EASTMAN

Eastman Tenox™
food-grade

ntioxidants

Contents

Flavor and odor are important factors by which the consumer judges a food product.

The product may be accepted or rejected depending entirely on the freshness of flavor and aroma. Oxidation causes deterioration of these important qualities, resulting in foods with unpleasant flavors and unappetizing odors. Improvements in food preparation, storage temperatures, and packaging help to retard oxidation but may not be satisfactory or economically feasible in many instances. Consequently, substances are needed that can be introduced directly into the food product to inhibit the destructive processes that result in rancidity. For the food processor, Eastman Tenox™ food-grade antioxidants meet this need.

Eastman has been producing effective food-grade antioxidants for more than 50 years. Three basic antioxidant compounds — tertiary butylhydroquinone (TBHQ), butylated hydroxyanisole (BHA), and butylated hydroxytoluene (BHT) — are marketed under the trademark Tenox. "Easy-to-use" solution formulations are available containing antioxidants in various combinations and ratios dissolved in food-grade solvents. They also contain citric acid, an effective metal chelating agent and synergist.

Eastman Tenox™ food-grade antioxidants are kosher and are manufactured under rabbinical supervision in full accordance with Jewish dietary laws.

Eastman Tenox™ food-grade antioxidants

Excellent stability

Eastman Tenox™ TBHQ food-grade antioxidant —
is Eastman's most effective antioxidant for highly unsaturated vegetable oils and many edible animal fats. It will effectively "carry through" from frying oils and provide excellent stability to finished foods. Tenox TBHQ can be used with BHA and/or BHT in meat and poultry products to provide maximum protection while maintaining compliance with USDA regulations.

Eastman Tenox™ BHA food-grade antioxidant —
can be easily applied to food items because of its outstanding solubility in fats and oils. It is renowned for its carry-through effect into baked foods, providing extended shelf life. Tenox BHA imparts excellent stability to an array of food products, fats, oils, vitamins, pet foods, and packaging materials.

Eastman Tenox™ BHT food-grade antioxidant —
offers excellent solubility in fats and oils and provides carry-through effectiveness in baked foods. Used singly or with other Tenox antioxidants, it imparts stability to fats, oils, cereals, and packaging materials.

Features

Safe

For more than 50 years, Eastman Tenox™ food-grade antioxidants have had a record of safe use at effective concentrations in food.

Safe — For more than 50 years, Eastman Tenox™ food-grade antioxidants have had a record of safe use at effective concentrations in food. They are cleared for use by the Federal Food and Drug Administration (FDA), the United States Department of Agriculture (USDA), and the regulatory agencies of many other countries.

Easily applied — A wide variety of formulations of Eastman Tenox™ food-grade antioxidants are available to fit specific requirements for solubility and addition technique.

Effective in low concentrations — The individual Eastman Tenox™ food-grade antioxidants are effective at concentrations of 0.02% or less.

Do not contribute objectionable odor or flavor to the stabilized product — The purity of Eastman Tenox™ food-grade antioxidants and the low concentration required to stabilize food products preclude the contribution of undesirable odor or flavor.

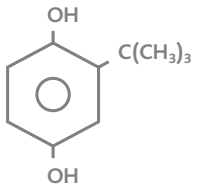
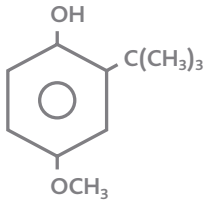
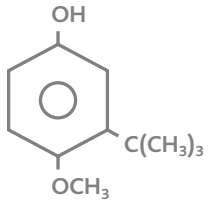
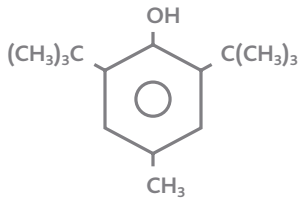
Stable at high temperature — TBHQ will carry through the heat of the frying vat; Eastman Tenox™ TBHQ, BHA, and BHT food-grade antioxidants have the ability to carry through the heat of the baking oven to protect the final product.

Ensure continued supply — Eastman's basic manufacturing position ensures the food processor both immediate and continued antioxidant availability.

Reasonable cost — Because of the low concentration required, stabilization with Eastman Tenox™ food-grade antioxidants usually costs only a few cents per hundred pounds of the food product.

