wjpmr, 2025, 11(8), 236-244

SJIF Impact Factor: 6.842

WORLD JOURNAL OF PHARMACEUTICAL
AND MEDICAL RESEARCH
www.wjpmr.com

Review Article
ISSN (O): 2455-3301
ISSN (P): 3051-2557

OILS, FATS & WAXES; THE THREE MUSKETEERS OF ESTERS ADULTRATION CHECK POINT

Dr. Viral Prajapati*[1], Zalak Sharma[1], Vidhi Patel[2], Divyaben Rajendrakumar Shah[3] & Dr. Dhrubo Jyoti Sen[4]

[1]Shree Swaminarayan Sanskar Pharmacy College, Near Zundal Circle, S. P. Ring Road, Between Chandkheda−Adalaj, Zundal, Gandhinagar−382421, Gujarat, India.
[2]Gandhinagar Institute of Pharmacy, Khatraj Kalol Rd, Moti Bhoyan, Kalol, Gujarat−382725, India
[3]K. B. Raval College of Pharmacy, At. Shertha, Po. Kasturinagar, B/H IFFCO Township, nr. Tri Mandir, Adalaj, Gujarat-382423, India.
[4]School of Pharmacy, Techno India University, Salt Lake City, Sector−V, EM: 4/1, Kolkata−700091, West Bengal, India.

***Corresponding Author: Dr. Viral Prajapati**
Shree Swaminarayan Sanskar Pharmacy College, Near Zundal Circle, S. P. Ring Road, Between Chandkheda−Adalaj, Zundal, Gandhinagar−382421, Gujarat, India.

Article Received on 20/06/2025 **Article Revised on 10/07/2025** **Article Accepted on 30//07/2025**

ABSTRACT

Adulteration is the practice of secretly mixing a substance with another. The secretly added substance will not normally be present in any specification or declared substances due to accident or negligence rather than intent, and also for the introduction of unwanted substances after the product has been made. Adulteration, therefore, implies that the adulterant was introduced deliberately in the initial manufacturing process, or sometimes that it was present in the raw materials and should have been removed, but was not.

KEYWORDS: Oil, Fat, Wax, Lipid, Adulteration, Rancidity, Iodine value, Acid value, Acetyl value, Ester value, Saponification value, Hydroxyl value, Reichert−Meissl (RM) value.

INTRODUCTION

Oil adulteration is the practice of adding cheaper or non−edible substances to pure oil to increase quantity and reduce costs, potentially harming consumers. This practice is widespread, with various oils like mustard, palm, and cooking oils being commonly adulterated. Adulterants can include other oils, artificial colours, or even harmful substances like aflatoxins or heavy metals. Aflatoxins are a group of toxic and carcinogenic compounds produced by certain fungi, primarily *Aspergillus flavus* and *Aspergillus parasiticus* that can contaminate various agricultural products. They are a major concern because of their potential to cause serious health problems in both humans and animals. An adulterant is a substance secretly added to another that may compromise the safety or effectiveness. Typical substances that are adulterated include food, cosmetics, pharmaceuticals or fuels. An adulterant is distinct from, for example, permitted food preservatives. There can be a fine line between adulterant and additive; chicory may be added to coffee to reduce the cost or achieve a desired flavour—this is adulteration if not declared, but may be stated on the label. Chalk was often added to bread flour; this reduces the cost and increases whiteness, but the calcium confers health benefits, and in modern bread, a little chalk may be included as an additive for this reason. Adulteration is the practice of secretly mixing a substance with another. The secretly added substance will not normally be present in any specification or declared substances due to accident or negligence rather than intent, and also for the introduction of unwanted substances after the product has been made.[1]

Food adulteration refers to the process of intentionally adding or substituting inferior, low−quality, or harmful substances into food to increase its quantity or improve its appearance, often at the expense of nutritional value and safety. This practice can range from harmless additions like water in milk to dangerous additions like toxic chemicals.

- **Intentional adulteration:** This involves deliberate actions to deceive consumers by adding or substituting substances to increase profit margins or make food appear more appealing.
- **Unintentional adulteration:** This can occur due to factors like poor hygiene, improper storage, or lack of proper facilities during food production and distribution.

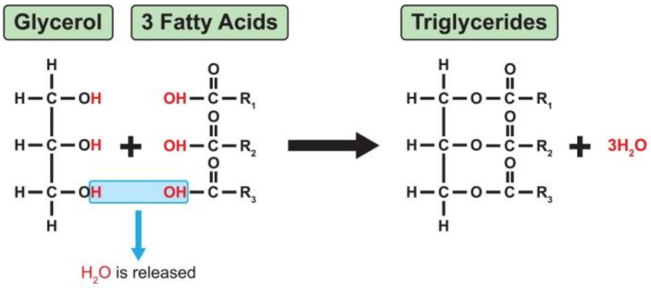

Figure 1: Fats/Oils.

