JOURNAL OF CHEMICAL EDUCATION

pubs.acs.org/jchemeduc

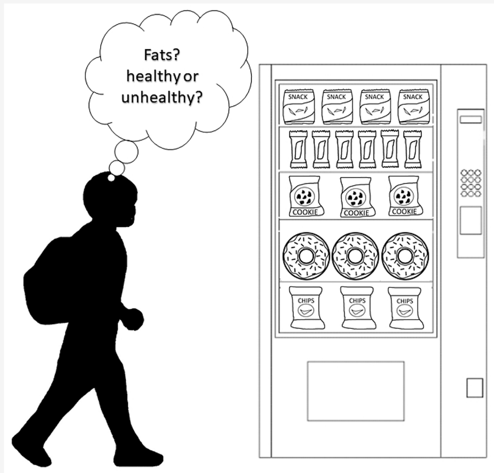
Laboratory Experiment

How Do High School Students Learn the Importance of Fats in the Diet? Analysis of the Fatty Acid Composition of Bakery Products

Enrique J. Clavijo-Bernal, Rosario Sánchez, Mónica Villoslada-Valbuena, Cristina DeAndrés-Gil, Rafael Garcés, Enrique Martínez-Force, Joaquín J. Salas, and Mónica Venegas-Calerón*

Cite This: *J. Chem. Educ.* 2023, 100, 1958–1964

Read Online



ABSTRACT: The high level of consumption of processed foods has an effect on human health. The consumption of doughnuts, pastries, fried chicken, French fried potatoes, snack chips, and imitation cheese is high among teenagers. These foods are generally rich in fats, although the focus has often been on the quantity rather than the quality of these fats. These products often contain saturated and trans fatty acids, which have adverse effects on triglycerides and cholesterol levels and raise lipoprotein(a) levels in plasma. These modifications are associated with the risk of developing certain health conditions, such as heart disease, stroke, type 2 diabetes, and obesity. It is important to note that not all fats have this negative effect on health. Dietary fats are an essential part that cannot be substituted for a healthy diet. A diet rich in healthy fats, such as monounsaturated and polyunsaturated fats, has an important benefit in human health. For this reason, it is crucial to read, identify, and interpret food labels in processed food to identify the presence of saturated or trans fats and choose healthier alternatives. Therefore, in this workshop, students in the first year of baccalaureate extracted oils and fats from a range of processed foods, quantifying and characterizing their nature by analyzing their fatty acid composition by gas chromatography. Subsequently, students compared their results according to the information given on the food package label and the literature. Finally, the students gave a talk on the work done in the laboratory and the knowledge gained from the students in lower grades, third and fourth years of high school, to raise awareness among these students.

KEYWORDS: *High School/Introduction to Chemistry, Analytical Chemistry, Analogies/Transfer, Collaborative Learning, Applications of Chemistry, Industrial Chemistry, Instrumental Methods, Nutrition, Gas Chromatography, Qualitative Analysis, Lipids, Fatty Acids, Esters*

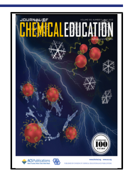
INTRODUCTION

"Science influencers" is a science outreach project aimed at pre-university students, funded by the Spanish Foundation for Science and Technology, FECYT. The main objective of the proposal was to promote scientific vocation in students in the first year of the baccalaureate (students aged 16−17 years old) through scientific workshops and to teach them how to transmit science in the most effective way to students in the third and fourth years of high school, thus promoting interest for science in students who have not yet chosen a specialization branch and who will do so shortly. To achieve this objective, actions on social networks, the building of a website, the creation of videos (https://cienciainfluencers.ig.csic.es/), and the organization of workshops were developed. In addition, training was provided to facilitate the dissemination of workshops and the science of the students.

All activities were centered on the realization of workshops based on the use of practical applications of the knowledge acquired in high school. Therefore, it can be consolidated for the subsequent knowledge of science. Sixteen workshops were held in at the research institution Instituto de la Grasa (Seville, Spain), involving 80 high school students from two local Secondary Schools. This action was carried out twice, once for each Secondary School.

One of these workshops, number 3, was the determination of the oil and fat content of processed foods. Oils and fats are used by the food industry in processed foods due to their physicochemical properties. Their presence is obvious in some of them but not in most of them (e.g., industrial bakery products). Only the description of the nutritional and ingredient label indicates their presence and origin. In this

