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Title of the thesis : Formulation of Blended Vegetable Oils and Investigation of their Fatty Acid Profile in Cooked Products

(i) In Roman Script Formulation of Blended Vegetable Oils and
(ii) In roman Script Investigation of their Fatty Acid Profile in Cooked Products

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Abstract within 300 words:

Dietary variations play a crucial role in determining a country's health and well-being. The onset of diet-related disorders is closely associated with food intake, specially oil intake. Blending of oils has become a more financially successful technique to improve oxidative stability and nutrient profile of oil by maintaining a balanced fatty acid profile in recent years. Thus, blending oils to create an alternative cooking medium with desired health advantages is the need of the day. The study was carried out in four phases. In Phase I, a survey on household consumption of dietary fat was done among 196 households at Coimbatore and a market survey on the availability of blended vegetable oil was carried out in eight outlets. In Phase II, the formulation of six blended vegetable oils (BOGN-I, BOGO-II, BOSF-III, BOSFO-IV, BOFO-V, BOEP-VI) using groundnut, gingelly, sunflower, safflower, and flaxseed oil was done and their physical, chemical and sensory attributes were tested using standard procedure. In Phase III, the fatty acids profile of formulated blended vegetable oil was analyzed using a gas Chromatography - Flame Ionization Detector). In Phase IV, the absorption of oil and fatty acids profile of selected recipes cooked (Deep fat frying - vadai, Pan frying - chapatti, Sautéing - potato poriyal) using formulated blended vegetable oils were analyzed (GC-FID). Forty eight percent of households belonged to an upper lower socio-economic group. The consumption of groundnut oil was found to be maximum (108ml) followed by sunflower oil (87 ml). Blending of more than three oils was not observed. The physical properties of all the six formulated blended vegetable oils were in par with stand-alone oil. The chemical properties of the blended vegetable oils reported better oxidative stability than stand-alone oils. The sensory attributes of all the blended vegetable oils were in par with the stand-alone oils and hence can serve as an alternate cooking medium. The blended oils BOSF-III and BOSFO-IV reported the least oil absorption in cooked products and were found to be low in saturated fats, and high in MUFA and PUFA. Hence they can be recommended as healthier oils compared to stand-alone oil.

Keywords: Fatty Acids, Flaxseed oil, Gingelly oil, Groundnut oil, Vegetable Oils, Safflower oil and Sunflower oil.

i) Major objectives :

Primary Objectives

The primary objective of the study is to **“Formulate Blended Vegetable Oils and Investigate their Fatty Acid Profile in Cooked Products”**

Secondary objectives

The secondary objectives is to

- study the consumption of fats and oils in selected households of Coimbatore.
- survey the market availability of blended vegetable oils.
- formulate blended vegetable oils and to assess their quality attributes.
- analyze the fatty acids profile of the formulated blended vegetable oils and
- to investigate the fatty acids profile of products cooked using the formulated blended vegetable oils.

ii) Hypothesis:

- Hypothesis₀₁ There is no significant difference in the refractive index of the formulated blended vegetable oils with that of stand-alone oils
- Hypothesis₀₂ There is no significant difference in the density of the formulated blended vegetable oils with that of stand-alone oils
- Hypothesis₀₃ There is no significant difference in the viscosity of the formulated blended vegetable oils with that of stand-alone oils
- Hypothesis₀₄ There is no significant difference in the organoleptic acceptability level of the formulated blended vegetable oils with that of stand-alone oils.
- Hypothesis₀₅ There is no significant difference in the peroxide value of the formulated blended vegetable oils with that of stand-alone oils
- Hypothesis₀₆ There is no significant difference in the iodine value of the formulated blended vegetable oils with that of stand-alone oils
- Hypothesis₀₇ There is no significant difference in the saponification value of the formulated blended vegetable oils with that of stand-alone oils

- Hypothesis₀₈ There is no significant difference in the acid value of the formulated blended vegetable oils with that of stand-alone oils
- Hypothesis₀₉ There is no significant difference in the free fatty acid profile of the formulated blended vegetable oils with that of stand-alone oils

iii) Methodology :

The methodology of the study “**Formulation of Blended Vegetable Oils and Investigation of their Fatty Acid Profile in Cooked Products**”, is discussed under the following phases.

Phase I: A Survey on Consumption of Fats and Oils and Market Availability of Blended Vegetable Oils

A) Survey on Household Consumption of Fats and Oils

Fats and oils are necessary components of a well-balanced diet and plays an important role in the maintenance of health and well-being of any individual irrespective of age, sex, region, and cultural difference. Hence as a primitive step to understand, the consumption pattern of dietary fat, a survey was conducted by the investigator.

The research study was approved by the Institutional Human Ethics Committee of Avinashilingam Institute for Home Science and Higher Education for Women **IHEC/19-20/FSMD/28** (Annexure I).