Table 1

Physical properties

	Eastman Tenox™ TBHQ food-grade antioxidant	Eastman Tenox™ BHA food-grade antioxidant		Eastman Tenox™ BHT food-grade antioxidant
				
	tertiary butylhydroquinone	3-tertiarybutyl-4-hydroxyanisole	2-tertiarybutyl-4-hydroxyanisole	3,5-di-tert-butyl-4-hydroxytoluene
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

Regulations inside the United States

Table 2 shows a summary of current regulations published by the Food and Drug Administration and the United States Department of Agriculture that permits the direct addition of BHA, BHT, and TBHQ in foods. Every effort has been made to ensure the accuracy of information given in this publication. The reader, however, should refer to each appropriate FDA regulation before using any listed product. It is the responsibility of our customers to determine that their use of our product(s) is safe, lawful, and technically suitable in their intended applications.

Table 2

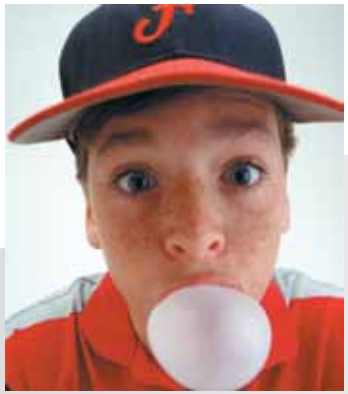
Food and Drug Administration (FDA)

Food additive regulation	Application	Permitted antioxidant	Limitation or tolerance (Percent by weight of food unless otherwise specified)	
21 CFR 182.3169	General uses	BHA	0.02% (200 ppm) singly or in combination, by weight, in fat or oil portion of food including the essential (volatile) oil except where prohibited by Standard of Identity	
21 CFR 182.3173		BHT		
21 CFR 172.185		TBHQ		
Specific foods				
21 CFR 172.615	Chewing-gum base	BHA, BHT	0.1% (1,000 ppm) singly or in combination	
21 CFR 172.515	Synthetic flavoring substances and adjuvants	BHA	0.5% (5,000 ppm) of flavoring oil	
21 CFR 172.110	Active dry yeast	BHA	0.1% (1,000 ppm)	These limits on total product weight
	Beverages and desserts from dry mixes		0.0002% (2 ppm)	
	Dry mixes for beverages and desserts		0.009% (90 ppm)	
	Dry diced glazed fruit		0.0032% (32 ppm)	
21 CFR 172.110 and/or 21 CFR 172.115	Dry breakfast cereals	BHA and/or BHT	0.005% (50 ppm)	
	Emulsion stabilizers for shortening		0.02% (200 ppm)	
	Potato granules		0.001% (10 ppm)	
	Potato flakes, sweet potato flakes, and dehydrated potato shreds		0.005% (50 ppm)	
Food standards				
21 CFR 137.350	Enriched rice	BHT	0.0033% (33 ppm)	
21 CFR 161.175	Frozen raw breaded shrimp	BHA, BHT	0.02% (200 ppm) on fat or oil content	
21 CFR 166.110 and 9 CFR 318.7	Margarine	BHA, BHT, TBHQ	0.02% (200 ppm) singly or in combination based on finished product (TBHQ based on fat or oil)	
21 CFR 164.110	Mixed nuts	BHA, BHT, TBHQ	0.02% (200 ppm) singly or in combination based on fat or oil content	

Table 2 *(Continued)*

United States Department of Agriculture (USDA)

Food additive regulation	Application	Permitted antioxidant	Limitation or tolerance (Percent by weight of food unless otherwise specified)
Meat and meat food products			
9 CFR 318.7	Dry sausage	BHA, BHT TBHQ	0.003% (30 ppm) singly, 0.006% (60 ppm) in combination, with no antioxidant exceeding 0.003% (30 ppm), based on total weight of finished product
	Fresh pork and/or beef sausage, brown-and-serve sausage, pregrilled beef patties, pizza toppings, and meatballs		0.01% (100 ppm) singly, 0.02% (200 ppm) in combination, with no antioxidant exceeding 0.01% (100 ppm), based on fat or oil content of finished product
	Dried meats		0.01% (100 ppm) singly or in combination based on total weight of finished product
	Rendered animal fat or a combination of such fat and vegetable fat		0.01% (100 ppm) singly, 0.02% (200 ppm) in combination, with no antioxidant exceeding 0.01%
Poultry and poultry food products			
9 CFR 381.147	Rendered poultry fat or various poultry products	BHA, BHT, TBHQ	0.01% (100 ppm) singly, 0.02% (200 ppm) in combination, with no antioxidant exceeding 0.01%, based on fat content