Received: October 25, 2022
Revised: April 4, 2023
Published: April 27, 2023



https://doi.org/10.1021/acs.jchemed.2c01044
J. Chem. Educ. 2023, 100, 1958−1964

Table 1. Fatty Acid Composition of Several Edible Fats and Oils[a]

	standard fatty acid composition, by weight (percentages with respect to the total mass of oil)													
	fatty acid													
	vegetable sources									animal and fish sources				
	olive oil	coconut	palm	sunflower	sunflower ho	rapeseed	soybean	corn	walnut	beef fat	chicken fat	lard	tallow	salmon
Caprylic Acid (C8:0)	–	8	–	–	–	–	–	–	–	–	–	–	–	–
Capric Acid (C10:0)	–	7	0.48	–	–	0.56	–	–	–	–	–	–	0.10	–
Lauric Acid (C12:0)	–	49	–	0.10	–	0.09	0.09	–	–	–	–	–	0.19	–
Myristic Acid (C14:0)	–	18	1.05	0.10	–		0.09	–	–	3	1	2	2.55	3
Palmitic Acid (C16:0)	13.9	8	41.59	6.31	5.31	4.04	11.07	10.8	5.73	27	22	27	23.85	11
Palmitoleic Acid (C16:1)	1.06	–	0.19	0.10	0.21	0.09	0.18	–	–	11	6	4	2.55	5
Stearic Acid (C18:0)	2.7	2	3.6	3.55	3.36	2.1	3.72	2.9	2.24	7	6	11	17.86	4
Oleic Acid (C18:1)	66	6	40.41	21.39	81.5	57.26	22.61	67.8	23.93	48	37	44	41.42	25
Linoleic Acid (C18:2)	14.5	2	9.3	63.35	6.85	20.69	51.33	9.7	52.14	2	20	11	4.32	5
Linolenic Acid (C18:3)	0.9	–	0.29	1.46	–	8.08	5.63	0.4	15.96	–	1	–	0.88	5
Arachidic Acid (C20:0)	0.5	–	0.29	0.29	0.64	0.37	0.27	–	–	–	–	–	0.20	–
Eicosenoic Acid (C20:1)	0.2	–	0.10	0.19	0.29	2.02	0.27	–	–	–	–	–	0.59	–
Behenic Acid (C22:0)	0.1	–	0.10	0.58	1.03	0.28	0.27	–	–	–	–	–	0.10	–
Erucic Acid (C22:1)		–	–	0.10	0.49	0.46	0.09	–	–	–	–	–	0.10	–
Others[b]	0.14	–	2.6	2.48	0.32	3.96	4.38	8.4	–	2	7	1	5.29	42
Total saturated	**17.2**	**92**	**45.58**	**10.73**	**10.34**	**6.79**	**15.33**	**13.7**	**7.97**	**34**	**28**	**38**	**42.01**	**15**
Total unsaturated	**82.66**	**8**	**50.29**	**86.59**	**89.34**	**88.6**	**80.11**	**77.9**	**92.03**	**61**	**64**	**59**	**49.86**	**82**

[a]Data obtained and table format modified from Douvartzides et al.[19] [b]Other fatty acids present in minor quantities.

workshop, the students extracted oils and fats from various processed foods, quantified them, and characterized their origin/nature through their analysis.

In this workshop, the objective was not only to promote scientific activities but also to carry out nutritional education work in regard to fats with high school students. Teenagers show very strong food preferences and, to some extent, quite far from the healthiest dietary patterns. A published study found that American university students eat at fast food restaurants 6−8 times a week.[1] The acquisition of basic knowledge of food and nutrition is necessary to value this vital function as a pillar of their health in the future. Adolescents who had learned to eat properly were likely to maintain a healthy and balanced diet as adults. This behavior is undoubtedly the best tool for the prevention of many disorders and diseases.

Therefore, it was important to remind students of the importance of oils and fats. These are lipids, constitute one of the four main classes of biological molecules, together with proteins, carbohydrates, and nucleic acids, and are involved in a wide range of intra- and extracellular functions. Lipids have a wide variety of structures characterized by the presence of hydrophobic groups. Lipids are usually divided into two classes, complex lipids, such as "fats" and "oils" (depending on whether they are solid or liquid at room temperature), and simple lipids, such as vitamin A or cholesterol.

Edible oils and fats are products of vegetable or animal origin consisting of triglycerides (triacylglycerols) in which a glycerol has been esterified with three fatty acids. Fatty acids are long-chain carboxylic acids that generally have an even number of carbon atoms, usually between 12 and 24. A fatty acid is considered saturated if the carbon backbone does not have a double C═C bond and is considered unsaturated if at least one double bond is present. Unsaturated fatty acids with a single double bond are named monounsaturated, whereas those with more than one double bond are known as polyunsaturated. Fatty acids are necessary for normal growth and development as well as various physiological functions, including energy production and cell signaling. However, our bodies cannot produce all of them on their own, and they must be obtained through diet. Therefore, it is important to consume a balanced diet that includes essential and nonessential fatty acids to support overall health and wellness. Accordingly, in 2015, the U.S. Food and Drug Administration (FDA) recommended that individuals limit their intake of saturated and trans fats and choose foods that are low in these types of fat for overall health and well-being.[2] Among others, these fatty acids have been associated with increased low-density lipoprotein cholesterol and lipoprotein(a) and decreased high-density lipoprotein cholesterol levels.[3,4] Due to this concern, different governments have established regulations requiring food manufacturer's to list the amount of these fats on the Nutrition Facts label of packaged foods and

https://doi.org/10.1021/acs.jchemed.2c01044
J. Chem. Educ. 2023, 100, 1958−1964

have even set limits on the use of these fats in certain food products. On the other hand, monounsaturated fatty acids (MUFAs) and polyunsaturated fatty acids (PUFAs) are considered healthy.[5−8] In bakery products, the fatty acid (FA) profile, the sum of saturated fatty acids (SFAs), monounsaturated fatty acids, and polyunsaturated fatty acids, varies depending on the origin. This fact provided the basis for this workshop on gas chromatography (GC) analysis.