Adulterants: These are the substances added to food that make it adulterated. They can range from harmless (like water) to highly dangerous (like toxic chemicals).

Examples of Adulteration:

Milk: Adding water, starch, or harmful chemicals like urea.

Spices: Adulterating turmeric with metanil yellow or chilli powder with brick dust.

Honey: Diluting it with sugar syrup.

Ghee and Butter: Adulterating them with cheaper vegetable fats.

Fruits and Vegetables: Injecting them with harmful chemicals to ripen them quickly.

Consequences of Adulteration

Reduced Nutritional Value: Adulteration can lower the amount of nutrients in food, making it less beneficial for consumption.

Health Hazards: Some adulterants can cause a range of health problems, from minor stomach issues to serious illnesses and even death.

Economic Loss: Consumers may pay a higher price for adulterated food, believing they are getting a higher quality product.

Legal Offenses: Adulteration is often illegal and can lead to legal penalties.

Why it happens

Economic Gain: Adulteration can be a way to increase profits by reducing production costs or making products look more appealing to consumers.

Lack of Awareness: Ignorance or lack of proper knowledge about food safety can also lead to unintentional adulteration.

Weak Enforcement of Regulations: Insufficient monitoring and enforcement of food safety standards can contribute to the problem.

Combating Adulteration

Consumer Awareness: Educating consumers about food safety and how to identify adulterated products is crucial.

Strict Regulations and Enforcement: Implementing and enforcing strict food safety laws is essential.

Improved Testing Methods: Developing and implementing reliable methods for detecting adulteration can help identify and prevent the sale of adulterated food.

Oil adulteration is the addition of substances not naturally found in the pure oil, often to increase volume or reduce production costs. These substances can range from other edible oils to non−edible oils, artificial colors, or even harmful chemicals. Adulteration can significantly impact the nutritional value and safety of the oil, potentially leading to health problems.[2]

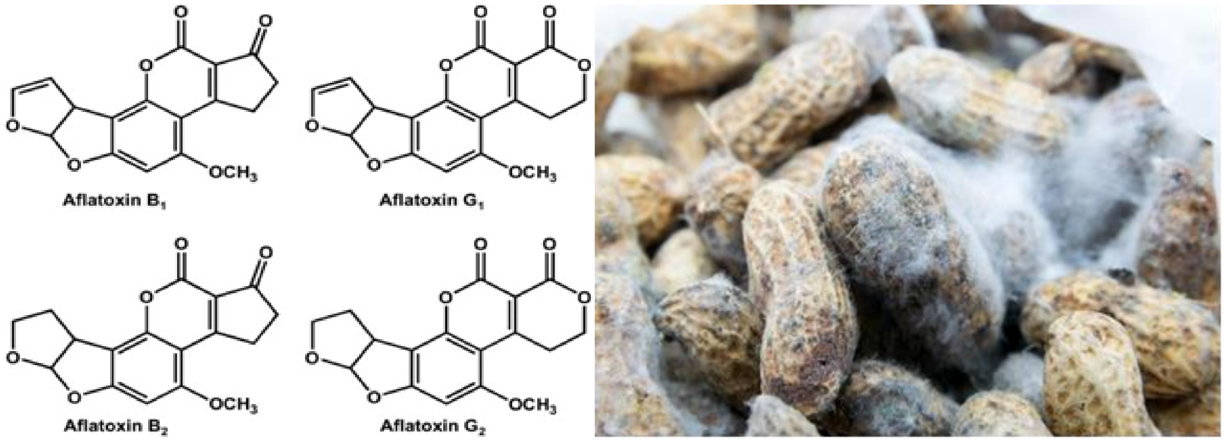

Figure 2: Aflatoxins & Adulteration.

Rancidity is the process where fats and oils in food spoil due to oxidation, leading to unpleasant odors and tastes. It occurs when unsaturated fats in food are exposed to oxygen, breaking down and producing compounds like ketones, esters, and aldehydes. This process can be accelerated by factors like heat, light, and moisture.

Causes of Rancidity

Oxidation: The primary cause is the reaction of fats and oils with oxygen, which breaks down the unsaturated bonds in the fat molecules.
Hydrolysis: Fats can also react with water, leading to the breakdown of triglycerides and the release of fatty acids, which can contribute to rancidity.
Microbial Activity:
Microorganisms can also play a role in rancidity, particularly in foods with high moisture content.

Types of Rancidity

Oxidative Rancidity: This is the most common type and is caused by the direct oxidation of fats and oils.
Hydrolytic Rancidity: This type involves the breakdown of fats by hydrolysis.
Microbial Rancidity: This occurs when microorganisms produce enzymes that break down fats and oils.

