Robert M. Kerr Food & Agricultural Products Center

FOOD TECHNOLOGY FACT SHEET

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Edible Oil Quality

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Introduction

Majority of the edible oils used for cooking, frying and food formulations are derived from plant sources, specifically from oilseeds such as soybean, canola, sunflower seeds, cottonseed and peanuts. Edible vegetable oils are liquid at room temperature and comprised of mainly triacylglycerides that are made up of three fatty acids attached to a glycerol molecule through ester bonds (see fact sheet FAPC-196 Lipid Glossary). Physical, chemical and nutritional properties of vegetable oils vary significantly depending on the type of fatty acids present in the oil. Unsaturated fatty acid content of vegetable oils is significantly higher than that of animal fats. Although high unsaturated fatty acid content makes the oil healthier, highly unsaturated oils are prone to fast oxidation and quality deterioration during processing, handling and storage. Vegetable oils also contain other compounds in minor amounts that affect their quality and nutritional value. Phytosterols, tocopherols, waxes are some of the minor components of vegetable oils (less than 1 percent of the oil). These compounds are not regularly analyzed for oil quality evaluation purposes partly due to the complexity of the analytical protocols and the need for expensive instruments for testing.

Oil quality deteriorates by hydrolysis, oxidation and polymerization of the oil. Hydrolysis increases the amount of free fatty acids (FFA), mono- and diacylglycerols and glycerols in oils. Oxidation produces hydroperoxides and low molecular weight volatile compounds such as aldehydes, ketones, carboxylic acids, and short chain alkanes and alkenes. Dimers and polymers also are formed when oil is exposed to high temperatures during cooking and frying.

Monitoring and maintaining edible oil quality are paramount importance to ensure safety of the product for consumption. Although there is no official standard set for evaluating edible oil quality, FFA content, peroxide value (PV) and p-anisidine value (AV) are commonly used in industry to report edible oil quality. This fact sheet summarizes edible oil quality parameters used in industry and for research purposes.

Quality Parameters

Free Fatty Acid Content

Free fatty acids (FFA) are formed by the hydrolysis of oils (triacylglycerides). They are not bound or esterified to a glycerol molecule. Crude oils and fats in natural form, not refined, contain small amounts of FFA, which are usually removed during the refining process. FFA are not desirable in edible oils because when oils with high FFA content are used in foods, they lower the oxidative stability of the product, increase acidity and lead to off-flavor formation. The standard methods for determining FFA content of oils are American Oil Chemists' Society (AOCS) Ca-5a-40 [1] and European Union Regulation No.2568/91 [2]. There are other analytical methods, which are faster and suitable for small sample sizes [3,4]. Chemical analysis kits and various automated hand-held instruments also are available for analyzing FFA concentrations in oils [5].

Voluntary industry standard for FFA content in refined edible oil is ≤0.05 percent (based on oil weight). In the food industry, frying oils with FFA content exceeding 2 percent are either discarded or fresh oil is added to bring the FFA content down.

Acid value

Acid Value is an important indicator of vegetable oil quality. Acid value is expressed as the amount of potassium hydroxide (KOH, in milligrams) necessary to neutralize free fatty acids contained in 1 g of oil. The standard method for determining acid value is AOCS Cd 3d-63 [1].

Peroxide Value

Peroxide value (PV) is an index used to quantify the amount of hydroperoxides present in fats and oils. Hydroperoxides, which are shown to be toxic to humans, are the primary oil oxidation products formed during the initial stages of oxidation. The standard method for PV determination is AOCS Cd 8-53 [1]. Although Fourier transform infrared (FTIR) and near-infrared (FT-NIR) spectroscopy methods developed for PV measurement have the advantages of analytical speed and automation, the instruments used for these tests are quite expensive and require extensive calibration [6]. Evaluating oil quality based on only PV can be misleading. Because low PV does not necessarily indicate low level of oxidation, it could be due to the advanced level of oil oxidation during which primary oxidation products are converted to secondary oxidation product (see the section for anisidine value) lowering PV but increasing AV of the oil. Hence, both PV and AV should be used for oil quality evaluation (see totox value).

Refined oils usually have PV of <1 meq/kg. Oils are considered oxidized when PV > 3 meq/kg.

p-Anisidine Value

p-Anisidine value (AV) is a measure of the secondary oxidation products that are formed by breakdown of the primary oxidation products during extensive oxidation. The secondary oxidation products are mainly aldehydes such as 2,4-dienals and 2-alkenals. AV is strongly correlated with overall oil odor intensity. The standard method for AV content determination in oils is the AOCS Cd 18-90 [1].

Refined oils should have AV of <5.

