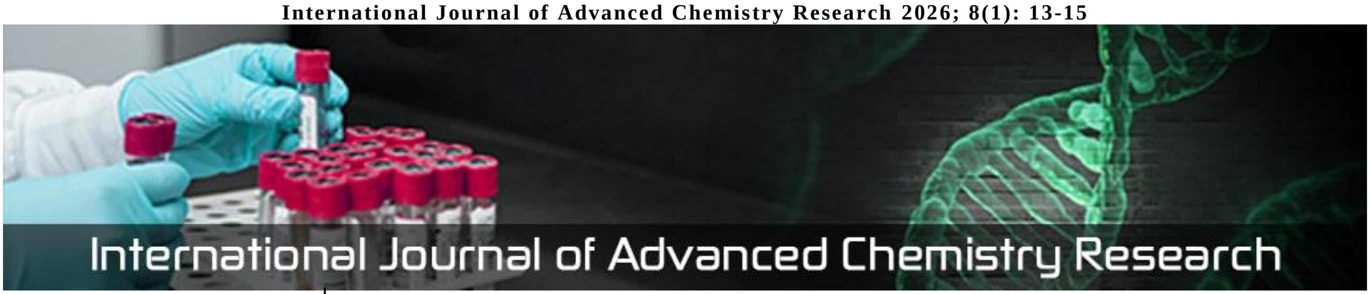

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A review-study of FTIR analysis of linseed oil

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Abstract
Fourier Transform Infrared (FTIR) spectroscopy is a powerful analytical technique for investigating the molecular composition and chemical properties of oils. This study focuses on the FTIR analysis of linseed oil, a widely used drying oil rich in polyunsaturated fatty acids, to characterize its functional groups and assess its chemical structure. The oil sample was analyzed in the mid-infrared region (4000-400 cm^{-1}) to identify characteristic absorption bands corresponding to hydroxyl (-OH), carbonyl (C=O), and unsaturated (C=C) groups. Prominent peaks were observed at ~1745 cm^{-1}, indicating ester carbonyl stretching, and at ~3010 cm^{-1}, associated with =C-H stretching of unsaturated fatty acids. Additional bands corresponding to -CH_2 and -CH_3 stretching (~2920 cm^{-1} and ~2850 cm^{-1}) and C-O stretching (~1160 cm^{-1}) were also identified. The FTIR spectral profile provided insight into the degree of unsaturation and oxidative state of linseed oil, which is crucial for its applications in coatings, paints, and polymer formulations. The study demonstrates that FTIR spectroscopy offers a rapid, non-destructive, and reliable method for characterizing linseed oil and monitoring its quality.

Keywords: Linseed oil, FTIR, spectroscopy

Introduction

Vegetable oils are water insoluble products of plants and represent triesters of glycerol (or triglycerides) with saturated and unsaturated fatty acids. They can also be produced through reaction of glycerol with fatty acids [4]. Vegetable oil molecule includes an ester part (triglyceride) and a non-ester part represented by: phospholipids, sterols, vitamins and their precursors, antioxidants, pigments and impurities [5]. Triglyceride itself represents that part of the oil molecule which can be exploited in the industry, due to a great number of the double bonds on the fatty acid structure. The fatty acid composition of vegetable oils is the main factor influencing their properties, concerning both nutrition and exploitation as raw materials for oleo chemistry [6, 7].

Linum usitatissimum, is a member of the family *Linaceae*. The unsaturated fatty acids content of linseed oil are in a range of 90% with high content of omega-3 and omega-6 fatty acids which makes it an excellent choice as edible oil (nutritional supplement), in surfactants and detergents, cosmetics and pharmaceutical industry. With iodine value of 175 - 204 g I2/100g.

The object of this article is to determine the chemical composition of flax seed oil by FTIR spectroscopy [8-17].

Materials and methods

All measurements for linseed oil were carried out using a Thermo Scientific Nicolet 6700 FT-IR (has DLaTGS detector and CsI beamsplitter) with a “Smart Orbit” micro-ATR in mid-IR and far-IR region (4000-225 cm^{-1}).

Results and discussions: Figure 2 shows the FTIR spectrum of linseed oil with frequencies between 3010 and 459cm^{-1}.