Selection of Area

Coimbatore, a tier II city is a known industrial and education hub of the state of Tamil Nadu. The city is also known for its rich agricultural farming practices. Agricultural production of edible oil accounts for the overall production of 10,507 tonnes which includes 10,370 tonnes of groundnut and 137 tonnes of gingelly seeds per year (Statistical Handbook of Tamil Nadu – 2020-2021). With a population of 13,08,675 (census of India 2011), the morbidity and mortality rate of Coimbatore was observed to be 1.928 million (Jebakumar *et al.*, 2020) and 29,959 for the year (Vital Statistics-Statistical Handbook of Tamilnadu 2020-2021). Also, literature survey on the incidence of diet-related non-communicable diseases such as cardiovascular, obesity, hypertension, and diabetes was found to be 1.92 million (Jebakumar *et al.*, 2020). Thus the city of Coimbatore was selected for the conduct of the study using purposive sampling.

Selection of Sample

Out of 2,82,839(census 2011) households from the urban part of Coimbatore, 272 households were selected using Cochran formula $n = X^2 p^{\wedge} (1 - p^{\wedge}) / E^2$.The households were selected using convenient sampling. Since the study was initiated during COVID-19 pandemic period,the investigator was not able to survey all the selected houses and hence had to restrict the survey to 196 houses. Thus,a total of 196 female members from selected households were selected for the conduct of the study.

Development of Tool

The investigator developed an interview schedule to collect information on fat consumption patterns in the selected household. Information such as background details, dietary patterns, food frequency, purchase of different types of fats and oils, the quantum of consumption of different types of oil, and the type of cooking with oil as a medium were elicited. The developed interview schedule was tested and validated.

Background Information

The background information for name, age, sex, family type, family size, marital status, educational qualification, occupation, and family income of all the selected households was obtained using an interview schedule (Annexure II).

Dietary Pattern

Dietary pattern is defined as the amount, portion size, diversity or combination of several foods and beverages. It also comprises the frequency of food consumption. Food intake is a multi-dimensional process that is complex in nature. There are various distinguished combinations of foods to potentially enquire. The changes in dietary habits are generally characterized by substitution effects, where an increased consumption of some foods is associated with decreased intake of other foods. This defines the challenge in consumption of particular foods. Hence, the investigator also studied the dietary pattern, to account for interrelationships in food choices, reflecting the cumulative exposure to different dietary components.

The dietary pattern of the selected household namely, the types of diet consumed, meal pattern, preference for particular food, and the different methods of cooking were collected from the female subjects, with the help of the interview schedule.

Food Frequency

The modified food frequency schedule was developed, tested and validated (Annexure-III). The schedule was administered to all the selected subjects and they were asked to specify the quantum of consumption in terms of grams and milliliters and the frequency of consumption for daily, weekly, fortnightly and occasionally was obtained. To avoid missing data, proper prompting in between was made by the investigator whenever necessary.

Assessment of Average Consumption of Dietary Fats and Oils

Intake of dietary fats and oils, greatly influences the health and well-being of the individual, hence using an Inventory list (Annexure IV) the consumption of oil by the selected household was obtained. The investigator collected information on the type of fat and oil consumed (saturated and unsaturated fats and oils). The frequency and purpose of oil usage and the types of frying done were also elicited. To have precise data on the amount of oil consumed by the household, the investigator measured the intake of oil used for the preparation of each meal. For this, the investigator provided 100 ml of oil every day and instructed the female to measure the oil used for every single preparation made. The total amount of oil used for the preparation of all the meals was calculated. Flexibility to use excess oil in case of deep fat frying was allowed, however the investigator requested the subjects to maintain data on the excess use of oil. The consumption pattern was observed for five consecutive days and the average consumption of oil per person was calculated using the formula

$$\text{Average oil consumption per person} = \frac{\text{Quantum of oil used per month}}{\text{Number of family members}}$$

B) Market Survey on Availability of Blended Vegetable Oils

The city of Coimbatore was geographically divided into four regions namely north, east, south, and west. A total of eight retail shops comprising two shops (one commercial supermarket and one wholesale) were selected from each zone. The investigator developed a checklist (Annexure V) to collect information on the availability of different types of oil, brands of oil, their price, the available quantity, manufacturing details, food, and nutritional labeling, if any. The investigator also surveyed on market availability of blended vegetable oil, types, and number of oils used for blending.

Phase II: Formulation of Blended Vegetable Oil and its Quality Analysis

Selection of oil

According to nutritionists, single oil may not always provide the proper ratio of fatty acids in the triacylglycerol (TG) of oils and fats. One straightforward and different approach to accomplish this is to create Structural Lipids (SLs) from various oils or create a physical mixture of various oils in the appropriate ratio (FSSAI 2006, Rule 2011). Thus to make cooking oil a medium of healthier food choice, the investigator felt the need to blend oil.