Previous educational activities in the science field were carried out in different institutions on many different topics such as sustainable chemistry and preventing environmental degradation,[9] software development for Nuclear Magnetic Resonance (NMR)-derived data collection,[10] the development of a simulation tool for undergraduate students to analyze UV-absorption spectra,[11] or biodiesel production-focused workshops to address environmental issues[12] and to learn the basis of analytical techniques as Thin Layer Chromatography (TLC).[13] These previous activities are relevant because of the similarity shared with our workshop, as students were also involved in the laboratory experiments and data analysis. In our workshop, students are introduced to a different analytical technique: the GC analysis method, the most widely extended analytical technique for analyzing oil fatty acid composition, as it provides information about the types of fatty acids present in the samples and their relative abundance. Its widespread use in analytical science lies on the effective separation of the major fatty acid species that it provides, as other laboratory works with undergraduate students described.[14−17] The majority of dietary fat comes in the form of triglycerides. Triglycerides are the most common form of fat found in both animal and plant foods. Triglycerides are made up of three fatty acid molecules attached to a glycerol molecule, and they can be saturated or unsaturated, depending on the types of fatty acids they contain. Triglycerides have high boiling points, which can make GC analysis challenging. To overcome this, before GC analysis, triacylglycerols were transesterified in one step with their corresponding volatile methyl ester (fatty acid methyl esters, FAMEs). To develop our workshop, five bakery products commonly consumed by high school students were selected from the market to determine their fatty acid composition. Each student analyzed the fat content of one of these products. The fat was extracted, and then, its fatty acids were derivatized to the corresponding FAMEs and analyzed by GC with a flame ionization detector (GC-FID). The main peaks of the fatty acid esters were identified by comparing the retention times (RTs) of their components with the RTs of known standards (commercial high stearic high oleic sunflower oil (HSHO) from the CAS3 sunflower line).[18] For all samples analyzed, the percentage area of each FA peak in relation to the total area was calculated. Afterward, students compared their results with the values of other oils (Table 1) and commented on the main differences. Thus, after sharing the data, students had a better understanding of their food choices. Moreover, the participating students gave a talk to their third and fourth grade classmates showing the scientific activities carried out with the objective of promoting interest in science among an audience of approximately 480 students in total between both high schools.

■ EXPERIMENTAL SECTION

The students were organized with five members per workshop to educate them toward a teamwork perspective when faced with analytical problems.

The work was completed in two laboratory sessions of approximately 4 h each. This time was sufficient to carry out all planned tasks. On the first day, laboratory work was carried out. Subsequently, in a second session, the students reviewed the handling of the GC/FID as well as its software control program; the results of the FAME analysis were collected, and the fatty acid profile of edible oils and fats (as an ingredient of processed foods) was determined. Once every student had obtained the analysis of data from the fatty acids of the selected food, they were given time to analyze the data and see if there was agreement with the composition of the oil indicated on the label, according to the composition of the oils presented in Table 1. Afterward, the data obtained were shared among the different members of the group, and there was a discussion. The group discussion was used to prepare the presentation that was later given to students of lower grades in high school providing a basis for understanding why some fats should be reduced. The duration of this second session may be shorter, depending on availability.

Materials

The selection of processed snacks for analysis was based on the breakfast eating habits of high school students. Five types of snacks (oil cake, potato chips, donut, digestive cookies, and energy bars) were used to study their lipid compositions. The processed food samples were purchased from a supermarket. Each student selected a food sample. All reagents and supplies were from Sigma-Aldrich.

Lipid Extraction

Lipid extraction was performed according to the modified protocol[20] for the extraction of lipids from food. The students selected a sample of food from the variety of options provided and weighed a 1g piece of each sample. The sample was placed in a 15 mL glass tube, crushed, and homogenized with a pestle. Under a fume hood, 5 mL of hexane:isopropanol (3:2, v/v) and 2.5 mL of a 6.7% sodium sulfate solution were added to each tube. The tube was shaken for 4 min and then centrifuged at 2000 rpm for 10 min to extract the fatty acids. The solids were allowed to settle. The upper phase, where total lipids are found, was transferred to a new 15 mL glass tube using a glass pipet. The separation process was repeated one more time, adding a 3.75 mL of hexane:isopropanol mixture (7:2 v/v) to the lower phase. The tubes were shaken and centrifuged for 10 min. The upper phase was collected and mixed with the previous one. The solvent was evaporated under nitrogen atmosphere to dryness. The samples were used directly for methylation.

