A New Method of Measuring Total Polar Compounds in Frying Oil: RGB Color Code

Group Code: #0194

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Abstract

During the frying process, physical and chemical changes occur within frying oil. These changes produce harmful components named Total Polar Compounds (TPC) which also threaten human health. TPC measuring methods are generally expensive, time-consuming, and require special equipment. In this study, we aimed to develop a simpler, more accessible, and affordable method to measure TPC in frying oils by taking Red-Green-Blue color codes (RGB) as a basis.

Waste oil provided by the ministry authorized vegetable waste oil company was diluted with bottled oil into 10 different oil concentrations. Samples' TPC values were measured with a Testo 270 device and corroborated with a spectrophotometric measuring method. Additionally, the samples' pictures were taken and RGB's of individual samples have been noted with the help of a computer and cell phone.

It is indicated that there is a direct correlation between acidity and TPC. RGBs have a high correlation with TPC. TPC level which is measured by RGBs on images gathered from both the computer and cell phone are found compatible with TPC reference values. Best results are obtained from the Red/Green ratio.

Through this quick, easy, inexpensive, repeatable method; the TPC content of frying oil can be measured easily with the help of a photograph. As a matter of fact, the harmful effects of frying oil on human health will be prevented.

Keywords

Carcinogenic; Color code; Frying Oil; RGB; Total Polar Compound.

Introduction

Frying is one of the most popular cooking processes in the world and it is defined as cooking of food items in (150-190ºC) oil. [1] In this process heat and mass transmission react together. During the transmission of heat from oil through food items, water escapes and it is replaced by oil. This process causes chemical and physical reactions to take place in the oil. These reactions induce a change in viscosity, darkening of color, foaming, and a change in the oil's smoke point.

Frying oils which are exposed to high temperatures for a long time and used repeatedly form various harmful compounds for human and environmental health. [2,3] The process causes three fundamental reactions: hydrolysis, oxidation, and thermal decay. [4] As a result of hydrolysis mono- and diglycerides, free fatty acids, and glycerol are formed while the frying oils' acidity increases.

As a result of all these reactions, a large number of volatile and non-volatile polymerization products are formed. [5] Polar substances which are non-volatile components contain fat-soluble and suspended substances, and they are named Total Polar Components (TPC), including free fatty acids, monoglycerides, diglycerides, sterols, TAG polymers, carotenoids, antioxidants, and soaps. The amount and chemical compositions of these substances depend on multiple factors such as type of nutrient and the oil, temperature, frying duration, and method of frying. There are more than 400 kinds of degradation products. However, the common feature of these degradation products is that their chemical structure is polar. Therefore, by measuring the amount of polar substances in frying oil; in other words, by indicating the total polar component content (%TPC), it is feasible to make an evaluation of the total content of degradation reactions. These variables are crucial indicators for the quality and healthiness of the oil. [6]

According to multiple studies, the polar substances formed in frying oils have many negative effects on health. [2,7,8] Impacts of polar substances on human health vary depending on the type of the oil and polar component. [8] Polar substances can alter carbohydrate, protein, and lipid metabolisms. Thus, they create toxicological, cytotoxic effects, and their redox potential can modulate energy metabolism. This may cause various diseases. [9,8] According to International Food Law and Policy, frying oil gets into the status of waste oil and becomes inconvenient for cooking when the TPC content hits 25%. [10,11] In terms of TPC amount in frying oils, governments have felt it necessary to set restrictions on them because of the potential health effects. In The European Union, the maximum (TPC) amount has been set between 24-26% by experts. This limit value is 24% in Germany; 25% in Belgium, France, Portugal, Italy, and Spain; 27% in Australia, China, Switzerland. [2,12,13]

There are some techniques used to determine the amount of TPC in frying oils. In this context, the Official Analytical Chemists Association and the International Standards Organizations' methods are used as a reference. [14,15,16] However, these techniques are time-consuming, expensive, require expertise and lab conditions, and especially require routine monitoring of commercial and industrial frying oils methods that involve sample preparation procedures that make it difficult. [17] Thus, in recent years, methods and devices

have been developed which are portable and detect polar substance content by using a dielectricity method or taking biosensory data as the basis.

Some of the most popular rapid tests in order to evaluate frying oils utilize the changes in the permittivity of the oil which depends on the level of polar compounds in it. An ideal rapid test should be low cost, easy to use, practical, repeatable, give precise results and not require calibration. Additionally, supplemental chemical substances should not be needed and the oils' temperature should not need to be adjusted before taking measurements.