Based on the intense literature survey, functional properties and observations of the investigator on the consumption of a standalone oil by the majority of the household in the first phase of the study, the following oils namely groundnut, gingelly, sunflower, safflower and flaxseed oil were chosen for blending.

Groundnut oil otherwise called as peanut oil is widely used in cooking in many parts of India (Ojiewo *et al.*, 2020) and is also rich in monounsaturated (53.89 g), polyunsaturated (27.17 g), and saturated fatty acids (18.94 g) (Herrera *et al.* 2013).

Gingelly oil (or) sesame oil is the most popular among the South Indian population. Gingelly oil contains an equal proportion of polyunsaturated (42.34g), monounsaturated (41.41g), and saturated (16.25g) fatty acids. It is well-balanced in ω 3, ω 6, and ω 9 fatty acids. Studies suggest that diets rich in these healthy fats can reduce the risk of heart disease. Consumption of gingelly oil has been associated to lower levels of LDL cholesterol and triglycerides, contributing to heart health. Additionally, the lecithin in gingelly oil acts as an emulsifier, preventing the buildup of cholesterol and saturated fats in the arteries. Furthermore, sesamin in gingelly oil is known to inhibit Δ 5-desaturase activity and cholesterol absorption. Along with the antioxidant properties of sesaminol, sesamin plays a role in cancer prevention (Wu *et al.*, 2019).

Sunflower oil is India's most popular cooking oil and it contains desirable polyunsaturated (62.65g), monounsaturated (25.96g), and saturated fatty acids (11.39g). Monounsaturated and polyunsaturated fats found in sunflower oil are good for heart when consumed in moderation. They also include plenty of antioxidants, like vitamin E, which may help reduce inflammation and risk for heart diseases.

Safflower oil is rich in polyunsaturated (76.78g), monounsaturated fatty acids (14.04g), and saturated fatty acids (9.19g). Regular safflower oil contains approximately 2-13% stearic acid, 6-20% palmitic acid, 71-75% linoleic acid, and 6-20% oleic acid (Liu *et al.*, 2016). By lowering the area of myocardial infarction, relieving myocardial ischemia, raising heart rate, and boosting oxygen delivery to the myocardium, the safflower oil rich in flavonoids, protects the heart (Ji *et al.*, 2018). Nutritional factors found in safflower can be applied to a variety of medical and pharmaceutical applications as anti-inflammatory, antioxidant, antibacterial, and anticoagulant agents (Mani *et al.*, 2020).

Flaxseed (*Linum usitatissimum L.*), is well-studied for its numerous health benefits but has not yet become popular in the cooking oil market. To counteract the instability caused by its high omega-3 fatty acid content, blending flaxseed oil is a viable solution (Grover *et al.*, 2021). Flaxseed oil is one of the richest plant-based sources of Alpha-Linolenic Acid (ALA), a primary omega-3 fatty acid known for its strong anti-inflammatory properties.

Procurement of oil

Traditionally cold-pressed groundnut, gingelly, sunflower, safflower, and flaxseed oils were procured from a cold-pressed oil vendor. To retain the homogeneity of the oil sample for quality attributes, the investigator made all effort to procure the oils on the same date of cold pressed for all the oils on request. The procured cold-pressed oils were further transferred to a one-liter airtight glass bottle and were stored at room temperature (27⁰ C- 34⁰ C). Care was taken to prevent rancidity and spoilage.

Blending of oil

Formulation of blended vegetable oil

According to Grover *et al.*, (2021) one of the simplest, most affordable, and effective ways to enhance the nutritional, physical, and sensory properties of any oil is to combine edible vegetable oil. The compositional variation of the oils may allow for the production of a superior blend with higher quality.

To the best of the knowledge of the investigator, blending of oil was attempted only with two oils. Since Indian cuisine uses a variety of vegetable oils by different populations in different states, an attempt to blend five standalone vegetable oils namely groundnut, gingelly, sunflower, safflower and flaxseed oils with high polyunsaturated fatty acid and functional properties was made by the investigator. Using the above standalone oils, six variations of blends as projected in the Plate 2 was done.

Out of six variations of blended vegetable oil, five variations with hundred milliliters of blended vegetable oils comprising 50 ml of stand-alone oil and the remaining 50 ml with equal distribution of (12.5 ml) each of gingelly, sunflower, safflower and flaxseed oil was formulated. The sixth variation was blended with an equal quantum (20 ml) of selected stand-alone oil.

Process of Blending

The formulated oils for blending were taken in a conical flask and shaken for 90 rpm using an orbital shaker at 37⁰ C for 24 hours and were kept in the sonicator for 15 minutes. The blended vegetable oil was then transferred into an airtight container. Care was taken by the investigator to prevent any oxidative changes.