Polar Compounds

Presence of polar compounds in oil is one of the best indicators of heated oil quality. Polar compounds consist of dimeric and higher polymeric triacylglycerides formed through thermal polymerization of triacylglycerides, monomeric oxidized products, mono- and diacylglycerides and FFA formed through hydrolytic cleavage of triacylglycerides. The analysis of the polar compounds is conducted by high-performance size exclusion chromatography, which allows the separation and quantification of polymeric compounds, dimers, oxidized triacylglycerides, mono- and diacylglycerides and FFA [7]. The standard method for analyzing total polar content (TPC) in frying oils is the AOCS Cd 20-91 [1]. As the name implies, this method determines the total polar compounds in the oil, not the individual polar compounds.

Regulations in some countries specify that oils should contain less than 25–27 percent TPC.

TBARS

This is one of the oldest tests used for evaluating lipid oxidation in foods. When heated under acidic conditions, thiobarbituric acid (TBA) reacts with a number of compounds including nucleic acids, amino acids, proteins, phospholipids and aldehydes to produce a pink chromophore that can be measured by UV or fluorescence detection. These substances are termed TBARS (thiobarbituric acid reacting substances). The extent of lipid oxidation is reported as TBA value, which corresponds to milligram of malonaldehyde equivalents per kilogram of sample or micromoles of malonaldehyde per gram of sample [8,9]. It is recommended other tests such as PV and AV also should be used when evaluating lipid quality in complex food systems due to the limitations of TBARS method. The standard method for analyzing TBA value is the AOCS Cd 19-90 [1].

Conjugated Dienes

Oxidation of polyunsaturated fatty acids results in an increase in the ultraviolet absorption of the product due to conjugate formation. Measurement of the content of conjugated dienes at 234 nm and conjugated trienes at 268 nm is a quick physical method, which may be helpful to assess the oxidative stability of vegetable oils [10].

Unsaponifiable Matter

Unsaponifiable matter (USM) fraction of vegetable oils naturally contains hydrocarbons, terpene alcohols, sterols, tocopherols and other phenolic compounds, which may act as oxidation inhibitors. Vegetable oils typically contain 0.5-2.5 percent USM while some others have higher amounts, 5-6 percent. USM of edible oils is used for their characterization and authentication of the products. The standard method for analyzing USM is the AOCS Ca 6b-53 [1].

Phospholipids

Phospholipid is a common name for lipids containing phosphoric acid or other phosphorus-containing acids in ester form such as glycerophospholipids (e.g. phosphatidic acid, phosphatidylcholine, phosphatidylethanolamine) or sphingophospholipids (e.g. sphingomyelin). Although these compounds (also called gum because of their gummy consistency in oil) have some health benefits and surfactant/emulsifier properties, they need to be separated from crude oil during the refining process, which is referred to as degumming. Otherwise, they impart a cloudy appearance and precipitate out of the oil during storage creating a unpleasant solid residue at the bottom of the containers and adversely affect the functionality of refined oils, i.e. cause foaming during frying. The phospholipid content of oils is commonly measured as phosphorous (AOCS Ca 19-86), which can be converted to phospholipids by using conversion factors calculated by using the phospholipid composition and the molecular weight of individual phospholipids present in the oil. The standard method for analyzing phospholipids is the AOCS Ca 12b-92 [1].

Refined oils have about 30 mg/kg phosphorous, while super degummed oils contain less than 10 mg/kg phosphorous.

Color

The color of crude and refined vegetable oils is an important factor in the determination of their market value. Removal of color pigments, which are extracted along with the oil from the seeds during the extraction process, is achieved during the oil refining referred to as bleaching. The color compounds in the oil mainly consist of carotenoids, chlorophyll, gossypol and related compounds. Chlorophyll is a sensitizer of photo-oxidation and promotes oil oxidation in the presence of light and decreases the oxidative stability of oils. Chlorophyll also acts as a catalyst poison during oil hydrogenation process. The color of the edible oils also can be an issue for food formulations adversely affecting the color of the final product which incorporated. Lovibond is the most common method (AOCS Wesson Cc 13b-45 and ISO Cc 13e-92) used to determine color of the commercial oils [1]. In Lovibond method color is expressed as red and yellow components. In general, fully refined oil may be 0.8 R (red) and 8.0 Y (yellow). Frying oils often are discarded when their Lovibond red color increases from 1.5-3.5 to 20-30.

Totox value

Totox value is used as an empirical assessment of oxidative deterioration based on PV and AV of an oil.

$$\text{Totox value} = 2 \times PV + AV$$

Conclusions

Commonly used edible oil industry voluntary quality parameters are FFA, PV and AV. National Oil Processors Association (NOPA) and American Oil Chemists' Society (AOCS) provide laboratory services that include AOCS methods, certified reference materials, quality reference materials and consulting. The AOCS Laboratory Proficiency Program (LPP), formerly the Smalley Check Sample Program, is the world's most extensive and respected collaborative proficiency testing program for oilseeds, oilseed meals, and edible oils and fats. More than 500 chemists who participate in this program use AOCS or similar standard methods for sample analyses and then compare their results with the test results generated at other laboratories using the same methods and samples and verify their quality control practices (http://www.aocs.org/LabServices/content.cfm?ItemNumber=841).

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