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Results and Discussion

The results and discussion pertaining to the study titled **"Formulation of Blended Vegetable Oils and Investigation of their Fatty Acid Profile in Cooked Products**"is discused under the following phases.

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

A)Survey on Household Consumption of Dietary Fat

B) Market Survey on Availability of Blended Vegetable oils

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

Phase III : Fatty acid Profile of Formulated Blended Vegetable oils

Phase IV: Fatty acid Profile of Cooked Products Using Blended Vegetable Oils

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

Since Fats and oils are major components of a well-balanced diet and play a vital role in the maintenance of the health and well-being of individuals irrespective of their age, sex, region, and cultural difference, a survey was conducted to understand the consumption pattern of dietary fat intake among 196 households from the city of Coimbatore.

The results and discussion of the baseline survey on household consumption of fats and oils are discussed under the following headings.

Background information

The background information of all the selected households, namely for age, sex, marital status, type of family, educational and occupational status, and income level was collected using an interview schedule. The background information of the selected household is given in (Table I) and discussed below.

Table I

Background Information on Household

(N=196)

Variable	Range	Frequency (N=196)	Percentage (%)
Age	25-55 years	196	100
Marital status	Married	181	94
	Unmarried	16	8
Type of family	Nuclear family	134	68
	Joint family	62	32
Educational	Illiterate	Nil	-
Qualification	Primary	24	12
	Secondary	31	16
	Higher Secondary	8	4
	Undergraduate	104	53
	Postgraduate	29	15

The age of the selected female respondents was between 25-55 years. Ninetyfour percent of them were married, 68% of the respondents lived in a nuclear family, and 53% of the respondents were found to have completed their undergraduate level.

Occupation Status

Table II presents the occupational status of the selected household and the observations are discussed below.

Table II

Occupation Status of the Selected Household

(N=196)

Occupation	Frequency (N=196)	Percentage (%)
Professional	26	13
Semi Professional	45	23
Clerical/shop/farmer	62	32
Skilled worker	13	7
Semi-skilled worker	43	22
Unemployed	7	3
Total	196	100

Kuppuswamy Scale, 2018

The person's occupation or profession significantly influences their buying behavior. Lifestyles choices, purchasing priorities and decision – making processes vary greatly depending on the nature of their work (Ramya *et al*., 2016). From Table II, it was evident that thirty-two percent of households had members doing clerical jobs. Twenty-two percent of the respondents in the household were semi skilled workers. Also, three percent of the respondents were unemployed and only 13% were found to be professionals.

Income status

The income status of the selected household is given in (Table III) and is discussed below.

Table III

Income Status of the Selected Household

(N=196)

Income Status of the selectedHousehold (₹)	**Frequency (N=196)**	**Percentage (%)**
≥ 126,360	Nil	Nil
63,182-126,359	18	9
47,266-63,181	12	6
31,591-47,265	30	15
18,953-31,590	73	37
6327-18,952	54	28
≤ 6326	9	5

Kuppuswamy Scale (2018)

The above Table III indicates, that 37 percent of households had a monthly family income ranging between Rs 18,953 and 31,590 followed by 28% of households with an income of Rs 6327-18,952. None of the selected households had a monthly income less than Rs 6326 and greater than Rs 1, 26,360.

Lower educated and lower- income individuals had a poor- quality diet with increased caloric consumption, including total fat and PUFA from vegetable oils. Both groups consumed lower amounts of MUFA and fiber. (McLellan *et al*., 2010).

Higher education and income levels are associated with higher protein and SFA intake due to increased eating of meat, which is a rich source of both nutrients.

Protein- rich foods (meat, poultry, milk and dairy products) are more expensive than carbohydrate and vegetable oil, and are more commonly consumed by individuals with higher income (McLellan*et al*., 2010).

Socio-economic Status of the Selected Households

Based on the information collected on education, occupation, and income level using the Kuppuswamy scale (2018) the socioeconomic status of the selected household was studied and the results are shown in (Table IV) and discussed below.

Table IV

Socioeconomic Status of the Selected Households

(N=196)

Socioeconomic Status	Score	Frequency (N=196)	Percentage (%)
Upper (I)	26-29	Nil	Nil
Upper Middle (II)	16-25	45	23
Upper Lower (IV)	5-10	95	48
Lower Middle (III)	11-15	53	27
Lower (V)	<5	3	2

(Kuppuswamy Scale, 2022)

From the above Table (IV)it was observed that out of 196 households, 48 percent of thehousehold's belonged to upper lower socioeconomic category followed by the lower middle-class(27%). Only 23 percent of the household belonged to the upper-middle-class category. None of the respondents belonged to the upper-class category.

Types of Fats and Oils Consumed

Using an interview schedule the consumption of different types of fats and oils among the selected subject was elicited. The observation of the same is depicted in (Figure 3) and discussed below.

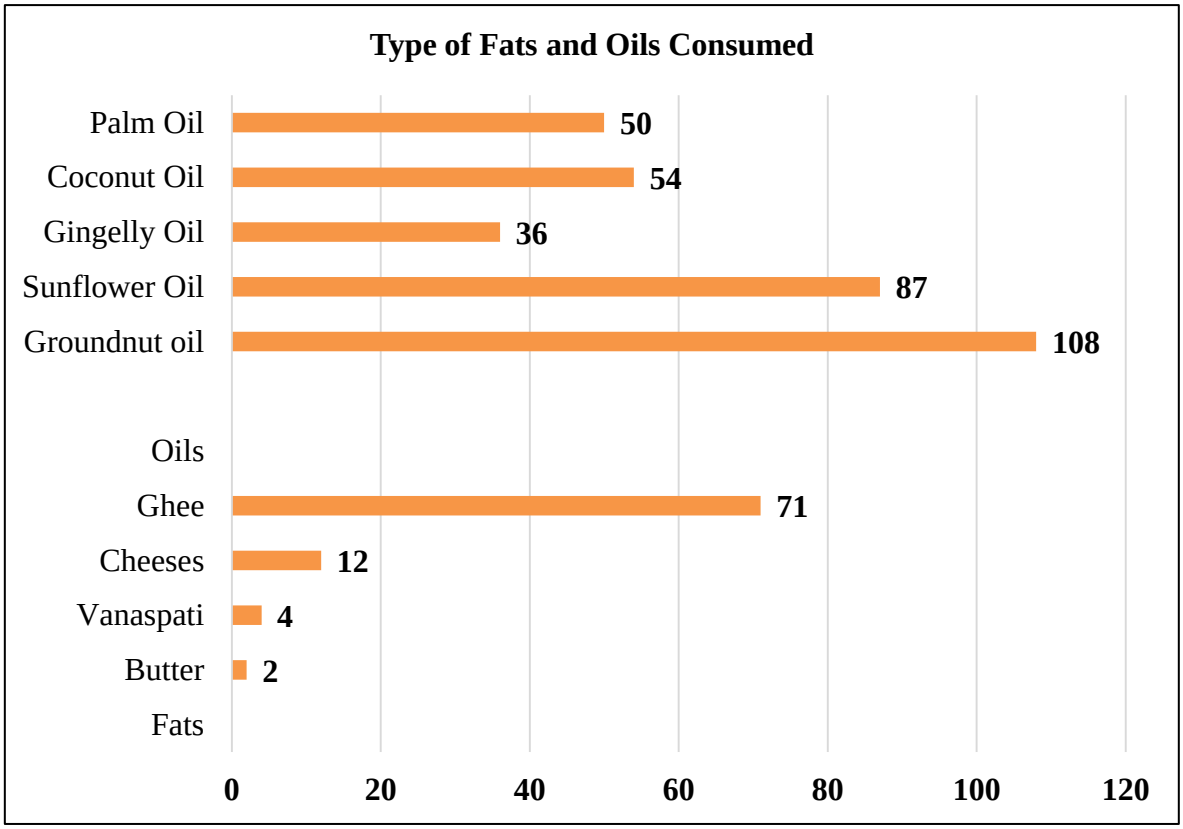


Figure 3: Types of Fats and Oils Consumed

Out of 196 households, consumption of groundnut oil was found to be the maximum (108), followed by sunflower oil (87). Also, consumption of palm oil was seen in 50 households. Consumption of ghee – a saturated fat was observed among 71 households. Also, we observed the intake of cheese, vanaspati, and butter to be very low.

Frequency of Consumption of Fats and Oils

The frequency of consumption of different types of fats and oils is given in Table V and discussed below.

Table V

Frequency of Consumption of Fats and Oils

Types of Oils	Daily	Weekly	Fortnightly	Monthly	Occasionally
Groundnut Oil	✔		✔		
Gingelly Oil		✔		✔	✔
Sunflower Oil	✔		✔		
Safflower Oil			✔		
Palm Oil		✔	✔		
Coconut Oil		✔	✔	✔	
Types of Fat	**Daily**	**Weekly**	**Fortnightly**	**Monthly**	**Occasionally**
Ghee		✔			✔
Cheese			✔	✔	
Vanaspati					✔
Butter			✔	✔	

From the Table it is evident that groundnut and sunflower oil were consumed daily. Research evidence shows the usage of groundnut and sunflower oil as the stable source of regional cusines of South India. However, consumption of gingelly, palm, and coconut oil wasseen only once a week or once in fortnightly. Though ghee was consumed by a larger number of households as given in figure-5, it was consumed only once a week or during festival times.

Monthly Consumption of Oils

The monthly consumption of oils like groundnut, gingelly, sunflower, palm, and coconut oil is projected in Table VI and discussed below.

Table VI

Monthly Consumption of Oils

Types of Oils Liter/month	**Upper Middle***	**Upper Lower***	**Lower Middle***	**Lower***
Groundnut oil	3.510	2.764	3.260	2.400
Gingelly oil	1.650	1.350	1.209	0.185
Sunflower Oil	2.940	2.298	2.649	3.600
Palm oil	Nil	0.800	1.000	1.500
Coconut oil	0.690	0.425	0.210	0.150

***Kuppuswamy Scale, 2022**

The quantum ofmonthly purchase of oil was found to be high in the households of upper-middle-income and lower-middle-income class.

The investigator also observed a higher quantum of consumption of palm oil among lower-income households which was used for deep frying once a week or fortnightly.

Quantum of Consumption of Oils

The average household consumption of oil is tabulated in (Table VII) and discussed below.

Table VII

Quantum of Consumption of Oils

Types of Oils ml/day	Consumption per household*				Consumption per person*			
	Upper Middle*	Upper Lower*	Lower Middle*	Lower*	Upper Middle*	Upper Lower*	Lower Middle*	Lower*
Groundnut oil	117	92	107	80	30	23	28	20
Gingelly oil	55	45	40	6	14	11	10	1.5
Sunflower Oil	98	77	88	120	25	19	22	30
Palm oil	Nil	200	250	375	Nil	50	63	63
Coconut oil	23	14	7	5	6	4	2	1

***Kuppuswamy Scale, 2022**

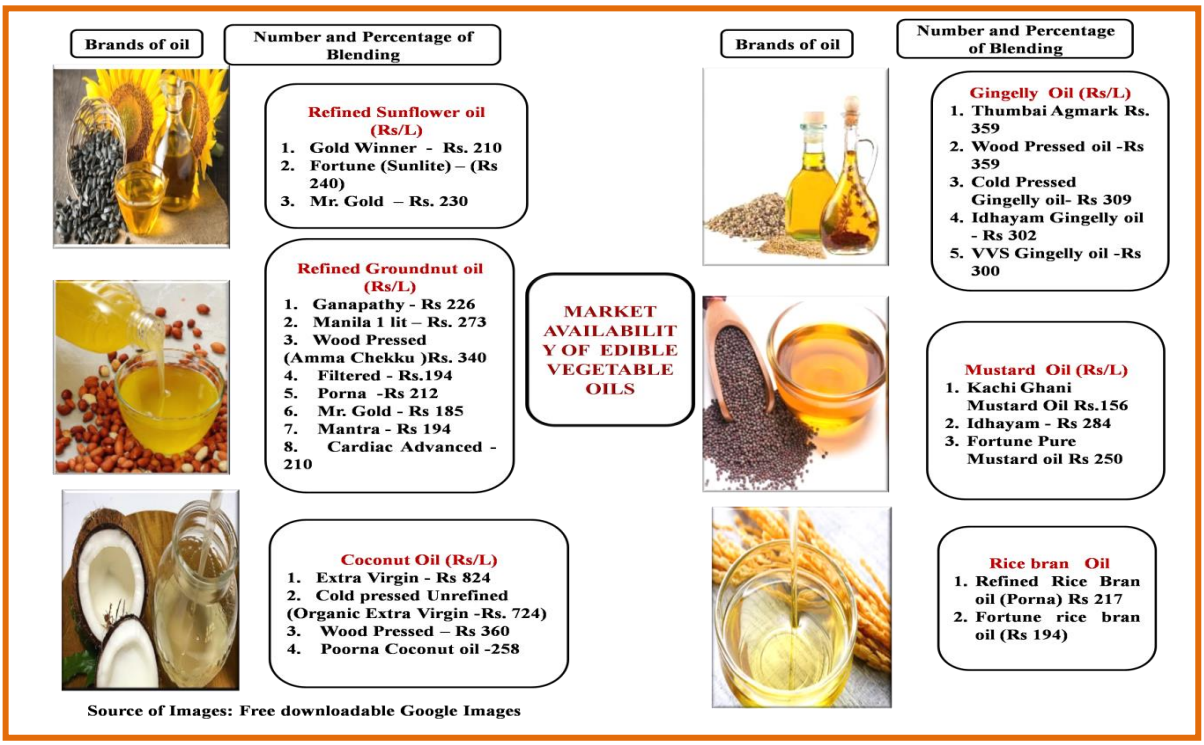
Per day consumption of groundnut (80 ml/day) and gingelly oil (6ml/day) was found to be low among the lower income group, at the same time consumption of palm oil was found to be high (375ml/day) in lower income group.The quantum of consumption of coconut oil was found to be lower irrespective of the income category.

