EASTMAN

Eastman Tenox™ *food-grade antioxidants*

for refined vegetable oils

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Eastman Tenox™ food-grade antioxidants can contribute stability to vegetable oils during processing and help increase their shelf life.

Using Eastman Tenox™ antioxidants can result in less waste and increased sales of these food products. Tenox antioxidants are easy to handle and incorporate into oils. They are effective stabilizers at low-use levels with good "carry-through" properties, making them economical to use.

Worldwide, more than 60 million metric tons of vegetable oils are produced annually for food use. Soybean oil, sunflower oil, and palm oil make up more than half of the total production. All vegetable oils must be extracted, refined, and purified by bleaching and deodorizing before being sold as foods such as salad oils or used in foods such as mayonnaise, margarine, baked goods, and salad dressings (where permitted by FDA standards of identity). Most oils should be stabilized during production to protect against rancidity. Eastman Tenox™ antioxidants can accomplish this in many types of oils. This publication reviews effective Tenox antioxidant formulations for each type of oil, their incorporation into the oils, and appropriate levels of use.

Oxidative rancidity — a problem in edible vegetable oils

Rancidity makes edible products unacceptable to consumers. Oxidative rancidity in oils occurs when heat, light, metals, or other catalysts cause unsaturated oil molecules to convert to free radicals. These are easily oxidized to form hydroperoxides and organic compounds, such as aldehydes, ketones, or acids, that can cause undesirable odors and flavors. This process accelerates rapidly in vegetable oils as a chain reaction. Antioxidants absorb the energy of activated fat molecules and retard oxidation.

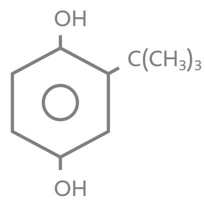
Eastman Tenox™ food-grade antioxidants — an effective answer

Eastman offers three antioxidants that are lawful under existing food-additive regulations by the U.S. Food and Drug Administration for use in vegetable oils at levels outlined in this publication. They are Eastman Tenox™ TBHQ antioxidant (tertiary-butyl hydroquinone), Eastman Tenox™ BHA antioxidant (butylated hydroxyanisole), and Eastman Tenox™ BHT antioxidant (butylated hydroxytoluene). In addition, formulations containing combinations of these three antioxidants, citric acid (chelating agent or synergist), and edible solvents (carriers) are available. With this range of choices, oil producers can tailor an antioxidant to specific requirements and maximize its efficiency and benefits to the end product.

Eastman offers antioxidants that are lawful under existing food-additive regulations.

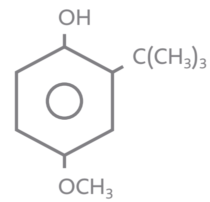
Physical properties of Eastman Tenox™ food-grade antioxidants

Eastman Tenox™ TBHQ

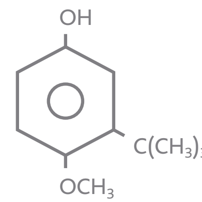


tertiary butylhydroquinone

Eastman Tenox™ BHA

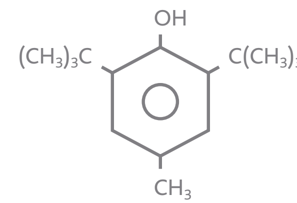


3-tertiarybutyl-4-hydroxyanisole



2-tertiarybutyl-4-hydroxyanisole

Eastman Tenox™ BHT



3,5-di-tert-butyl-4-hydroxytoluene

	Eastman Tenox™ TBHQ	Eastman Tenox™ BHA	Eastman Tenox™ BHT
Molecular weight	166.22	180.25	220
Physical appearance	White to light tan powder	White to slightly yellow solid	White granular crystals
Boiling point, 760 mm Hg, °C	300	264–270	265
Melting point, °C	126.5–128.5	48–63	69.7
Odor	Very slight	Slight	Very slight

Solvent		**Solubility, % (approx.)**	
Water, 25°C	<0.4	<0.1	Insoluble
Glycerol, 25°C	23	1	Insoluble
Ethyl alcohol, 25°C	60	80	32
Propylene glycol, 25°C	30	63	2
Cottonseed oil, 25°C	10	30	27
Corn oil, 25°C	10	30	26
Canola oil, 25°C	6	30	26
Soybean oil, 25°C	10	30	26
Palm oil, 50°C	10	65	55
Lard, 50°C	15	65	50