Regulations outside the United States

In countries other than the United States, prospective antioxidant users should consult the appropriate government agency in the specific country regarding the specific regulatory requirements for antioxidants. It is the responsibility of our customers to determine that their use of our product(s) is safe, lawful, and technically suitable in their intended applications.

Table 3

European Community — Directive 95/2/EC

Permitted antioxidant	EC regulation
BHA	E320
BHT	E321
TBHQ	E319

Note: Each EC member country establishes maximum permitted levels for various uses for antioxidants.

Selecting the appropriate antioxidant

Protection

Cooked foods require antioxidants that will remain stable when exposed to the temperatures of baking or frying.

Legal status — The selection of antioxidants is limited to compounds approved under applicable regulations.

Type of fat or oil — The selected antioxidant must be highly effective in the particular fat or oil being stabilized.

Ease of dispersion — For maximum efficiency, the antioxidant system should be one that can be easily dissolved and thoroughly dispersed in the fat and oil portions of the food product.

Need for carry through — Cooked foods require antioxidants that will remain stable when exposed to the temperatures of baking or frying and provide protection to the finished products.

Discoloration tendencies — Some discoloration may occur with TBHQ in the presence of alkaline pH, certain proteins, and sodium salts.

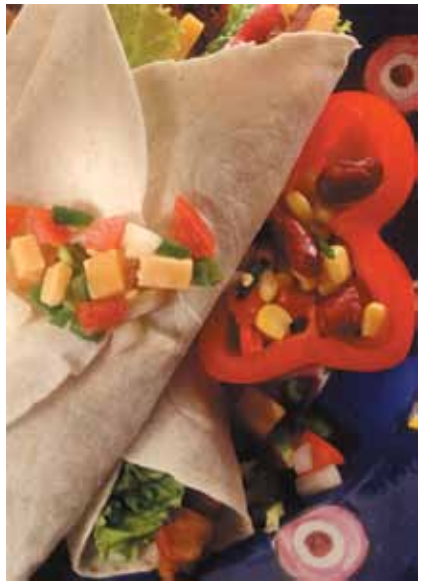
Method of application — The technique for application may dictate the antioxidant systems that can be used.

Table 4

Eastman Tenox™ food-grade antioxidant formulations

Food-grade antioxidant solution	Maximum usage levels (weight % of fat or oil)		Composition, %[a]			
	FDA	USDA	BHA	BHT	TBHQ	Citric acid
Eastman Tenox™ 4	0.05	0.05	20	20	—	—
Eastman Tenox™ 4B	0.1	0.05	20	—	—	—
Eastman Tenox™ 8	0.1	0.05	—	20	—	—
Eastman Tenox™ 20	0.1	0.05	—	—	20	10
Eastman Tenox™ 20A	0.1	0.05	—	—	20	3
Eastman Tenox™ 21	0.1	0.05	—	—	20	1
Eastman Tenox™ 25	0.1	0.1	—	10	10	3
Eastman Tenox™ R	0.1	0.05	20	—	—	20

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



In addition to the solutions listed, solution formulations can be custom-made on request for specific uses (minimum order required).

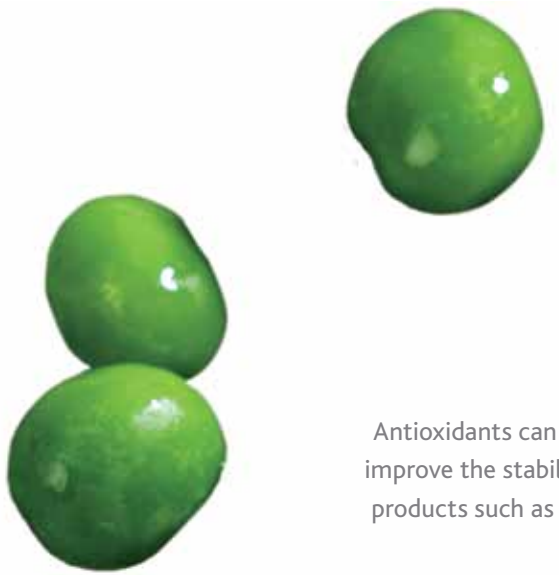
Animal fats need antioxidant protection to help stabilize them for use in foods such as broths and soups.