The results are consistent with the study conducted by Dorni *et al*., (2018), which stated that In the North Indian region, including Delhi, Punjab, Jammu and Kashmir, Himachal Pradesh and Uttar Pradesh about 61.1% of the population predominantly consumed mustard oil, followed by sunflower oil (12%), rice bran oil (9%), olive oil (7%) and other oils (11%). In the southern states- Telangana, Andra

Pradesh, Tamil Nadu, Karnataka, Kerlala and Goa- Sunflower oil was the most commonly used (44%), followed by groundnut oil (29%), rice bran oil (7%), palm oil (9%) and others (14%). In the western zone, covering Gujarat, Maharashtra, Rajasthan and Madhya Pradesh, soybean oil was the primary choice (28%), followed closely by mustard and sunflower oils (25%). Similarly, in the eastern zone, mustard oil was the most consumed (29%), followed by sunflower oil (19%). Most respondents reported using variety of major edible oils, with minimal use of palm oil and no consumption of cottonseed oil. Oil consumption ranged widely, from less than 6kg per person year to over 20kg per person year.

b) Market Availability of Edible Vegetable Oils

The investigator developed a checklist to collect information on the availability of the different types of oil, brands of oil, their price, quantity, manufacturing details, food, and nutritional labeling if any. The market availability of edible vegetable oils is depicted in (Figure 4) and is discussed below.



Price of the oil as claimed in the packing

Figure 4: Market Availability of Edible Vegetable Oil

The number of brands available for groundnut oil (8) was more followed by gingelly (5) and coconut oil (4). In general, except for cold-pressed groundnut oil the price of groundnut oil was found to be lower (Rs.185-273) than that of other oils. The price of the gingelly oil ranged between Rs. 300-359 per liter. Likewise, the cost of the coconut oil ranged betweenRs 258 and Rs360 in the case of refined oil and Rs.724 to 824 in the case of cold pressed oil.

The demand for edible oils in Tamil Nadu is projected to grow at an annual rate of 7.0% with sunflower oil (6.6%), peanut oil (6.6%) and palm oil (3.1%). Between 2009-10 and 2020, the total edible oil demand in rural Tamil Nadu increased from 3.14 lakh tons to 5.3 lakhs tones, while in urban areas, it rise from 3.24 lakh tones to 5.45 lakh tones. Non- traditional oils such as sunflower oil, soybean oil, corn oil, rice bran oil and palm oil have gained significant fraction in the consumption patterns and are expected to dominate the market in the future (Govindaraj *et al*., 2012).

Market Availability of Blended Vegetable Oil

The investigator also surveyed on market availability of blended vegetable oils, types, and number of oils used for blending. The observation is illustrated in (Figure 5) and discussed below.

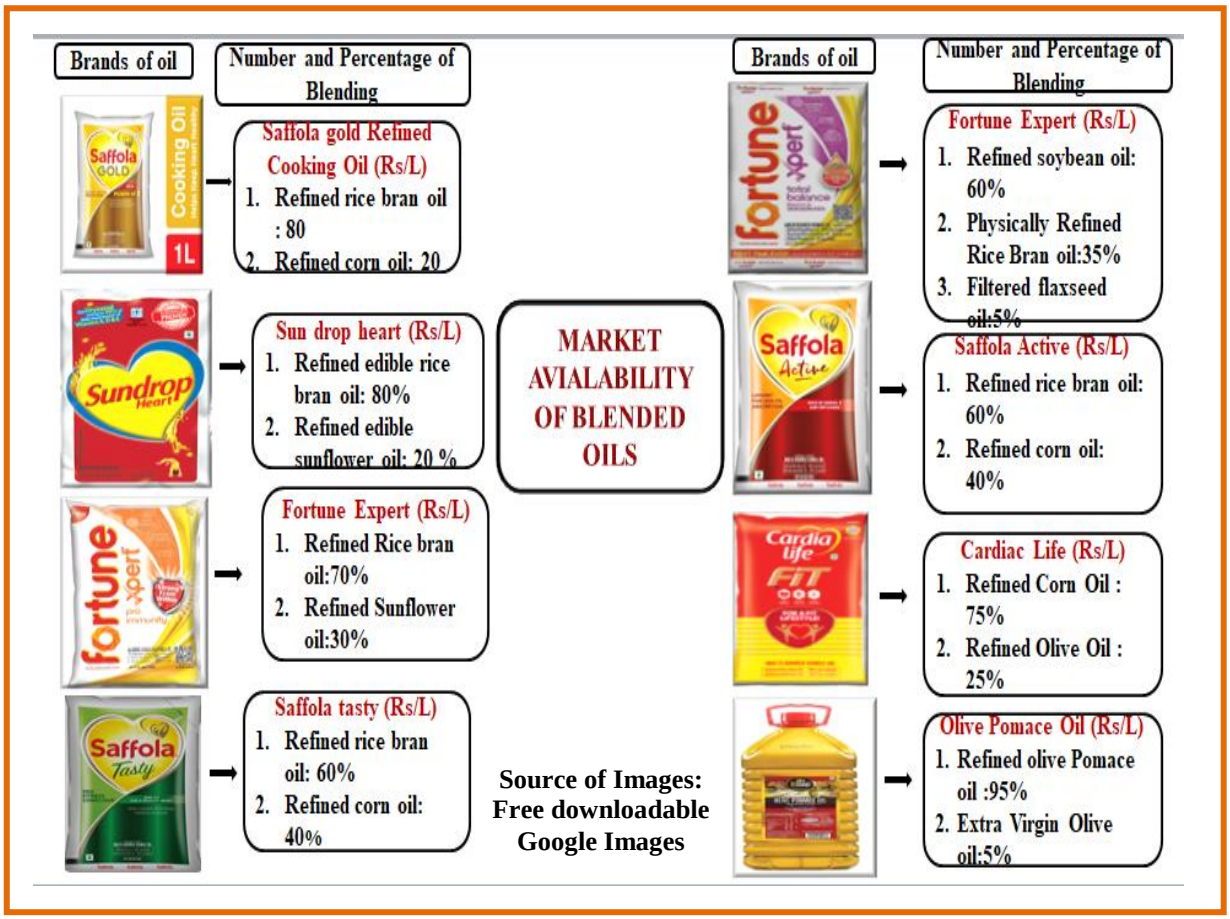


Figure 5: Market Availability of Blended Vegetable Oil

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.

A variety of blended oils are available for healthier cooking, each offering unique benefits. Saffola Active combines 80% refined rice bran oil and 20% soybean oil, enriched with vitamin-A and D, antioxidants and dual-seed technology, promoting weight management and overall health. Oleev Active blends 80% rice bran oil with

20% olive pomace oil, ensuring enriched flavor, long-lasting freshness and a healthy balance of fats. Sundrop Vitamin Rich features 80% rice bran oil and 20% sunflower oil, ideal for cooking, frying and grilling, with no cholesterol or trans fat. Fortune Xpet Pro Immunity blends 70% rice bran oil with 30% sunflower oil, enhancing flavor and providing essential nutrients. Saffola Gold, with 80% rice bran oil and 20% sunflower oil delivers versatility and quality for nutritious meals. Finally, Fortune Xpert Pro Sugar Conscious combines 80% rice bran oil with 20% sesame oil, specially formulated for a cholesterol- conscious lifestyle with added antioxidants and a healthy fat profile (Times of India, 2024). .

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

To the best of the knowledge of the investigator, the blending of oil was done only with two oils, and triple oil blending was found to be limited. Since Indian cuisine uses a variety of vegetable oils by different populations in different states, an attempt to blend six vegetable oils with high Polyunsaturated Fatty Acid (PUFA) content and functional properties was made by the investigator. Thus vegetable oils namely groundnut, gingelly, sunflower, safflower, and flaxseed oils were formulated into six variations as projected in (Plate-7). Quality of the formulated blended vegetable oil for physical, chemical and sensory attributes were tested and their results are presented in the following tables and discussed below.

Physical Properties of Blended Vegetable Oils

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

Colour

The colour of oils was determined by using Gowegroup Multitesters digital food colour card reader and the findings are given in the Table-VIII and discussed underneath.

Table VIII

Colour of the Formulated Blended Vegetable Oils andStand-Alone Oils

Types of Oil	ΔE (groove/mm)	Colour
Blended vegetable oils		
BOGN-I	19.39	Dark Yellow
BOGO-II	16.25	Brownish Yellow
BOSF-III	20.6	Light Yellow
BOSFO-IV	20.40	Dark Yellow
BOFO-V	20.32	Light yellow
BOEP-VI	12.45	Golden Yellow
Stand-alone oils		
Flaxseed oil	17.40	Yellowish
Groundnut oil	10.61	Reddish Yellow
Safflower oil	11.12	Pale yellow
Gingelly oil	10.51	Yellowish red
Sunflower oil	15.80	Clear white

Note: BOGN-I – Groundnut oil-50 ml + gingelly oil-12.5 ml + sunflower oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOGO-II- Gingelly oil-50 ml + groundnut oil-12.5 ml + sunflower oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOSF-III-Sunflower oil-50 ml + groundnut oil-12.5 ml + gingelly oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOSFO-IV – Safflower oil-50 ml + groundnut oil-12.5 ml +gingelly oil-12.5 ml+ sunflower oil-12.5 ml + flaxseed oil-12.5 ml, BOFO-V-Flaxseed oil-50 ml + groundnut oil-12.5 ml + gingelly oil-12.5ml+ sunflower oil-12.5 ml + safflower oil-12.5 ml, BOEP-VI- Groundnut oil-20 ml + gingelly oil-20 ml + sunflower oil-20 ml + safflower oil-20 ml and flaxseed oil-20 ml.

ΔL^+- White , ΔL^- Black , Δ a+ Red , a- Green, b− Blue , L* Black/White, a* Red/Green, b* Yellow/Blue

The colour of the blended vegetable oils BOGN-I and BOSFO-IV was found to be dark yellow and blended vegetable oil BOSF-III and BOFO-V were found to be light yellow. The presence of coloring materials such as chlorophyll and carotene determines the color of the oils. Sunflower oil, for instance, typically displayed a pale yellow hue, indicating the presence of these colour pigments. Rich colour pigments in sunflower oil helps to maintain its colour stability (Mohammed *et al*., 2023).

Simon *et al*., (2017) observed different colour variations in blended oils depending on the combinations. When soybean oil was blended with sunflower oil, it exhibited a pale yellow hue. Blending soybean oil with rice bran oil resulted in a yellow colour, while mixing soybean oil with palm oil produces a golden yellow shade. Similarly, blending sunflower oil with rice bran oil yielded a light yellow colour and combining sunflower oil with palm oil resulted in a golden yellow hue. Lastly, the combination of palm oil and rice bran oil showed a yellow colour. These variations represent the diverse colour outcomes achievable through blending oils.

According to Serjouie *et al*., (2010) and Wang *et al*., (2016) the key characteristics that influence customer's desirability is colour. Purified oils have different colours, some of which may have unflavorable consequences on their acceptance due to their strength or weakness. They can have their colour moderated by blending the right oils. Additionally, the buildup of oxidation chemicals can result in oils becoming darker and their colours becoming more intense. Research showed that mixing oils with improved stability slowed the deep- frying procdure tendency to discolour.

Refractive Index

The oxidative stability of oil was measured using refractive index.The refractive index of the formulated blended vegetable oils and the stand-alone oils was analyzed using Abbs Refractometer following standard procedure (AOAC 17th Ed, 2000). The table (IX) projects the refractive index of the blended and stand-alone oils.

Table IX

Refractive Index of Formulated Blended Vegetable Oils and Stand-Alone oils

Blended vegetable oils		Stand-alone oils		t value	P value
Name of the oil	Mean± SD	Name of the oil	Mean ±SD		
BOGN-I	1.45 ± 0.004	Groundnut oil	1.46 ± 0.00	1.9917	0.1172^{NS}
BOGO-II	1.45 ± 0.004	Gingelly oil	1.46 ± 0.00	1.7500	0.1550^{NS}
BOSF-III	1.45 ± 0.004	Sunflower oil	1.46 ± 0.00	2.7500	0.0514^{NS}
BOSFO-IV	1.45 ±0.0058	Safflower oil	1.46 ± 0.00	1.7500	0.1550^{NS}
BOFO-V	1.46 ±0.0115	Flaxseed oil	1.47± 0.00	2.0000	0.1161^{NS}
BOEP-VI	1.45± 0.005	Groundnut oil	1.46 ± 0.00	1.0000	0.3739^{NS}

Name of the oil	Literature Review	Reference
Groundnut oil	1.460-1.465	Standard AOAC 921.08
Gingelly oil	1.465-1.469	
Sunflower oil	1.461-1.470	
Safflower oil	1.469	Katkade*et al*., 2018
Flaxseed oil	1.47	Adam Omer Isha*get al*., 2020
Blended oils		
Groundnut oil: 95Palm oil: 5	1.47	Padurangan *et al*., 2014
Groundnut oil: 90 Palm oil: 10	1.47	
Groundnut oil:85 Palm oil: 15	1.47	
Groundnut oil:95 Rice bran oil: 5	1.46	
Groundnut oil: 90 Rice bran oil: 10	1.47	
Groundnut oil:85 Rice bran oil:15	1.47	

^{NS}- Non-significant

Note: BOGN-I – Groundnut oil-50 ml + gingelly oil-12.5 ml + sunflower oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOGO-II- Gingelly oil-50 ml + groundnut oil-12.5 ml + sunflower oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOSF-III- Sunflower oil-50 ml + groundnut oil-12.5 ml + gingelly oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOSFO-IV – Safflower oil-50 ml + groundnut oil-12.5 ml + gingelly oil-12.5 ml+ sunflower oil-12.5 ml + flaxseed oil-12.5 ml, BOFO-V- Flaxseed oil-50 ml + groundnut oil-12.5 ml + gingelly oil-12.5ml + sunflower oil-12.5 ml + safflower oil-12.5 ml, BOEP-VI- Groundnut oil-20 ml + gingelly oil-20 ml + sunflower oil-20 ml + safflower oil-20 ml and flaxseed oil-20 ml.