Eastman Tenox™ antioxidants for use in vegetable oils

Antioxidant compound or formulation	Characteristics: Physical state	Characteristics: Typical color	Composition, wt %, Active ingredients[a]: BHA	BHT	TBHQ	Citric acid
Eastman Tenox™ BHA	Solid	White to slightly yellow	100	—	—	—
Eastman Tenox™ BHT	Solid	White to light tan	—	100	—	—
Eastman Tenox™ TBHQ	Solid	White to light tan	—	—	100	—
Eastman Tenox™ 4	Liquid	Light straw	20	20	—	—
Eastman Tenox™ 4B	Liquid	Light straw	20	—	—	—
Eastman Tenox™ 8	Liquid	Light straw to light amber	—	20	—	—
Eastman Tenox™ 20	Liquid	Light amber to golden brown	—	—	20	10
Eastman Tenox™ 20A	Liquid	Golden brown	—	—	20	3
Eastman Tenox™ 21	Liquid	Golden brown	—	—	20	1
Eastman Tenox™ 25	Liquid	Golden brown	—	10	10	3
Eastman Tenox™ R	Liquid	Light straw	20	—	—	20

[a]*Carriers used in solution formulations include vegetable oil, propylene glycol, and/or mono- and diglycerides.*

Regulations governing antioxidant use in refined vegetable oils

United States

Many of the suggested applications in this publication are the subject of standards of identity published by the U.S. Food and Drug Administration (FDA). Customers must determine that their use of Eastman Tenox™ antioxidants is lawful in their intended application.

In accordance with existing FDA food-additive regulations, BHA, BHT, and TBHQ are lawful for use singly or in combination at a level not to exceed 0.02% based on the weight of fat or oil, including essential oil, content of the food.

In accordance with FDA regulations, the ingredients in a food must be declared on the product label in descending order of predominance. Antioxidants must be identified by their common names and purpose. Example, "TBHQ added to protect flavor."

Regulations outside the United States

Eastman Tenox™ antioxidants may be used in refined vegetable oils in most countries. The following information provides a broad indication of the wide acceptance of the major phenolic antioxidants.

This information is not to be taken as a complete and currently accurate representation of food-antioxidant regulatory status in the listed countries, nor is it intended to imply that antioxidants are not permitted in countries not included in this listing. Prospective antioxidant users should consult the appropriate regulatory agency in their country concerning the use of antioxidants.

European Community (EC)

Permitted antioxidant	EC regulation	
BHA	E320	Each EC member country establishes maximum permitted levels for various uses for antioxidants.
BHT	E321	
TBHQ	E319	

Other countries — permitted use

	International Numbering System (INS) number		
Country	BHA (320)	BHT (321)	TBHQ (319)
Argentina	✔	✔	✔
Australia	✔	✔	✔
Austria	✔	✔	✔
Bahamas	—	—	✔
Bahrain	—	—	✔
Belgium	✔	✔	✔
Bermuda	—	—	✔
Bolivia	—	—	✔
Brazil	✔	✔	✔
Canada	✔	✔	✔
Chile	✔	✔	✔
China (People's Republic)	✔	✔	✔
China (Taiwan)	✔	✔	✔
Codex Alimentarius	—	—	✔
Colombia	✔	✔	✔
Costa Rica	—	—	✔
Cyprus	—	—	✔
Czech Republic	—	—	✔

Other countries — permitted use *(continued)*

	International Numbering System (INS) number		
Country	BHA (320)	BHT (321)	TBHQ (319)
Denmark	✔	✔	✔
Ecuador	—	—	✔
Egypt	✔	—	—
Estonia	—	—	✔
Finland	✔	✔	✔
France	✔	✔	✔
Germany	✔	✔	✔
Greece	✔	✔	✔
Guatemala	—	—	✔
Hungary	—	—	✔
India	✔	—	✔
Indonesia	✔	✔	✔
Ireland	✔	✔	✔
Israel	✔	✔	—
Italy	✔	✔	✔
Japan	✔	✔	—
Korea, South	✔	✔	✔
Kuwait	✔	✔	✔
Latvia	—	—	✔
Lithuania	—	—	✔
Luxembourg	✔	✔	✔
Malaysia	✔	✔	✔
Malta	—	—	✔
Mexico	✔	✔	✔
Netherlands	✔	✔	✔
New Zealand	✔	✔	✔
Nigeria	—	—	✔
Norway	✔	✔	—