FAMES Synthesis and Sample Preparation

The preparation of fatty acid methyl esters (FAMES) with methanolic:HCl was according to the modified Browse et al. protocol.[21] 1 mL of methanolic reagent HCl (1 M) was added to the tube. All tubes were briefly purged with N_2 and closed with a Teflon cap. The tube was then placed in a heat bath at 90 °C for 60 min. After the reaction, the tube was left standing at room temperature to cool. Later, 1 mL of hexane and 1 mL of 0.9% NaCl were added, and the sample was vigorously shaken and briefly centrifuged at 2000 rpm for 4 min. Again, the organic phase was transferred to a new tube. The same extraction method was used twice, adding 1 mL of hexane each time to the lower phase. The combined organic phases were evaporated under a stream of nitrogen to dryness. Fatty acid methyl esters were dissolved in 1 mL of hexane and transferred

https://doi.org/10.1021/acs.jchemed.2c01044
J. Chem. Educ. 2023, 100, 1958−1964

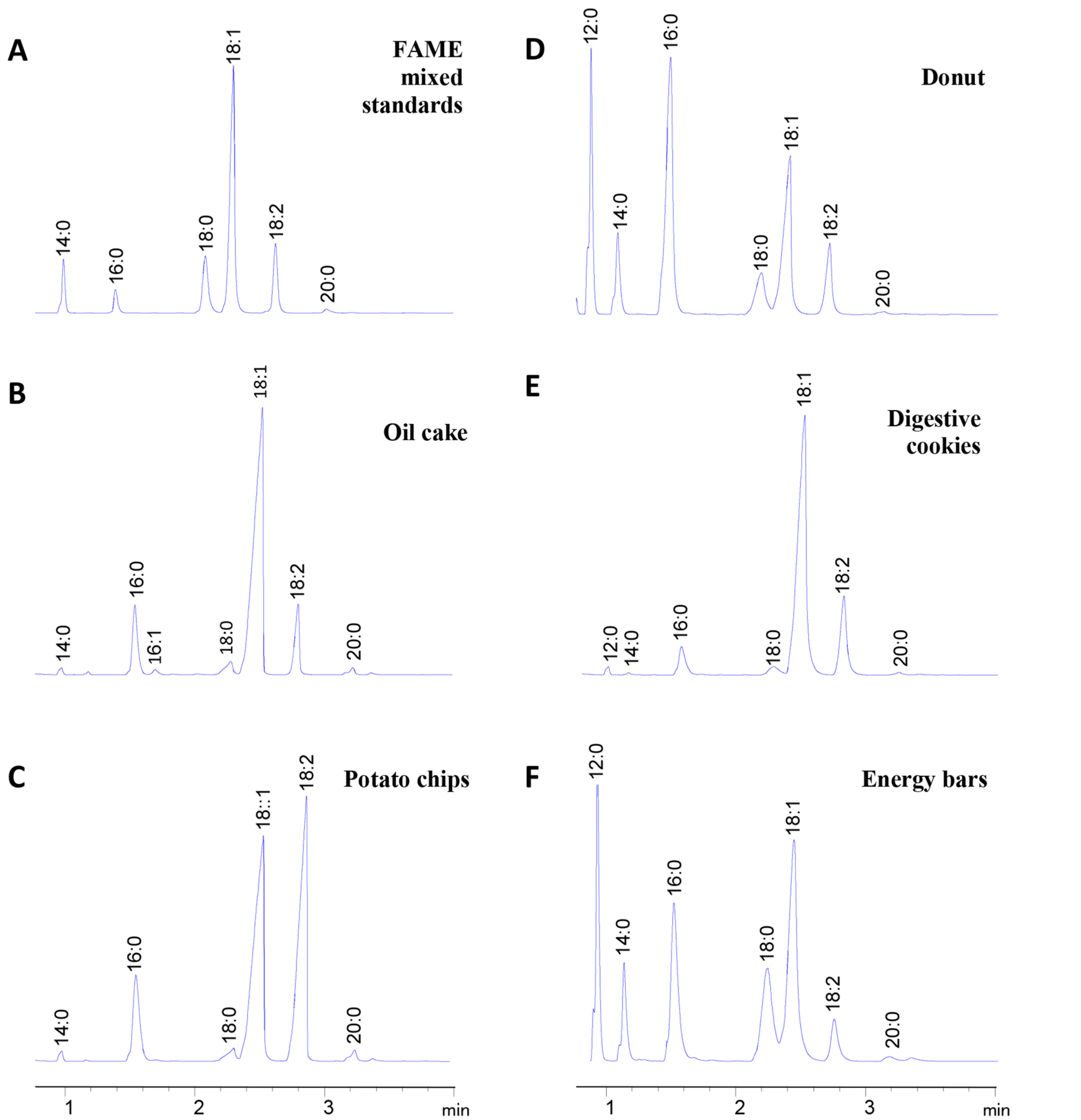


Figure 1. Chromatograms of fatty acid methyl ester samples from (A) FAME mixed standard, (B) oil cake, (C) potato chips, (D) donut, (E) digestive cookies, and (F) energy bars samples. Peak labels are determined by comparison of retention time with commercial mixed standards: 14:0, methyl myristate; 16:0, methyl palmitate; 18:0, methyl stearate; 18:1, methyl oleate; 18:2, methyl linoleate; 18:3, methyl linolenate; 20:0, methyl arachidate; and 22:0, methyl behenate.

to the vials of the gas chromatograph for direct injection into the gas chromatograph.