Refractive index measures are very helpful in determining oil contamination / adulteration, but they rarely yield enough information to identify a pure sample quantitatively (Bhavsar *et al*., 2017).The refractive index is mostly used to quantify a change in unsaturation that occurs when hydrogenation occurs in fat or oil.

On the whole, the refractive index of all the formulated blended vegetable oils was observed to be more or less similar with the values ranging between 1.45 ± 0.004 to 1.46 ±0.0115. Also, the analyzed refractive index of the stand-alone oils was found to be in the range of 1.46 ± 0.000 to 1.47 ±0.00. The t-test analysis indicated no significant difference between the six blended vegetable oils with that of five stand-alone oilsnamely groundnut, gingelly, sunflower, safflower, and flaxseed oil. Thus, from the above result, it can be inferred that the molecular weight, fatty acid, and chain length of fatty acid of the formulated blended vegetable oils are on par with that of the stand-alone oils. There is no significant difference in the refractive index of the formulated blended vegetable oils with that of stand- alone oils. Hence the null hypothesis (H_{01}) was accepted.

According to Godswill *et al*. (2018), the chemistry of oil shows potential changes in the development of rancidity. Increased refractive index increases the likelihood of oxidative spoiling. The observed refractive index of all the blended vegetable oil (1.45-1.46) is similar to that of the literature reference of blended vegetable oils (1.46-1.47) tested by Pandurangan*et al*.,2014.

However, according to Suzanne et al., (2010) the refractive index values of USA vegetable oil (1.475), soybean oil (1.474), sunflower oil (1.475), and sunlit oil (1.473) to be somewhat higher than FAO/WHO recommended range (1.466-1.470).

Density

Density is a crucial factor that impacts absorption of oil and the drainage rate after frying and also 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 the 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 formulated blended vegetable oils with stands-aloneoils is given in Table-X and discussed below.

Table X

Density of the Formulated Blended Vegetable Oils and Stand-Alone Oils

Blended vegetable oils*		Stand-alone oils*		t value	P value
Name of the oil	**Mean ±SD**	**Name of the oil**	**Mean± SD**		
BOGN-I	0.94 ± 0.02	Groundnut oil	0.91 ± 0.00	2.0000	0.1161^{NS}
BOGO-II	0.95± 0.05	Gingelly oil	0.92 ± 0.00	2.7735	0.0502^{NS}
BOSF-III	0.98± 0.11	Sunflower oil	0.98 ±0.00	2.0000	0.1161^{NS}
BOSFO-IV	0.92 ± 0.11	Safflower oil	0.94 ± 0.00	0.5000	0.6433^{NS}
BOFO-V	0.94 ± 0.017	Flaxseed oil	0.92 ± 0.00	2.0000	0.1161^{NS}
BOEP-VI	0.94 ± 0.01	Groundnut oil	0.91 ± 0.00	2.0000	0.1161^{NS}

Name of the oil (ml)	Literature Review	Reference
Groundnut oil	0.73	Pandurangan *et al*, 2014
Gingelly oil	0.99	Olaleye *et al.*, 2019
Sunflower oil	0.98	Neagu *et al.*, 2013
Safflower oil	0.94	Katkade*et al.*, 2018
Flaxseed oil	0.93	Zhang *et al.*, 2011
Blended oils **(ml)**		
Palolein : sunflower oil		Siddiqu*eet al.*, 2010
10:90	0.906	
20:80	0.921	
30:70	0.910	
40:60	0.914	
50:50	0.905	
60:40	0.914	
70:30	0.911	
80:20	0.902	
90:10	0.933	

^{NS}-Non significant, *- unit for blended and stand- alone oil- $kg/_{m}^{3}$

Note: BOGN-I – Groundnut oil-50 ml + gingelly oil-12.5 ml + sunflower oil-12.5 ml + safflower oil-12.5 ml +flaxseed oil-12.5 ml, BOGO-II- Gingelly oil-50 ml + groundnut oil-12.5 ml + sunflower oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOSF-III-Sunflower oil-50 ml + groundnut oil-12.5 ml + gingelly oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOSFO-IV – Safflower oil-50 ml + groundnut oil-12.5 ml + gingelly oil-12.5 ml + sunflower oil-12.5 ml + flaxseed oil-12.5 ml, BOFO-V-Flaxseed oil-50 ml + groundnut oil-12.5 ml + gingelly oil-12.5ml + sunflower oil-12.5 ml + safflower oil-12.5 ml, BOEP-VI- Groundnut oil-20 ml + gingelly oil-20 ml + sunflower oil-20 ml + safflower oil-20 ml and flaxseed oil-20 ml.

Edible oil has a lower density than water, which has a density of 1.00 $kg/_{m}^{3}$.On the whole, the density of all the formulated blended vegetable oils was observed to be

more or less similar with the values ranging between 0.92 ± 0.11 to 0.98± 0.11. Also, the analyzed density of the stand-alone oils was found to be in the range of 0.91 ± 0.00 to 0.98± 0.00. The analysis of the test indicated no significant difference between the six blended vegetable oils with that of five stand-alone oils namely groundnut, gingelly, sunflower, safflower, and flaxseed oil. As rightly pointed out by Fakhri *et al*., (2023) the density of vegetable oils is dependent on their fatty acid composition, minor components, and temperature. The above observation is in par with a study conducted by siddique *et al*., (2010) who reported that the blend of palmolein: sunflower oil (90:10) has a density of 0.93kg/$_m^3$ when compared to allother blended oils. Hence the null hypothesis (H_{02}) "there is no significant mean difference in the density of the blended vegetable oils and stand-alone oil" was accepted.

Viscosity

The thermal behavior of the cooking oil can be well predicted based on its viscosity. The viscosity of the oil was measured using a viscometer and the observations are presented in Table XI and discussed below.

Table XI

Viscosity of the Formulated Blended Vegetable Oils and Stand-Alone Oils

Blended vegetable oils		Stand-alone oils		t value	P value
Name of the oil	Mean± SD (cPS)	Name of the oil	Mean± SD (cPS)		
BOGN-I	67±9.81	Groundnut oil	79±0.00	14.500	0.0001**
BOGO-II	69.33 ±1.15	Gingelly oil	55.00 ± 0.00	9.500	0.0007**
BOSF-III	48.67 ± 1.15	Sunflower oil	60.00 ± 0.00	25.000	0.0001**
BOSFO-IV	52.00 ± 5.20	Safflower oil	46.00 ± 0.00	26.000	0.0001**
BOFO-V	53.00 ± 1.73	Flaxseed oil	70.00 ± 0.00	49.000	0.0001**
BOEP-VI	53.00 ± 1.73	Groundnut oil	79±0.00	94.000	0.0001**

****1 percent level of significance**

Note: BOGN-I – Groundnut oil-50 ml + gingelly oil-12.5 ml + sunflower oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOGO-II- Gingelly oil-50 ml + groundnut oil-12.5 ml + sunflower oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOSF-III-Sunflower oil-50 ml + groundnut oil-12.5 ml + gingelly oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOSFO-IV – Safflower oil-50 ml + groundnut oil-12.5 ml + gingelly oil-12.5 ml + sunflower oil-12.5 ml + flaxseed oil-12.5 ml, BOFO-V-Flaxseed oil-50 ml + groundnut oil-12.5 ml + gingelly oil-12.5ml + sunflower oil-12.5 ml + safflower oil-12.5

ml, BOEP-VI- Groundnut oil-20 ml + gingelly oil-20 ml + sunflower oil-20 ml + safflower oil-20 ml and flaxseed oil-20 ml.

The thermal behavior of the cooking oil can be well predicted based on the viscosity of the blended vegetable oils. On the whole, all the formulated blended vegetable oils were observed to be more or less similar with the values ranging between 48.67 ± 1.15 to 69.33 ± 9.81cPS. Also, the analyzed viscosity of the stand-alone oils was found to be in the range of 46.00 ± 0.00 to 79± 0.00cPS. Blended oil (BOSF-III) reported the least viscosity (48.67cPS) followed by blended oil BOSFO-IV (52.00±5.20cPS). The viscosity of blended oil BOFO-V (53.00 ± 173cPS) and BOEP-VI (53.00± 1.73 cPS) was similar indicating a uniform thermal behavior while heating. Though there was a significant difference in the value between formulated blended oil with that of stand-alone oil (1% level of significance), the viscosity value of blended oil-II (69.33±1.15 cPS) and IV (52.00± 5.20cPS) was significanty greater than gingelly (55.00 ± 0.00) and sunflower oil (46.00 ± 0.00).Thus the null hypothesis (H_{03}) there is no significant difference in the viscosity of blended vegetable oil was rejected.

According to Nangbes *et al*., (2013) oils that have low viscosity values are likely to be light and highly unsaturated; the high value could be the consequence of suspended particles remaining in the sample of crude oil.

Also as per the words of Wali *et al*. (2015) triglycerides (TGs) are crucial component in edible oils. Viscosity is determined by the fatty acid composition and order on the glycerol backbone of a triglyceride. Oil viscosity is directly related to the degree of unsaturation and chain length of fatty acids in lipids and the value increases with increasing saturation level.

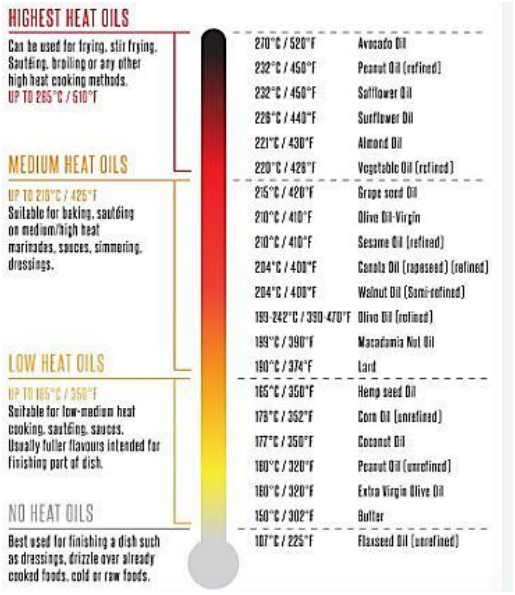
Smoking Temperature

The smoking temperature of the formulated blended vegetable oils was measured adhering to standard procedure and was compared with the smoke chart. The findings are given in Table XII and discussed below.

Table XII

Smoking Temperature of the Formulated Blended Vegetable Oils andStand-Alone Oils

Blended vegetable oils	Smoking Point
BOGN-I	194.4ºC (381.92ºF)
BOGO-II	181ºC (357.8ºF)
BOSF-III	157.5ºC (315.5ºF)
BOSFO-IV	185.9ºC (365ºF)
BOFO-V	157ºC (314.6ºF)
BOEP-VI	172ºC (341.6ºF)



Source: https://en.wikipedia.org/wiki/smoke_point

Note: BOGN-I – Groundnut oil-50 ml + gingelly oil-12.5 ml + sunflower oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOGO-II- Gingelly oil-50 ml + groundnut oil-12.5 ml + sunflower oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOSF- III-Sunflower oil-50 ml + groundnut oil-12.5 ml+ gingelly oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOSFO-IV – Safflower oil-50 ml + groundnut oil-12.5 ml + gingelly oil-12.5 ml + sunflower oil-12.5 ml + flaxseed oil-12.5 ml, BOFO-V-Flaxseed oil-50 ml + groundnut oil-12.5 ml + gingelly oil-12.5ml + sunflower oil-12.5 ml + safflower oil-12.5 ml, BOEP-VI- Groundnut oil-20 ml + gingelly oil-20 ml + sunflower oil-20 ml + safflower oil-20 ml and flaxseed oil-20 ml.

The temperature at which an oil starts to constantly smoke and appears as bluish smoke is known as the smoke point (AOAC- 2012). This smoke is a sign that fat is being chemically broken down to produce glycerol and FFAs. One of the primary ingredients of the bluish smoke, acrolein (2-propenal), is then produced by further breaking down the glycerol.