	International Numbering System (INS) number		
Country	BHA (320)	BHT (321)	TBHQ (319)
Pakistan	✔	✔	—
Paraguay	✔	✔	✔
Peru	—	—	✔
Philippines	✔	✔	✔
Poland	—	—	✔
Portugal	✔	✔	✔
Qatar	—	—	✔
Romania	—	—	✔
Russia	—	—	✔
Saudi Arabia	✔	✔	✔
Singapore	✔	✔	✔
Slovakia	—	—	✔
Slovenia	—	—	✔
South Africa	✔	✔	✔
South Korea			✔
Spain	✔	✔	✔
Sri Lanka	—	—	✔
Sultanate of Oman	—	—	✔
Sweden	✔	✔	✔
Taiwan	—	—	✔
Thailand	—	—	✔
Trinidad & Tobago	—	—	✔
Turkey	—	—	✔
United Arab Emirates	—	—	✔
United Kingdom	✔	✔	✔
Uruguay	—	—	✔
Vietnam	—	—	✔
Zimbabwe	—	—	✔

Methods of incorporation

Complete solution or dispersion of antioxidants in vegetable oil is necessary for maximum effectiveness. One of the following methods may be used, depending on plant facilities and type of antioxidant.

Direct method

The oil should be heated to 63°C–80°C (145°F–176°F) and then agitated until the entire body is in motion. (Agitation should not be so vigorous that excessive air is entrapped.) The antioxidant should then be added slowly. After addition is complete, agitation should be continued an additional 20 minutes to ensure uniform antioxidant distribution.

Proportionate method

The antioxidant or antioxidant concentrate in the oil to be stabilized may be proportioned or metered into a pipeline through which the hot oil (60°C/140°F minimum) is being circulated. A stainless steel proportioning pump is used to meter the antioxidant or antioxidant concentrate into the oil at the desired rate. The antioxidant solution is fed into the inlet to the circulating pump.

The success of the proportioning technique depends on the length of the pipeline and the turbulence provided by the circulating pump. It is suggested that the pipeline be a minimum of 2 inches in diameter and approximately 100 feet long. Turbulence should be sufficient to thoroughly mix the antioxidant in the oil before the mixture reaches the final storage tank.

Evaluating Eastman Tenox™ antioxidants in refined vegetable oils

Stability tests

Oxidative stability of antioxidant-treated refined vegetable oils can be determined by storing the product under normal use conditions and examining the samples periodically for changes in odor or flavor, or by testing them chemically for rancidity. These procedures generally require an extended time period. Therefore, accelerated tests are often used to compare untreated (controls) and antioxidant-treated products. This is particularly useful for quality control or product development.

Active Oxygen Method (AOM)

The Active Oxygen Method has been widely used for years on fats and oils that are liquid at the test temperature. It is not applicable to solid material. Air is bubbled through the heated test sample to speed oxidation and shorten testing time. Periodic analyses determine when the peroxide content reaches the rancidity point. For vegetable fats and oils, the accepted industry standard is 70 meq peroxide/kg of fat or oil.

The AOM is labor-intensive and can take substantial time. Although some processors continue to use this method, the American Oil Chemist's Society (AOCS) discontinued the AOM as an approved method in 1994.

Oil Stability Index (OSI)

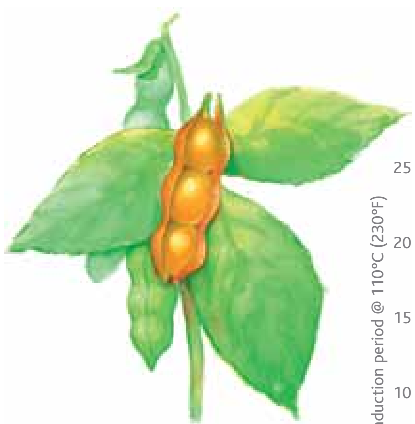
The Oil Stability Index is an automated, accelerated method of measuring stability of fats and oils. Fat or oil samples held at a constant temperature between 110°C and 130°C are exposed to a stream of purified air. Over time the fat or oil begins to oxidize, giving rise to volatile organic acids. The volatile decomposition products, trapped in a measuring vessel filled with distilled water, are continuously monitored with a conductivity probe. The "induction period" is the time at which the rapid acceleration of oxidation occurs and is recorded as number of hours.