GC Analysis

A Hewlett-Packard 6890 gas chromatograph (GC) was used to analyze the FAMEs obtained from each food sample and a known mixture of fatty acid esters. Each ester sample was run twice. The Supelco SP-2380 fused-silica capillary column was 15 m long with a 0.25 mm i.d. 1 μL of the sample was directly injected into the gas chromatograph. The carrier gas was nitrogen, and the initial column pressure was 40 kPa; this was maintained for 2 min, then increased to 100 at 20 kPa/min for 5 min, and finally, increased to 400 at 40 kPa/min for 10 min. The initial oven temperature was 170 °C, and it was kept constant at 170 °C for 10 min. The total run time was 10 min. The instrument is controlled by ChemStation software (Hewlett-Packard). The students identified the individual peaks in the chromatogram, corresponding to different fatty acids and their derivatives on the basis of comparison with the reference laboratory standards. Methylated high-stearic and high-oleic sunflower oil[18] was used to calibrate the GC analysis and provide a basis for comparison with the samples analyzed.

https://doi.org/10.1021/acs.jchemed.2c01044
J. Chem. Educ. 2023, 100, 1958−1964

Table 2. Fatty Acid Composition of Food Samples[a]

	standard fatty acid composition, by weight				
	food samples; oil source				
	oil cake; extra-virgin olive	potato chips; corn/sunflower	donuts; palm	digestive cookies; sunflower HO	energy bars; coconut
Caprylic Acid (C8:0)	–	–	–	–	–
Capric Acid (C10:0)	–	–	–	–	2.09 ± 0.05
Lauric Acid (C12:0)	0.81 ± 0.25	0.80 ± 0.43	16.89 ± 0.70	1.02 ± 0.05	16.60 ± 0.10
Myristic Acid (C14:0)	0.31 ± 0.02	0.10 ± 0.1	6.95 ± 0.60	0.36 ± 0.02	7.19 ± 0.07
Palmitic Acid (C16:0)	11.19 ± 0.10	11.40 ± 0.06	34.48 ± 1.30	6.28 ± 0.03	18.41 ± 0.08
Palmitoleic Acid (C16:1)	0.90 ± 0.01	0.19 ± 0.15	0.19 ± 0.00	0.21 ± 0.05	0.44 ± 0.04
Stearic Acid (C18:0)	3.23 ± 0.12	2.29 ± 0.05	7.92 ± 0.07	2.95 ± 0.03	16.10 ± 0.06
Oleic Acid (C18:1)	71.62 ± 0.2	43.45 ± 0.16	24.34 ± 0.16	70.71 ± 0.07	32.21 ± 0.08
Linoleic Acid (C18:2)	10.21 ± 1.20	39.56 ± 0.05	8.41 ± 0.63	16.78 ± 0.06	5.03 ± 0.05
Linolenic Acid (C18:3)	–	–	–	–	–
Arachidic Acid (C20:0)	1.25 ± 0.3	1.45 ± 0.03	0.52 ± 0.04	0.69 ± 0.01	0.79 ± 0.12
Eicosenoic Acid (C20:1)	0.32 ± 0.03	0.35 ± 0.06	0.14 ± 0.05	0.27 ± 0.04	0.63 ± 0.02
Behenic Acid (C22:0)	0.10 ± 0.04	0.35 ± 0.03	0.11 ± 0.07	0.73 ± 0.03	0.52 ± 0.01
Erucic Acid (C22:1)	–	–	–	–	–
Total saturated	16.89 ± 0.82	16.40 ± 0.88	66.88 ± 3.93	12.03 ± 0.24	61.70 ± 0.69
Total unsaturated	83.06 ± 2.04	83.55 ± 0.59	33.08 ± 1.19	87.97 ± 0.31	38.30 ± 0.27

[a]The data correspond to the average and standard deviation of two independent extractions of each student group.

Once the peaks were identified, the integrated peak areas were measured in the chromatogram and used to calculate the percentage of each fatty acid present in the sample. Fatty acids were expressed as percentages of total fat.

HAZARDS

Before performing any laboratory experiment, it is important to consult the materials safety data sheet (MSDS) for all chemicals that will be used. Many organic solvents used in the laboratory experiments are volatile and flammable liquids. To minimize the risks associated with the use of organic solvents, chemicals should be handled in a fume hood and students should wear appropriate personal protective equipment (PPE), such as gloves and safety goggles, to prevent skin and eye exposure to the following chemicals: hexane (skin, eye, and respiratory tract irritant), isopropanol (eye and respiratory tract irritant), sodium sulfate (skin and eye irritant), methanol (skin irritant, sensitizer, and mutagen), and hydrochloric acid (corrosive, irritant, and inflammatory). FAMEs are not considered hazardous materials, although they may cause eye and skin irritation and respiratory and digestive tract irritation. Though triglycerides are organic compounds that can be flammable and pose a fire hazard if not handled properly, they should be collected in a separate organic waste container and labeled appropriately before disposal. Working with GC-FID and a water bath requires careful attention to safety precautions to minimize the risk of accidents or exposure to hazardous substances. The presence of an instructor can help to ensure that the experiment is conducted safely and effectively.