Prevention of Rancidity

Antioxidants: Adding antioxidants to food can help prevent oxidation by scavenging free radicals.
Proper Storage: Storing food in airtight containers and at low temperatures can slow down the oxidation process.
Flushing with Inert Gases: Packaging food in nitrogen or other inert gases can displace oxygen and prevent rancidity.
Reducing Exposure to Light and Heat: Minimizing exposure to light and heat can also help prevent rancidity.

Consequences of Rancidity

Unpleasant Odours and Tastes: Rancid food develops a characteristic off−flavor and odor, making it unpalatable.
Loss of Nutrients: Rancidity can also lead to a loss of vitamins and other essential nutrients in food.
Potential Health Concerns: In some cases, rancid food may pose health risks, especially if consumed in large quantities.

Common Examples of Oil Adulteration

Mustard oil: Often adulterated with rice bran oil or argemone oil.
Palm oil: Can be adulterated with higher−priced sesame or groundnut oils.
Cooking oils: May be adulterated with carcinogenic food colorants like metanil yellow.

Health Risks *Associated with Oil Adulteration:*

Heart problems: Adulterated oils can contribute to heart disease.
Liver diseases: Certain adulterants can damage the liver.
Digestive issues: Adulterated oils can lead to indigestion and allergies.
Increased risk of cancer: Some adulterants like aflatoxins and heavy metals can be carcinogenic.

How to Detect Adulteration

Visual Inspection: While some adulterants may not be easily detectable by sight, changes in colour or texture can be a sign.
Freezing Test: Some oils, like coconut oil, can be tested by refrigerating them. Adulterated oils will show separate layers after solidification due to different freezing points.
Reputable Sources: Purchasing oil from reliable and trusted sources can help minimize the risk of adulteration.
FSSAI Guidelines: The Food Safety and Standards Authority of India (FSSAI) provides guidelines and testing methods for edible oils.
Laboratory Testing: Advanced techniques like spectroscopy (FTIR, ATR−FTIR) and chemometrics can be used for accurate detection of adulteration.

Oils, fats, and waxes are all types of lipids, which are a diverse group of naturally occurring organic compounds that are generally insoluble in water and soluble in organic solvents. While they share this common characteristic, they differ in their specific chemical structures and physical properties.[3]

Oils and Fats

Definition: Both are esters of glycerol and fatty acids.
Key Difference: The primary difference is their state at room temperature. Oils are liquid, while fats are solid.
Examples: Vegetable oils (like olive oil and canola oil) and animal fats (like butter and lard).

Waxes

Definition: Waxes are also esters, but they are formed from long−chain fatty acids and long−chain monohydric alcohols (instead of glycerol).
Key Difference: They are typically harder, more brittle, and have a higher melting point than fats.
Examples: Beeswax, carnauba wax, and spermaceti.

Lipids in General

Solubility: Lipids are generally insoluble in water due to their predominantly hydrocarbon (nonpolar) nature.
Solvents: They are soluble in organic (nonpolar) solvents like ether, chloroform, and benzene.
Biological Roles: Lipids play crucial roles in living organisms, including energy storage, insulation, and forming cell membranes.

Oils, fats, and waxes are all types of lipids, which are a diverse group of naturally occurring organic compounds that are generally insoluble in water and soluble in organic solvents. While they share this common characteristic, they differ in their specific chemical structures and physical properties.

Oils and Fats

Definition: Both are esters of glycerol and fatty acids.
Key Difference: The primary difference is their state at room temperature. Oils are liquid, while fats are solid.
Examples: Vegetable oils (like olive oil and canola oil) and animal fats (like butter and lard).

Waxes

Definition: Waxes are also esters, but they are formed from long−chain fatty acids and long−chain monohydric alcohols (instead of glycerol).

Key Difference: They are typically harder, more brittle, and have a higher melting point than fats.
Examples: Beeswax, carnauba wax, and spermaceti.

Lipids in General

Solubility: Lipids are generally insoluble in water due to their predominantly hydrocarbon (nonpolar) nature.
Solvents: They are soluble in organic (nonpolar) solvents like ether, chloroform, and benzene.
Biological Roles: Lipids play crucial roles in living organisms, including energy storage, insulation, and forming cell membranes.

Waxes are a diverse group of organic compounds that are typically malleable, lipophilic solids at room temperature. They are characterized by their ability to soften and melt at relatively low temperatures, forming low−viscosity liquids. Chemically, waxes are esters formed by the combination of long−chain fatty acids and long−chain alcohols.
Lipophilic: Waxes are soluble in non−polar solvents like oils and fats, but not in water.
Malleable: They can be easily shaped or moulded, especially when warmed.
Low melting point: Waxes melt at temperatures usually above 40°C, but significantly lower than many other solids.

Chemical Composition

Esters: Waxes are esters, meaning they are formed by the reaction between a long chain fatty acid and an fatty alcohol. A wax is a simple lipid which is an ester of a long−chain alcohol and a fatty acid. The alcohol may contain from 12−32 carbon atoms. Waxes are found in nature as coatings on leaves and stems.
Long chains: Both the fatty acid and alcohol components of waxes have long hydrocarbon chains, often with more than 20 carbon atoms.
Examples: Common examples include beeswax, carnauba wax, and paraffin wax.