Nowadays, there are three different systems of measuring TPC rapidly and directly. These are based on physical changes in the frying oil and TPC amount; Fri-check, Testo 270, and Viscofrit systems. [18,19,20] Firstly, Fri-check measurements take the oil density, viscosity, and interface based on changes in voltage. The method is reliable and shows a correlation with the results that are gathered from reference measurements. [18,21,22] Secondly, the Testo 270 device measurements take changes in the dielectric constant of the frying oil as a basis in its working procedure. Measurements that are taken by Testo 270 have shown good correlations in terms of frying duration and polar compound percentages. Among the fast methods that are examined, Testo 270 gives the most accurate measurement. Therefore, it can be used as the reference method. While meticulous calibration of the equipment is required, it's suggested to use a calibration oil with a known source and content in order to set the device. Thirdly, Viscofrit measurements depend on changes of viscosity in the oil. [20] As long as procedures are followed correctly, this method is also reliable. However, special attention should be paid to calibration, cleaning, test temperature, oil filtering, and hygiene of the funnel.

All these tests require a certain temperature and a reference material to calculate accurately. Although they are repeatable, these tests are costly and have controversial accuracy. In this regard, there has still been a need for a faster and more cost-effective measurement system.

As it is known that every matter has a color tone in nature, and these tones also have an equivalent value in a digital environment. In this digital coding system, RGB is the most known and commonly used color code system. This abbreviation stands for the three main colors (green, red, blue). Every color tone has an equivalent numerical value. This coding system can be used for color tone-based measurements and can make subjective assessments of color tonğe objective. Thus, it will contribute to the accuracy and objectivity of the color-based measurement.

In this study, we aimed to develop a simple, affordable, practical method for measuring TPC values of sunflower oil used for frying in order to make measurement of the oil quality made by everybody everywhere and it will not require expertise.

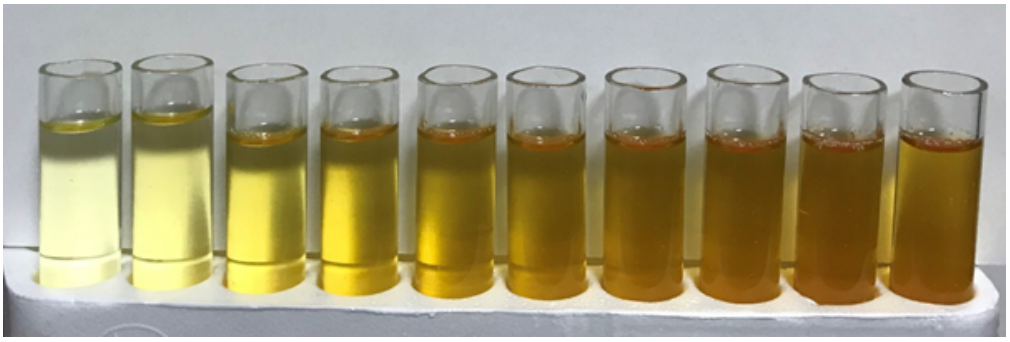
Material and Methods

Waste oil used in the experiments is gathered from a ministry authorized vegetable waste oil collection company, Habitat Recycling and Environment San. Tic. Ltd. Company.

Preparation of Frying Oils

All experiments are carried out in Ege University Faculty of Medicine, Laboratory of the Department of Biochemistry. The oils with various TPC values were prepared as follows: Commercially purchased and unused oil is mixed with used waste oils in various proportions (0% - 100%) and standards are obtained. (Figure 1)

Figure 1, Outlook of samples for color analysis



Measurements Done By Testo 270

A Testo 270 instrument was purchased for reference TPC measurements. TPC values in oil samples were measured by following the suggested application in the manufacturers' guide. Briefly, prepared oil standards are stored in 100 ml containers individually and are held in Benmari, 55 o C for 30 minutes. After that, TPC measurements are carried out with the help of the Testo 270 device, and values are recorded. Each concentration measurement is repeated 5 times, and results are indicated as the average of five measurements of each concentration. (Figure 2)

Figure 2, Samples In Benmari and Testo 279

Peroxide, acidity, and density indication

Indication of peroxide, acidity, and density levels of samples are done in an accredited laboratory in Ege University Argefar Environment and Food Analysis Laboratory.