Table 5

Typical properties[a]

Food-grade antioxidant solution	Color	Viscosity @ 25°C, cP[b]	Specific gravity, 20°/20°C	Solubility in fats and oils	Effectiveness in vegetable oils	"Carry through" in baked foods
Eastman Tenox™ 4	Light straw	61	0.942	Excellent	Good	Excellent
Eastman Tenox™ 4B	Light straw	69	0.951	Excellent	Good	Excellent
Eastman Tenox™ 8	Light straw to light amber	49	0.925	Excellent	Good	Good
Eastman Tenox™ 20	Light amber to golden brown	235	1.087	Good	Excellent	Good
Eastman Tenox™ 20A	Golden brown	369	0.998	Excellent	Excellent	Good
Eastman Tenox™ 21	Golden brown	284	0.991	Excellent	Excellent	Good
Eastman Tenox™ 25	Golden brown	190	0.938	Excellent	Excellent	Excellent
Eastman Tenox™ R	Light straw	229	1.117	Good	Good	Excellent

[a]*Properties reported here are typical of average lots. Eastman makes no representation that the material in any particular shipment will conform exactly to the values given.*
[b]*Brookfield Model RVT–Spindle 2, speed 20 rpm*



Antioxidants can be used to improve the stability of food products such as margarine.

Application methods

Application

Stabilize by blending the antioxidant with seasoning mix.

When applying antioxidants to food products, it is essential that the antioxidants are thoroughly dissolved and dispersed in the fat or oil portions. Since only small amounts of Eastman Tenox™ food-grade antioxidants are required for protection of foods, the method of incorporating the antioxidants may determine the success of stabilization. Choice of method depends on the product, the process, and available equipment. Tenox antioxidants can be applied by one or more of the following techniques.

Direct method — A fat, oil, or wax can be stabilized by heating to a minimum of 60°C (140°F) and agitating sufficiently to dissolve the antioxidant. The agitation (not so vigorous that excessive air is entrapped) should be continued for an additional 20 minutes to ensure uniform distribution.

Antioxidant concentrate method — Concentrated solutions of antioxidants can be prepared by dissolving Eastman Tenox™ food-grade antioxidant in a small quantity of fat or oil heated to 93°C–121°C (200°F–250°F). The hot concentrate or a predissolved formulation of Tenox antioxidant can be introduced into the fat directly or by metering. Agitation is required for thorough distribution.

Proportionate method — The antioxidant or a concentrate of the antioxidant 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.

Spray method— Food products such as nuts can be sprayed directly with a dilute antioxidant solution. The concentration of the solution should be adjusted to provide the desired amount of antioxidant and to ensure uniform distribution on the surface of the products.

Other methods — Other innovative means can be used to apply Eastman Tenox™ food-grade antioxidants to various food products. For instance, meat products such as sausages may be effectively stabilized by blending the antioxidant formulation and seasoning mix into the sausages. Cereal products can be protected by incorporating the antioxidant into the waxed liners of the packages.

Antioxidant effectiveness

Evaluating antioxidant performance

Accelerated tests conducted under controlled conditions are normally used to evaluate antioxidant performance.

The effect of antioxidants on the oxidative stability of fats, oils, or food products can be most realistically measured by subjecting samples to actual storage conditions and examining them periodically. This method of testing usually requires too much time to be practical. For this reason, accelerated tests conducted under controlled conditions are normally used to evaluate antioxidant performance.