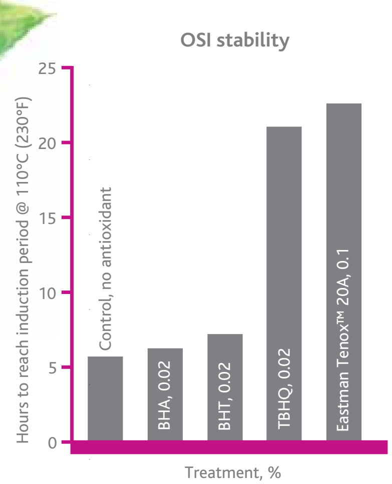
Oven storage tests

Higher temperatures will accelerate oxidation. Oven storage tests are shelf storage tests conducted at elevated temperatures to speed up the procedure. Periodic odor and flavor evaluations are commonly used, but chemical analyses (for example, peroxide content) may be used to determine rancidity development in the samples.

Soybean oil

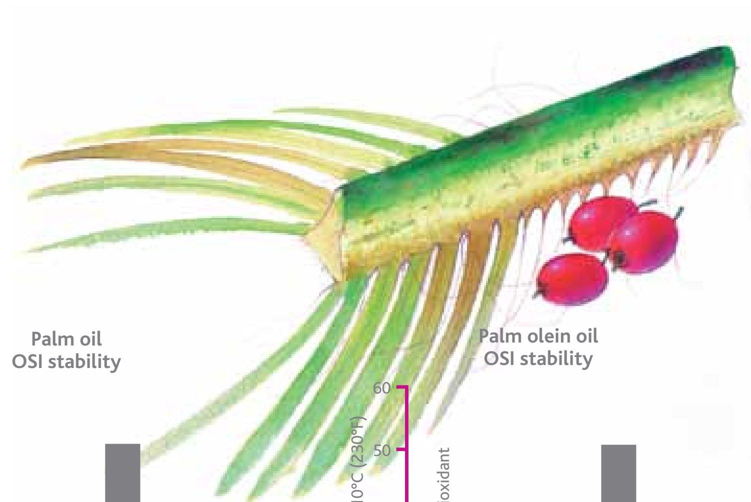
Soybean oil constitutes more than one-quarter of the world production of vegetable oils used in margarines, shortenings, salad dressings, mayonnaise, and cooking oil. This oil is highly unsaturated, and its high linolenic acid content leads to oxidative deterioration. This must be countered by partial hydrogenation or addition of an antioxidant. Eastman Tenox™ antioxidant formulations, containing TBHQ, provide increased stabilization of soybean oil as compared with BHA and BHT.

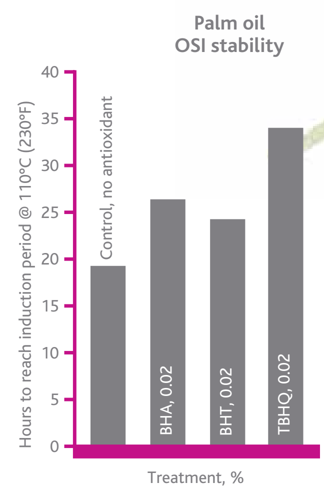


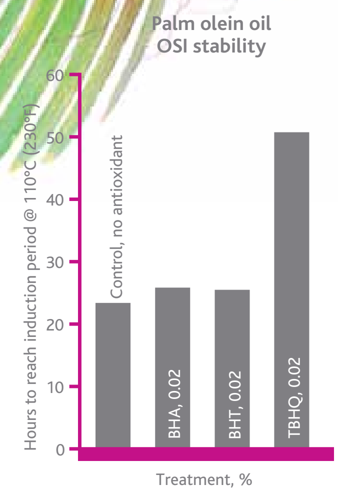


Palm and palm olein oils

Palm and palm olein oils are really fats, since they are semisolid at room temperature. They are pressed from the fruit of the oil palm grown in Africa, Malaysia, and Indonesia. These oils are used in margarine, shortening, and as frying oils. Strong enzyme activity in the fruit pulp leads to hydrolytic rancidity that is not responsive to antioxidants. Heat treatment of the pulp will inactivate these enzymes. Due to their high saturation, palm oils are quite resistant to oxidation; however, their stability can be significantly improved with Eastman Tenox™ TBHQ antioxidant.