Spectrophotometric Measurements

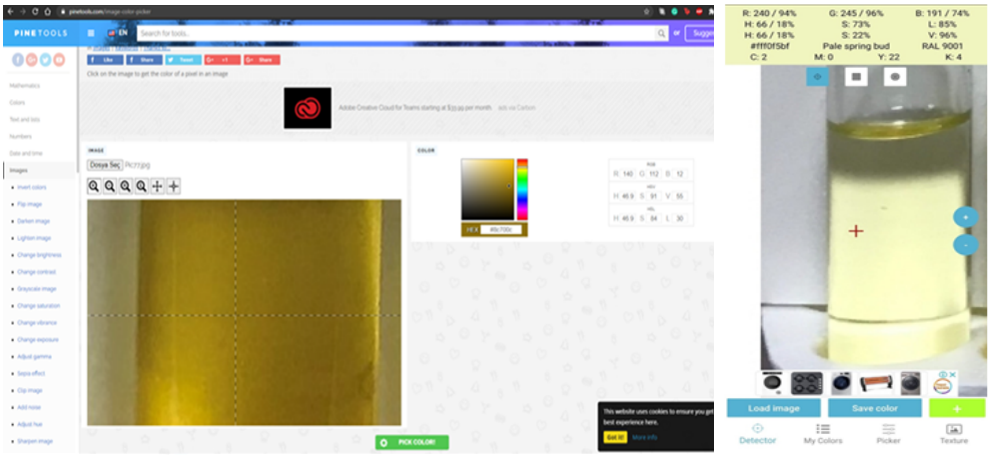
Samples taken from oils are prepared, dropped, and placed in a 96-hole bowl for spectroscopic inspection. Samples are scanned spectrophotometrically by Thermo Varioskan device (Thermo Fisher Scientific, Vantaa, Finland) between 300-760 nm, and the wavelength

with the maximum absorbance is indicated as 335 nm. Measurements were repeated 5 times for each sample.

Optic Measurements On Computer and Smartphone

Examples prepared for spectrophotometric measurements are simultaneously placed in standard glass laboratory tubes and then photographs are taken with the help of a smartphone (Samsung Galaxy S9+) in order to analyze the color. (Figure 1 and 3)

Figure 3, color analysis applications for computer and smartphone



RGB color codes are obtained by using PineTools (Online image color picker program on computer) and Color Detector (Color picker program on smartphone). RGB color codes were obtained from ten different points. Each picture measurement is repeated 5 times, and results are indicated as the average of five measurements of each concentration.

Measurements made with Digital Image processing and machine learning techniques

In order to conduct the color analysis of the photographs on a computer or another type of smart device, OpenCV library with the Python 3 program is used and machine learning techniques are applied. RGB values are obtained from standard 9 dots on every tube. These 9 measurements averages are taken into account for analysis. Additionally, the TPC ratios were calculated with the help of smart learning techniques regarding RGB / TPC values obtained on the computer.

Statistical Evaluation

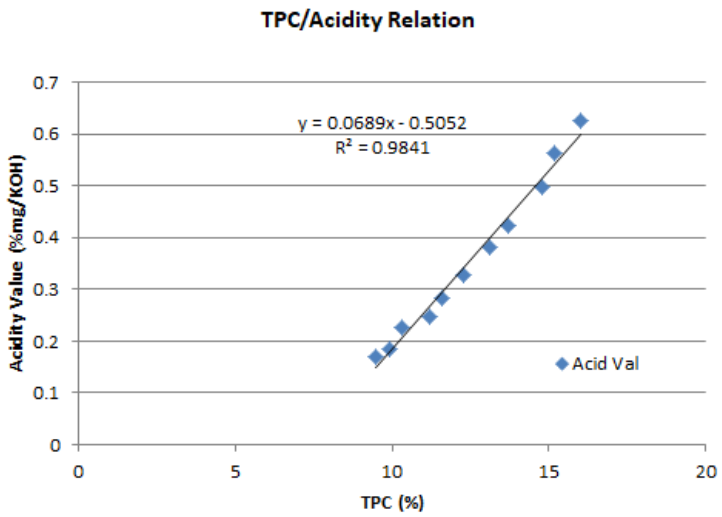
Statistical analyses were made in the Department of Medical Informatics and Biostatistics, Ege University, and IBM SPSS 25.0 program was used. Results that belong to samples are given as averages and standard deviations. TPC measurements which are made with Testo 270 device utilized as the golden standard. TPC values that are calculated by spectroscopic measurement results, computer RGB color codes, smartphone RGB color codes, and the color codes calculated by the image processing technique are analyzed with

the help of a compatibility test. Two-way mixed model and absolute agreement type were chosen for Reliability Analysis Statistics.