ATR-FTIR signals: FTIR (ATR, cm^{-1}): 3010 (ν=CH-); 2923, 2853 (νC-H asim, sim), 1742 (νC=O); 1655 (νC=C from unsaturated acids); 1461 (δCH2); 1376 (δCH3); 1237, 1160, 1098(νC-O); 721 (ρCH2). The Fourier Transform Infrared (FTIR) spectrum of linseed oil was recorded in the mid-infrared region (4000-400 cm^{-1}) to investigate its chemical composition and functional groups. The spectrum revealed several characteristic peaks that correspond to the molecular structure of linseed oil, which is predominantly composed of triglycerides rich in polyunsaturated fatty acids, such as linolenic, linoleic, and oleic acids.

A broad absorption band observed around 3400 cm^{-1} corresponds to the stretching vibration of hydroxyl (-OH) groups. Although linseed oil is primarily composed of esterified fatty acids, small amounts of free fatty acids or residual moisture can contribute to this broad band. The presence of this band suggests minor hydrolysis or the presence of trace water content, which is common in natural oils. The broad nature of the band indicates hydrogen bonding interactions, which can slightly influence the oil's viscosity and oxidative stability.

Fig 1: Thermo Scientific Nicolet 6700 FT-IR

Strong absorption bands were observed at approximately 2920 cm^{-1} and 2850 cm^{-1}, corresponding to the asymmetric and symmetric stretching vibrations of methylene (-CH_2) and methyl (-CH_3) groups, respectively. These vibrations are characteristic of long aliphatic chains present in the fatty acids of linseed oil. The relative intensity of these peaks provides information about the chain length and the relative abundance of saturated versus unsaturated fatty acids. In linseed oil, these peaks are consistent with its high content of long-chain unsaturated fatty acids.

A prominent peak at 1745 cm^{-1} is assigned to the carbonyl (C=O) stretching vibration of ester functional groups in triglycerides. This is a key feature of all natural oils and confirms that linseed oil exists primarily in an esterified triglyceride form. The sharpness and intensity of this peak indicate a relatively low degree of hydrolysis, suggesting the sample is of good quality. Additionally, the C=O stretching band can shift slightly in cases of oxidation or chemical modification, making it an important marker for monitoring oil stability.

A peak near 1655 cm^{-1} corresponds to the stretching vibration of cis carbon-carbon double bonds (C=C) in unsaturated fatty acids. This band confirms the high degree of unsaturation in linseed oil, which is primarily responsible for its drying properties and reactivity in polymerization and crosslinking reactions. The intensity of this peak correlates with the content of polyunsaturated fatty acids such as linolenic acid. FTIR analysis thus provides a simple method to assess the unsaturation level, which is crucial for predicting the oil's performance in industrial applications like paints, varnishes, and coatings.

Bands observed around 1465 cm^{-1} and 1375 cm^{-1} are attributed to bending vibrations of methylene and methyl groups, respectively. These peaks are indicative of the aliphatic backbone of the fatty acid chains. The presence of these bands confirms that linseed oil contains long-chain hydrocarbon structures, which contribute to its hydrophobic nature and stability. Variations in these peaks can indicate structural modifications, such as oxidation or polymerization, which are relevant in quality assessment.

The absorption bands between 1160 and 1240 cm^{-1} correspond to C-O stretching vibrations of ester groups. These peaks further support the triglyceride structure of linseed oil and are consistent with literature reports on vegetable oils. These bands are particularly useful for distinguishing esterified oils from free fatty acids or degraded samples. The relative intensity and position of the C-O bands can also provide information about the oil's oxidative state and purity.

Weak bands in the 720-730 cm^{-1} region are attributed to -CH_2 rocking vibrations and out-of-plane bending modes of the hydrocarbon chains. These bands are characteristic of long-chain fatty acids and provide additional confirmation of the molecular structure of linseed oi

The FTIR spectrum of linseed oil reflects its chemical integrity and high degree of unsaturation. The presence of prominent C=O and C-O bands confirms the triglyceride structure, while the C=C band indicates polyunsaturation critical for drying and oxidative polymerization. Minor O-H absorption suggests trace free fatty acids or moisture, which may influence storage stability. The FTIR profile also serves as a reference for detecting adulteration or degradation in commercial samples, making it a valuable tool for quality control.

