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# Comparative assessment of algal oil with other vegetable oils for deep frying

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A R T I C L E I N F O

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A B S T R A C T

Algae is an emerging source of vegetable oil. In this study, a comparative assessment of algal oil for deep frying with sunflower and palm oil was performed. Potato sticks were fried for four consecutive days in each of the individual oils under study. These oils were analyzed for density, refractive index, viscosity, oil uptake, acid value, percentage free fatty acid, acidity, peroxide value, total polar compounds, color, radical scavenging activity and fatty acid profile. Fried potato sticks were evaluated for texture and sensorial properties, the latter was performed using a fuzzy logic method. Principle component analysis was done for a variety of physicochemical parameters. This study revealed that the algal oil had the highest physical and chemical stability during the frying process compared to sunflower and palm oils. Potato sticks fried in algal oil had a superior texture and improved sensorial properties. Based on these results it can be concluded that algal oil has a great potential to be used for deep frying foods.

## 1. Introduction

Over the last 25 years, the global vegetable oil production has been booming due to exponential population growth and depletion of fossil fuels [1]. Palm oil is a major contributor in vegetable oil; but, unfortunately, increased palm plantation has resulted in deforestation which is one of the main environmental issues linked to global warming [2]. Microalgae are reported to have seized the focus of research as a valuable biomass for food, feed and fuel in recent years [3]. Microalgae oil, which has similar chemical composition as vegetable oil with rich monounsaturated fatty acids content, could be a suitable alternative to palm oil. Many recent studies have revealed the health potentials associated with the monounsaturated fatty acids from microalgae [4]. In this regard, San Francisco-based TerraVia Holdings, Inc., US (Formally, Solazyme) is using heterotrophic microalgae fermentation for specially tailored oils containing 87% of monounsaturated fatty acids. These microalgae utilizes sugar and directly produce oil [5]. Vegetable oils are prone to undergo oxidation under various process conditions. To overcome this problem; many strategies have been put in place such as genetic modification of plants (83% oleic acid containing soybean seeds produced by DuPont Technology), chemical modification or use of various additives [6].

Deep frying, that involves immersing food in oil at high temperatures that range from 150 to 190 °C, is one of the most popular methods of cooking to achieve desirable product attributes [7,8]. During the frying process, oil undergoes a series of reactions which can produce toxic or carcinogenic compounds. Initially, due to primary oxidation free fatty acids, conjugated diene or conjugated triene and peroxides are produced. Afterwards alcohol, aldehydes, ketones and cyclic compounds are generated as secondary oxidation products [9]. These generated products can deteriorate the functional, sensory and nutritional quality of oils [10]. Amongst all frying oils, those with high oleic acid content such as sunflower and palm oils have better health profiles and stability [11].

In the global context, it is important to possess comparative data of the performance of a completely new source of deep frying oil with prevailing vegetable oils. Therefore, the present research was carried out for comparative assessment of algal oil with the most commonly used vegetable oils (from sunflower and palm) during deep-frying processes. Effect of deep-frying on the characteristics of algal, sunflower and palm oils such as density, refractive index, viscosity, oil uptake, acid value, percentage free fatty acid, acidity, peroxide value, total polar compounds, color, radical scavenging activity and fatty acid profile was assessed. Potato sticks were used as food matrix for the textural and sensorial evaluation of deep frying oil based on previous studies [8,12].

## 2. Material and methods

### 2.1. Material

Refined sunflower oil (Liberty oil mills limited, Thane, Maharashtra, India) and refined palm oil (Yog oil traders, Mumbai, India) were

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purchased from local market of Mumbai, India. Algal oil (AlgaWise™ High stability High oleic oil, RBD) was gifted by TerraVia Holdings, Inc., USA. McCain® potato sticks were purchased from D-mart® Mumbai, India. All chemical used were analytical grade and purchased from SD fine Ltd., Mumbai, India.

### 2.2. Experimental design and frying of potato sticks

The frying experiment was carried out in an electrically heated sand bath in which 3 frying baths were kept simultaneously. Each frying bath was filled with 800 ml of oils. Each day, the oil was heated at 160 ± 5 °C and allowed to equilibrate for 30 min. The time required for attaining 160 °C was approximately 60 min. Each batch of 40 g of potatoes were fried for 5 min, four times a day at an interval of 45 min. The frying process was repeated with each oil sample for four consecutive days. A total of 16 frying batches were processed and the alternative batches were used for sensorial and texture analysis. The frying baths were kept open during frying. The frying heater was turned off at the end of each day and oils were allowed to cool. After approximately 90 min, the oils were cooled to 60 °C and filtered to remove any debris using a stainless steel strainer. Each day 40 ml of each oil was withdrawn and stored at −20 °C until analyzed.