Results

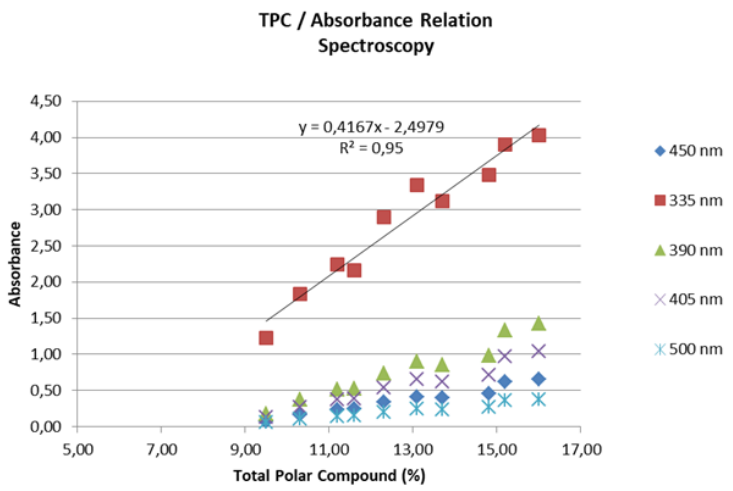
TPC value of waste oil, which was utilized in the experiment, is 16%, the acid value is 0.626% mg / KOH, density is 0.914 g / ml and peroxide value is indicated as 15 meq/kg. The mint state frying oil, which was bought from the market, TPC value is indicated as 9.5%, acid value 0.169% mg / KOH, density 0.912 g / ml, and peroxide value is determined as 12 meq/kg. When the waste oil is diluted with the mint state oil, it is clearly observable that acidity decreases. As the acidity value increases, the RGB color code changes. Oil's acidity can be predicted by RGB color code 96%. (Graph 1)

Graph 1, TPC/Acidity Relation

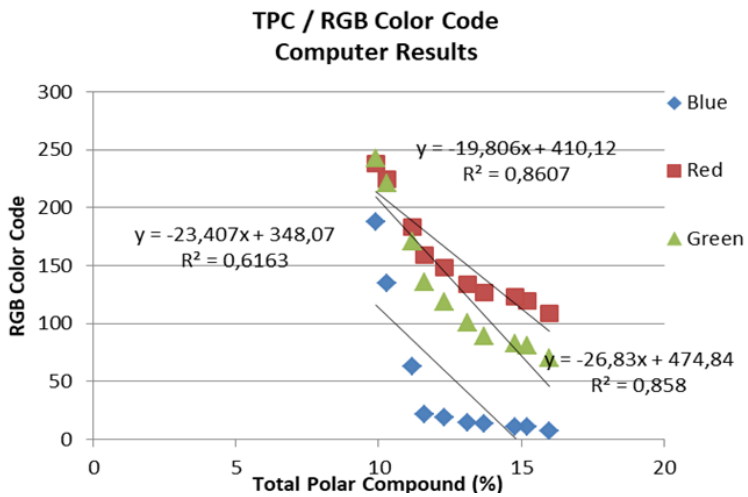


It is indicated that TPC values that are measured with Testo 270 and values measured by spectrophotometer have a high correlation (Graph 2). Our results show that RGB color codes have a high correlation with TPC values. TPC values which are measured by Color codes of oils on images gathered from both the computer (Graph 3) and cell phone (Graph 4) are found compatible with TPC reference values which were measured by Testo 270 device.

Graph 2, Scatter plot belong to TPC and different absorbance values

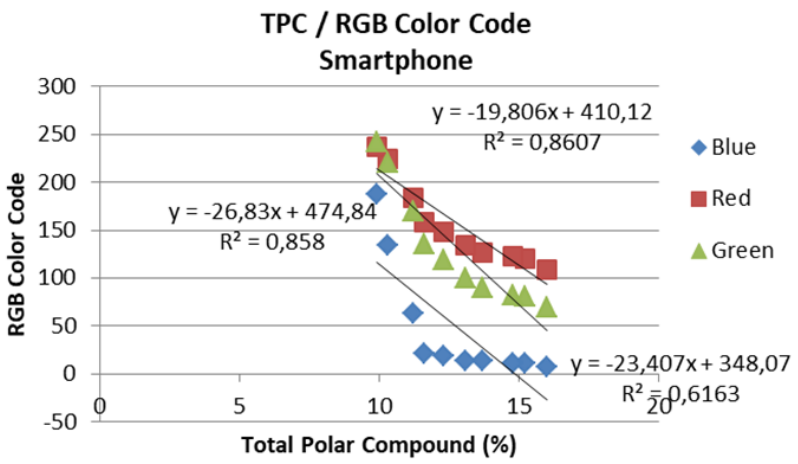


Graph 3, RGB color code measured with the help of a Computer and TPM relationship scatter plot.