Quantitative Analysis of Blended Vegetable Oil

The blended vegetable oil was then tested for their quality attributes namely physical and chemical properties, sensory attributes, antioxidant and shelf life using standard qualitative and quantitative techniques

Sensory Analysis and Acceptability Analysis

The acceptability of all six blended vegetable oils was tested for its organoleptic quality in terms of colour, flavour, texture, taste, and appearance using a nine-point hedonic scale. Three types of cooking were chosen by the investigator for this purpose namely deep frying, pan frying, and shallow fat frying. For the above cooking methods, the preparation of vada for deep fat frying, chapati for pan frying, and potato poriyal for shallow fat frying was done. The selected recipes were cooked using the formulated blended vegetable oils and were evaluated for acceptability among the 20 semi-trained panel members against the recipes cooked in stand-alone oils, namely groundnut oil, gingelly oil, sunflower oil, safflower oil, and flaxseed oil. The members were asked to rate each sensory character of the cooked recipes on a nine-point hedonic scale ranging from, like extremely to dislike extremely, with a maximum score of 45 and a minimum score of 5. Recipes that obtained a score between 35-45 were rated as highly acceptable, 25-35 as acceptable and a score less than 25 as not acceptable (Annexure VI).

Physical properties

The physical property of all the six formulated blended vegetable oil for colour, refractive index, density, viscosity, smoking temperature, and solubility were analyzed using standard procedure and are detailed below.

Colour

The colour change is a sign of oil deterioration due to oxidation. The colour of oils is determined by the presence of colouring materials such as chlorophyll and carotene. The colour of the six blended vegetable oil was tested using Gowegroup Multitesters digital food colour card reader. The black and white cavity of the instrument was calibrated. The oil sample was taken in a watch glass and was placed under the instrument's test aperture, the hue value of the oil sample was detected and was displayed as L*, a*, b*. The colour of the tested oil was calculated using the formula $\Delta E_{a^*b^*} = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$ and compared with the corresponding hue chart interpretation (Annexure VII)

Refractive Index

To understand the dispersion characteristic, unsaturation, and chain length of fatty acid present in the six blended vegetable oils, the refractive index was measured using Abbes Refractometer. The refractive index of the blended vegetable oil was measured in a thermo stable controlled environment (temperature of the refractometer maintained within $\pm 0.1^\circ \text{C}$) at the wavelength of 89.3 nm using the standard procedure (AOAC 17th ED, 2000). To know the level of deviation of the refractive index of blended vegetable oil with that of the stand-alone oils, the refractive index of the gingelly, groundnut, sunflower, safflower, and flaxseed oils was also measured. (Pandurangan *et al.*, 2014) (Annexure VIII).

The refractive index was calculated using the formula

$$R = R^1 + K (T^1 - T)$$

Where,

R = Reading of the refractometer reduced to the specified temperature T°C

R^1 = Reading at T¹C

K = constant 0.000365 for fats and 0.000385 for oils (Abbe Refractometer is used)

T¹ = temperature at which the reading R¹ is taken and

T = specified temperature (generally 40°C).

Density

Density is an important factor that influences oil absorption and it affects the drainage rate after frying and the mass transfer rate during the cooling stage of frying. It is also related to the

smoking temperature of oil and hence the investigator tested the density of all six blended vegetable oils against the stand-alone oils namely gingelly, groundnut, sunflower, safflower, and flaxseed oil by following standard procedure (AOAC 185.19).

The density of the blended vegetable oil was calculated using the formula,

$$d=M/ V$$

Where d is density, M is mass and V is volume (Annexure IX).

Viscosity

The thermal behavior of the cooking oil can be well predicted based on the viscosity of the blended vegetable oil using a viscometer. The viscometer was calibrated. The device was set at 27⁰ C as viscosity may vary with temperature. The spindle was inserted into the viscometer and was submerged in the oil without touching the sides of the container. The reading on the resistance of oil flow as displayed was recorded in Centipose (cP) (Annexure X).

Smoking Temperature

The smoking point of the formulated blended vegetable oil was measured by heating 100 ml of blended vegetable oil over a medium flame in a frying pan of eight inch in diameter. The investigator recorded the temperature of the oil using a thermometer (thermopro) when the oil began to emit a continuous stream of smoke. Care was taken to avoid overheating. The smoking temperature of groundnut, gingelly, sunflower, safflower and flaxseed oils were also measured and compared with a smoking chart (Agarwal and Porwal, 2018).

Solubility

Fat solubility is defined as the mass fraction of a substance that forms a homogeneous phase with a liquid fat (oil) without causing chemical reactions. As fats are soluble in organic solvents like, chloroform and alcohol, the solubility of blended vegetable oil was tested in ethanol, petroleum ether, chloroform and water. For this equal amounts of water, ethanol, petroleum ether and chloroform were taken in separate test tubes and 4 drops of oil sample was added to each test tubes. The test tubes were then shaken well and were kept for 15 minutes. The level of solubility was observed visually and was recorded.