RESULTS AND DISCUSSION

Before laboratory work, students were given a lecture to remind them of concepts previously studied in class, such as types of lipids, different nomenclatures and names for fatty acids, and their effects on health.

Once in the laboratory, students were first made aware of all the warnings about working in the laboratory. Once they understood the risks to which they may be exposed, they decided which food samples they wanted to analyze. The sample was then crushed and homogenized with a mortar and pestle for lipid extraction, as explained in the Experimental Section. To determine the fatty acid content of lipids in food samples, fatty acid esters are transesterified to more volatile FAMEs. These FAMEs are separated by GC. Students will learn the basics of the gas chromatographic analysis with the flame ionization detector (GC-FID) of volatile methyl esters (FAMEs) and the operation of a Hewlett Packards 6890 GC instrument with a split/splitless injector, flow rates, and optimization of temperature and evaluate the repeatability.

Also, the students were instructed in the use of the software to integrate the peaks and obtain the chromatographic parameters. By comparing the retention time (RT) of the components in their samples with the RT of the selected standard ester mixture, high-stearic high-oleic sunflower oil (14:0, 16:0, 18:0, 18:1, 18:2, and 20:0), the students could identify the different compounds present in their samples. For all samples analyzed, after FAME identification, students calculated the relative amounts of FAMEs in their samples in relation to the total peak area. Figure 1 shows the gas chromatographic elution pattern for the fatty acid methyl ester of food samples: oil cake, potato chips, donut, digestive cookies, and energy bars. The relative percent total composition for each of the major peaks is shown in Table 2. Table 2 summarized the results obtained by the students on the percentage of lipid extracted by the above procedure. The individual values in each line represent the mean percent and standard deviation of two independent extractions from each student group. After doing their calculations, the students compared their data and discussed the main differences. In the process, students compared their results with the values of the FAMEs in the literature in their samples and commented on the differences between their data and the literature. The type of edible oils was determined on the basis of the relative percentage of the peak areas of each FA. When comparing the results obtained with those expected, the students were aware of the differences and peculiarities of each of these oils. First, the students looked at the total content of saturated and

https://doi.org/10.1021/acs.jchemed.2c01044
J. Chem. Educ. 2023, 100, 1958−1964

unsaturated fatty acids. In this way, two groups of oils were distinguished: oils with a high content of saturated fatty acids, such as palm and coconut oil, and oils with a high content of unsaturated fatty acids, such as extra virgin olive oil, high oleic sunflower oil, and a mixture of corn and normal sunflower oil. When comparing palm and coconut oils, the students were able to distinguish one from the other, as palm oil has a higher content of palmitic acid, while coconut oil has shorter chain saturated fatty acids. Extra virgin olive oil and high oleic sunflower oil have a similar fatty acid composition, the only difference being that the latter has a lower palmitic acid content. However, the main difference for the various uses of these oils is due to their processing. Extra virgin olive oil comes from direct extraction of the fruit, so it is rich in minor components that are extracted together with glycerides and give it part of its beneficial health properties. Sunflower oil, on the other hand, undergoes a cleaning or refining process, where undesirable components are removed to improve the stability of this oil. The mixture of corn and sunflower is characterized by its high content of monounsaturated acid, oleic acid, and polyunsaturated acid, linoleic acid. After analyzing the peculiarities of each oil, the students presented their results and successfully identified olive, cotton-sunflower blend, high-oleic sunflower, palm, and coconut oil. The results are generally in good agreement with those in the literature. Accordingly, student data consistently confirmed the composition of the oil specified on the food label while gaining a better understanding of their food choices. This knowledge allows them to better understand food labeling and the importance of the type of fat present and make informed choices with implications for health and wellness.

It is also important to note that there is no better way to include knowledge than to explain it later. Therefore, the group discussion was used to prepare the slides that they later used in the oral presentation. Thus, under the supervision of their teachers, the students presented the prepared presentation to students of lower grades in high school to promote science. Due to the large number of workshops and time constraints, the students had only 5 min to present. The objective was to be able to summarize the problems and the results obtained in a short period of time. Afterward, a few minutes were left to answer any questions that arose. The concept of science is identified with complicated activities that are difficult to understand. The opportunity to spread science through the same group of students who have conducted the workshops makes this dissemination closer and more effective through a simple language. Science communication not only helps them better understand and comprehend the world around us but also can inspire future generations of scientists. By spreading the excitement and enthusiasm that scientific discoveries can generate, young people can be motivated to pursue careers in science, technology, engineering, and mathematics (STEM).

