ii) E 335	Disodium L-tartrate	$C_4H_4O_6Na_2.2H_2O$
E 336	Potassium tartrates:	
(i) E 336	L-Monopotassium tartrate, potassium hydrogen	$C_4H_5O_6K$
(ii) E 336	L-Tartrate dipotassium	$C_4H_4O_6K_2.½H_2O$
E 337	Potassium sodium L(+)-tartrate	$C_4H_4O_6KNa.4H_2O$

types of cheese and fruit or crystallized fruit. It has also been used in desserts and powder mixes for desserts, toppings, bakery products and fine bakery, powdered sugar, gum, flour, liquid egg, sauces, soups and broths, spirits (other than wine and beer), breakfast cereals and snacks, crab sticks, fish pastes and shellfish, frozen fish fillets, shellfish and frozen crustaceans, meat products, potato products, dehydrated foods, some types of pasta, sports drinks and some foods for babies and children (Commission Regulation (EU) No. 1129/2011; Directive 95/2/EC).

Sodium phosphates (E339) have antioxidant functions but also act as synergistic or acidity regulators, emulsifiers, stabilizers, thickeners, fillers, toughening agents, chemical raising agents, anti-caking agents, sequestering agents and emulsifying salts. It is described their use as emulsifiers and stabilizers in partially dehydrated milk, powdered milk, cream (of various types), cheeses (except mozzarella) as acidity regulator in various desserts and with melting salts cheeses (Commission Regulation (EU) No. 1129/2011; Directive 95/2/EC; Rebollar, 1991).

Potassium phosphate (E340), calcium phosphates (E341) and magnesium phosphate (E343) have similar technological functions to each other and to sodium phosphate, being used as antioxidants, synergists and acidity regulators, emulsifiers, stabilizers, thickeners, fillers, hardeners, raising agents, anti-caking agents and builders. Still, E340 can be used in table waters, dietary supplements and beverages based on vegetable proteins (Commission Regulation (EU) No. 1129/2011; Directive 95/2/EC). It is also authorized to use the (E341) in white beverage mixes, ice creams and desserts.

Moreover, the use of phosphates in meat products is critical because these additives interact with the proteins, reducing dehydration and increasing the rate of moisture food products. This effect is used particularly in the production of hams and other meat products. Yet, its use is limited, not for health reasons, but to avoid excessive incorporation

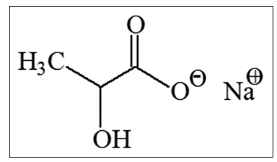

Fig 27. Sodium lactate (E325) structure.

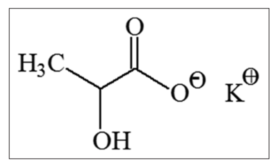

Fig 28. Potassium lactate (E326) structure.

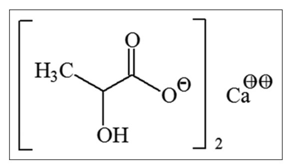

Fig 29. Calcium lactate (E327) structure.

Table 9: Lactic acid and lactates used as antioxidants

Additive code	Designation	Chemical formula
E 270	Lactic acid	$CH_3CH(OH)COOH$
E 325	Sodium lactate	$CH_3CH(OH)COONa$
E 326	Potassium lactate	$CH_3CH(OH)COOK$
E 327	Calcium lactate	$(CH_3CH(OH)COO)_2Ca$

Table 10: Phosphoric acid and its derivatives used as antioxidants

Additive code	Designation	Chemical formula
E338	Phosphoric acid	H_3PO_4
E339	Sodium Phosphates:	
(i) E339	Sodium Dihydrogen Phosphate	NaH_2PO_4 (anhydrous); $NaH_2PO_4.nH_2O$ (n=1 to 2)
(ii) E339	Disodium Hydrogen Phosphate	Na_2HPO_4 (anhydrous); $Na_2HPO_4.nH_2O$
(iii) E339	Trisodium phosphate	Na_3PO_4 (anhydrous); $Na_3PO_4.nH_2O$
E340	Potassium Phosphates	
(i) E340	Potassium dihydrogen phosphate	KH_2PO_4(anhydrous); $KH_2PO_4.nH_2O$
(ii) E334	Dipotassium hydrogen phosphate	K_2HPO_4 (anhydrous); $K_2HPO_4.nH_2O$
(iii) E334	Tripotassium phosphate	K_3PO_4 (anhydrous); $K_3PO_4.nH_2O$
E341	Calcium Phosphates	
(i) E341	Calcium dihydrogen phosphate	$Ca(H_2PO_4)_2.H_2O$
(ii) E341	Dicalcium phosphate	$CaHPO_4.2H_2O$
(iii) E341	Tricalcium Phosphate	$10CaO.3P_2O_5.H_2O$ a)
E343	Magnesium Phosphate	
	(i) Magnesium dihydrogen phosphate	$Mg(H_2PO_4)_2.nH_2O$ (n=0 to 4)
	(ii) Magnesium hydrogen phosphate	$MgHPO_4.3H_2O$

a) $10CaO.3P_2O_5.H_2O$ is the approximate composition of the mixture of various calcium phosphates, which constitute the additive, the analyzes revealed that at least 90% of $Ca_3(PO_4)_2$

of water in food, thus defrauding the consumer (Rebollar, 1991). Also a characteristic flavor enjoyed in some cheaper hams is the use of sodium phosphate instead of potassium phosphate which is more expensive. Besides, in UHT, sterilized, condensed and powder treated milk, as well as in cream, these products are used to prevent gelation. They are used as constituents of the melt processed cheese salts to prevent fat separation from the other compounds during melting.

