PANEL 1

VITAMIN C IN FOOD PROCESSING

Ascorbic acid (vitamin C) is used extensively in the food industry, not only for its nutritional value but for its many functional contributions to product quality.

Acting as an antioxidant, ascorbic acid can improve the color and palatability of many kinds of food products. By removing oxygen from its surroundings, ascorbic acid in its reduced form becomes the oxidized form, dehydroascorbic acid (Figure 1). This oxidizing action reduces the available oxygen in its immediate environment, making ascorbic acid an effective antioxidant.

Figure 1. Enzymatic browning occurs when oxygen and polyphenolases are present.

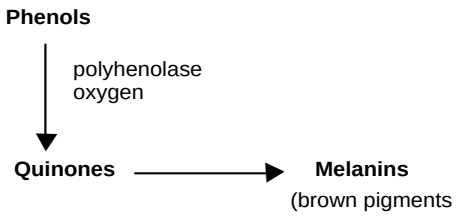
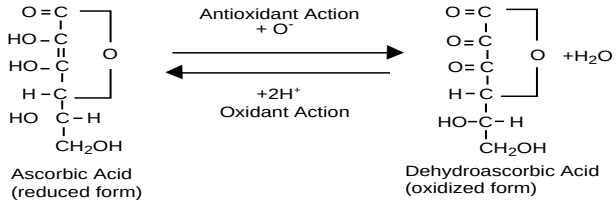


Figure 2. By the oxidation of ascorbic acid to deydroascorbic acid, quinones are reduced back to phenols and/or oxygen is removed from the immediate environment.



Beverages

Ascorbic acid addition is common in the manufacture of beverages, especially those made from fruit juices. Ascorbic acid not only restores nutritional value lost during processing, but also contributes to the products' appearance and palatability.

Fruits can be divided into two categories: those that show discoloration upon cutting and those that do not. Fruits such as apples, bananas and peaches belong to the first group, while oranges, lemons, and other fruits that contain a large amount of ascorbic acid belong to the second. Besides variety, natural vitamin C content in fruit varies (Table 1) with growing region, climate, and time of harvest.

In the manufacture of fruit juices or purees from fruits such as apples and peaches, ascorbic acid may be added during the crushing, straining, or pressing processes to prevent enzymatic browning of the raw fruits. Browning takes place when enzymes called polyphenolases, which occur naturally in fruit tissue, catalyze the oxidation of phenols, also naturally present in the fruit, to form compounds called quinones. The quinones can then polymerize to form melanins, which cause the brown pigments (Figure 1).

Ascorbic acid can inhibit browning reactions by reducing the quinones back to the original phenol compounds. In the presence of oxygen or metal ions, the phenols can readily convert to quinones.

Table 1. Ascorbic acid content of fruits

	mg/100g
Apple	2-10
Apricot	7-10
Banana	10-30
Cantaloupe	40
Cherry	5-8
Grapefruit	40-50
Guava	300
Lemon	50
Lime	25
Orange	50
Peach	7
Pear	4
Pineapple	25
Strawberry	60
Tomato	25

PANEL 2

By chelating metal ions and reducing oxygen, ascorbic acid can make each compound unavailable for reacting with the phenols (Figure 2). Also, because polyphenolases are most active in a pH range between 6.0 and 7.0, combinations of ascorbic acid and citric or malic acids are sometimes used to diminish enzyme activity by lowering the pH of the juice or fruit puree. Heat treatment or pasteurization during processing will also inactivate the enzymes and prevent any further enzymatic browning in the final juice products.

Other benefits of ascorbic acid addition

- When secondary processed products such as fruit drinks or soft drinks are made from fruit juices or purees, additional ascorbic acid is often added during the mixing process to restore nutrient losses that might have occurred during processing.
- Ascorbic acid is added to soft drinks and fruit beverages to prevent oxidative flavor deterioration.
- Adding extra ascorbic acid to bottled and canned beverages reduces the oxygen in the head spaces of the containers to prevent future oxidation of the product. Usually 3.3 mg of ascorbic acid will remove the oxygen in 1cc of headspace.