The smoking temperature of blended vegetable oils ranged between 157ºC and 194.4ºC. The lowest smoking temperature was observed for blended vegetable oil with 50 ml of flaxseed oil, and the highest smoking temperature was observed for

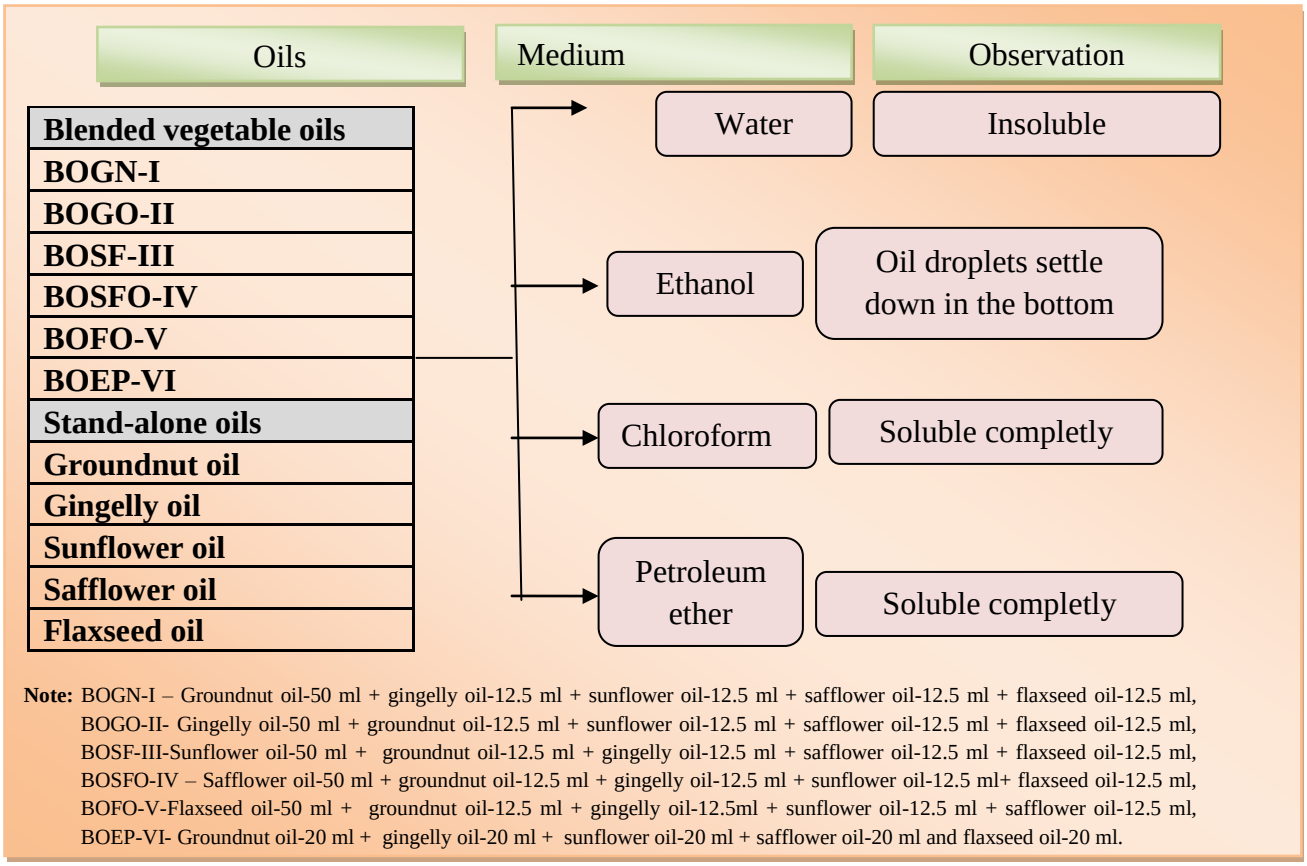
blended vegetable oil BOGN-I (194.4ºC) with 50 ml of groundnut oil. The difference in the smoking temperature can be attributed to the free fatty acid content of blended vegetable oils. Compared with the oil smoke chart, all six blended vegetable oils fell within the low-heat to medium-heat oil range and can be effectively used for sautéing, baking, and stir-frying.

The smoke point is largely influenced by the content of Free Fatty Acids (FFA) and, to a lesser extent, by partial glycerides. While the degree of unsaturation has minimal impact, the chain length of the fatty acids plays a crucial role. Oils with shorter chain fatty acids, such as lauric acid, generally have a lower smoke point compared to those with predominantly longer chain fatty acids (Katragadda *et al*., 2010).

Katragadda *et al*., (2010) claims assessing the oxidative stability of fats, particularly unsaturated fats, as the most crucial factor to take into account since the oxidation mechanism varies depending on the temperature and the presence of different linoleatehydroperoxides, which function as precursors of volatile flavors, decompose at different temperatures. Moreover, a dietary lipid's shelf life reduces logarithmically with rising temperature since the rate of oxidation is exponentially correlated with temperature.

Solubility of the formulated Blended Vegetable Oils and Stand-Alone Oils

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. Thus the solubility of the formulated blended vegetable oil was tested in water, ethanol, chloroform, and petroleum ether and the findings are given in (Figure 6) and discussed below.



Note: BOGN-I – Groundnut oil-50 ml + gingelly oil-12.5 ml + sunflower oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOGO-II- Gingelly oil-50 ml + groundnut oil-12.5 ml + sunflower oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOSF-III-Sunflower oil-50 ml + groundnut oil-12.5 ml + gingelly oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOSFO-IV – Safflower oil-50 ml + groundnut oil-12.5 ml + gingelly oil-12.5 ml + sunflower oil-12.5 ml+ flaxseed oil-12.5 ml, BOFO-V-Flaxseed oil-50 ml + groundnut oil-12.5 ml + gingelly oil-12.5ml + sunflower oil-12.5 ml + safflower oil-12.5 ml, BOEP-VI- Groundnut oil-20 ml + gingelly oil-20 ml + sunflower oil-20 ml + safflower oil-20 ml and flaxseed oil-20 ml.

Figure 6: Solubility of Formulated Blended Vegetable Oils

The solubility of the formulated blended vegetable oil was evaluated in several solvents to determine how each oil interacts with water, ethanol, chloroform, and petroleum ether. All of the listed stand-alone oilsand formulated blended vegetable oils are insoluble in water, which means they do not dissolve when mixed with water. In ethanol, the oils produce droplets that settled to the bottom, showing limited solubility but with some interaction. However, all the stand-alone oils and formulated blended vegetable oils were completely soluble in chloroform and petroleum ether.

The oils' total solubility in chloroform and petroleum ether reflects their nonpolar solvents property.

Sensory Examination

As part of sensory examination, the blended vegetable oils were subjected to physical examination (observation) and acceptability analysis. The acceptability of the blended vegetable oil was tested for three common cooking methods namely deep fat frying (vadai), pan frying (chapatti) and sauteing (potato poriyal) by a panel of 20 semi trained member using a nine point hedonic scale. The observation of the sensory examination are presented underneath.

Physical examination

The physical examinations of the formulated blended vegetable oils is given in Table XIII and discussed below.

Table XIII

Sensory Examination of the Formulated Blended Vegetable Oils

Blended vegetable oils	Sensory Examination of the Formulated Blended Vegetable Oils				
	Appearance	Colour	Texture	Flavour	Taste
BOGN-I	Clear	Dark Yellow	Non Greasy	Nutty aroma	Neutral taste
BOGO-II	Clear	Brownish Yellow	Slightly greasy	The nutty and smoky flavor	The nutty and smoky taste
BOSF-III	Clear	Light Yellow	Non Greasy	Light and slightly nutty odor	Neutral taste
BOSFO-IV	Clear	Dark yellow	Light and nongreasy	Odorless	Neutral taste
BOFO-V	Clear	Brownish-yellow	Non Greasy	Nutty aroma	Fish flavor
BOEP-VI	Clear	Golden Yellow	Light and smooth	Fresh	Plain taste

Note: BOGN-I – Groundnut oil-50 ml + gingelly oil-12.5 ml + sunflower oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOGO-II- Gingelly oil-50 ml + groundnut oil-12.5 ml + sunflower oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOSF-III-Sunflower oil-50 ml + groundnut oil-12.5 ml + gingelly oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOSFO-IV – Safflower oil-50 ml + groundnut oil-12.5 ml + gingelly oil-12.5 ml + sunflower oil-12.5 ml + flaxseed oil-12.5 ml, BOFO-V-Flaxseed oil-50 ml + groundnut oil-12.5 ml + gingelly oil-12.5ml + sunflower oil-12.5 ml + safflower oil-12.5 ml, BOEP-VI- Groundnut oil-20 ml + gingelly oil-20 ml + sunflower oil-20 ml + safflower oil-20 ml and flaxseed oil-20 ml.

The above Table (XIII) projects the visual examination of blended vegetable oils.The colour of the formulated blended vegetable oils ranged from light yellow to

dark yellow and from dark yellow to brownish yellow, reflecting the oils composition and potential oxidation level. Except for BOGO-II, the rest of the oil were absorbed to be non-greasy. All the formulated blended vegetable oils were found to be tasteless. The BOFO-V with 50 ml of flaxseed oil reported a nutty odour at room temperature however on heating a distinct fishy odour was observed. Also, the blended vegetable oils BOSFO- IVwith 50 ml of safflower oil wasodour less.

Mean Acceptability score of formulated Blended vegetable oils Against Stand-alone oils Deep fat Frying (Vadai)

The overall acceptability level of the formulated blended vegetable oils was evaluated by a panel of 20 semi-trained members on a scale of nine-point hedonic rating and was compared with acceptability levels of stand-alone oils.The observations are tabulated in Table-XIV (Plate 7) and discussed below.

Table XIV

Mean Acceptability score of formulated Blended vegetable oils Against Stand-alone oils for Deep fat Frying (Vadai)

Name of the oils	Colour	Flavour	Texture	Taste	Appearance	Overall Acceptability
BOGN-I	8.40±0.27	8.01±0.37	8.38±0.36	7.83 ± 0.59	8.35±0.36	40.37±2.21
BOGO-II	8.45±0.21	7.77±0.44	7.82±0.44	7.73±0.38	7.84±0.58	38.26±0.77
BOSF-III	7.98± 0.64	8.28±0.18	8.18±0.20	8.40±0.02	8.45±0.09	40.97±0.63
BOSFO-IV	7.29±0.21	8.1±0.04	7.69±0.65	7.61±0.32	7.76±0.43	38.34±0.28
BOFO-V	8.1±0.03	6.32±0.43	7.65±0.28	7.16±0.05	7.44±0.21	37.50±0.23
BOEP-VI	7.52±0.31	7.22±0.24	7.44±0.19	7.4±0.13	7.31±0.48	38.31±0.17
Sunflower oil	7.87 ±.54	8.33±0.38	7.75±0.66	7.45±0.31	7.833±0.59	38.45±0.40
Gingelly oil	8.25±0.19	7.85±0.52	7.77±0.50	7.833±0.59	7.68±0.37	39.27±0.75
Groundnut oil	8.010±0.21	7.76±0.55	7.87±0.54	7.79±0.50	7.85±0.45	39.14±0.60

Note: BOGN-I – Groundnut oil-50 ml+ gingelly oil-12.5 ml + sunflower oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOGO-II- Gingelly oil-50 ml + groundnut oil-12.5 ml + sunflower oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOSF-III- Sunflower oil-50 ml + groundnut oil-12.5 ml + gingelly oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOSFO-IV – Safflower oil-50 ml + groundnut oil-12.5 ml + gingelly oil-12.5 ml + sunflower oil-12.5 ml + flaxseed oil-12.5 ml, BOFO-V- Flaxseed oil-50 ml + groundnut oil-12.5 ml + gingelly oil-12.5ml + sunflower oil-12.5 ml+ safflower oil-12.5 ml, BOEP-VI- Groundnut oil-20 ml + gingelly oil-20 ml + sunflower oil-20 ml + safflower oil-20 ml and flaxseed oil-20 ml.

It was observed that all the formulated blended vegetable oils were rated as highly acceptable, with their mean score ranging between (35-45). In general, the overall acceptability level of the formulated blended vegetable oils was in par with the acceptability levels of the stand-alone oils. BOSF-III obtained the highest acceptability score followed by BOGN-I.The reason for the high acceptability of two blends (BOGN-I and BOSF-III) can be attributed to the distinct flavor of groundnut oil and the nonsticky texture of the sunflower oil used in the blending. The least acceptability score was obtained for BOFO-V.