Occurrence and Functions

Natural waxes: Found in plants (e.g., on leaves and fruits to prevent water loss) and animals (e.g., earwax, sebum).
Industrial uses: Waxes are used in a wide range of applications, including cosmetics, coatings, polishes, lubricants, and 3D printing.

Types of Waxes

Natural waxes: Derived from plants (e.g., carnauba, soy wax) or animals (e.g., beeswax).
Synthetic waxes: Produced through chemical synthesis, such as polyethylene and polypropylene waxes.
Support waxes: Designed for specific applications like 3D printing or investment casting.
In essence, waxes are versatile substances with a wide range of applications due to their unique physical and chemical properties.

1. The **iodine value** (IV or iodine number) is a measure of the degree of unsaturation in fats and oils. It indicates the amount of iodine absorbed by a substance, which is directly related to the number of double bonds present in its fatty acids. Specifically, it represents the number of grams of iodine that will react with 100 grams of the fat or oil.
Here's a more detailed explanation:

- **Unsaturation:** Fats and oils can be saturated (containing only single bonds between carbon atoms) or unsaturated (containing one or more double or triple bonds).
- **Iodine's Role:** Iodine reacts with the double bonds in unsaturated fatty acids, forming iodine derivatives.
- **Measurement:** The iodine value is determined by reacting a known weight of the fat or oil with a known excess of iodine monochloride (Wijs solution). The excess iodine is then titrated with sodium thiosulfate, and the amount of iodine consumed is calculated.
- **Higher Iodine Value:** A higher iodine value indicates a greater degree of unsaturation, meaning the fat or oil contains more double bonds.

Significance: Iodine values are used to characterize and compare different fats and oils, as well as to assess their stability and suitability for various applications. For example, higher iodine values are associated with oils that are more prone to oxidation and rancidity.[4]

The iodine value formula, used to determine the degree of unsaturation in fats and oils, is calculated as:

$$\mathbf{(V1 - V2) \times N \times 12.69 / W}$$

Where:
V1: is the volume (in mL) of sodium thiosulfate solution used to titrate the blank (no oil sample).
V2: is the volume (in mL) of sodium thiosulfate solution used to titrate the oil sample.
N: is the normality of the sodium thiosulfate solution.
12.69: is a conversion factor (126.9 / 10, where 126.9 is the gram equivalent weight of iodine, and 10 is a conversion factor).
W: is the weight (in grams) of the oil sample.
This formula essentially measures how much iodine is consumed by the oil sample, which is directly related to the amount of unsaturated bonds present. The higher the iodine value, the more unsaturated the fat or oil.

Examples: Different fats and oils have different iodine values. For instance, linseed oil (used in paints and varnishes) has a high iodine value, while coconut oil (used in cooking) has a lower iodine value, according to some publications

The determination of iodine value is a particular example of iodometry. A solution of iodine I_2 is yellow/brown in colour. When this is added to a solution to be tested, however, any chemical group (usually in this test −C=C− double bonds) that react with iodine effectively reduce the strength, or magnitude of the colour (by taking I_2 out of solution). Thus the amount of iodine required to make a solution retain the characteristic yellow/brown colour can effectively be used to determine the amount of iodine sensitive groups present in the solution. The chemical reaction associated with this method of analysis involves formation of the diiodo alkane (R and R' symbolize alkyl or other organic groups):

$$R - CH = CH - R' + I_2 \longrightarrow R - CH\,(I) - CH\,(I) - R'$$

The precursor alkene (RCH=CHR′) is colourless and so is the organoiodine product (RCHI−CHIR′). In a typical procedure, the fatty acid is treated with an excess of the Hanuš or Wijs solution, which are, respectively, solutions of iodine monobromide (IBr) and iodine monochloride (ICl) in glacial acetic acid. Unreacted iodine monobromide (or monochloride) is then allowed to react with potassium iodide, converting it to iodine I_2, whose concentration can be determined by back−titration with sodium thiosulfate ($Na_2S_2O_3$) standard solution by starch indicator.

Table 1: Iodine value.