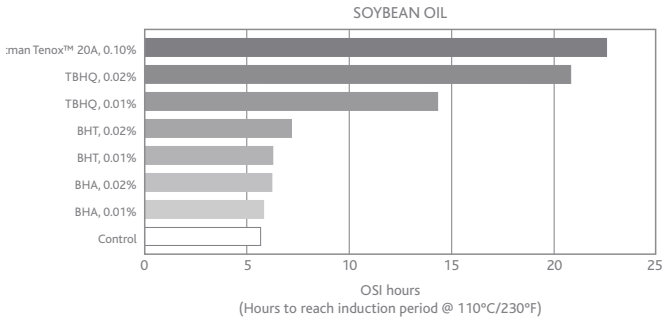
If comparing data obtained by different methods, it is important to consider how the methods differ and what is being measured. For these reasons, direct data comparisons are not feasible if data is obtained by varying methods.

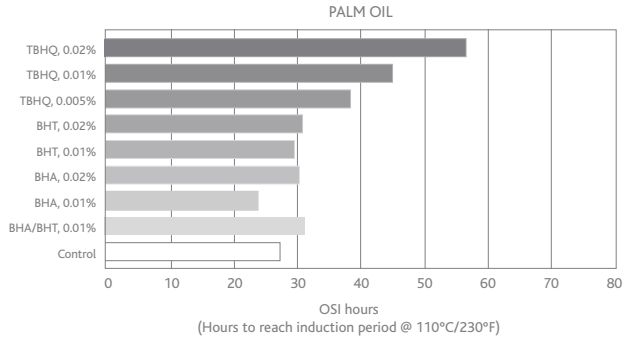
Active Oxygen Method (AOM) — The Active Oxygen Method has been widely used for years on fats and oils that are liquid at the test temperature. It is not applicable to solid material. Air is bubbled through the heated test sample to speed oxidation and shorten testing time. Periodic analyses show when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

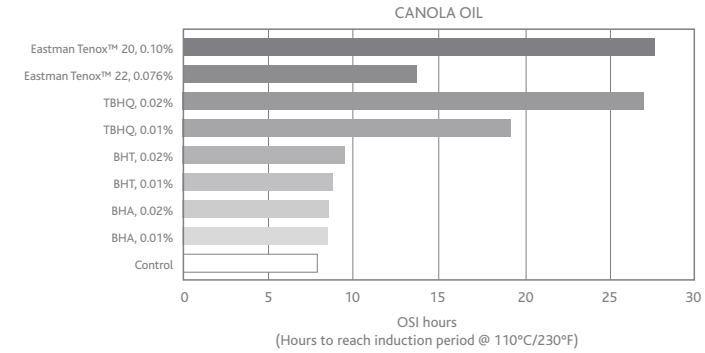
Oil Stability Index (OSI) — The Oil Stability Index is an automated, accelerated method of measuring stability of fats and oils. Fat or oil samples held at a constant temperature between 110°C and 130°C are exposed to a stream of purified air. Over time the oil or fat begins to oxidize, giving rise to 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.

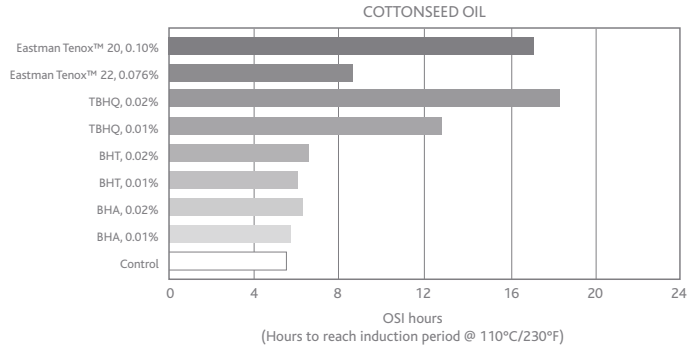
Oven storage tests

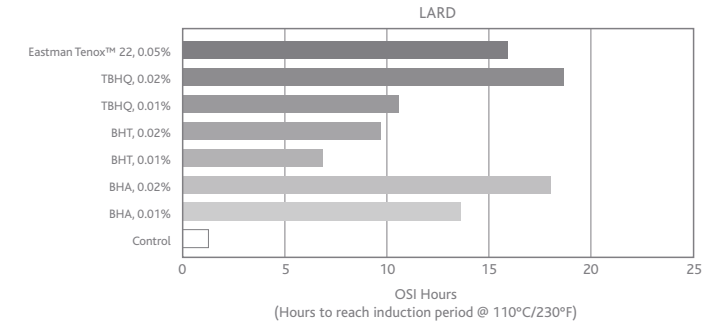
Higher temperatures will accelerate oxidation. Oven storage tests, such as the Schaal Oven Stability test, are shelf storage tests conducted at elevated temperatures to speed up the procedure. Periodic odor and flavor evaluations are commonly used; however, chemical analyses such as peroxide value may be used to determine rancidity development in the samples.