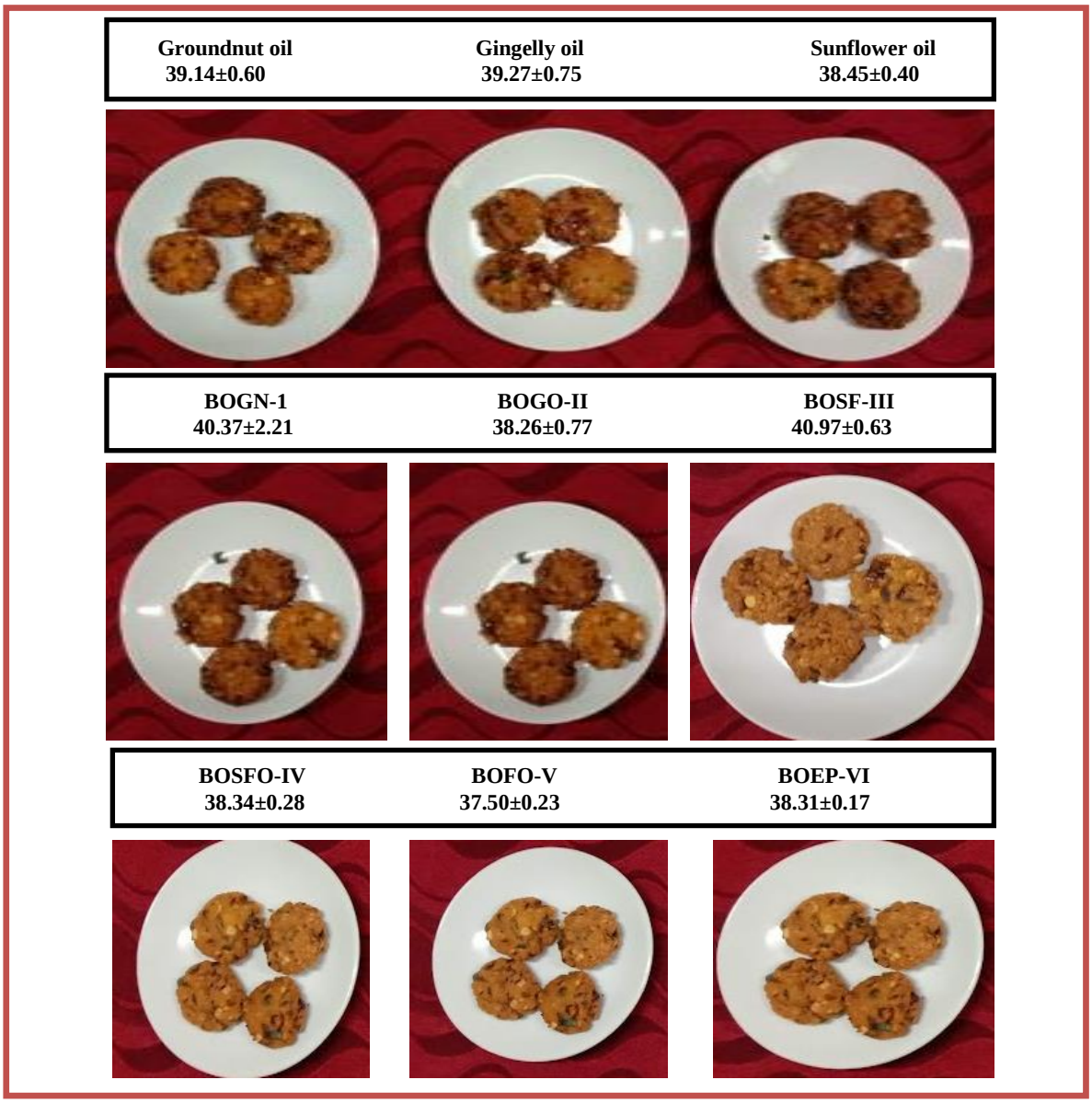


Plate 7: Acceptability score of formulated Blended vegetable oils Against Stand-Alone Oils Deep fat Frying (Vadai)

T-test analysis of blended vegetable oils for Deep Frying (Vadai)

The t-test analysis of blended vegetable oils for deep frying (Vadai) is shown in Table XV and discussed below.

Table XV

T-test analysis of blended vegetable oils for Deep Frying (Vadai)

Name of the oils	t-value	p-value
BOGN-I	1.5935	0.2573^{NS}
	0.1732	0.4596^{NS}
	0.3948	0.4055^{NS}
BOGO-II	0.329	0.3073^{NS}
	1.7484	0.7229^{NS}
	0.2078	0.4414^{NS}
BOSF-III	2.6327	0.3768^{NS}
	0.8322	0.3538^{NS}
	1.4376	0.2221^{NS}
BOSFO-IV	1.9226	1.000^{NS}
	0.1212	0.4706^{NS}
	0.5292	0.4087^{NS}
BOFO-V	3.3775	0.0122**
	4.7978	0.0049**
	4.5726	0.0004**
BOEP-VI	1.4896	0.2573^{NS}
	0.0693	0.4596^{NS}
	0.5632	0.4055^{NS}

Sunflower oil- Red, Gingelly oil-Violet, Groundnut oil- Green

Note : BOGN-I – Groundnut oil-50 ml + gingelly oil-12.5 ml + sunflower oil-12.5 ml+ safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOGO-II- Gingelly oil-50 ml + groundnut oil-12.5 ml + sunflower oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOSF-III- Sunflower oil-50 ml + groundnut oil-12.5 ml + gingelly oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOSFO-IV – Safflower oil-50 ml + groundnut oil-12.5 ml + gingelly oil-12.5 ml + sunflower oil-12.5 ml + flaxseed oil-12.5 ml, BOFO-V- Flaxseed oil-50 ml + groundnut oil-12.5 ml + gingelly oil-12.5ml + sunflower oil-12.5 ml + safflower oil-12.5 ml, BOEP-VI- Groundnut oil-20 ml + gingelly oil-20 ml + sunflower oil-20 ml + safflower oil-20 ml and flaxseed oil-20 ml.

Except for blended vegetable oils BOFO-V, no significant difference in the overall acceptability for deep fat frying was noted between the formulated blended vegetable oils (BOGN-I, BOGO-II, BOSF-III, BOSFO-IV, and BOEP-VI) with that of sunflower, groundnut, and gingelly oil. The above observation clearly indicates that the formulated blended vegetable oils can be used as an effective alternative to existing stand-alone oils. However, the overall acceptability of blended vegetable oils

BOFO-V was observed to be (37.05±0.23) lesser than the acceptability score of sunflower oil (38.45±65), groundnut oil (39.27 ± 0.75) and gingelly oil (39.14 ± 0.60) which was significant at one percent level of the confidence interval. The reason for the lower score can be attributed to the dominant distinct flavor of the fish odour of the flaxseed oil (Table XV).Thus there is no significant difference in the organoleptic acceptability of the formulated blended vegetable oil with that of stand alone oil was accepted for BOGN-I, BOGO-II, BOSF-III, BOSFO-IV and BOEP-VI and was rejected for BOFO-V.

Mean Acceptability Score of Formulated Blended vegetable oils against stand-alone oil for Pan frying (Chapatti)

The overall mean acceptability score of the formulated blended vegetable oils for pan frying (Plate 8) is shown in Table XVI and discussed below.

Table XVI

Mean Acceptability Score of Formulated Blended Vegetable Oils against Stand-Alone Oil for Pan Frying (Chapatti)

Name of the oils	Colour	Flavour	Texture	Taste	Appearance	Overall Acceptability
BOGN-I	7.41±0.40	7.35±0.10	7.22±0.01	7.37±0.21	7.69±0.24	37.62±0.5
BOGO-II	7.61±0.32	7.44±0.19	7.4±0.30	7.40±0.27	7.55±0.27	38.08±0.075
BOSF-III	7.42±0.39	7.41±0.15	7.27±0.12	7.48±0.18	7.41±0.42	38.13±0.03
BOSFO-IV	7.42±0.06	7.59±0.25	7.29±0.2	7.75±0.08	7.41±0.15	38.27±0.13
BOFO-V	8.4±0.10	8.5±0.04	8.3±0.26	7.59±0.25	8.39±0.10	41.41±0.10
BOEP-VI	8.31±0.14	7.45±0.06	7.31±0.22	7.27±0.56	8.46±0.16	38.45±0.15
Sunflower oil	8.20±0.35	7.35±0.26	7.30±0.09	7.41±0.26	8.23±0.18	37.44±0.42
Gingelly oil	7.54±0.28	7.36±0.07	7.35±0.095	6.43±0.45	8.12±0.20	37.32±0.26
Groundnut oil	7.46±0.2	7.25±0.19	7.466±0.16	7.45±0.24	6.8±0.99	37.34±0.24

Note: BOGN-I – Groundnut oil-50 ml + gingelly oil-12.5 ml + sunflower oil-12.5 ml+ safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOGO-II- Gingelly oil-50 ml + groundnut oil-12.5 ml + sunflower oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOSF-III- Sunflower oil-50 ml + groundnut oil-12.5 ml + gingelly oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOSFO-IV – Safflower oil-50 ml + groundnut oil-12.5 ml + gingelly oil-12.5 ml+ sunflower oil-12.5 ml + flaxseed oil-12.5 ml, BOFO-V- Flaxseed oil-50 ml + groundnut oil-12.5 ml + gingelly oil-12.5ml + sunflower oil-12.5 ml + safflower oil-12.5 ml, BOEP-VI- Groundnut oil-20 ml + gingelly oil-20 ml + sunflower oil-20 ml + safflower oil-20 ml and flaxseed oil-20 ml.

From the Table (XVI), it was evident that all the formulated blended vegetable oils were highly acceptable with their mean score ranging between 37.62 ± 0.5 to 41.41±0.10.In general, the overall acceptability level of formulated blended vegetable oils for pan frying was in par with the stand-alone oil. Contrary to the acceptability level of the formulated blended vegetable oils for deep fat frying, the maximum acceptability score was observed for BOFO-V a blend of 50ml of flaxseed oil with equal proportion (12.5 ml) of groundnut, gingelly, sunflower and safflower oil.

This is because the extent of the breakdown of aromatic component is less in pan frying compared to deep fat frying, since the oil used for pan frying may not reach the smoking temperature. Also, on the whole the overall acceptability levels of the blended vegetable oils were found to be slightly higher than the stand-alone oils.

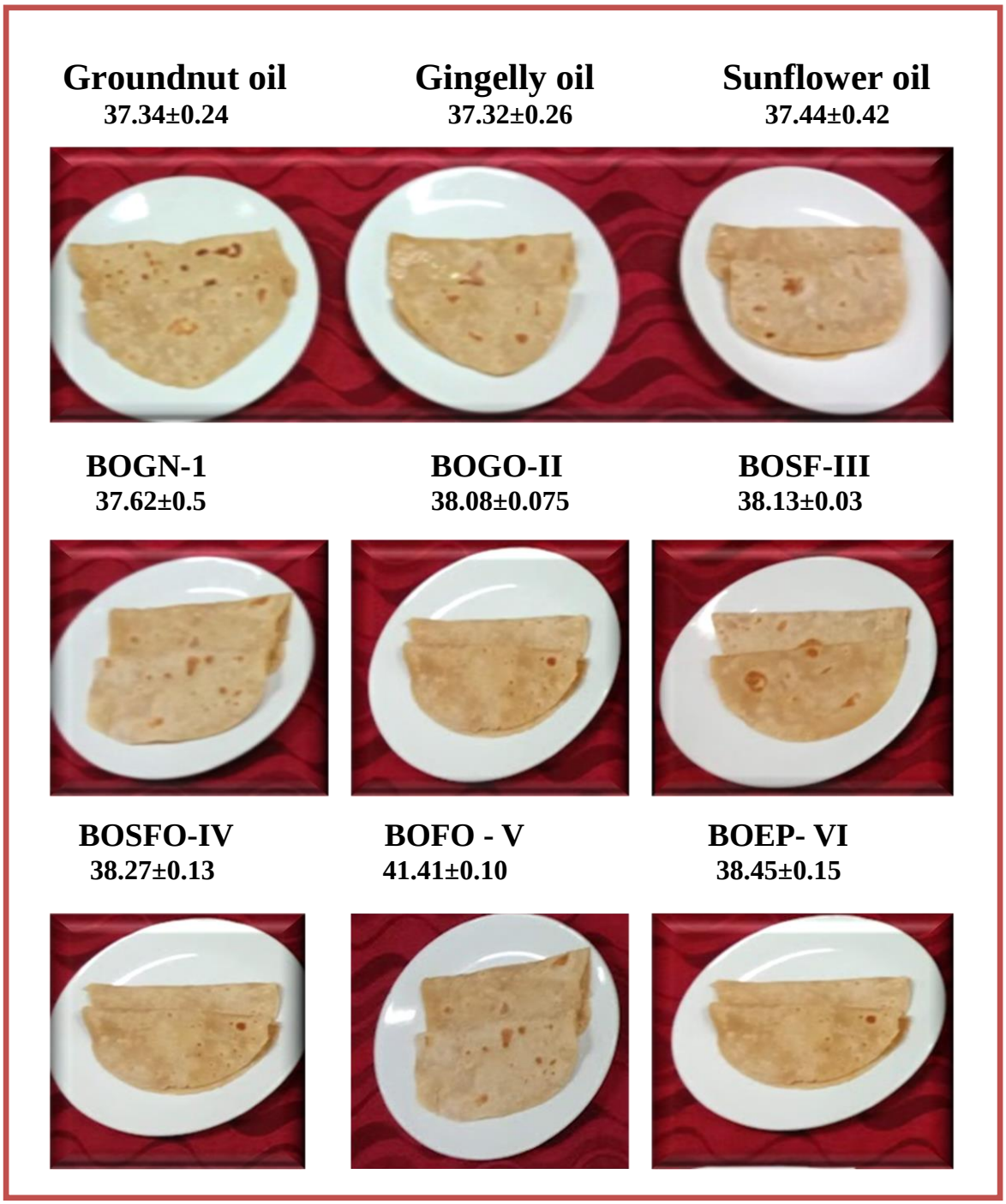


Plate 8: Acceptability Score of Formulated Blended Vegetable Oils against Stand Alone Oil for Pan frying (Chapatti)

T-test analysis of blended vegetable oils for Pan Frying (Chapatti)

The t-test analyses of formulated blended vegetable oils for pan frying (Chapatti) is given Table-XVII and discussed below.

Table XVII

T-test Analysis of Blended Vegetable Oils for Pan Frying (Chapatti)

Name of the oil	t-value	p-value
BOGN-I	1.4203	0.8774^{NS}
	1.2124	0.2921^{NS}
	1.2471	0.2804^{NS}
BOGO-II	1.1037	0.3317^{NS}
	1.2397	0.2828^{NS}
	1.2817	0.2692^{NS}
BOSF-III	2.9272	0.0429^{NS}
	3.1350	0.0350*
	3.1004	0.0362*
BOSFO-IV	3.1697	0.0339*
	3.3775	0.0278*
	3.2374	0.0318*
BOFO-V	5.1442	0.0068**
	5.3520	0.0059**
	5.3174	0.0060**
BOEP-VI	3.4814	0.0253*
	3.4814	0.0253*
	3.6581	0.0216*

NS- Non-significant *-Five percent level of significance, ** - One percent level of significance
Sunflower oil- Red, Gingelly oil-Violet, Groundnut oil- Green

Note: BOGN-I – Groundnut oil-50 ml + gingelly oil-12.5 ml + sunflower oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOGO-II- Gingelly oil-50 ml + groundnut oil-12.5 ml + sunflower oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOSF-III-Sunflower oil-50 ml + groundnut oil-12.5 ml + gingelly oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOSFO-IV – Safflower oil-50 ml + groundnut oil-12.5 ml + gingelly oil-12.5 ml+ sunflower oil-12.5 ml + flaxseed oil-12.5 ml, BOFO-V-Flaxseed oil-50 ml + groundnut oil-12.5 ml + gingelly oil-12.5ml + sunflower oil-12.5 ml+ safflower oil-12.5 ml, BOEP-VI- Groundnut oil-20 ml + gingelly oil-20 ml + sunflower oil-20 ml + safflower oil-20 ml + and flaxseed oil-20 ml.