Overall, FTIR spectroscopy provides rapid, non-destructive, and accurate information about linseed oil's functional groups, unsaturation level, and structural features. The spectral analysis confirms that the sample under study is of standard quality, suitable for industrial applications, and highlights the technique's utility in monitoring chemical changes such as oxidation, hydrolysis, or polymerization over time.

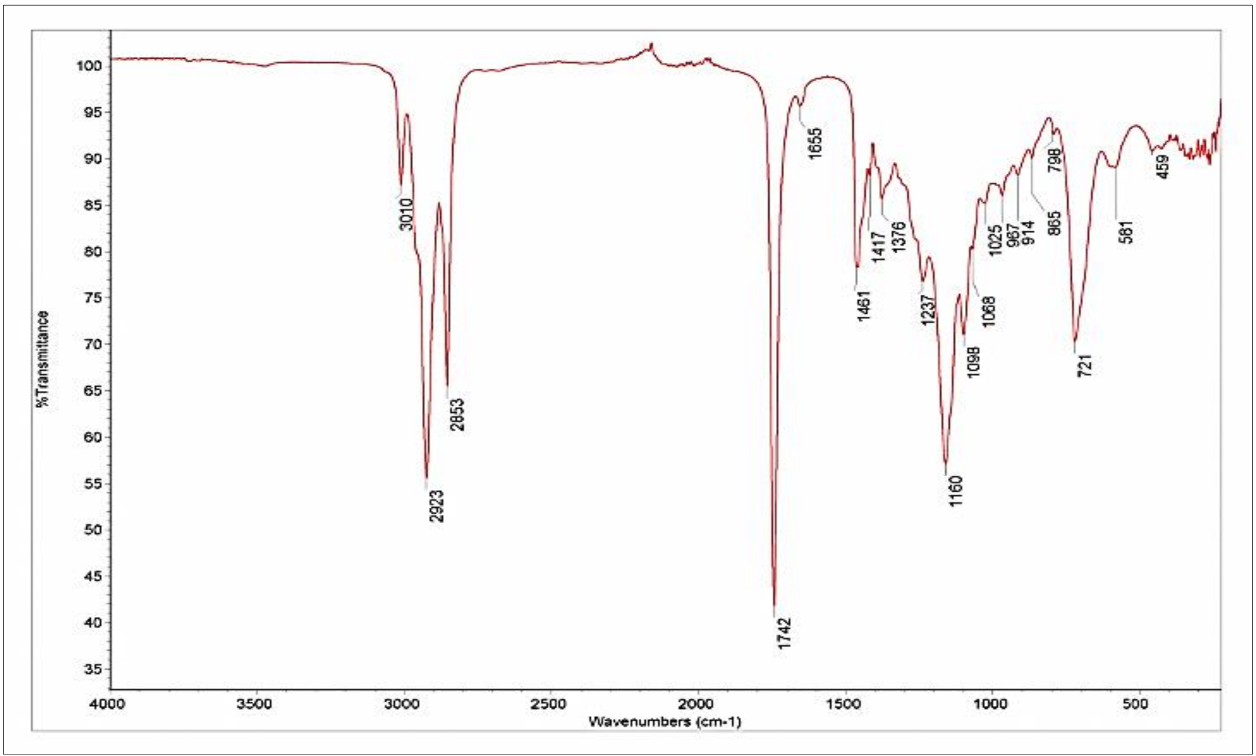

Fig 2: FTIR spectra of linseed oil

Conclusions

The FTIR analysis of linseed oil successfully identified its characteristic functional groups and provided detailed insight into its chemical structure. Key absorption bands corresponding to ester carbonyl (C=O), hydroxyl (-OH), unsaturated (C=C), and aliphatic ($-CH_2$/$-CH_3$) groups were clearly observed, confirming the presence of polyunsaturated fatty acids typical of linseed oil. The spectral data also revealed information about the degree of unsaturation and potential oxidative changes, which are critical for its performance in industrial applications such as paints, varnishes, and polymer formulations. Overall, FTIR spectroscopy proved to be a rapid, non-destructive, and reliable analytical tool for characterizing linseed oil, monitoring its quality, and assessing its chemical integrity. This study reinforces the utility of FTIR as an essential technique for both research and quality control in natural oils.

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