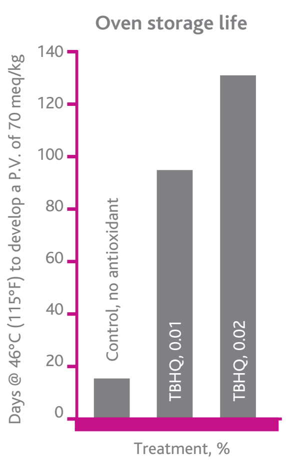


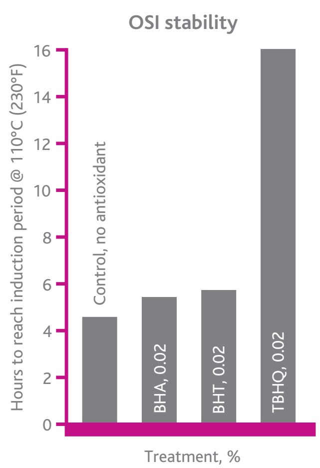
Sunflower oil

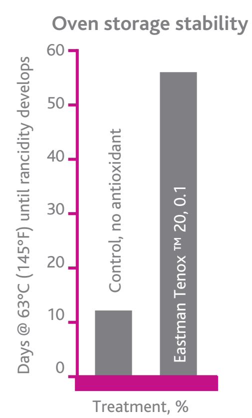
Sunflower oil is used as a cooking or salad oil and is also used in the production of margarine and shortening. It contains a high level of unsaturated fatty acids and responds measurably to Eastman Tenox™ TBHQ food-grade antioxidants.

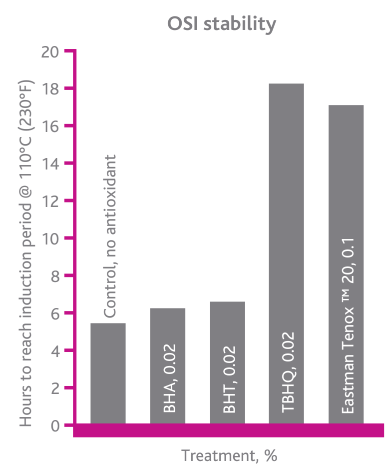
Cottonseed oil

Cottonseed oil is used mainly as a cooking or salad oil and, after partial hydrogenation, in the production of margarine and shortening. Its oxidative stability is enhanced appreciably by Eastman Tenox™antioxidant formulations containing TBHQ.



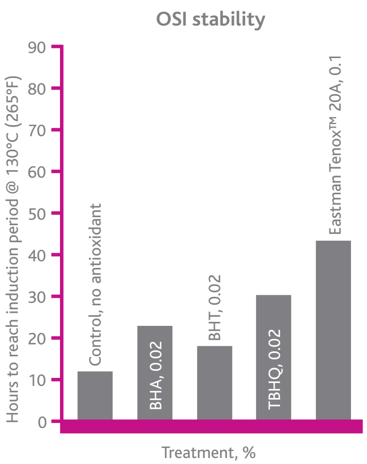






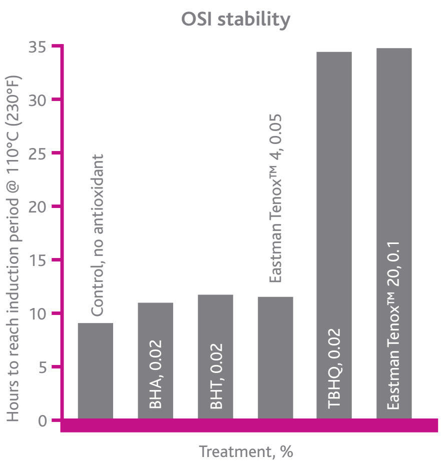
Coconut oil

Coconut oil, a lauric acid fat, has a relatively sharp melting point, bland flavor, and is highly resistant to oxidation. Coconut oil is used in margarine production, baking, and in confectionery applications. A significant disadvantage is its susceptibility to hydrolytic rancidity, which imparts a soapy flavor to food and oils. Antioxidants are ineffective in preventing this type of rancidity; however, they do increase the overall oxidative stability of coconut oil.