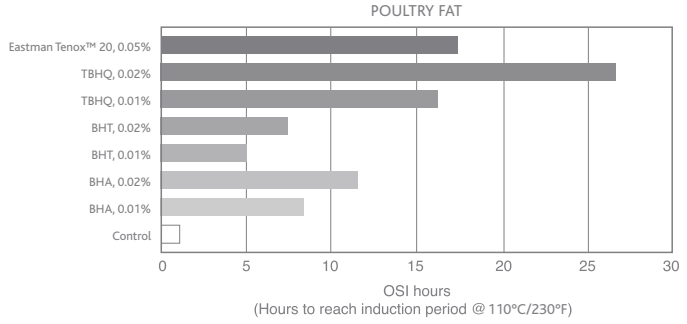


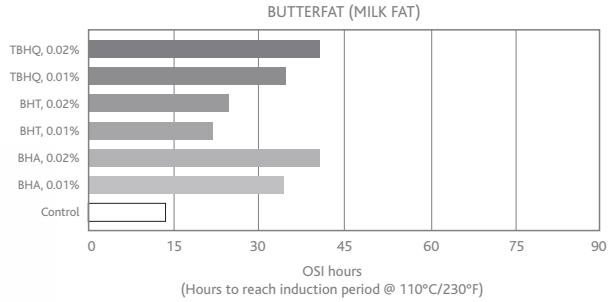


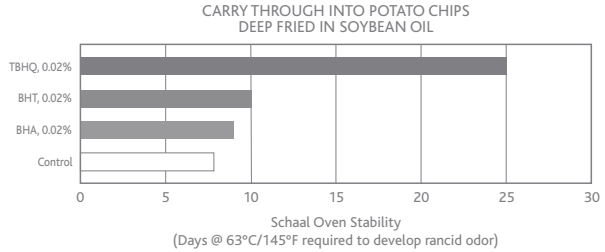


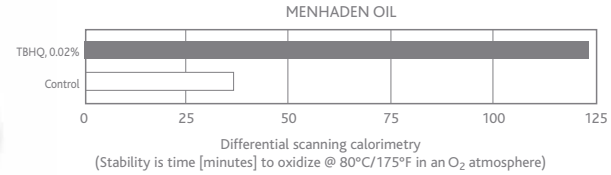


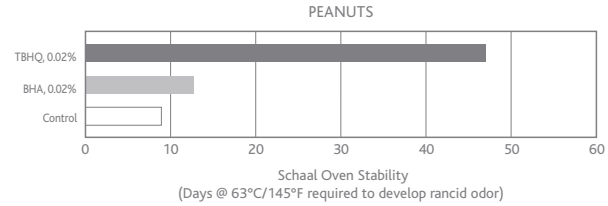


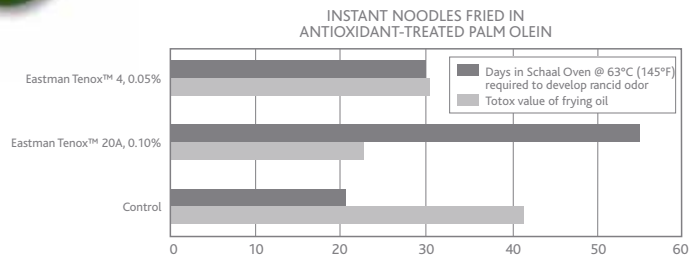


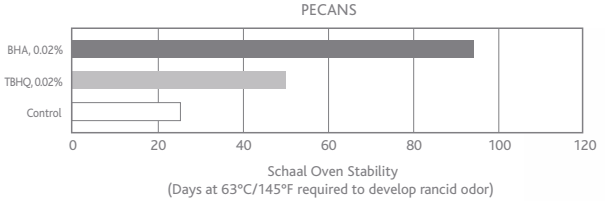

BUTTERFAT (MILK FAT)
TBHQ, 0.02%
TBHQ, 0.01%
BHT, 0.02%
BHT, 0.01%
BHA, 0.02%
BHA, 0.01%
Control
0
15
30
45
60
75
90
OSI hours
(Hours to reach induction period @ 110°C/230°F)