Fat	**Iodine value (gI/ 100g)**	**Fat**	**Iodine value (gI/ 100g)**	**Fat**	**Iodine value (gI/ 100g)**	**Fat**	**Iodine value (gI/ 100g)**
Beef tallow	42 – 48	Beeswax	7 – 16	Butter	25 – 42	Canola oil	110 – 126
Castor oil	81 – 91	Dehydrated castor oil	127 − 140	Cocoa butter	32 – 40	Coconut oil	6 – 11
Cod liver oil	148 – 183	Corn oil	107 – 128	Cottonseed oil	100 – 115	Fish oil	190 – 205
Grape seed oil	94 – 157	Hazelnut oil	83 – 90	Jojoba oil	80 – 85	Kapok seed oil	86 – 110
Lard	52 – 68	Linseed oil	170 – 204	Olive oil	75 – 94	Oiticica oil	139 – 185
Palm kernel oil	14 – 21	Palm oil	49 – 55	Peanut oil	82 – 107	Pecan oil	77 – 106
Pistachio oil	86 – 98	Poppy seed oil	140 – 158	Rapeseed oil	94 – 120	Rice bran oil	99 – 108
Safflower oil	135 – 150	Sesame oil	100 – 120	Sunflower oil	110 – 145	Soybean oil	120 – 139
Tung oil	160 – 175	Walnut oil	132 – 162	Wheat germ oil	115 – 128		

2. The **saponification value** (SV or number) is a measure of the amount of alkali (usually potassium hydroxide or sodium hydroxide) required to saponify a given amount of fat or oil by reflux. It's expressed as the number of milligrams of alkali needed to neutralize the fatty acids in one gram of the substance. This value is an indicator of the average molecular weight of the fatty acids present in a fat or oil.

Saponification: This is the chemical process where a fat or oil reacts with a base (like KOH or NaOH) to produce glycerol and fatty acid salts (soap). A higher saponification value generally indicates that the fat or oil contains a higher proportion of fatty acids with shorter chain lengths, as these require more alkali for saponification. Conversely, a lower value suggests longer chain fatty acids.

Practical uses

Saponification value is a useful parameter for:

Quality control: Helps assess the purity and composition of fats and oils.

Soap making: Used to calculate the amount of alkali needed for a specific recipe.

Fatty acid composition: Provides information about the average molecular weight of the fatty acids in a sample.

A known quantity of the fat or oil is reacted with a known excess of alkali. The remaining alkali is then titrated with an acid to determine how much alkali was consumed in the saponification reaction.

Examples: Different oils have varying saponification values. For example, coconut oil has a high saponification value (around 250−260), while olive oil's is lower (around 188−196).

Waxes, like beeswax, typically have much lower saponification values than fats and oils.[5]

Relationship to molecular weight: The saponification value is inversely proportional to the average molecular weight of the fatty acids in the fat or oil. To determine saponification value, the sample is treated with an excess of alkali (usually an ethanolic solution of potassium hydroxide) for half an hour under reflux. The KOH is consumed by reaction with triglycerides, which consume three equivalents of base. Diglycerides consume two equivalents of KOH. Monoglycerides and free fatty acids, as well as other esters such as lactones, consume one equivalent of base. At the end of the reaction the quantity of KOH is determined by titration using standard solution of hydrochloric acid (HCl). Key to the method is the use of phenolphthalein indicator, which indicates the consumption of strong base (KOH) by the acid, not the weak base (potassium carboxylates). The SV (mg KOH/g of sample) is calculated as following:

$$\mathbf{SV = (B - S) \times M \times 56.106 / W_{oil/fat}}$$

Where:
B=is the volume of HCl solution used for the blank run, in mL;
S=is the volume of HCl solution used for the tested sample, is the molarity of HCl solution, in mol / L;
56.1 is the molecular weight of KOH, in g / mol;
W= oil/fat is the weight of sample, in g.

Table 2: Saponification & Unsaponification value.

Lipids	Saponification value	Unsaponification value	Lipids	Saponification value	Unsaponification value
Beeswax	60 – 102	> 52	Canola oil	182 – 193	< 0.2
Cocoa butter	192 – 200	0.2 – 1	Coconut oil	248 – 265	0.1 – 1.4
Corn oil	187 – 195	1 – 3	Cottonseed oil	189 – 207	< 2
Fish oil	179 – 200	0.6 – 3	Lanolin	80 – 127	40 – 50
Lard	192 – 203	< 10	Linseed oil	188 – 196	0.1 – 2
Mineral oil	0	100	Olive oil	184 – 196	0.4 – 1.1
Palm kernel oil	230 – 254	< 1	Palm oil	190 – 209	< 1.4
Peanut oil	187 – 196	0.2 – 4.4	Rapeseed oil	168 – 181	0.7 – 1.1
Safflower oil	188 – 194	< 1.6	Shea butter	170 – 190	6 – 17
Soybean oil	187 – 195	1.5 – 2.5	Sunflower oil	189 – 195	0.3 – 1.2

3. The **acid value** (AV) of an oil is a measure of the amount of free fatty acids present, expressed as the number of milligrams of potassium hydroxide (KOH) required to neutralize the acids in one gram of oil. It's a key indicator of an oil's quality and degree of deterioration, with higher values often suggesting increased rancidity.

Free fatty acids: These are formed when triglycerides (the main component of fats and oils) break down, often due to factors like moisture, temperature, or enzymatic activity.
Rancidity: The presence of free fatty acids contributes to rancidity, which is the spoilage of fats and oils, resulting in undesirable flavours and odours.
Corrosiveness: High acid values can also indicate that the oil might be corrosive.