Peanut oil

Peanut oil (also known as groundnut, arachis, or earthnut oil) is primarily used in the production of shortenings, margarine, and as a cooking or salad oil. Compared with other major vegetable oils, peanut oil is highly unsaturated. Its stability may be substantially increased by the use of Eastman Tenox™ antioxidant formulations containing TBHQ.

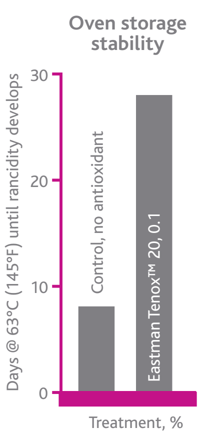


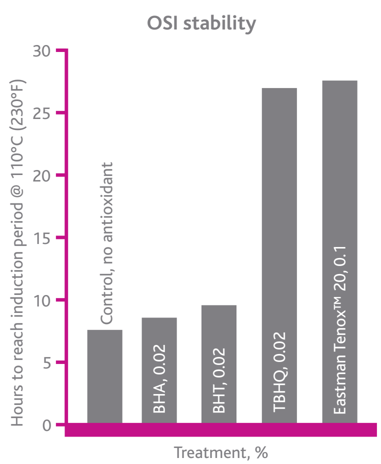
Canola (low-erucic rapeseed) oil

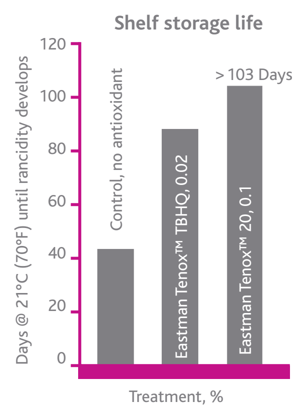
Canola oil is characterized by a high content of long-chain fatty acids, giving this oil the unique feature of high viscosity which differentiates it from other vegetable oils. Canola oil is used in the production of margarine, shortenings, and salad oil. Like soybean oil, it is high in linolenic acid and susceptible to oxidation. Eastman Tenox™ antioxidants can be used to inhibit oxidative rancidity, particularly those containing TBHQ.

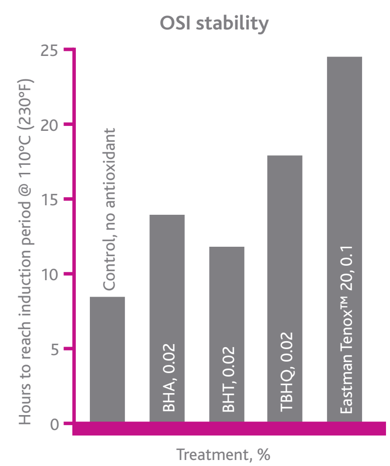
Olive oil

Virgin olive oil is not deodorized and is prized for its high flavor, odor, and color characteristics. It is used almost exclusively for cooking and as salad oil. Containing low levels of polyunsaturated fatty acid, olive oil has greater oxidative stability than other liquid vegetable oils, and its high natural flavor and odor tend to mask rancidity when it does occur. Its oxidative stability is measurably improved with the use of antioxidant-chelating agent (citric acid) combinations such as Eastman Tenox™ 20 antioxidant.



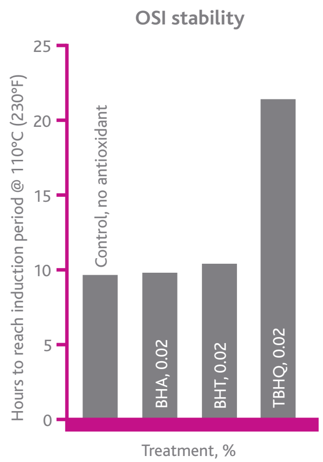






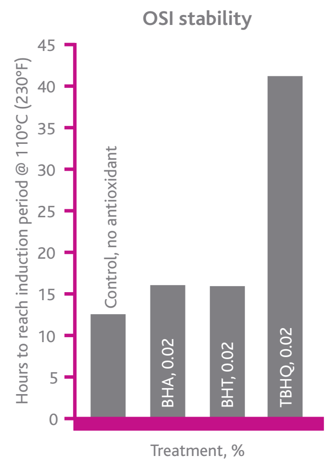
Corn oil

Corn oil is extracted from the germ of the corn kernel. It is used as salad and cooking oil and in mayonnaise. When partially hydrogenated, it is used to produce margarine and shortenings. Corn oil, which is relatively unsaturated, is oxidation-prone but responds well to treatments with Eastman Tenox™ antioxidants, particularly TBHQ.