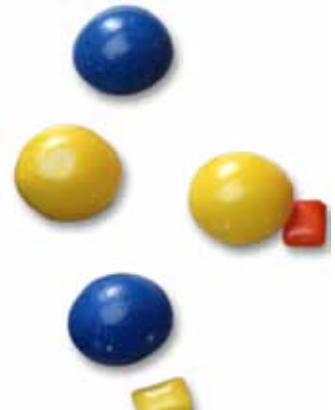

CARRY THROUGH INTO POTATO CHIPS
DEEP FRIED IN SOYBEAN OIL
TBHQ, 0.02%
BHT, 0.02%
BHA, 0.02%
Control
0
5
10
15
20
25
30
Schaal Oven Stability
(Days @ 63°C/145°F required to develop rancid odor)


MENHADEN OIL
TBHQ, 0.02%
Control
0
25
50
75
100
125
Differential scanning calorimetry
(Stability is time [minutes] to oxidize @ 80°C/175°F in an O_2 atmosphere)


PEANUTS
TBHQ, 0.02%
BHA, 0.02%
Control
0
10
20
30
40
50
60
Schaal Oven Stability
(Days @ 63°C/145°F required to develop rancid odor)


INSTANT NOODLES FRIED IN
ANTIOXIDANT-TREATED PALM OLEIN
Eastman Tenox™ 4, 0.05%
Eastman Tenox™ 20A, 0.10%
Control
Days in Schaal Oven @ 63°C (145°F) required to develop rancid odor
Totox value of frying oil
0
10
20
30
40
50
60
Instant noodle shelf life and totox value
Totox value = 2 (peroxide value) + anisidine value


PECANS
BHA, 0.02%
TBHQ, 0.02%
Control
0
20
40
60
80
100
120
Schaal Oven Stability
(Days at 63°C/145°F required to develop rancid odor)



Antioxidants can be added to essential oils and flavorings to protect against oxidation during shipment and storage. The protection can also carry over into the food product.

Table 6

Types of packaging

Solid forms			
	Fiber drums or bags		
Food-grade antioxidant	50 lb (22.68 kg)	100 lb (45.36 kg)	110.23 lb (50 kg)
Eastman Tenox™ BHA	■	■	
Eastman Tenox™ BHT	■		
Eastman Tenox™ TBHQ			■

Solution formulations				
	Bulkdrum II	Plastic drums		Polyethylene jugs
Food-grade antioxidant solution	275 U.S. gal (1040.99 L)	30 U.S. gal (113.56 L)	55 U.S. gal (208.19 L)	6 U.S. gal (22.71 L)
Eastman Tenox™ 4	■	■	■	■
Eastman Tenox™ 4B		■		■
Eastman Tenox™ 8	■	■	■	■
Eastman Tenox™ 20	■	■	■	■
Eastman Tenox™ 20A	■	■	■	■
Eastman Tenox™ 21	■	■	■	■
Eastman Tenox™ 25		■		■
Eastman Tenox™ R	■	■	■	■

Applications

Several Eastman Tenox™ food-grade antioxidants are recommended for each product in the following application guide. This is due to the vast differences in existing regulations in various countries.