How it's determined
Titration: The acid value is typically determined by titrating the oil with a standardized solution of potassium hydroxide (or sometimes sodium hydroxide) using a suitable indicator like phenolphthalein.
Calculation: The amount of base needed to neutralize the acid is measured, and this value is then used to calculate the acid value in mg KOH/g of oil.

The acid value formula is used to determine the amount of free fatty acids in a fat or oil. It's calculated by multiplying the volume of the alkali (usually KOH or NaOH) used in titration by its normality and a factor (56.1 for mg KOH/g fat or 28.2 for FFA in %), then dividing by the weight of the sample.

Here's a breakdown of the formula:

Acid Value (mg KOH/g fat) = (Volume of KOH used (mL) × Normality of KOH × 56.1) / Weight of sample (g)

Or, expressed differently:

Acid Value (mg KOH/g fat) = (S × N × 56.1) / W

Where:
S: Volume of standard alkali solution used for titration (mL)
N: Normality of the standard alkali solution
W: Weight of the sample (g)
56.1: A factor derived from the molecular weight of KOH (56.1 g/mol), representing the amount of KOH in milligrams equivalent to 1 mL of 1N solution

For determining the Free Fatty Acids (FFA) as a percentage, the formula can be modified:

FFA (%) = (Volume of KOH used (mL) × Normality of KOH × 28.2) / Weight of sample (g)

Where 28.2 is the molecular weight of oleic acid (a common fatty acid) divided by 10.

The acid value is determined through a titration process where a known volume and concentration of a standard alkali solution (KOH or NaOH) is used to neutralize the free fatty acids present in a fat or oil sample.

The volume of alkali required for neutralization is recorded, and this volume, along with the normality of the alkali and the weight of the sample, is used in the formula to calculate the acid value.

The acid value is a measure of the degree of rancidity of the fat or oil, with higher values indicating a greater degree of rancidity. The phenolphthalein indicator is often used to determine the endpoint of the titration.

Importance

Quality Control: Acid value is a crucial parameter for assessing the quality of edible oils and fats.

Refining Process: It helps monitor the effectiveness of oil refining processes aimed at reducing free fatty acids.

Food Safety: It's used to ensure that oils and fats meet food safety standards and are suitable for consumption.

Predicting Shelf Life: Higher acid values are generally associated with shorter shelf lives and increased risk of spoilage.

Table 3: Acid value.

Fat/oil	Acid value (mg KOH per g sample)	Fat/oil	Acid value (mg KOH per g sample)
Beeswax	17 – 36	Canola oil	0.071 – 0.073
Maize oil	0.223 – 0.224	Soybean oil	0.60 – 0.61
Used frying oil	0.1 – 2.5	Virgin olive oil	0.8 – 2

4. The **hydroxyl value** (HV) represents the amount of potassium hydroxide (KOH) needed to neutralize the acetic acid produced by the acetylation of one gram of a substance containing hydroxyl groups. In simpler terms, it indicates the concentration of hydroxyl groups in a substance. It's a crucial parameter, particularly in the analysis of polyols and other hydroxyl−containing polymers, as it relates to crosslinking efficiency and quality control of raw materials.

Definition: HV is the mass (in milligrams) of potassium hydroxide required to neutralize the acetic acid formed when reacting with the hydroxyl groups in one gram of a substance.[6]

Measurement: It's typically determined by reacting the substance with acetic anhydride (acetylation), and then titrating the resulting mixture with a standardized solution of potassium hydroxide by phenolphthalein indicator.

Significance

Polymer Synthesis: HV is a key factor in determining the crosslinking density of polymers, particularly polyurethanes.

Quality Control: It helps assess the purity and consistency of raw materials like polyols, which are used in various industrial applications.

Reaction Efficiency: HV can be used to monitor the progress and efficiency of reactions where hydroxyl groups are involved.

Figure 3: Ghee & Butter.

Methods of Determination: While traditional chemical methods (like titration) are common, spectroscopic methods, especially Fourier Transform Near−Infrared (FT−NIR) spectroscopy, are also employed for faster and more accurate results.

Example: In the context of polyol analysis, the HV indicates the concentration of hydroxyl groups available for reaction with isocyanates in polyurethane synthesis. The hydroxyl value can be calculated using the following equation. Note that a chemical substance may also have a measurable acid value affecting the measured endpoint of the titration. The acid value (AV) of the substance, determined in a separate experiment, enters into this equation as a correction factor in the calculation of the hydroxyl value (HV):

$$\mathbf{HV = 56.1 \times N \times (VB - V_{acet}) / W_{acet} + AV}$$

Where HV is the hydroxyl value; VB is the amount (ml) potassium hydroxide solution required for the titration of the blank; V_{acet} is the amount (ml) of potassium hydroxide solution required for the titration of the acetylated sample; W_{acet} is the weight of the sample (in grams) used for acetylation; N is the normality of the titrant; 56.1 is the molecular weight of potassium hydroxide (g/mol); AV is a separately determined acid value of the chemical substance.