Stability of ascorbic acid when added as a nutrient

If ascorbic acid is added as a nutrient to beverages, either to replace processing losses or as fortification, the stability of the ascorbic acid over the shelf-life of the product becomes important. There have been many studies on the stability of ascorbic acid in different beverages, different containers, and under exposure to different types of light. Marcy and coworkers observed a 40% loss of ascorbic acid in an aseptically packaged orange drink containing 10% orange juice after six months at storage temperatures of 4°and 15°C and up to a 75% loss at 22° and 30°C. Sattar and coworkers observed the greatest losses of ascorbic acid in a HTST pasteurized orange drink pack-

Table 2. Losses of ascorbic acid in an aseptically packaged orange drink after six months of storage.

	Percent Ascorbic Acid Loss	
Temperature (°C)	**A***	**B****
4	13	40
15	20	40
22	40	75
30	72	75

* Initially containing 0.8ppm dissolved oxygen

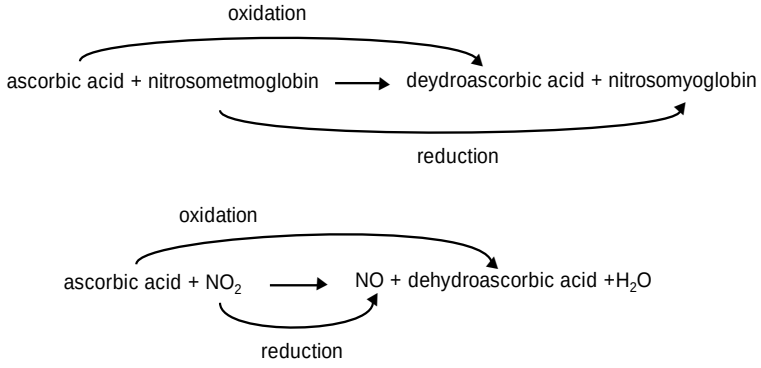
Table 3. Effect of container and light on the percent losses of ascorbic acid in HTST-pasteurized oran drink after 32 days' storage at room temperature.

	Percent loss	
	Fluorescent light	Incandescent light
Clear glass	60.60	66.00
Green glass	54.60	59.90
Tetra Pak	51.00	51.90
Amber glass	45.50	50.30
Control*	42.40	42.40

* Control remained unexposed to light.

aged in clear or green glass; tetraPak and amber glass had lower losses when exposed to fluorescent light over a 30 day storage period at temperatures between 25-30°C. Similar findings were observed by Sattar and coworkers using the same packaging and temperature conditions, but exposed to incandescent light. Ahmed and coworkers observed greater ascorbic acid losses in orange juices and drinks stored in plastic and paperboard containers held at 5-7°C than in glass containers held at similar temperatures.

Figure 3. The main reactions involving ascorbic acid in cured meats.



Meat Products

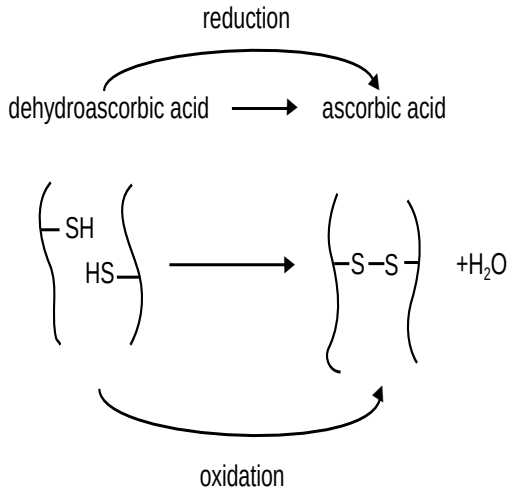
Ascorbic acid is also widely used in the meat industry for its antioxidant properties. In cured meats, ascorbic acid can: (1) accelerate color development, (2) inhibit nitrosamine formation, (3) prevent oxidation, and (4) prevent color fading. Ascorbic acid is also used in fresh meat to prevent oxidation and color fading during storage.