Chemical Properties of Blended Vegetable Oil

The chemical properties of all six blended vegetable oils for peroxide value, iodine value, saponification value, and acid value were analyzed using standard procedure and are detailed below.

Peroxide Value

To test the oxidative stability of the blended vegetable oil, the peroxide value was analyzed by adding five milliliters of oil sample to 12 ml of chloroform in a 25 ml beaker. Potassium iodide KI solution (0.5-1.0 ml) was added to the beaker. The beaker was shaken for at least one minute and 30 ml distilled water was added. The mixture was titrated with sodium thiosulphate (0.01M) until the disappearance of yellow color and the peroxide value was calculated using the formula,

$$\text{Peroxide value} = \frac{\text{Titre} \times N \times 1000}{\text{wt of the sample}} \text{(Annexure X)}.$$

Where,

Titre = ml of Sodium Thiosulphate used (blank corrected)

N = Normality of sodium thiosulphate solution (0.01N).

Iodine Value

The iodine value of fat and oils indicates the degree of unsaturation. In fatty acids, unsaturation occur mainly in double bonds which are very reactive towards halogens like iodine. Thus estimation of iodine value will give an idea about the degree of unsaturation present in the blended vegetable oil. The iodine value of blended vegetable oil was analyzed using the Wijs method (AOAC-920.159) as given in (Annexure XI).

The iodine value was calculated using the formula

$$\text{Iodine value} = \frac{12.69 (B - S) N}{W}$$

B = volume in ml of standard sodium thiosulphate solution required for the blank

S = volume in ml of standard sodium thiosulphate solution required for the sample

N = normality of the standard sodium thiosulphate solution (0.1N)

W = weight in gm of the sample

Units: gm of iodine per 100g of oil

Saponification Value

The saponification value is an important parameter used for the characterization and assessment of the quality of edible fats and oils. To understand the average molecular weight of the fatty acids present in the formulated blended vegetable oils, the saponification value was estimated.

For this two to five grams of oil sample was accurately weighed and transferred to the conical flask. Twenty-five milliliters of 0.5N alcoholic potassium hydroxide (KOH) and a few anti-bumping granules were added to the conical flask. The conical flask was placed in a water bath and refluxed gently for one hour. Care was taken to prevent the loss of alcohol. After refluxing, the mixture was cooled and titrated against 0.5N hydrochloric acid (HCl) solution using phenolphthalein as an indicator. The quantum of hydrochloric acid used was noted. The saponification value of blended vegetable oil was calculated using the formula: (Annexure XII).

$$\text{Saponification value} = \frac{56.1 (B - S) N}{W}$$

Where,

B = Volume in ml of standard hydrochloric acid required for the blank.

S = Volume in ml of standard hydrochloric acid required for the sample

N = Normality of the standard hydrochloric acid (0.5N) and

W = Weight in gm of the oil taken for the test.

Units: mg of KOH/1 g oil

Acid Value

Acid value (AV), which measures free fatty acid content, is a crucial component in determining refined fats and oils and how their quality varies over time. The hydrolysis of triglycerides leads to the generation of free fatty acids, which gets aggravated when moisture reacts with the oil. To measure the acid value, two to five grams of the oil sample was weighed and transferred into a conical flask. A few drops of phenolphthalein indicator were added along with 50 ml of neutralized isopropyl alcohol.

Potassium hydroxide (KOH) solution (0.1N) was added to the mixture until a steady pink hue develops (Annexure XIII). The acid value was calculated using the formula,

$$\text{Acidvalue} = \frac{56.1 V \times N}{W}$$

Where V = Volume in ml of standard sodium hydroxide used

N = Normality of the Sodium hydroxide solution (0.1N) and

W = Weight in gm of the sample

Free Fatty Acids

Fifty milliliters of alcohol was taken in a clean, dry 150 ml flask. A few drops of the oil were added along with 2 ml of phenolphthalein. The flask was placed in water at 60-65°C until it turned warm and enough of 0.1N NaOH was added to produce a slight permanent pink colour. Then, 56.4g oil was weighed into the neutralized alcohol and titrated against 0.1N NaOH, with occasional warming and vigorous shaking of the mixture until the appearance of faint permanent pink. The volume of 0.1N NaOH used was multiplied by 0.05 and reported as a percent of free fatty acids and was expressed in terms of oleic acid (Annexure XIV). Free fatty acids may also be expressed in terms of acid value (mgKOH necessary to neutralize 1g oil) (AOAC-940.28).

$$\text{Free fatty acids (as oleic acid\%)} = \frac{\text{Titre Volume X Strength of NaOH X 28.2}}{\text{Sample weight}}$$

Here, the strength of NaOH = 0.1N.