Safflower oil

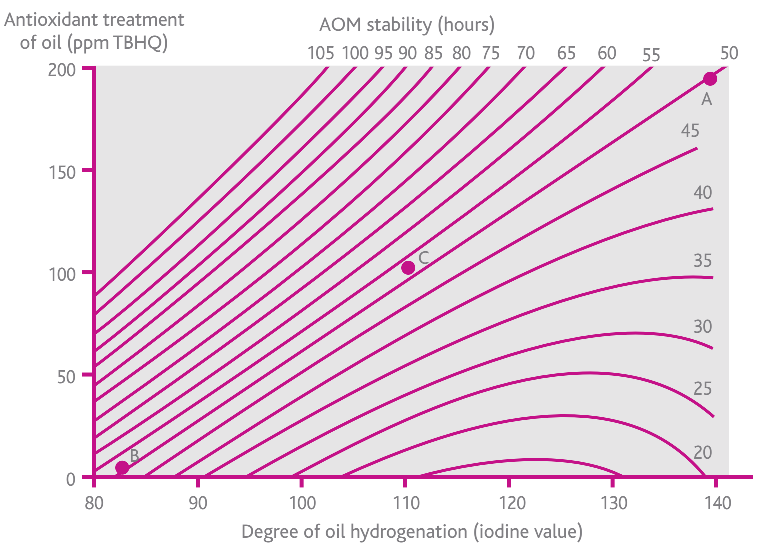
Safflower oil, the most highly unsaturated of edible oils, is used when polyunsaturated oil is desired. It is oxidation-prone; however, Eastman Tenox™ antioxidants can be used to inhibit oxidative rancidity.



Eastman Tenox™ TBHQ food-grade antioxidant — an alternative to hydrogenation

Refined vegetable oils are often hydrogenated to "harden" them so they will be suitable for use as shortenings or in other applications requiring higher-melting fats. Hydrogenation improves oxidative stability of the oil, but it is expensive and hydrogenation capacity is limited. Eastman Tenox™ TBHQ food-grade antioxidant is an alternative or supplement to oil hydrogenation for increased oxidative stability. The graph compares the effects of hydrogenation and treatments with Tenox TBHQ antioxidants, individually and in combinations, on the oxidative stability of soybean oil.

Effects of antioxidant treatments and hydrogenation on oxidative stability (AOM) of soybean oil



Point A – Oil with 0.02% TBHQ = 50 AOM hours at 140 iodine value
Point B – Hydrogenated oil = 50 AOM hours at 80 iodine value
Point C – Combination of hydrogenation to 110 iodine value and 0.01% TBHQ = 50 AOM hours

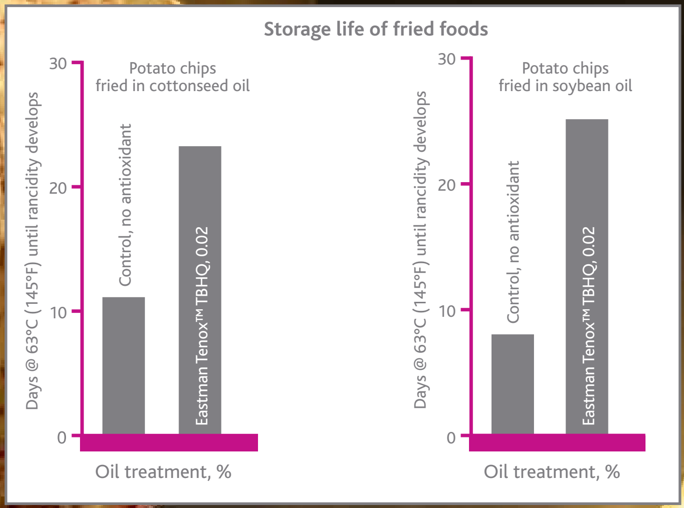
Eastman Tenox™ food-grade antioxidants — effective in frying oils

Antioxidants are added to frying oils early in their production to protect them during handling, shipping, and storage. Eastman Tenox™ food-grade antioxidants are effective in this application. They also provide good "carry-through" properties into foods fried in these oils, thus increasing the shelf life of the end product. The charts on page 14 show this effect in potato chips.

