THERMOANALYSIS OF SOYBEAN OIL EXTRACTED BY TWO METHODS


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The thermal stability of vegetable oils is an important factor that affects their quality. In this study, we investigated the thermal stability of oil and lecithin extracted from soybeans by two distinct processes: mechanical extraction (pressing) and physical extraction (solvent). Thermal analysis was used to obtain information about different methodologies of extraction. The physically extracted products proved more stable than those extracted mechanically. Raman and UV-Vis techniques were applied to underpin the discussion of process differences.

Keywords: thermal analysis; vegetable oils; soybean oil.

INTRODUCTION

Vegetable matter usually contains 0.3 – 2.5% (dry weight) of phospholipids, while animal sources contain higher levels (eggs 14%, brain 6%, milk 2%). Oilseeds, cereal germs, egg yolk, and fish are the richest sources of phospholipids1. Although the soybean is one of the world’s ancient agricultural products, interest in this plant was much heightened by the discovery of the edible oil it contains. Soybean oil is low in saturated fat and high in monounsaturated fat and polyunsaturated fat and in essential linoleic and linolenic fatty acids, which are necessary to human health. Oxidation of unsaturated lipids is one of the major causes of the development of off-flavor compounds and the reduction in nutritive value of food products2. Also, the antioxidants naturally present in soybean oil help to reduce damage by free radicals in the body. Soybeans have a very high phosphatides content, i.e., about 2%, known as lecithin. Soy lecithin consists mainly of three types of phospholipids: phosphatidylcholine (PC), phosphatidylethanolamine (PE) and phosphatidylinositol (PI), which are commonly used as natural emulsifiers or stabilizers in a variety of foods.

Lecithin provides an excellent source of choline, which is essential to every living cell in the body and is one of the main components of cell membranes. Not only is dietary choline important for the synthesis of the phospholipids in cell membranes, but it is also necessary for methyl metabolism, cholinergic neurotransmission, transmembrane signaling and lipid-cholesterol transport and metabolism. Most of the choline in the body is present in phospholipids such as phosphatidylcholine and sphingomyelin3.

The stability and final quality of edible vegetable oils and their by-products are determined by the residual presence of certain minor compounds such as phospholipids, which provide good information about the proper oil processing and storage conditions4.5. Classical extraction technologies are based on the use of an appropriate solvent to remove lipophilic compounds from inside plant tissues. The choice of a suitable sorbent in combination with sufficient mechanical agitation influences mass transport processes and the subsequent efficiency of the extraction6. Solvent extraction with n-hexane is a widely used approach for obtaining edible oil because of its low cost and its efficiency in terms of oil and solvent recovery7,8. Other methods for extracting edible oil are ultrasound and mechanical extraction (pressing).

In this work, we used thermal analysis to study the stability of soybean oil and lecithin extracted using or physical procedure (with hexane) and mechanically (by pressing) and Raman study interaction.

EXPERIMENTAL

Raw soybean oil, refined soybean oil and soybean lecithin obtained by solvent and press extraction were thermally analyzed using TA Q 600 SDT simultaneous TG/DTA/DSC; at heating rates of 10 °C min⁻¹, in a nitrogen atmosphere and a temperature range of 25 to 650 °C. The mass of the samples was 12 to 15 mg.

The Raman spectra were obtained using a Raman System II Ocean Optics spectrooscope.

The phospholipids contained in soybean lecithin were examined by thin-layer chromatography, following the AOCS standard9. UV-Vis electron spectroscopy was used to determine the phospholipids in lecithin, based on the standard curve. The HP 8452 diode array was used to obtain the spectra.

The soybean oil was obtained by solvent and pressing10. The samples were analyzed as received from the supplier.

RESULTS AND DISCUSSION

Figure 1 shows the typical thermogravimetric curve for soybean oil extracted by solvent and pressing.

The samples displayed distinct thermal behaviors, with the oil obtained by the solvent technique showing greater thermal stability than that produced by pressing. The thermogravimetric curve revealed nonhomogeneity, probably due to the decomposition of oil in different steps, indicating the various components present in soybean oil. The oil extracted by pressing presented a slightly lower mass at temperatures above 500 °C, unlike the oil obtained by solvent extraction, whose decomposition stopped at 485.6 °C. Figure 2 presents the derivative of the thermogravimetric curve (DTG), which was used to identify the oil’s initial, maximum and final decomposition temperature (Table 1).

The DTG curve presented a nonsymmetric peak, indicating that the decomposition occurred in several steps. The calculation of the entire area of the peak provided information about the amount of...
organic matter decomposition. The temperatures and area are shown in Table 1.