STUDENT LEARNING

With this work, we have sought mainly two types of learning, working in a research laboratory and, at the same time, understanding how science relates to their daily life in a topic as important as food. Regarding learning in the laboratory, the students successfully isolated the oil or fat present in several snacks. Additionally, this experiment trains students in advanced analysis techniques such as GC−FID. They identified peaks in the GC chromatogram using retention time data and compared the experimental ones with known standards. Students learn to calculate the percent mass of the compounds in each sample and determine the saturated, unsaturated, monounsaturated, polyunsaturated, and total fatty acids in the food samples. In addition, students become familiar with the literature to compare their data with Table 1 and the nomenclature systems for fatty acids (IUPAC, omega, simplified, and common system). Altogether, through practical experience in a controlled environment, students have understood the fundamental concepts studied in the classroom and developed specific skills and knowledge related to chemistry of oils and fats and their analysis.

Moreover, this work not only promotes laboratory work but also relates to aspects of daily life such as nutrition. Today, we hear a lot of talk about good and bad oils as well as new nutritional labeling systems. But do teenagers really understand these concepts? It is important to consider the relevance of fats in food and understand the labeling. Our students have found it very interesting to compare various snacks to compare *health vs unhealthy* oils. The results of this study indicate the importance of fats and the types of fats present in food and the convenience of the consumption of *healthy* food. In addition, students have the task of sharing the experience and knowledge acquired during this workshop. The students had a double objective: to improve their communication skills and promote science from the knowledge gained to younger students.

SUMMARY

The goals of this experiment are to train students to

- Identify the relevant literature.
- Learn to work in a laboratory.
- Perform experiments according to a preestablished protocol.
- Discuss and effectively communicate results with their group.
- Prepare a presentation on healthy oils to undergraduate students.

ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available at https://pubs.acs.org/doi/10.1021/acs.jchemed.2c01044.

Complementary instructions for instructors (PDF, DOCX)

Complementary instructions for students (PDF, DOCX)

AUTHOR INFORMATION

Corresponding Author

Mónica Venegas-Calerón − *Instituto de la Grasa (CSIC), 41013 Seville, Spain;* orcid.org/0000-0002-1562-5025; Email: mvc@ig.csic.es

Authors

Enrique J. Clavijo-Bernal − *Instituto de la Grasa (CSIC), 41013 Seville, Spain*

Rosario Sánchez − *Instituto de la Grasa (CSIC), 41013 Seville, Spain*

Mónica Villoslada-Valbuena − *Instituto de la Grasa (CSIC), 41013 Seville, Spain;* orcid.org/0000-0003-4401-0764

Cristina DeAndrés-Gil − *Instituto de la Grasa (CSIC), 41013 Seville, Spain*

https://doi.org/10.1021/acs.jchemed.2c01044
J. Chem. Educ. 2023, 100, 1958−1964

Rafael Garcés − *Instituto de la Grasa (CSIC), 41013 Seville, Spain*
Enrique Martínez-Force − *Instituto de la Grasa (CSIC), 41013 Seville, Spain;* orcid.org/0000-0001-5324-9537
Joaquín J. Salas − *Instituto de la Grasa (CSIC), 41013 Seville, Spain*

Complete contact information is available at: https://pubs.acs.org/10.1021/acs.jchemed.2c01044

Notes

The authors declare no competing financial interest.

■ ACKNOWLEDGMENTS

The authors thank the Spanish Foundation for Science and Technology, FECYT (ref FCT-19-14478).