Antioxidant properties of Blended Vegetable Oil

Tocopherols

Tocopherol is the main antioxidant that helps in the retardation of rancidity and also serves as a source of the essential nutrient vitamin E. Thus, the investigator analyzed the tocopherol content of the formulated blended vegetable oil using HPLC-UV (High-Performance Liquid chromatography with UV detector) as per standard procedure (AOAC-2012.09) [Annexure XV].

Shelf Life

The shelflife of the formulated blended vegetable oil was studied using the peroxide value, which indicates the oxidative stability of the blended vegetable oils. The peroxide value was analyzed by adding antioxidant and without antioxidant using the standard protocol (AOAC-965.33). The formulated blended oils were examined weekly once for a period of 56 days, to determine its storage stability (Annexure X).

Phase III: Fatty Acid Profile of Formulated Blended Vegetable Oils

Quantitative analysis for the fatty acids profile of all six blended vegetable oils was carried out using the Gas Chromatography – Flame Ionization detection method (AOAC 996.06) – AOAC, 2019.

Using soxhlet extraction the fat samples were collected. The collected fat samples (100 µl) were taken in a test tube. The mouth of the test tube was closed and shaken well for 10 seconds using a vortex mixture. The tube was made to rest for two minutes and 2 ml of hexane was added and shaken well for four minutes. To the sample, 50 ml of sodium sulfate was added and centrifuged at 1500 rpm for three minutes. The hexane layer was collected through a 0.22 µm filter and injected in Gas Chromatography- Flame Ionization for detection. The fatty acids were then identified in a chromatogram by comparing their retention time to that of the corresponding peak. Similarly, the fatty acid profile of the stand-alone oils namely, groundnut, gingelly, sunflower, safflower, and flaxseed oil was done (Annexure XVII).

Phase IV: Fatty Acids Profile of Selected Recipes Cooked Using Formulated Blended Vegetable Oils

Preparation of recipes with blended vegetable oil

The investigator was curious to study the fatty acid profile of foods cooked using the formulated blended vegetable oil to understand its dietary contribution. Three commonly consumed recipes namely vadai (deep fat frying), chapatti (pan frying), and potato poriyal (sauteing) were selected for this purpose.

Vadai a common deep-fried snack was prepared by soaking 100gms of Bengal gram dhal for 20 minutes and grinding it to a coarse consistency. Finally chopped onions (20gm), ginger (small piece), green chills (1 no.), curry leaves (3 leaves), asafetida (pinch) and salt to taste were added and mixed well. The mixture was made into small balls and pressed gently to fit flat. Three hundred milliliter of blended vegetable oil was added to the frying pan and was brought to respective smoking temperature. The vadai was deep fried to a golden brown colour and was removed and strained for excess oil. Likewise for sauteing potato poriyal which is a common recipe prepared by combining potato with spices and condiments was selected. Hundred grams of potato was sliced and sautéed in 15 ml of blended vegetable oil seasoned with mustard seeds, onion, chili powder, and salt.

Chapatti, a north Indian flat bread was prepared with wheat flour dough, was chosen for the pan frying method. For preparing chapatti, wheat flour, was mixed well with measured quantity of

water and salt. The dough was kneaded and made into a soft and pliable consistency. Twenty-five grams of dough was made into a small ball and rolled out into round flatbread using a rolling pin. The pan was heated and the flattened chapatti dough was cooked on both sides by adding one teaspoon of oil.

a) Procedure for Oil Extraction from the Cooked Products

The necessary glassware used for oil extraction was initially rinsed with petroleum ether dried in an oven at 102°C and kept in desiccators. Five to 10gm of food sample was weighed and placed in the thimble. The thimble was then placed in a soxhlet extractor. In 150 ml of round bottom flask, 90 ml of petroleum ether was taken and the soxhlet extraction unit was set up. The petroleum ether was allowed to boil and the extraction process was continued for six hours (AOAC 948.22). The condensing unit was removed and allowed to cool. The extract was collected and weighed (Annexure XVIII). The percentage of fat absorption was calculated using the formula,

$$\text{Fat percentage} = \frac{(\text{Weight of the flask with extracted fat} - \text{Weight of empty flask}) \times 100}{\text{Sample weight}}$$

b) Fatty acid profile of Blended vegetable oils (GC-FID)

The fatty acid profile of the oil extracted from the cooked food sample was again analyzed using a gas chromatography- Flame Ionization Detector.

The findings of the study was statistically analyzed.

iv) Findings:

The salient findings are

Phase I: A Survey on Consumption of Fats and Oils and Market Availability of Blended Oils

A) Survey on Household Consumption of Fats and Oils

- The age of the selected female respondents was between 25-55 years.
- Fifty-three percent of the respondents were found to have completed their undergraduate level of education.
- The monthly income of 37% of households ranged between Rs.18, 953 to Rs. 31,590.