Animal feeds		Baked products		Bakery mixes		Bakery shortening		Beverage mixes	
Tenox™ 20	Tenox™ 25	Tenox™ 4	Tenox™ 8	Tenox™ 4		Tenox™ 4			
Tenox™ 20A	Tenox™ R	Tenox™ 4B	Tenox™ 25	Tenox™ 4B	Tenox™ 25	Tenox™ 25	Tenox™ 20A	Tenox™ 4B	Tenox™ BHA
Candies		**Cereals**		**Chewing gum**		**Citrus oils**		**Cookies**	
Tenox™ 4	Tenox™ 20A	Tenox™ 4						Tenox™ 4	Tenox™ 20A
Tenox™ 4B	Tenox™ 25	Tenox™ 4B	Tenox™ 8	Tenox™ BHA	Tenox™ BHT	Tenox™ 4B	Tenox™ BHA	Tenox™ 4B	Tenox™ 25
Cosmetics		**Crackers**		**Desert mixes**		**Edible fats**		**Fish oils**	
	Tenox™ 25					Tenox™ 4	Tenox™ 25 Tenox™ BHA		
Tenox™ 4	Tenox™ BHA	Tenox™ 4	Tenox™ 8	Tenox™ 4B		Tenox™ 4B	Tenox™ BHT	Tenox™ 20	
Tenox™ 4B	Tenox™ BHT	Tenox™ 4B	Tenox™ 25	Tenox™ A	Tenox™ BHA	Tenox™ 20A	Tenox™ TBHQ	Tenox™ 20A	Tenox™ TBHQ
Fish products		**Flavorings**		**Frying oils**		**Inedible fats**		**Lard**	
Tenox™ 20				Tenox™ 20	Tenox™ 21	Tenox™ 20			Tenox™ 20A
Tenox™ 20A	Tenox™ TBHQ	Tenox™ 4B	Tenox™ BHA	Tenox™ 20A	Tenox™ TBHQ	Tenox™ 20A	Tenox™ R	Tenox™ 4	Tenox™ 25
Margarines		**Meat products**		**Mineral oils**		**Nuts**		**Packaging materials**	
			Tenox™ 8			Tenox™ 4 Tenox™ 4B	Tenox™ BHA	Tenox™ 4	
Tenox™ 20A	Tenox™ 25	Tenox™ 4	Tenox™ 20A		Tenox™ BHA	Tenox™ 8	Tenox™ BHT	Tenox™ 4B	Tenox™ BHA
Tenox™ 21	Tenox™ TBHQ	Tenox™ 4B	Tenox™ 25	Tenox™ 4B	Tenox™ BHT	Tenox™ 20A	Tenox™ TBHQ	Tenox™ 8	Tenox™ BHT
Pet foods		**Potato chips**		**Poultry fat**		**Poultry products**		**Rice (brown, polished & rice bran)**	
Tenox™ 20		Tenox™ 20						Tenox™ 4	
Tenox™ 20A	Tenox™ R	Tenox™ 20A	Tenox™ 21	Tenox™ 20	Tenox™ TBHQ	Tenox™ 20	Tenox™ 20A	Tenox™ 4B	Tenox™ 8

Rice (enriched)		Sausages		Shrimp (breaded)		Snack foods		Spices	
		Tenox™ 4	Tenox™ 20A	Tenox™ 4	Tenox™ 8	Tenox™ 20	Tenox™ 21	Tenox™ 4	
Tenox™ 8		Tenox™ 4B	Tenox™ 25	Tenox™ 4B	Tenox™ A	Tenox™ 20A	Tenox™ 25	Tenox™ 20A	Tenox™ 25
Tallow		**Vegetable oils**		**Vitamins**		**Waxes**		**Yeast**	
	Tenox™ 20A	Tenox™ 20	Tenox™ 21	Tenox™ 4					
				Tenox™ 4B	Tenox™ A	Tenox™ BHA			
Tenox™ 4	Tenox™ 25	Tenox™ 20A	Tenox™ TBHQ	Tenox™ 8	Tenox™ BHA	Tenox™ BHT	Tenox™ TBHQ	Tenox™ 4B	Tenox™ BHA

Additional information

Z-1 *Quality Products From Eastman for the Food Market*

Z-15 *Tenox TBHQ Antioxidant Versus BHT in Fats and Oils*
(also available in Portuguese and Spanish)

Z-17 *TBHQ Safety*

ZG-183 *Tenox Antioxidants for Meat and Poultry*

ZG-194 *Schaal Oven Storage Stability Test*

ZG-248 *Tenox Food-Grade Antioxidants for Refined Vegetable Oils*
(also available in Spanish)

ZG-268 *AOCS Oil Stability Index*

ZG-269 *Antioxidants for Cereal, Confectionery, and Snack Foods*

P-207 *Certification of Kosher Products From Eastman Chemical Company*

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Material Safety Data Sheets providing safety precautions, that should be observed when handling and storing Eastman products, are available online or by request. You should obtain and review the available material safety information before handling any of these products. If any materials mentioned are not Eastman products, appropriate industrial hygiene and other safety precautions recommended by their manufacturers should be observed.

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