5. The **acetyl value** is a measure of the number of hydroxyl groups present in a fat or oil, specifically indicating the amount of potassium hydroxide (KOH) needed to neutralize the acetic acid produced when 1 gram of the acetylated substance is saponified. It is a crucial parameter in determining the composition and quality of fats and oils, particularly in the context of identifying the presence of free fatty acids and hydroxyl groups.

What it measures

Hydroxyl Groups: Acetyl value primarily reflects the number of hydroxyl (−OH) groups in a molecule. These groups are often found in fatty acids with hydroxy substituents, like ricinoleic acid.

Free Fatty Acids: While not its primary function, the acetyl value can also indirectly indicate the presence of free fatty acids (FFAs), as they can be acetylated and contribute to the overall value.

How it's determined

1. Acetylation: The fat or oil sample is first reacted with acetic anhydride. This process acetylates the hydroxyl groups, converting them into acetylated derivatives.
2. Saponification: The acetylated substance is then saponified (hydrolyzed) using a known amount of potassium hydroxide (KOH). This releases acetic acid, which is then neutralized by excess KOH.
3. Titration: The amount of KOH needed to neutralize the acetic acid is determined through titration. The acetyl value is then calculated based on the amount of KOH used by phenolphthalein as indicator.

Significance

Quality Control: Acetyl value is used to assess the quality and purity of fats and oils.

Rancidity: High acetyl values can indicate the presence of free fatty acids and potential rancidity in oils.

Composition Analysis: It helps in determining the composition of fats and oils, particularly the proportion of hydroxyl−containing fatty acids.

Industrial Applications: The acetyl value is relevant in various industrial applications, including the production of lubricants, cosmetics, and pharmaceuticals, where the properties of fats and oils are critical.

The acetyl value is a measure of the hydroxyl (OH) groups present in a substance, expressed as the number of milligrams of potassium hydroxide (KOH) equivalent to the acetic acid that can be formed by acetylating 1 gram of the substance. It's determined by acetylating the substance (usually a fat or oil) with acetic anhydride, then hydrolyzing the acetylated product and titrating the liberated acetic acid with a base, usually KOH by phenolphthalein indicator.

The formula to calculate acetyl value is:

$$\textbf{Acetyl Value} = [(b - a) \times 56.1 \times 1000] / (\text{weight of sample in grams})$$

Where:

a: is the volume (in mL) of the KOH solution used to neutralize the free fatty acids in the sample (before acetylation).

b: is the volume (in mL) of the KOH solution used to neutralize the acetic acid after acetylation and hydrolysis of the acetylated sample.

56.1: is the molecular weight of KOH.

1000: is a factor to convert grams to milligrams.

Alternatively, the formula can be expressed as:

Acetyl Value = $[(b - a) \times 56.1 \times 1000)] / $ (weight of acetylated sample in grams).

This formula is based on the amount of potassium hydroxide (KOH) required to neutralize the acetic acid liberated during the hydrolysis of the acetylated sample. The difference between the volume of KOH used before and after acetylation represents the amount of acetic acid produced during acetylation.

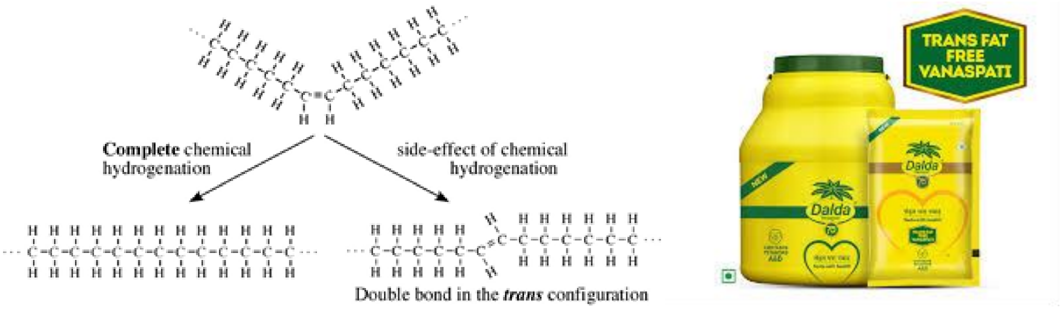

Figure 4: Hydrogenation of fat.

6. The **Reichert−Meissl** (RM) value is calculated using the formula: **RM Value = (A − B) × N × 11**, where A is the volume of NaOH solution used to neutralize the volatile fatty acids in the sample, B is the volume of NaOH used in the blank test, and N is the normality of the NaOH solution. This value is a measure of the water−soluble, steam−volatile fatty acids (primarily butyric and caproic acids) present in 5gms fats and oils.[7]

Explanation

A (Volume of NaOH for the sample): This is the volume of the sodium hydroxide (NaOH) solution (usually 0.1N) required to neutralize the volatile fatty acids distilled from the fat or oil sample by phenolphthalein indicator.