- Out of 196 households, 48% of households belonged to upper lower socio-economic status. None of the selected households belonged to the upper class.
- Consumption of groundnut oil was found to be maximum (108 ml/d), followed by sunflower oil (87 ml/d). However, palm oil consumption was seen in 50 households.
- The quantum of monthly purchase of oil was found to be high in upper-middle income and lower-middle income class. Also a higher quantum of consumption of palm oil among lower-income households was observed.
- Per day consumption of groundnut oil (80 ml/d) and gingelly oil (6 ml/d) was found to be low among the lower income group, at the same time consumption of palm oil (375 ml) was found to be high in the lower income group.

B) Market Survey on Availability of Blended Vegetable Oils

- The number of brands available for groundnut oil was more (8) followed by gingelly (5) and coconut oil (4).
- A total of eight brands of blended vegetable oils were available in the market, out of which seven brands were blended with only two oils, and only one brand was blended with three oils. Blending with more than three oils was not observed. Five out of eight brands used rice bran oil for blending, since it is the richest source of vitamin E.

Phase II: Formulation of Blended Vegetable Oils and their Quality Analysis

- The refractive index of blended vegetable oils ranged between 1.45 and 1.46. No significant difference between the six blended oils and stand-alone oils was observed.
- The density of blended vegetable oils ranged between 0.92 g/ml and 0.98 g/ml. The BOSFO-IV (0.92 ± 0.11 g/ml) with 50 ml of safflower oil had a lower density than other blended vegetable oils.
- On the whole the viscosity of all the formulated blended oil ranged between 48.67 ± 1.15 to 69.33 ± 9.81 . The viscosity of blended oil BOFO-V (52.00 ± 1.73) and BOEP-VI (53.00 ± 1.73) was reported to be similar indicating a uniform thermal behavior while heating.
- All the stand-alone oil and formulated blended vegetable oils were observed to be soluble in water, chloroform, petroleum ether and ethanol.

- The smoking temperature of blended vegetable oils ranged between 157⁰ C and 194.4⁰ C. The lowest smoking temperature was observed for BOFO-V (157⁰C) with 50 ml of flaxseed oil and 12.5 ml each of groundnut, gingelly, sunflower and safflower oil and the highest smoking temperature was observed for BOGN-I (194.4⁰ C) with 50 ml of groundnut oil and 12.5 ml each of gingelly, sunflower, safflower and flaxseed oil.
- All six blended oils were tasteless, and the BOFO-V with the 50 ml of flaxseed oil and 12.5 ml each of groundnut, gingelly, sunflower and safflower had a fish odor which intensified while heating. The texture of all blended vegetable oils was light and non greasy.
- The colour of the BOGN-I and BOSFO-IV was found to be dark yellow and BOSF-III and BOFO-V were found to be light yellow.
- On the whole the peroxide value of all the formulated blended oil was observed to be more or less similar with the values ranging between 0.003 ± 0.05Meq/kg to 0.06 ± 0.05 Meq/kg). A significance difference in the peroxide value between the blended vegetable oil and stand-alone oil was observed at 1% level of significance indicating a better oxidative stability.
- The iodine value of stand-alone oils ranged between 84 mg KOH/g and 150 mg KOH/g. The highest iodine value was observed for safflower oil (150.33 ± 0.58 mg KOH/g). A significant increase in iodine value was observed between the formulated blended vegetable oils and stand-alone oils at a one percent level of significance.
- The saponification value of blended vegetable oil ranged between (190.67 ± 0.58 mg/KOH to 261.67 ± 0.58 mg/KOH).
- The acid value of blended vegetable oil ranged between 1.36 ± 0.00 and 2.21 ± 2.02mg KOH/g. The lowest acid value was reported in BOFO-V (1.36 ± 0.00 mgKOH/g), followed by BOSFO-IV (1.92 ± 0.017 mgKOH/g).
- The free fatty acid level of blended vegetable oil ranged between 0.66±0.05 % to 1.11 ± 0.01% and stand-alone oil ranged between (0.33± 0.00% to 5.52 ± 0.00%).
- In general, the overall acceptability level of the formulated blended vegetable oils was on par with the acceptability levels of the stand-alone oils.

- Also, out of the six formulations, BOFO-V comparatively obtained the lowest acceptability score (37.50 ± 0.23), which can be attributed to a distinct fish odor during deep fat frying.
- No significant difference in the overall acceptability score was observed at 1% level of significance for pan frying for BOGN-I (37.62 ± 0.5) and BOGO-II (38.08 ± 0.075), with that of the stand-alone oil namely groundnut oil (37.34 ± 0.24), gingelly (37.32 ± 0.26), sunflower oil (37.44 ± 0.42).
- The alpha-tocopherol content of BOSF- III (36.80mg/g) was higher, followed by BOSFO-IV (32.93mg/g) and BOGN-I (23.53mg/g). The least alpha-tocopherol content was observed in BOFO- V (2.80mg/g).