Best results are obtained from the R/G ratio. Both computer and cell phone measurements are compatible with measurements gathered from machine learning techniques.

Graph 4, RGB color code measured with the help of a smartphone and TPM relationship scatter plot.



According to the results of the reliability statistics, the nearest measurements to our gold standard, which is made with the Testo 270 device, were the results of the R/G ratio. Computer, smartphone, and machine learning calculation of R/G proportion have shown great relevance with each other (Table 1).

Table 1. TPC results obtained from different methods and correlation with Testo 270.

	Testo 270	Spectroscopy	Computer	Smartphone	Machine Learning
100%	16,00	15,59	15,63	15,71	15,61
90%	15,20	15,31	14,84	15,45	14,74
80%	14,80	14,34	14,95	14,44	15,10
70%	13,70	13,53	14,32	14,33	14,49
60%	13,10	14,03	13,38	13,30	13,40
50%	12,30	13,02	12,52	12,47	12,62
40%	11,60	11,33	11,72	11,16	11,55
30%	11,20	11,53	10,78	10,80	10,69
20%	10,30	10,60	10,14	10,23	10,05
10%	9,90	9,14	9,80	10,19	9,84
mean	12,81	12,841	12,,809	12,808	12,,809
variance	4,42	4,49	4,53	4,55	4,72
correlation with Testo270		0,967	0,987	0,985	0,981

Discussion

In this study, a new method of measuring TPC values of frying oils based on RGB color codes is developed. Since there is no study done with RGB in literature, our study brings innovation to oil measurement methods as a practical method based on RGB-code. Additionally, it is shown in our study that the TPC value can be extrapolated from a picture that has been taken by a smartphone with the help of machine learning techniques. The operability of our method is tested with the help of basic software.

Generally, in frying oil TPC measuring methods, it is required to heat the oil, to calibrate the tool with reference oil at regular intervals, to use some chemical substances for color comparison, or to reference a color catalogue before analysis. [22] None of these are practical. As stated in our study, it is feasible to calculate the TPC value of a particular frying oil with the help of only one picture taken by a smartphone. The mechanism is easy, practical, repeatable, and affordable. In this regard, the main question of our study has been answered. Our method is tested with the TPC measuring device that has already been used and spectrophotometric measurement methods.

According to the results of the compliance statistics, the nearest measurements to our gold standard, which is made with the Testo 270 device, were the results of the R/G proportion. Pc, smartphone, and machine learning calculation of R/G proportion have shown great relevance with each other.

There aren't adequate studies regarding the usage of image analysis to define the oil quality. RGB color codes can be used in defining the type of vegetable oils. [23,24] Their cooking quality can also be evaluated in another study by making a color analysis of images of the food items after they are cooked. [25] In another study, it may be possible to indicate the rottenness of the oil using image processing techniques, artificial neural networks, and evaluating RGB values. [26] Besides our main focus, one of the major indicators of the oil quality is acidity value, and it is also feasible to calculate that using RGB color codes.

In our study, we have demonstrated that TPC values in frying oils can be measured by image processing. More recently in another study, it is shown that nucleic acid assay can be measured via RGB color code analysis with the help of a smartphone application. [27] It contributes to the reliability of our study.

We determined that the TPM value of the waste frying oil we procured from the waste oil collection center is 16%. This shows that while trying to be extremely sensitive about health, unnecessary disposal of waste frying oil is happening. Hence, this dilemma has a negative impact on both the country's economy and the environment. Thanks to the method we have found, the amount of TPC can be determined with a photo anywhere. Thus, preservation of the environment won't be forgotten while providing an economic profit.

Conclusion

It will be feasible to directly determine when the oil will be useless and harmful with this quick, easy, affordable, repeatable method. Before frying oils reach a state that is harmful to human health, restriction of their usage at the right time will be easily decided by applying this method. Through this method, the TPC content of the oil can be measured easily with the help of a photograph. As a matter of fact, the harmful effects of oil on human health will be prevented. Additionally, it will contribute to the renewal of the environment and state economy.

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