B (Volume of NaOH for the blank): This is the volume of NaOH solution needed to neutralize the volatile fatty acids in a blank test, which is conducted without the fat

or oil sample.
N (Normality of NaOH): This refers to the concentration of the sodium hydroxide solution used in the titration.
11: This is a constant factor used in the calculation.

In essence, the Reichert−Meissl value is a quantitative measure of these specific fatty acids, which are significant in identifying and characterizing different fats and oils, particularly butter.

The Reichert−Meissl (RM) value of ghee, a measure of volatile, water−soluble fatty acids, typically ranges from 28 to 34 for pure ghee. Specifically, pure cow ghee generally has an RM value between 28.60 and 30.36, while buffalo ghee tends to be higher, ranging from 31.46 to 34.98. The RM value is a key indicator used to assess the purity of ghee and detect adulteration.

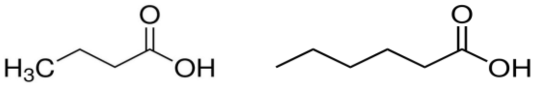

Figure 5: Butyric and Caproic acids.

Hydrogenated fat is a type of fat that has been chemically altered to change its properties. Specifically, hydrogenation is a process where hydrogen atoms are added to unsaturated fatty acids, often in vegetable oils, to make them more saturated and solid at room temperature. This process is used to extend shelf life and improve texture in various food products.

What it is: Hydrogenation turns liquid oils into solid or semi−solid fats, like margarine and shortening.

How it's made: It involves adding hydrogen to unsaturated fatty acids (found in oils) under pressure, often with a catalyst like nickel.

Table 4: Reichert−Meissl (RM) value.

Samples	Ratios	Reichert−Meissl (RM) value
Hydrogenated vegetable oil	5%	14
Tallow	5%	12
Coconut oil	5%	3
Soybean oil	5%	4
Cow Ghee	5%	28.60−30.36
Buffalo	5%	31.46−34.98

Why it's used: Food manufacturers use it to:

Extend shelf life: Hydrogenated fats are more stable and less prone to becoming rancid according to health publications.
Improve texture: It can create a more solid, spreadable, or stable consistency in food products says a health information site.
Lower costs: Hydrogenated oils can be cheaper than some other fats.

Examples: Hydrogenated fats are commonly found in:

Margarine, Shortening, Baked goods, Fried foods, some processed foods.

Health concerns: While hydrogenation can be beneficial for food production, it also creates trans fats, which have been linked to negative health effects like increased risk of heart disease.

Regulation: The FDA banned the use of partially hydrogenated oils (PHOs) in food products in 2018 due to health concerns.

CONCLUSION

Adulteration in edible oils is widespread, with distinctive contaminants, including cottonseed, mineral, and lower−cost oils like palm olein. In the case of ghee, it is repeatedly combined with animal fats, synthetic materials, or vanaspati. The most commonly adulterated oils are mustard, peanut, groundnut, olive, ghee, coconut, and refined sunflower oil. There are three types of adulteration namely: Intentional adulterants, Metallic contamination, Incidental adulterants.

REFERENCES

1. Food and Agriculture Organization and World Health Organization. (2001). The Codex Alimentarius. Rome: FAO/WHO. Volume 8: Fats and Oils, "Section 4.9.1: Estimation of Milk Fat Content". ISBN 92−5−104682−4.
2. Gunstone, F.D.; Harwood, J.L. The Lipid Handbook (Third ed.). Boca Raton, FL: CRC Press, 2007; 424. ISBN 978−1−4200−0967−5. OCLC 327018169.
3. Firestone D. "Determination of the iodine value of oils and fats: summary of collaborative study". Journal of AOAC International, May–Jun. 1994; 77(3): 674–6.
4. Moghimi, Abolghasem; Omrani, Ismail; Nabid, Mohammad Reza; Mahmoodi, Mehrdad. "Quantification of hydroxyl group in polymers containing trace water by 19F NMR spectroscopy". European Polymer Journal, 2013; 49: 228–234.
5. Lück, Erich; von Rymon Lipinski, Gert−Wolfhard (2000). "Foods, 3. Food Additives". Ullmann's Encyclopedia of Industrial Chemistry. Weinheim: Wiley−VCH.
6. EFSA Panel on Biological Hazards. "Scientific Opinion on Fish Oil for Human Consumption. Food Hygiene, including Rancidity". EFSA Journal, 2010; 8(10): 1874.
7. Feigenson GW. "Phase behavior of lipid mixtures". Nature Chemical Biology, November 2006; 2(11): 560–563.