When ascorbic acid is added to cured meats, it oxidizes to become dehydroascorbic acid. It is this oxidation that accelerates the reduction of nitrosomet-myoglobin to nitrosomyoglobin (Figure 3), which imparts to cured meats their characteristic color.

Ascorbic acid can prevent nitrosamine formation in cured meats by reducing nitrate to nitrogen oxide, which will not be able to react with the amines to form nitrosamines (Figure 4).

Ascorbic acid also prevents the oxidation of lipids and fats in both raw and cured meat products. Lipid oxidation causes the release of many lower-weight molecules, which can impart off-flavors and rancid notes to the meat. By reducing the oxygen in the environment, less oxygen is available to breakdown the lipids. The color of both fresh and cured meats is sensitive to decomposition caused by oxidation of the myoglobin in the tissues. Ascorbic acid's antioxidant action prevents

Figure 4. Reactions involving ascorbic acid as a dough improver



the myoglobin from oxidizing to metmyoglobin, which has a brown color.

Oils and Fats

The unsaturated long-chain fatty acids present in fats and oils readily oxidize when exposed to heat, light, and air. As in meats, lower molecular weight compounds are formed and impart rancid odors and flavors. Because ascorbic acid is a water soluble compound, it can control these reactions only to a certain extent. The antioxidant effects of ascorbic acid are more apparent in an oil system if ascorbic acid is used in combination with other antioxidants such as tocopherols, BHT, and BHA. In fat systems the use of fat soluble esters of ascorbic acid, such as ascorbyl stearate or ascorbyl palmitate are recommended.

Dough Systems

Ascorbic acid's ability to improve bread dough has been known since the 1930s. In dough systems, adding ascorbic acid to the flour improves both bread texture and loaf volume. The ascorbic acid is first oxidized to dehydroascorbic acid. Then the reduction of dehydroascorbic acid back to ascorbic acid drives the reaction of sulfhydryl compounds in the gluten to form intermolecular disulfide bonds (Figure 4). It is the network of disulfide bonds formed in the gluten structure that enables the dough to retain carbon dioxide produced by the yeast, which in turn allows for maximum volume and improved texture.

As a nutrient

In addition to its benefits as a processing aid and preservative, ascorbic acid has nutritional value in food products.

Fruits, vegetables and juices are primary sources of vitamin C in the diet (Table 2), but during processing and storage, vitamin C losses may occur. Many processors add ascorbic acid to their products to make up for processing losses.

Vitamin C may also be added for caloric density fortification, which is the addition of nutrients to a food based on the caloric content, and for standardization. Differences in crops and in processing conditions may affect final vitamin content, and standardization insures that all food products in the same category have the same amount of a particular nutrient per serving.

Several studies have shown that airtight and non-light penetrating (brown, amber, opaque) containers are best used to protect vitamin C from degradation. Overages of vitamin C above the label claim are usually necessary to insure label claim compliance after processing and storage.

Processing with Ascorbic Acid

Ascorbic acid has many applications in the food industry. It is used to reduce browning in fruits and vegetables; as a processing aid and to reduce nitrosamine formation in cured and raw meat products; to reduce the oxidation of fats and lipids; and as a dough conditioner.

Ascorbic acid stability is greatly influenced by temperature, oxygen, and metal ion content. Precautions should be used when adding ascorbic acid as a nutrient to processed fruit products:

(1) Use stainless steel or plastic manufacturing equipment.
(2) Remove as much oxygen as possible from equipment and containers.
(3) Use flash heat sterilization and/or add the ascorbic acid as close to the end of thermal processing as possible.

Summary

Ascorbic acid will not upgrade poor raw materials or cover poor processing techniques, and it should be used in connection with good manufacturing practices. Standards of identity regulating the amount of vitamin C addition vary for each product must be individually checked.

PANEL 5

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