In some types of bread, phosphates are used to improve the properties of the mass, fostering the growth of yeasts and to control its acidity. Sodium, potassium and calcium phosphates are also used as chemical raising agents, when combined with sodium bicarbonate (E500), to form "chemical yeast", used in pasta chips.

Phosphorus is essential to health. Therefore, the use of phosphates in a balanced manner is beneficial. Phosphates toxicity is restricted to a minimum and comparable to that of common salt (Rebollar, 1991). Phosphoric acid has even been used to combat the lack of heartburn. However, excessive intake of phosphates can cause decreased calcium absorption and an imbalance of the calcium/phosphorus ratio in the human body (Takeda et al., 2014; Voss, 2002).

Other antioxidants

In addition to the antioxidants mentioned above, several other substances are being used as antioxidants (Scotter and Castle, 2004) (Table 11).

Lecithins (E322) are natural substances extracted from soy beans, seeds of other leguminous plants, groundnut, corn and eggs. In food products may have antioxidant functions, or act as emulsifiers, supporter for dyes, coating agents for fruits, carriers and stabilizers (Holló et al., 1993). Lectins have no risk to health and can be used in most food products, particularly cocoa and chocolate products, powdered milk, cream, margarine and other spreadable fats in confectionery, mayonnaise, oils and fats emulsified in pastries and fine bakery, bread, fresh pasta, biscuits, ice cream, desserts and foods for infants and children (Commission Regulation (EU) No. 1129/2011; Directive 95/2/EC).

Calcium disodium EDTA (E385) is a substance of synthetic origin (Van de Sande et al., 2014). When added to food products, have antioxidant function but is also a strong sequestrant (Fig. 30). Calcium disodium EDTA is the sodium and calcium derivative of ethylenediaminetetraacetic acid (EDTA). This substance used as a food additive is present in the form of white or nearly white powder, slightly hygroscopic, is freely soluble in water, practically insoluble in ethanol.

Table 11: Other antioxidants substances used in food products

Additive code	Designation	Chemical formula
E322	Lectins	_____a)
E385	Calcium disodium EDTA, Calcium disodium ethylenediaminetetraacetate	$C_{10}H_{12}O_8CaN_2Na_2.2H_2O$
E512	Stannous chloride	$SnCl_2.2H_2O$

a) Lecithins are mixtures or fractions of phosphatides obtained by physical procedures from animal or vegetable foodstuffs; they also include hydrolyzed products obtained through the use of harmless and appropriate enzymes (Commission Regulation (EU) No. 231/2012).

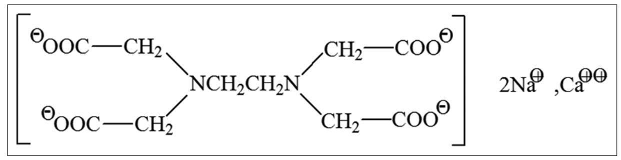

Fig 30. Calcium disodium EDTA (E385) structure.

E385 is a substance produced synthetically that has no known side effects when consumed in food products at recommended small doses (Van De Sande et al., 2014; Lanigan and Yamarik, 2002). This additive has been used in the treatment of heavy metal poisonings, yet since is a strong sequestrant, in high doses can combine to essential metals (iron, zinc, copper) in the human organism and prevent their metabolic use. At very high doses causes vomiting, diarrhea, abdominal cramps, urinary disturbances and blood in the urine. This additive is not authorized in Australia (Lanigan and Yamarik, 2002; Voss, 2002). E385 has been used in emulsified sauces, vegetables, legumes, mushrooms and artichokes canned, frozen crustaceans and fish products.

The stannous chloride (E512) is also a substance of synthetic origin, which is usually added to canned white asparagus to prevent oxidation and to fix the color. When consumed at high doses, some side effects might be gastric disorders (nausea and vomiting), whereas a metallic taste can occur (Arora et al., 2009).

CONCLUSION

There are a significant number and diversity of food additives having antioxidant properties that protect food products against oxidation (which thereby extend the shelf life). Jointly to other techniques, such as hermetically sealed packaging, the use of packaging with modified atmosphere without oxygen, and the use of sequestrant food additives, food additives antioxidants have an incontestable importance in food technology, to prevent oxidation of foodstuff. There are two main oxidation processes of foodstuff: (i) the enzymatic oxidation of fruits, vegetables and their processed derivatives; (ii) oxidation and ramification of fats and oils.

So the agrofood companies use antioxidant additives in a large amount of food products. Nevertheless, all additives and related uses are regulated by the EU legislation. The specific applications of each food additive depend of several factors, namely solubility, antioxidant characteristics and safety. However, the use of some of these food additives is not absent side effects to health. Food antioxidants, such as BHA, BHT, gallates, and stannous chloride might present meaningful side effects, and should be used in the smallest possible amount, maintaining the necessary technological features. Other food antioxidants, such as tocopherols, acid ascorbic and ascorbates, citric acid and citrates, tartaric acid and tartrates, lactic acid and lactates, when applied to foodstuffs do not appear to have side effects in the amounts indicated by the EU regulation.

Authors' contribution

Both the authors of the paper contributed equally to the writing of the paper and are involved in the overall planning and supervision of the work.

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