Phase III: Fatty Acids Profile of Blended Vegetable Oil

- The level of saturated fats in formulated blended vegetable oils ranged between 14.3g to 40g. The highest amount of saturated fat was found in BOSFO-VI (40g) and the least in BOGO-II (14.35g) reported the highest percentage of PUFA, BOGN-II (59g) reported the lowest percentage of PUFA BOGN-I (31g).
- The presence of methyl linoleate a n-6 fatty acids was found to be high in BOSF-III (59.299%) and BOSFO-IV (55.812%). Also, the presence of methyl eicosenate a MUFA was found to be high in BOFO-V (22.450%) compared to stand-alone oil (groundnut oil- 0.702%, gingelly oil- 0.239%, sunflower oil- 0.150%, flaxseed oil - 0.703%).

Phase IV: Fatty Acids Profile of Cooked Products using Blended Vegetable Oils

- For deep fat frying (Vadai), although the percentage of oil absorption of BOGN-I (24.20g) was similar to that of groundnut oil (24.83g), the quantum of absorption of saturated fatty acids was less (4.57g) than the groundnut oil (6.50g). Similarly the quantum of absorption of polyunsaturated fatty acids was found to be greater (10.02g) than groundnut oil (7.44g).
- For deep fat frying compared to groundnut oil (29.649%), the presence of methyl linoleate was found to be high in all the blended vegetable oils. The percentage of peak areas of BOSF-III (49.714%) for methyl linoleate was found to be similar to that of sunflower oil (49.234%). BOGO-II (22.450%) reported a higher percentage of peak area for methyl eicosenate. Also the

blended vegetable oils BOSFO-IV (1.29g) and BOGN-II (1.46g) reported a lesser percentage of saturated fats.

- For pan frying (Chapatti), the oil absorption of blended vegetable oils ranged between 4.08g to 12.56g. The least oil absorption was noted in BOSF-III (4.08g), followed by BOSFO-IV (5.15g) and BOFO-V (5.77g). The highest absorption was noted in BOEP-VI (12.56g). BOSF-III reported the least PUFA (1.21g) content. The percentage of trans fat was found to be <0.1g in all blended and stand-alone oils.
- For pan frying (Chapatti), all the six blended oils in this study reported a lesser percentage of peak area for all the saturated fat. Though methyl oleate was found to be higher in BOSF-III (45.147%) followed BOEP-VI (39.733), it was found to be lesser compared to all stand-alone oils.
- For sautéing (potato poriyal), the oil absorption of blended vegetable oils ranged between 4.72g to 26.33g. The least oil absorption was noted in BOGN-I (4.72g), followed by BOGO-II (5.61g) and BOFO-V (8.76g). The highest absorption was noted in BOSFO-IV (26.33g). BOGN-I reported the least PUFA (1.94g) content. The percentage of trans fat was found to be <0.1g in all blended and stand-alone oils.
- For sautéing (potato poriyal), the presence of methyl linoleate was found to be higher in BOSFO-IV (55.812%) followed by BOSF-III (47.860%) compared to gingelly oil (37.983%) and groundnut oil (34.151%).
- The shelf life of formulated blended vegetable oil (BOGN-I) without antioxidant reported 49 days of shelf life.
- The shelf life of formulated blended vegetable oil with antioxidants also reported 35-50 days of shelf life in general blended oil BOFO-II reported maximum shelf life of 49 days.

Conclusion

The chemical properties of the blended vegetable oils reported better oxidative stability compared to stand-alone oils. The sensory attributes of all the blended vegetable oils were in par with the stand-alone oils and hence can serve as an alternate cooking medium. The BOSF-III and BOSFO-

IV were found to be superior in physical and chemical properties. Also, the above two blends reported the least oil absorption in cooked products and were found to be low in saturated fats, and high in MUFA and PUFA. Hence it can be recommended as healthier oils compared to stand-alone oils.

Limitations

- Due to COVID pandemic, only 196 households were surveyed.
- Financial constraints limited the ability to explore fatty acid contents of more commonly consumed recipes under different types of frying.
- Optimizing the blended oils to meet the desirable ratio of 1:1.3:1 of SFA: MUFA: PUFA was not possible due to constraint of time.
- Literature on fatty acid profile of cooked products was not available to the best of the knowledge of investigator.

Recommendations

- Oil absorption studies using blended vegetable oils for various commonly consumed snacks and savories can be taken up in the future.
- As a follow-up study optimization of the blended vegetable oil for desirable SFA, PUFA, and MUFA (1:1.3:1) ratio can be taken up in future.
- In vivo study to investigate the digestibility and absorption of blended oils providing valuable insights into their bioavailability and nutritional efficacy.

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