No significant difference in the overall acceptability score was observed for blended vegetable oils BOGN-I and BOGO-II, with that of the stand-alone oil, thus from the above observation it is evident that blended vegetable oils BOGN-I and BOGO-II have the same sensory attribute as that of gingelly, groundnut and sunflower oil. However, a significant difference between the blended vegetable oils BOGO-V

and the stand-alone oil (t = 5.1442, 5.3520, 5.3174) was observed at a one percent level of confidence interval. It can be inferred that the overall acceptability of BOFO-V is superior in sensory attributes compared to the stand-alone oil. Thus the null hypothesis there is no significant difference in the organoleptic acceptability of formulated blended vegetable oil for pan frying with that of stand-alone oil was accepted for BOGN-I and BOGO-II and was rejected for BOSF-III, BOSFO-IV, BOFO-V and BOEP-VI.

Mean Acceptability Score of Formulated Blended vegetable oils against stand alone oil for Sauteing (Potato poriyal)

Table XVIII projects the mean overall acceptability of formulated blended vegetable oils for sauteing with proceeding discussion (Plate 9).

Table XVIII

Mean Acceptability Score of Formulated Blended Vegetable oils against Stand Alone Oil for Sauteing (Potato Poriyal)

Name of the oils	Color	Flavour	Texture	Taste	Appearance	Overall Acceptability
BOGN-I	8.17±0.04	7.10±0.08	7.12±0.25	7.15±0.13	7.00±0.16	36.02±2.00
BOGO-II	7.35±0.21	7.18±0.17	7.10±0.26	7.40±0.27	7.42±0.25	36.33±1.53
BOSF-III	8.17±0.05	8.25±0.089	7.43±0.35	7.48±0.18	8.3±0.045	40.38±0.22
BOSFO-IV	7.31±0.04	7.57±0.08	7.72±0.25	7.56±0.13	7.46±0.16	37.00±1.73
BOFO-V	8.27±0.10	8.39±0.11	8.15±0.10	7.41±0.15	8.28±0.06	40.78±0.40
BOEP-VI	6.31±0.13	6.24±0.10	6.95±0.49	6.33±0.12	7.24±0.10	32.67± 1.15
Sunflower oil	7.29±0.43	6.41±0.35	7.33±0.13	6.83±0.433	7.25±0.17	34.4±0.34
Gingelly oil	7.23±0.34	6.24±0.10	7.39±0.049	6.62±0.24	7.30±0.065	35.59±0.70
Groundnut oil	7.23±0.066	7.31±0.45	7.41±0.08	6.40±0.06	7.43±0.07	35.22±0.23

Note: BOGN-I – Groundnut oil- 50 ml + gingelly oil-12.5 ml + sunflower oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOGO-II- Gingelly oil- 50 ml + groundnut oil-12.5 ml + sunflower oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOSF-III- Sunflower oil- 50 ml + groundnut oil-12.5 ml + gingelly oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOSFO-IV – Safflower oil-50 ml + groundnut oil-12.5 ml + gingelly oil-12.5 ml + sunflower oil-12.5 ml + flaxseed oil-12.5 ml, BOFO-V- Flaxseed oil- 50 ml + groundnut oil-12.5 ml + gingelly oil-12.5ml + sunflower oil-12.5 ml + safflower oil-12.5 ml, BOEP-VI- Groundnut oil- 20 ml + gingelly oil-20 ml + sunflower oil-20 ml + safflower oil-20 ml and flaxseed oil-20 ml.

From the Table –XVIII it was noted that except for the blended vegetable oils BOEP-VI, the overall acceptability of the rest of the formulated blended vegetable oils

was found to be highly acceptable compared to sunflower oil, gingelly oil, and groundnut oil.

Out of all sensory characteristics, the organoleptic scores for the taste of the blended vegetable oils were found to be least compared to colour, flavor, texture, and appearance. However, the organoleptic score for the taste of stand-alone oil was lesser than the sunflower (6.83 ± 0.43), gingelly (6.62 ± 0.2), and groundnut oil (6.4 ± 0.06). The above observation can be attributed to the bland taste of potatoes. Since potato is bland in taste and oil act as a coating agent and brings pleasant flavour and texture to the product, it usually takes up the flavour and taste of the oil used for cooking and doesn't contribute any distinct taste like other vegetables.

Further the organoleptic score of all the six blended oil was found to be acceptable (30.4 ± 0.10) with the score ranging between 25 -35

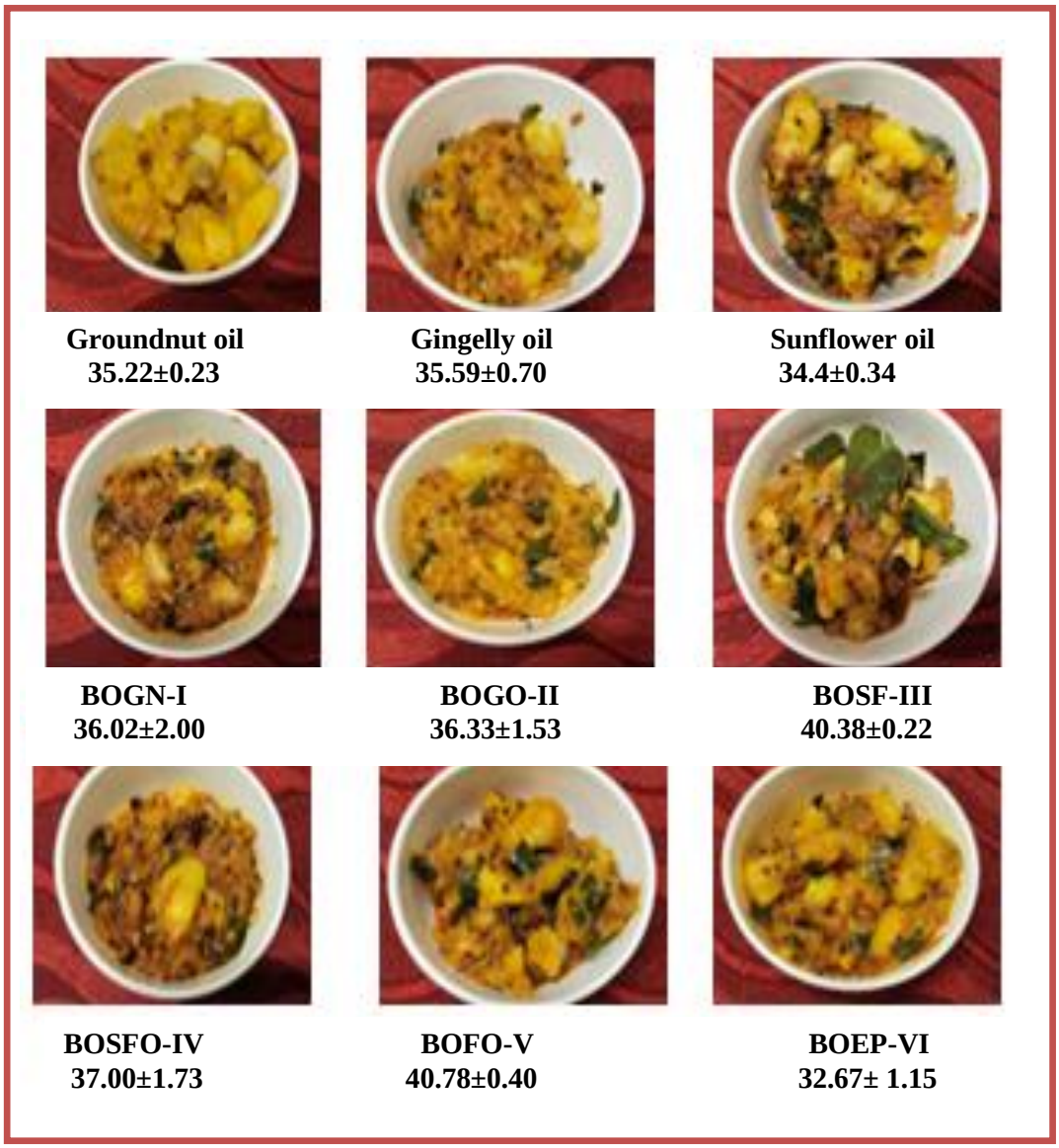


Plate 9: Acceptability Score of Formulated Blended Vegetable Oils against Stand-Alone Oil for Sauteing (Potato Poriyal)

T-test Analysis of Blended Vegetable Oils for Sautéing (Potato poriyal)

TableXIX projects a t-test analysis of formulated blended vegetable oil for sauteing with proceeding discussion.

Table XIX

T-test Analysis of Blended Vegetable Oils for Sautéing (Potato Poriyal)

Name of the oil	t value	P value
BOGN-I	1.7321 2.0000 1.9757	0.1583^{NS} 0.1161^{NS} 0.1194^{NS}
BOGO-II	2.6458 1.8353 1.7321	0.0572^{NS} 0.1404^{NS} 0.1583^{NS}
BOSF-III	19.0000 16.0000 16.0000	0.0001** 0.0001** 0.0001**
BOSFO-IV	3.0000 3.2857 4.0000	0.0399* 0.030* 0.0161^{*}
BOFO-V	17.0000 16.0000 8.5000	0.0001** 0.0001** 0.001**
BOEP-VI	3.5000 3.7796 1.6059	0.024* 0.019* 0.1836*

NS- Non-significant *-5% level of significance, ** - 1% level of significance osignificance

Sunflower oil- Red, Gingelly oil-Violet, Groundnut oil- Green

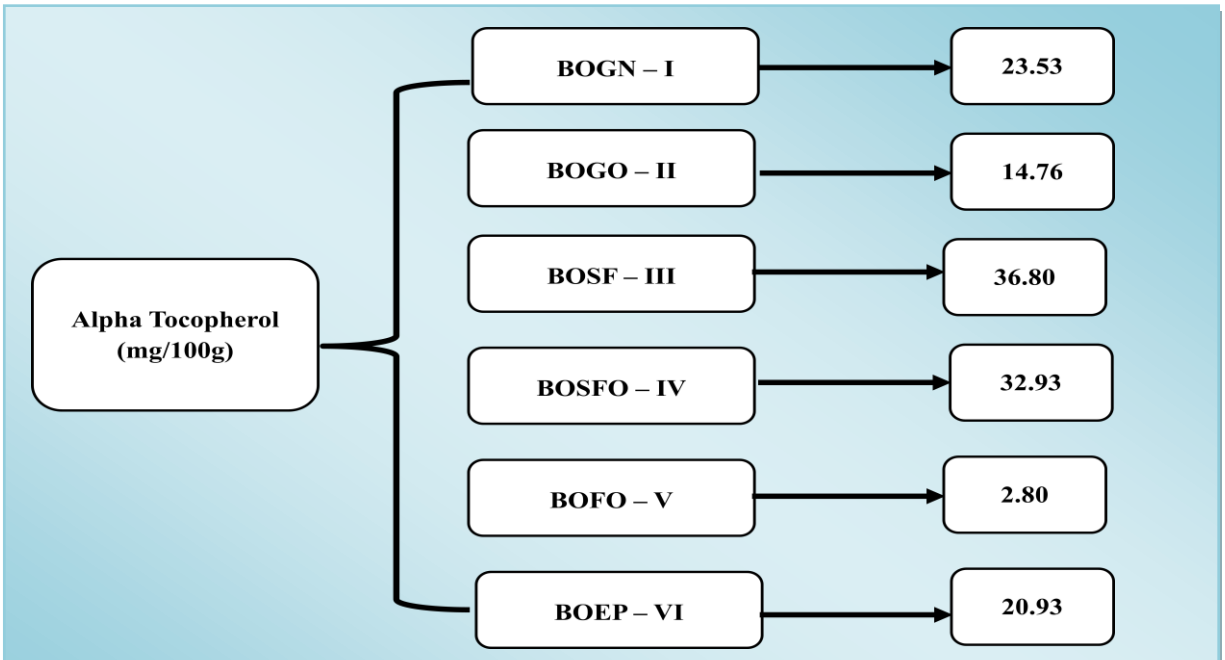
Note: BOGN-I – Groundnut oil-50 ml + gingelly oil-12.5 ml + sunflower oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOGO-II- Gingelly oil-50 ml + groundnut oil-12.5 ml + sunflower oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOSF-III-Sunflower oil-50 ml + groundnut oil-12.5 ml + gingelly oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOSFO-IV – Safflower oil-50 ml + groundnut oil-12.5 ml + gingelly oil-12.5 ml + sunflower oil-12.5 ml + flaxseed oil-12.5 ml, BOFO-V-Flaxseed oil-50 ml + groundnut oil-12.5 ml + gingelly oil-12.5ml + sunflower oil-12.5 ml+ safflower oil-12.5 ml, BOEP-VI- Groundnut oil-20 ml + gingelly oil-20 ml + sunflower oil-20 ml + safflower oil-20 ml and flaxseed oil-20 ml.