The maximum and final oil decomposition temperatures were very similar, but the initial decomposition temperature was 22.1°C higher for chemically extracted soybean oil (hexane). This temperature can be considered the temperature at which soybean oil remains stable. In this study, we found that the oil obtained by solvent presented greater stability than the oil obtained by pressing, possibly due to the presence of impurities in the mechanical extraction or decomposition of the oil's components. The areas of the peaks indicate that the product of solvent extraction presented more components than that of press extraction.

The differential thermoanalysis (DTA) revealed an endothermic peak corresponding to the decomposition of oil.

The soybean oil was refined to obtain degummed oil and lecithin. This process usually involves hydration of the oil, which produces oil-insoluble phospholipids that are easily removed. The degummed oil obtained by the solvent and press method showed decomposition of the oil occurring in two steps, as confirmed by the derivative curve in Figure 4.

The TG curve for the samples showed an increase in the initial decomposition temperature, possibly due to the absence of lecithin, these temperature is presented in Table 2. The degummed oil obtained by the solvent and press method showed decomposition of the oil occurring in two steps, as confirmed by the derivative curve in Figure 4.

<table>
<thead>
<tr>
<th>Soybean oil</th>
<th>IT (°C)</th>
<th>MT (°C)</th>
<th>FT (°C)</th>
<th>IA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solvent</td>
<td>312.4</td>
<td>421.1</td>
<td>484.6</td>
<td>99.6</td>
</tr>
<tr>
<td>Pressing</td>
<td>328.5</td>
<td>409.8</td>
<td>502.3</td>
<td>99.7</td>
</tr>
</tbody>
</table>

Figure 1. Thermogravimetric curve (TG) for soybean oil, (—) solvent and (…) press extraction at heating rates of 10°C min⁻¹, in a nitrogen atmosphere.

Figure 2. Derivative of the thermogravimetric curve (DTG) for soybean oil, (—) solvent and (…) press extraction.

Table 1. Integrated area (IA), initial temperature (IT), maximum temperature (MT) and final temperature (FT) of decomposition of soybean oil obtained chemically and mechanically.

The increase in the initial decomposition temperature indicates that lecithin (phospholipids) reduced the stability of soybean oil. The other temperatures presented little variation. The amount of decomposed material, in this case, was the same.

The thermogravimetric curve for lecithins showed a lower initial decomposition temperature than the oils and degummed oils. The degummed oil presented a higher initial temperature than soybean oil extracted by solvent and press, indicating that the lecithins reduced the oil's thermal stability. The lecithins obtained from press-extracted oil presented an area of 87.3, while those obtained from solvent-extracted oil showed an area of 82.9, suggesting the former method produced a larger quantity of this substance. Table 3 lists these temperatures and areas.

Many authors have discussed the stability of soybean oil in...
relation to the quantity of phospholipids (lecithins)\(^4\). Gennero et al\(^5\) stated that lipid autoxidation contributes significantly to the deterioration and reduction of the shelf life of many products due to a free-radical chain reaction, and that some of the effects of lipid oxidation are changes in color, texture, odor, and flavor. When triglycerides and phospholipids were removed, a remarkable difference in aroma was noted, indicating that structural phospholipids play a significant role in meat aroma specificity. Phospholipids contribute through lipid-derived odorants generated by thermally induced lipid oxidation\(^1,2,6\). Although lecithins interfere in the stability of oil, they nonetheless provide a functional benefit, since they are an excellent source of choline, which is essential to every living cell in the body and is one of the main components of cell membranes\(^3\).

The Raman spectra presented vibrational and stretching modes characteristic of phospholipids. The band at 1098 cm\(^{-1}\) was ascribed \(\delta\)-(C-H) of the phospholipids, and the one at 1445 cm\(^{-1}\) to the \(\delta\)-(CH\(_2\)) of the lipids (Figure 6).

Table 3 shows the concentration of phospholipids in lecithins, which was determined following the AOCS standard\(^9\).

<table>
<thead>
<tr>
<th>Soybean oil</th>
<th>IT (°C)</th>
<th>MT (°C)</th>
<th>FT (°C)</th>
<th>IA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solvent</td>
<td>165.0</td>
<td>360.7</td>
<td>512.9</td>
<td>82.9</td>
</tr>
<tr>
<td>Press</td>
<td>149.1</td>
<td>371.9</td>
<td>515.5</td>
<td>87.3</td>
</tr>
</tbody>
</table>

Figure 5. Thermogravimetric curve (TG) for lecithin obtained by extraction of soybean oil by: (—) solvent and (—) press extraction at heating rates of 10 °C min\(^{-1}\), in a nitrogen atmosphere.

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