■ REFERENCES

(1) Driskell, J. A.; Kim, Y. N.; Goebel, K. J. FEW DIFFERENCES FOUND IN THE TYPICAL EATING AND PHYSICAL ACTIVITY HABITS OF LOWER-LEVEL AND UPPER-LEVEL UNIVERSITY STUDENTS. *Journal American Dietetic Association* **2005**, *105* (5), 798−801.
(2) Food and Drug Administration.*Final Determination Regarding Partially Hydrogenated Oils (Removing Trans Fat)*; Food and Drug Administration, HHS, 2015; pp 2015−14883; 34650−34670.
(3) Nestel, P. TRANS FATTY ACIDS: ARE ITS CARDIOVASCULAR RISKS FULLY APPRECIATED? *Clin Ther.* **2014**, *36* (3), 315−21.
(4) Martin, C. A.; Carapelli, R.; Visantainer, J. V.; Matsushita, M.; de Souza, N. E. TRANS FATTY ACID CONTENT OF BRAZILIAN BISCUITS. *Food Chem.* **2005**, *93*, 445−448.
(5) Grundy, S. M. COMPARISON OF MONOUNSATURATED FATTY ACIDS AND CARBOHYDRATES FOR LOWERING PLASMA CHOLESTEROL. *N Engl J. Med.* **1986**, *314*, 745−748.
(6) Kris-Etherton, P. M. MONOUNSATURATED FATTY ACIDS AND RISK OF CARDIOVASCULAR DISEASE. *Circulation* **1999**, *100*, 1253−1258.
(7) Calder, P. C. POLYUNSATURATED FATTY ACIDS, INFLAMMATION, AND IMMUNITY. *Lipids* **2001**, *36* (9), 1007−1024.
(8) Minihane, A. M.; Lovegrove, J. A. HEALTH BENEFITS OF POLYUNSATURATED FATTY ACIDS (PUFAS). *Improving the Fat Content of Foods* **2006**, 107−140.
(9) Aubrecht, K. B.; Padwa, L.; Shen, X.; Bazargan, G. DEVELOPMENT AND IMPLEMENTATION OF A SERIES OF LABORATORY FIELD TRIPS FOR ADVANCED HIGH SCHOOL STUDENTS TO CONNECT CHEMISTRY TO SUSTAINABILITY. *J. Chem. Educ.* **2015**, *92* (4), 631−637.
(10) Anderson, S. L.; Rovnyak, D.; Strein, T. G. IDENTIFICATION OF EDIBLE OILS BY PRINCIPAL COMPONENT ANALYSIS OF 1H NMR SPECTRA. *J. Chem. Educ.* **2017**, *94* (9), 1377−1382.
(11) Jurinovich, S.; Domenici, V. DIGITAL TOOL FOR THE ANALYSIS OF UV-VIS SPECTRA OF OLIVE OILS AND EDUCATIONAL ACTIVITIES WITH HIGH SCHOOL AND UNDERGRADUATE STUDENTS. *J. Chem. Educ.* **2022**, *99* (2), 787−798.
(12) Nida, S.; Marsuki, M. F.; Eilks, I. PALM-OIL-BASED BIODIESEL IN INDONESIA: A CASE STUDY ON A SOCIO-SCIENTIFIC ISSUE THAT ENGAGES STUDENTS TO LEARN CHEMISTRY AND ITS IMPACT ON SOCIETY. *J. Chem. Educ.* **2021**, *98* (8), 2536−2548.
(13) Khamhaengpol, A.; Phewphong, S.; Chuamchaitrakool, P. STEAM ACTIVITY ON BIODIESEL PRODUCTION: ENCOURAGING CREATIVE THINKING AND BASIC SCIENCE PROCESS SKILLS OF HIGH SCHOOL STUDENTS. *J. Chem. Educ.* **2022**, *99* (2), 736−744.
(14) Siano, F.; Vasca, E. GC-FID ANALYSIS TO EVALUATE THE POSSIBLE ADULTERATION OF EXTRA VIRGIN OLIVE OIL WITH DIFFERENT VEGETABLE OILS. *J. Chem. Educ.* **2020**, *97* (11), 4108−4116.
(15) Larraza, I.; Malko, R. MICROWAVE-ASSISTED TRANSESTERIFICATION OF COOKING OILS AND GC-MS DETERMINATION OF THEIR FATTY ACID CONSTITUENTS: A RESEARCH-BASED INTEGRATED LAB EXPERIMENT. *ACS Appl. Mater. Interfaces* **2020**, *97*, 1128−1133.
(16) Harper, C. S.; Macdonald, F. v.; Braun, K. L. LIPID RESIDUE ANALYSIS OF ARCHAEOLOGICAL POTTERY: AN INTRODUCTORY LABORATORY EXPERIMENT IN ARCHAEOLOGICAL CHEMISTRY. *J. Chem. Educ.* **2017**, *94* (9), 1309−1313.
(17) Bendinskas, K.; Weber, B.; Nsouli, T.; Nguyen, H. v.; Joyce, C.; Niri, V.; Jaskolla, T. W. A TEACHING LABORATORY FOR COMPREHENSIVE LIPID CHARACTERIZATION FROM FOOD SAMPLES. *J. Chem. Educ.* **2014**, *91* (10), 1697−1701.
(18) Salas, J. J.; Bootello, M. A.; Martínez-Force, E.; Venegas-Calerón, M.; Garcés, R. HIGH STEARIC SUNFLOWER OIL: LATEST ADVANCES AND APPLICATIONS. *OCL* **2021**, *28*, 35.
(19) Douvartzides, S. L.; Charisiou, N. D.; Papageridis, K. N.; Goula, M. A. GREEN DIESEL: BIOMASS FEEDSTOCKS, PRODUCTION TECHNOLOGIES, CATALYTIC RESEARCH, FUEL PROPERTIES AND PERFORMANCE IN COMPRESSION IGNITION INTERNAL COMBUSTION ENGINES. *Energy* **2019**, *12* (5), 809.
(20) Hara, A.; Radin, N. S. LIPID EXTRACTION OF TISSUES WITH A LOW-TOXICITY SOLVENT. *Anal. Biochem.* **1978**, *90* (1), 420−6.
(21) Browse, J.; Warwick, N.; Somerville, C. R.; Slack, C. R. FLUXES THROUGH THE PROKARYOTIC AND EUKARYOTIC PATHWAYS OF LIPID SYNTHESIS IN THE '16:3' PLANT ARABIDOPSIS THALIANA. *Biochem. J.* **1986**, *235*, 25−31.