No significant difference in the overall acceptability score was observed for blended vegetable oils I and II, with that of the stand-alone oils. Thus from the above observation, it is evident that blended vegetable oils BOGN-I and BOGO-II had the same sensory attribute as that of gingelly, groundnut, and sunflower oil. However, a

significant difference between the blended vegetable oils BOSF-III (t = 19.0000, 16.0000,16.0000), BOFO-V(t = 17.0000,16.0000,8.500), and stand alone oil was observed at a one percent level of the confidence interval. Thus it can be inferred that the overall acceptability of BOFO-V is superior in sensory attributes compared to the stand-alone oil. Also the investigator observed a higher overall acceptability score for blended oil (BOSFO-IV) and (BOEP-VI) for sauteing significant at a one percent level of confidence interval compared with stand alone oil namely groundnut oil, gingelly oil, and sunflower oil (TableXIX). Thus the null hypothesis, there is no significant difference in the acceptability of formulated blended vegetable oil for sauteining with that of stand-alone oil was accepted and BOSF-I and BOGO-II was accepted and BOSF-III, BOSFO-IV, BOFO-V and BOEP-VI was rejected.

Antioxidant Content in Blended Vegetable Oils

Tocopherol is the main antioxidant that helps in the retardation of rancidity, thus the investigator evaluated the alpha-tocopherol content of the blended vegetable oil using an HPLC-UV detector as per the AOAC (2012.09) method. The observations are recorded and depicted in Figure7 and discussed below.



Note: BOGN-I – Groundnut oil-50 ml + gingelly oil-12.5 ml + sunflower oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOGO-II- Gingelly oil-50 ml + groundnut oil-12.5 ml + sunflower oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOSF-III-Sunflower oil-50 ml + groundnut oil-12.5 ml + gingelly oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOSFO-IV – Safflower oil-50 ml + groundnut oil-12.5 ml + gingelly oil-12.5 ml + sunflower oil-12.5 ml + flaxseed oil-12.5 ml, BOFO-V-Flaxseed oil-50 ml + groundnut oil-12.5 ml + gingelly oil-12.5ml + sunflower oil-12.5 ml + safflower oil-12.5 ml, BOEP-VI- Groundnut oil-20 ml + gingelly oil-20 ml + sunflower oil-20 ml + safflower oil-20 ml and flaxseed oil-20 ml.

Figure 7: Antioxidant Content in Blended Vegetable Oils

Natural antioxidents often known as vitamin E, are the naturally occurring phenoleicantioxidents present in vegetable oils.The alpha-tocopherol content of BOSF- III was higher (36.80), followed by BOSFO- IV (32.92) and BOGN- I (23.53). The least alpha-tocopherol content was observed in BOFO-V (2.80) with 50ml of flaxseed oil.the precise isomers of the tocopherols and their concentration are used to gauge the effectiveness of these inhibitors. Up to 200 ppm, tocopherols were found to be more effective at reducing oxidation process than tocopherol, but this difference was not observed at higher amounts. Studies also claims that as temperature rises above 40° C to 60°C, pro-oxidant properties enhance due to tocopherols declining antioxidant capacity (DeSouza *et al*., 2011).

Chemical Characteristics of Blended and Stand-Alone Oil

The chemical characteristics of blended and stand-aloneoils like peroxide (titration method AOAC-965.33), iodine (Wijs method AOAC-920.159), saponification (AOAC-920.160), acid value (AOAC-940.28), free fatty acid(AOAC-940.28) and tocopherol content - (High-Performance Liquid chromatography with UV detector-AOAC-2012.09) of all the six formulated blended vegetable oils were analyzed using a standard procedureand the results are tabulated and discussed below.

Peroxide Value

Oils with a higher degree of unsaturation are more prone to auto-oxidation. The peroxide value (PV) is the most reliable test for detection of auto-oxidation (oxidative rancidity), as peroxides are intermediates in this process. However, Peroxide Value (PV) alone is not always sufficient for quality control, especially without sensory evaluation and other test. Lipid oxidation is, often undesirable chemical change that affects the flavor, aroma, nutritional quality and also the safety of the product. Tertiary oxidation products, such as dimers and polymers, forms through the polymerization of secondary oxidation products. These compounds can cause oil colour darkening foam formation on the surface and an increase in viscosity (Kaleem *et al*., 2015).

The peroxide values of formulated blended vegetable oils with stand-alone oils is given in the TableXX and discussed below.

TableXX

Peroxide Valueof the Formulated Blended Vegetable Oils and Stand-Alone Oils

Blended vegetable oils (Meq/kg)		Stand-Alone Oils (Meq/kg)		t value	P value
Name of the oil	Mean± SD	Name of the oil	Mean± SD		
BOGN-I	0.03±0.05	Groundnut oil	3.36±0.00	99.8000	0.0001**
BOGO-II	0.03±0.05	Gingelly oil	3.62±0.00	99.80000	0.0001**
BOSF-III	0.06±0.05	Sunflower oil	4.36 ±0.00	107.6000	0.0001**
BOSFO-IV	0.033±0.05	Safflower oil	5.99±0.00	128.8000	0.0001**
BOFO-V	0.03±0.05	Flaxseed oil	3.74 ± 0.00	178.700	0.0001**
BOEP-VI	0.03±0.05	Groundnut oil	3.36±0.00	111.2000	0.0001**

** 1 percent level of significance

Note: BOGN-I – Groundnut oil-50 ml + gingelly oil-12.5 ml + sunflower oil-12.5 ml+ safflower oil-12.5 ml +flaxseed oil-12.5 ml, BOGO-II- Gingelly oil-50 ml + groundnut oil-12.5 ml + sunflower oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOSF-III- Sunflower oil-50 ml + groundnut oil-12.5 ml + gingelly oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOSFO-IV – Safflower oil-50 ml+ groundnut oil-12.5 ml + gingelly oil-12.5 ml + sunflower oil-12.5 ml + flaxseed oil-12.5 ml, BOFO-V- Flaxseed oil-50 ml + groundnut oil-12.5 ml+ gingelly oil-12.5ml + sunflower oil-12.5 ml + safflower oil-12.5 ml , BOEP-VI- Groundnut oil-20 ml + gingelly oil-20 ml + sunflower oil-20 ml + safflower oil-20 ml and flaxseed oil-20 ml.

The peroxide value is affected by packaging also. Transparent plastic bottles are more exposed to sunlight which causes photo-oxidation. Tin packed cooking oils are safe from photo-oxidation. Anthor factor is due difference in conditions and climate of area where the process of refinement take place. More over storage time also has an effect on the quality of oil (Kaleem *et al*., 2015).

On the whole, the peroxide value of all the formulated blended vegetable oils was observed to be more or less similar with the values ranging between 0.003 ± 0.05 to 0.06± 0.05. Also, the analyzed peroxide value of the stand-alone oils was found to be in the range of 3.36 ± 0.00 to 5.99 ± 0.00. Peroxide value less than 10 milliequalivent / kg indicates the oxidative stability of the blended oil (Ichu *et al*., 2019). Thus, compared to stand-alone oils, blended oils reported lower peroxide value, indicating a longer shelf life. This is because the blending of oils itself helps to stabilize each other. The antioxidant present in the blended vegetable oils prevented oxidazation of other compound and effectively reduced the peroxide value by

suppressing the formation of free radicals. A significant difference in the peroxide value between the blended and stand-alone oil was observed at a 1 % significance level, indicating better oxidative stability. Thus, the null hypothesis (H_{05}) "there is no significant difference in the peroxide value of the formulated blended vegetable oils with that of stand-alone oils"was rejected.

According to Prescha *et al*., (2014), oil blends including flaxseed oil are not advised for long-term preservation. Low temperatures and the absence of oxygen access, on the other hand, can extend their shelf-life by preventing oxidation. Futhermore, research indicates that the peroxide value of flaxseed oil barely increases even after six months of storage.

Iodine Value

To estimate the degree of unsaturation present in formulated blended vegetable oil, the iodine value was analyzed based on (AOAC-920.159). The results of the analysis is given in the (Table-XXI) and discussed below.

TableXXI

Iodine Value of the Formulated Blended Vegetable Oils and Stand- Alone Oils

Blended vegetable oils(mgKOH/g)		**Stand-alone oils(mgKOH/g)**		**t value**	**P value**
Name of the oil	**Mean± SD**	**Name of the oil**	**Mean± SD**		
BOGN-I	198.5±0.5	Groundnut oil	84±0.00	61.0000	0.0001**
BOGO-II	120.67±0.58	Gingelly oil	105.00±0.00	396.6396	0.0001**
BOSF-III	138.00±0.00	Sunflower oil	120.67±0.58	47.0000	0.0001**
BOSFO-IV	84.00±0.00	Safflower oil	150.33±0.58	46.0000	0.0001**
BOFO-V	150.33±0.58	Flaxseed oil	105.33±0.58	136.0000	0.0001**
BOEP-VI	104.33±0.58	Groundnut oil	84±0.00	64.0000	0.0001**

**** 1 percent level of significance**

Note: BOGN-I – Groundnut oil-50 ml + gingelly oil-12.5 ml + sunflower oil-12.5 ml + safflower oil-12.5 ml +flaxseed oil-12.5 ml, BOGO-II- Gingelly oil-50 ml+ groundnut oil-12.5 ml + sunflower oil-12.5 ml + safflower oil-12.5 ml+flaxseed oil-12.5 ml, BOSF-III-Sunflower oil-50 ml + groundnut oil-12.5 ml + gingelly oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOSFO-IV – Safflower oil-50 ml+ groundnut oil-12.5 ml + gingelly oil-12.5 ml + sunflower oil-12.5 ml+ flaxseed oil-12.5, ml, BOFO-V-Flaxseed oil-50 ml + groundnut oil-12.5 ml+ gingelly oil-12.5ml + sunflower oil-12.5 ml + safflower oil-12.5 ml, BOEP-VI- Groundnut oil-20 ml + gingelly oil-20 ml + sunflower oil-20 ml + safflower oil-20 ml and flaxseed oil-20 ml.

The iodine value indicates the measure of unsaturation in oil. The iodine value of stand-alone oil ranged between 84 to 150.67 ± 0.58. In case of stand-alone oils the highest iodine value was observed for safflower oil, whereas in the case of blended oil, the lowest iodine value (84.00 ± 0.00) was observed in BOSFO-IV with 50 % safflower oil, and the highest iodine value was (198.5 ± 0.5) observed for BOGN-I. The analyzed iodine value was observed to be in par with the literature value. A significant increase in iodine value was observed between all the six formulated blended oil and stand-alone oil at a one percent level of significance. Thus the null hypothesis (H_{06}) there is no significant difference in the iodine value of the formulated blended vegetable oil with that of stand- alone oil was rejected. Further itcanbe inferred that the formulated blended oils has more unsaturated fatty acid and can be prone to oxidative damage at very high temperatures and may not be suitable for baking but can be stable during frying and sauteing.

The iodine value of the observed data did not agree with the literature data, According to Shahidi *et al*.,(2016) the oil quality, is detected by several physical and chemical parameters that are dependent on the source of oil, processing, and storage conditions.

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 acid present in the formulated blended vegetable oils the saponification value was estimated and the values are tabulated in Table-XXII and discussed below.

Table XXII

Saponification Value of the Formulated Blended Vegetable Oils and Stand-Alone Oils

Blended vegetable oils(mg/KOH)		Stand-alone oils (mg/KOH)		t value	P value
Name of the oil	Mean± SD	Name of the oil	Mean± SD		
BOGN-I	191.67± 0.58	Groundnut oil	186.00 ± 0.00	227.0000	0.0001**
BOGO-II	190.67± 0.58	Gingelly oil	190.00± 0.00	17.0000	0.0001**
BOSF-III	192.00± 0.00	Sunflower oil	183.67± 0.58	26.0000	0.0001**
BOSFO-IV	204.67± 0.01	Safflower oil	193.00± 0.00	25.0000	0.0001**
BOFO-V	203.67± 0.58	Flaxseed oil	196.00± 0.00	35.0000	0.0001**
BOEP-VI	261.67± 0.58	Groundnut oil	186.00 ± 0.00	23.0000	0.0001**

Name of the oil	Literature Review (mg/KOH)	Reference
Groundnut oil	189.90	Pandurangan *et al*, 2014
Gingelly oil	189	Aremu*et al.*, 2015
Sunflower oil	188-194	Fakhri*et al.*,2011
Safflower oil	191	El-gazzar*et al.*, 2021
Flaxseed oil	185.6	Adam Omer Ishag*et al.*, 2020
Blended oils (mg/KOH)		
Groundnut oil: 95 Palm oil: 5	195.20	Padurangan *et al*., 2014
Groundnut oil: 90 Palm oil: 10	202.40	
Groundnut oil:85 Palm oil: 15	203.57	
Groundnut oil:95 Rice bran oil: 5	189	
Groundnut oil: 90 Rice bran oil: 10	191	
Groundnut oil:85 Rice bran oil:15	193	

** 1percent level of significance

Note: BOGN-I – Groundnut oil-50 ml + gingelly oil-12.5 ml + sunflower oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOGO-II- Gingelly oil-50 ml + groundnut oil-12.5 ml + sunflower oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOSF-III-Sunflower oil-50 ml + groundnut oil-12.5 ml+ gingelly oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOSFO-IV – Safflower oil-50 ml + groundnut oil-12.5 ml+gingelly oil-12.5 ml + sunflower oil-12.5 ml+ flaxseed oil-12.5 ml, BOFO-V-Flaxseed oil-50 ml + groundnut oil-12.5 ml + gingelly oil-12.5ml + sunflower oil-12.5 ml+ safflower oil-12.5 ml, BOEP-VI- Groundnut oil-20 ml + gingelly oil-20 ml + sunflower oil-20 ml + safflower oil-20 ml and flaxseed oil-20 ml.