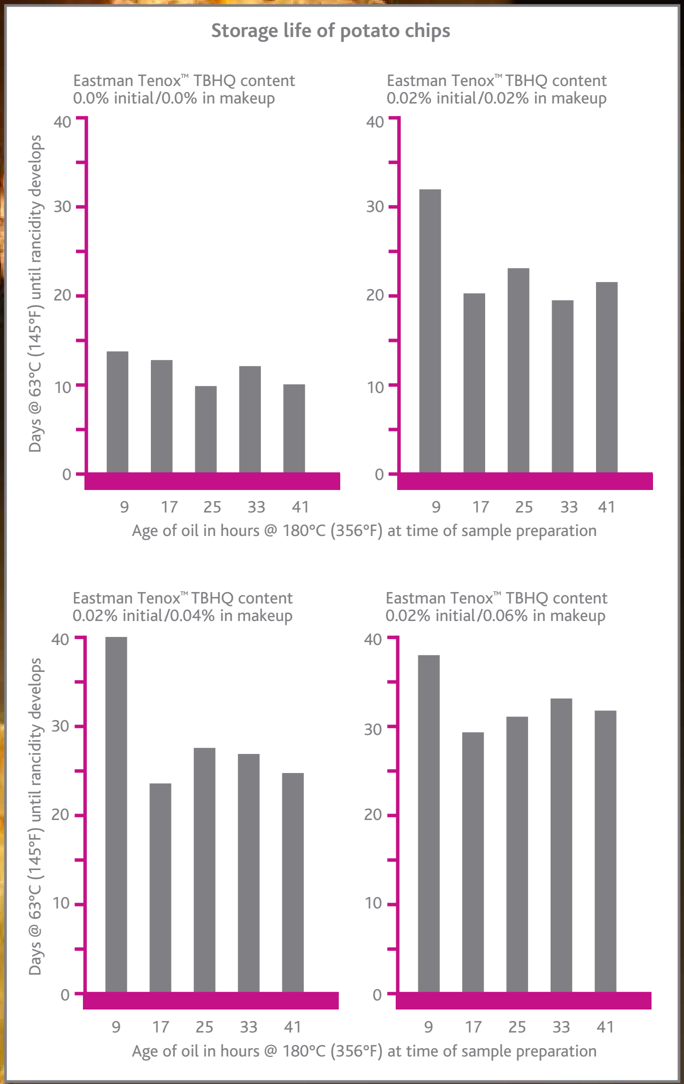
Extended frying of commercial quantities of food is continuous and the oil and antioxidant are constantly being depleted. If the antioxidant content of the cooking oil is to be replenished to an allowable high level of effectiveness, the makeup oil should contain an antioxidant concentration as high as initially present in the oil.

Laboratory tests at Eastman show that potato chips cooked in vegetable oils in which the antioxidant content has been maintained at proper, effective levels will have an enhanced, more reliable shelf life. An antioxidant content of 0.02% Eastman Tenox™ TBHQ in both the initial cooking oil and the makeup oil should impart satisfactory shelf life stability to fried foods distributed, stored, and displayed under preferred environmental conditions.

The use of higher concentrations of TBHQ (0.04%–0.06%) in the makeup oil may be considered to satisfy unusual stabilization needs such as extended hot-weather shelf life. The charts on page 14 show the effects of replenishing TBHQ antioxidant in the potato chip frying oil.



Storage life of fried foods
Potato chips fried in cottonseed oil
Potato chips fried in soybean oil
Days @ 63°C (145°F) until rancidity develops
30
20
10
0
Control, no antioxidant
Eastman Tenox™ TBHQ, 0.02
Oil treatment, %



Storage life of potato chips
Eastman Tenox™ TBHQ content 0.0% initial/0.0% in makeup
Eastman Tenox™ TBHQ content 0.02% initial/0.02% in makeup
Eastman Tenox™ TBHQ content 0.02% initial/0.04% in makeup
Eastman Tenox™ TBHQ content 0.02% initial/0.06% in makeup
Days @ 63°C (145°F) until rancidity develops
40
30
20
10
0
9
17
25
33
41
Age of oil in hours @ 180°C (356°F) at time of sample preparation

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