### 2.3. Physical properties

Various physical properties were studied to assess the influence of frying process on oil quality. The density of oil samples were measured using specific gravity bottles with 10 ml capacity [13]. Refractive index (RI) of oil samples were studied using Abbe refractometer (Guru Nanak Instruments, New Delhi) [14]. Measurement of viscosity was carried out with a Brookfield programmable rheometer (model DV-III, Brookfield Engineering Labs, USA) [15]. Oil absorption of fried samples were determined gravimetrically [16]. From the last batch of each frying day, oil was extracted from 1 g of fried potato sticks using petroleum ether (B. P. 60–80 °C) by the Soxhlet method (Instant Soxhlet apparatus-Socs plus, Pelican Equipment's, Chennai, India). Results were expressed as g of oil absorbed on g of fried potato sticks. All experiments were conducted in triplicate. Mean and standard deviations were reported.

### 2.4. Chemical properties

Acid value of oil samples were determined as described by Cho et al. and expressed as mg KOH/g of sample [17]. The percentage free fatty acid was calculated from the function below [18]: Percentage free fatty acid as oleic acid = 0.503 × acid value. Acidity of oil samples were analyzed as per the protocol of Chammem et al. [19]. Peroxide value (PV) was determined as described by Chammem et al., [19]. Total polar compounds (TPC) in oil samples were determined based on the methods of AOCS [20]. Weight of non-polar and polar fraction was recorded for each sample in duplicate. TPC was expressed as g of TPC per g of oil sample. For fatty acid profile of control and after frying processed oil samples were analyzed using gas chromatography equipped with flame ionization detector (GC-FID) (Agilent Technologies 7820A). Fatty acid methyl esters (FAME's) were prepared from oil using $H_2SO_4$ as described by Tarmizi et al. and Mishra et al. [21,22]. A DB-23 capillary column (30 m × 0.250 mm id., film thickness 0.25 μm was used. The oven temperature was held for 10 min at 100 °C and subsequently increased to 240 °C at 4 °C/min. Each FAME peak was identified and quantified by referring a 37 component FAME standard mix (Supelco®, Bellefonte, USA).

### 2.5. Color

The color of the oil samples were measured using μQuant Elisa plate reader (Biotek® Instrument Inc., Winooski). 200 μl of oil was placed in 96 well plates. The absorbance of oil samples were taken at 425 nm [23]. Three separate samples from collected oils were analyzed in triplicate.

### 2.6. Radical scavenging activity

Radical scavenging activity of oil was determined and compared to that of trolox, using DPPH radical scavenging methods. Ability to scavenge free radical of oil sample was tested based on the method of Sahreen et al. [24]. A standard curve was plotted using standard trolox (0–300 μM) and was linear within the given range. Radical scavenging activity was expressed as μM trolox equivalent per ml of oil.

### 2.7. Texture analysis

A texture analyzer (TA-XT2i, Stable Micro System Co. Ltd., Surrey, UK) was used to evaluate the texture of the fried potato sticks. An even number of batches of potato sticks fried in different oil were taken for texture analysis. The fried potato sticks were placed over the heavy duty platform and was compressed by a moving probe (P/2). Test conditions used were: pre-test speed- 10 mm/s, test-speed- 10 mm/s, and post-test speed- 10 mm/s. The deformation distance was maintained at 2 mm. The force used was 50 kg. The force-time curve was recorded, analyzed and was expressed in grams using software Texture expert exceed version 2.64 (Stable Micro Systems, Ltd). The parameters obtained were: hardness (g) and fracturability (mm). Three fried potato sticks were tested and values were reported as mean.

### 2.8. Sensory analysis

Sensory analysis was performed for potato sticks fried in sunflower, palm and algal oil. Odd number batches were taken for sensory analysis after they reached room temperature. Sensory analysis of fried potato sticks were performed by 10 trained panelists from Food Engineering and Technology Department, Institute of Chemical Technology, India. Panelists were educated by giving instructions about positive and negative control [25]. Sensory evaluation was conducted using fuzzy logic method as described by Sinija and Mishra [26].

### 2.9. Statistical analysis

All samples were analyzed in triplicate and expressed in the form of average. The significant differences between mean values were assessed by one-way analysis of variance (ANOVA). Tukey test was carried out using SPSS 16.0 software to determine whether there was any significant difference at the level of $p < 0.05$. Figures were plotted in OriginPro 9.1 software. All calculations were performed in Microsoft excel 2013. Principal component analysis (PCA) was performed using STATISTICA 7.0 software.

## 3. Result and discussion

### 3.1. Effect of deep frying on physical properties of oils

Density of oils can affect the frying of potato sticks as it is responsible for change in heat transfer and buoyant moment of gas bubbles in any oil during frying. Preferably, frying oil should not change its density even after several frying cycles [27]. Slight change in density was observed in the case of sunflower oil and palm oil; whereas algal oil density remained unchanged even after the fourth day of frying (Table 1).

RI, the physical method of characterization of materials including oils, is the ratio of speed of light in a vacuum to the speed of light through a given material. There is a relationship between fatty acid chemistry and RI of oils which includes chain length and degree of unsaturation. The RI of sunflower oil, as control, was 1.470. After frying