According to (Muhammad *et al*., 2011) the molecular mass of fatty acid is inversely related to saponification value, indicating that there is a substantial fraction

of fatty acid with lower molecular weight or chain length. The saponification score indicates the presence of more long-chain beneficial fatty acids in the blended vegetable oils, such as Eicosapentaenoic acid (EPA) and Docosahexaenoic acid (DHA).

On the whole, the saponification value of all the formulated blended vegetable oils ranged between 190.67 ± 0.58 to 261.67 ± 0.58. Also, the analyzed saponification value of the stand-alone oils ranged between 183.67 ± 0.58 mg/KOH to 196± 0.00 mg/KOH. The estimated values are on par with the reference value (Pandurangan*et al*., 2014). Similarly in the case of blended vegetable oil an increase in the saponification value was observed and the increase was significantly higher than the stand-alone oil at a one percent level of confidence interval.Thus, the null hypothesis (H_{07}) "there is no significant difference in the saponification value of the formulated blended vegetable oils with that of stand-alone oils" was rejected.

The saponification value serves as an indiactor of the oils's degradation and oxidation during storage. The volatility of oils increases with an increase in the saponification value of the oils. Smaller the molecular weight components, greater will be the energy efficancy on burning and oil quality (Alajtal *et al*.,2018). A saponification value between 168-196 indicates the presence of long-chain fatty acid (Patel *et al*., 2017).The long-chain fatty acid helps in weight reduction, suppresses appetite, and improves circulatory efficiency.

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 acid value of the formulated blended vegetable oils and stand-alone oils is shown in Table-XXIII and discussed below.

Table XXIII

Acid Value of Formulated Blended Vegetable Oils andStand-Alone Oils

Blended vegetable oils		Stand-alone oils		t value	P value
Name of the oil	Mean± SD (mg/KOH)	Name of the oil	Mean± SD (mg/KOH)		
BOGN-I	2.14±0.10	Groundnut oil	2.02± 0.00	29.0000	0.0001**
BOGO-II	2.16±0.05	Gingelly oil	10.99 ± 0.00	2.0000	0.1161^{NS}
BOSF-III	2.16±0.05	Sunflower oil	0.66 ± 0.00	274.33	0.0001**
BOSFO-IV	1.92±0.017	Safflower oil	1.48±0.00	50.0000	0.0001**
BOFO-V	1.36 ± 0.00	Flaxseed oil	1.14±0.00	44.0000	0.0001**
BOEP-VI	2.21±2.02	Groundnut oil	2.02± 0.00	68.0000	0.0001**

** 1 percent level of significance

Note: BOGN-I – Groundnut oil-50 ml + gingelly oil-12.5 ml+sunflower oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOGO-II- Gingelly oil-50 ml + groundnut oil-12.5 ml + sunflower oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOSF-III-Sunflower oil-50 ml + groundnut oil-12.5 ml+ gingelly oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOSFO-IV- Safflower oil-50 ml + groundnut oil-12.5 ml + gingelly oil-12.5 ml + sunflower oil-12.5 ml + flaxseed oil-12.5 ml, BOFO-V-Flaxseed oil-50 ml, + groundnut oil-12.5 ml + gingelly oil-12.5ml + sunflower oil-12.5 ml + safflower oil-12.5 ml , BOEP-VI- Groundnut oil-20 ml +gingelly oil-20 ml + sunflower oil-20 ml + safflower oil-20 ml and flaxseed oil-20 ml.

An analysis of the acid value was carried out to determine the free fatty acid content of the formulated blended vegetable oil on hydrolysis. The acid value of blended vegetable oil ranged from 1.36±0.00 to 2.21± 2.02. The lowest acid value was reported in BOFO-V with 50ml of flaxseed oil, followed by BOSFO-IV with 50ml of safflower oil. Although a slight increase in the acid value was observed during blending, the low acid value indicates that the blended vegetable oils will be stable over a long period of time and can protect against rancidity. P values indicate a

significant difference in the acid value between formulated blended vegetable oils and stand-alone oil, at one percent level significance except for BOGO-II. Thus, the null hypothesis (H_{08}) "there is no significant difference in the acid value of the formulated blended vegetable oils with that of stand-alone oils" was rejected.

The low acid value of BOSFO-V can be (Figure-7) can be attributed to low antioxidant content (analysed α tocopherol 2.08 mg/100g) as presence of higher amount of antioxidant can increase the acid value by oxidizing themselves.

According to Katkade *et al*., (2018) Oil with a higher acid value has more freefatty acid, resulting in a poorer quality of oil. Thus the above observations clearly indicate that all the blended vegetable oils were of good quality due to their low acid value.

Free Fatty acid

The free fatty acid content of the formulated blended vegetable oils with stand-alone oils is tabulated in Table-XXIV and discussed below.

Table XXIV

Free Fatty Acid content of Formulated Blended Vegetable Oils andStand-Alone Oils

Blended vegetable oils		**Stand-alone oils**		**t value**	**P value**
Name of the oil	**Mean± SD(%)**	**Name of the oil**	**Mean± SD(%)**		
BOGN-I	1.11 ± 0.01	Groundnut oil	1.02 ± 0.00	14.0000	0.0002**
BOGO-II	0.8 ± 0.02	Gingelly oil	5.52 ± 0.00	14.0000	0.0002**
BOSF-III	1.06 ± 0.05	Sunflower oil	0.33 ± 0.00	281.2000	0.0001**
BOSFO-IV	0.94±0.04	Safflower oil	0.33±0.00	22.1000	0.0001**
BOFO-V	0.66 ± 0.05	Flaxseed oil	0.74 ± 0.00	26.4286	0.0001**
BOEP-VI	1.11± 0.01	Groundnut oil	1.02 ± 0.00	2.6667	0.0560^{NS}

** 1 percent level of significance

Note: BOGN-I – Groundnut oil-50 ml+ gingelly oil-12.5 ml+ sunflower oil-12.5 ml+ safflower oil-12.5 ml +flaxseed oil-12.5 ml, BOGO-II- Gingelly oil-50 ml+ groundnut oil-12.5 ml + sunflower oil-12.5 ml + safflower oil-12.5 ml +flaxseed oil-12.5 ml, BOSF-III-Sunflower oil-50 ml+ groundnut oil-12.5 ml+ gingelly oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOSFO-IV – Safflower oil-50 ml+ groundnut oil-12.5 ml+ gingelly oil-12.5 ml + sunflower oil-12.5 ml + flaxseed oil-12.5 ml,

BOFO-V-Flaxseed oil-50 ml + groundnut oil-12.5 ml+ gingelly oil-12.5ml + sunflower oil-12.5 ml + safflower oil-12.5 ml, BOEP-VI- Groundnut oil-20 ml + gingelly oil-20 ml + sunflower oil-20 ml + safflower oil-20 ml and flaxseed oil-20 ml.

Oils and fats are hydrolyzed to release free fatty acids. Time, temperature, and moisture content all affect the amount of FFA since oils and fats are exposed to a variety of conditions during production, heating, frying, and storage (Mahesar *et al*., 2014).

The free fatty acid value of all the formulated blended vegetable oils ranged between 0.8 ± 0.11 to 1.11 ± 0.01. Also, the analyzed free fatty acid value of the stand-alone oils was found to be in the range of 0.33 ± 0.00 to 5.52 ± 0.00.

The free fatty acid content of stand-alone oil was more or less in agreement with the literature value for gingelly (5.890%) and flaxseed oil. Literature studies indicate FFA content above 2 percent as undesirable for frying (Ujong *et al*., 2023). Thus, from the above observation, it can be inferred that the percentage of free fatty acids in blended vegetable oils was within the desirable limit for frying. However the higher free fatty acid content of BOGN-I and BOEP-VI compared to the other blended oils and stand alone oil may be attributed to the moisture content, rate of hydrolysis and activity of lypolytic enzyme. Also, we observed a significant decrease in the free fatty acid level of blended vegetable oil at a 1% level of significance. Thus the null hypothesis (H_{09})"there is no significant difference in the free fatty acids content between blended oil and stand-alone oil" was rejected.

Oil oxidation and chemical changes caused by heating are characterized by an increase in the number of free fatty acids and a decrease in total unsaturation. The oxidative stability of oil is influenced by fatty acids, which comprise the majority of its composition (Nduka *et al*., 2021).

Furthermore the free fatty acids level less than 2 indicates that the blended oil were stable and were free from hydrolytic rancidity.

Phase III: Fatty acid Profile of Formulated Blended Vegetable oils

Quantitative analysis for a fatty acid profile of all the six blended vegetable oils was carried out using the Gas Chromatography – Flame Ionization detection method (AOAC 996.06) – AOAC, 2019. 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 oilsnamely, groundnut, gingelly, sunflower, safflower, and flaxseed oil was done. the results are tabulated and discussed in the proceeding table.

Fatty Acids Composition of the Blended and Stand-AloneVegetable oils

The fatty acid composition of the formulated blended vegetable oils and stand-alone oilsis illustrated in Figure 8 and interpreted below.

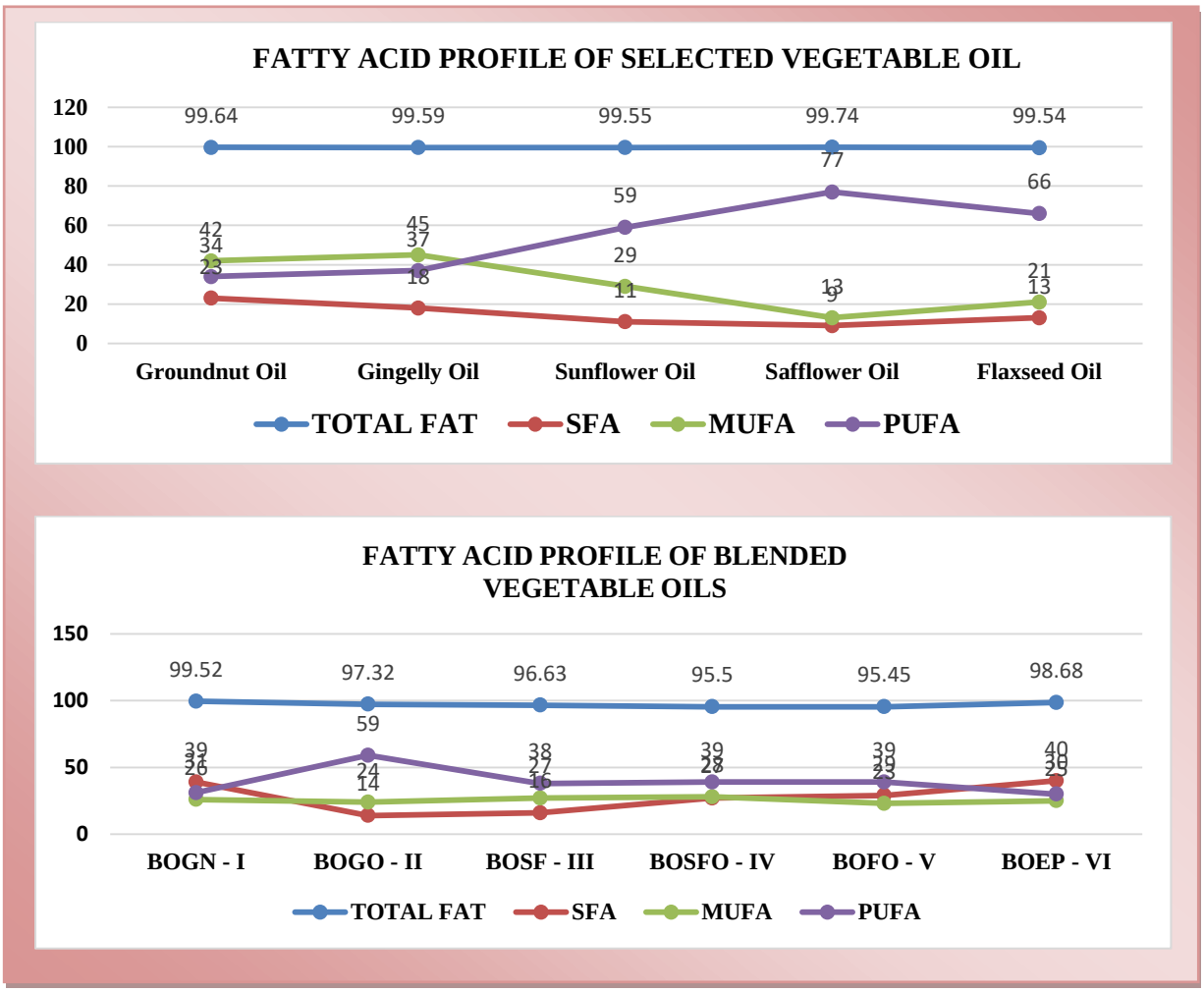


Figure 8: Fatty acid composition of the Formulated BlendedVegetable Oils and Stand Alone Oil

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 BOEP-VI (40g) and the least in BOSFO-II (14.35g). With respect to PUFA; BOGO- II (59g) reportedthe highest percentage, and BOGN- I (31g) reported the lowest percentage.

Also, the analyzed PUFA level in the stand-alone oil was elevated. Though a high level of PUFA is beneficial, a higher level of PUFA in oil is also a cause of concern for oxidative stability and the presence of free radicals. Thus, it can be inferred that the oxidative stability of blended vegetable oil is better than that of stand-alone oil.

Monounsaturated fatty acids (MUFAs) and polyunsaturated fatty acids (PUFAs) are abundant in vegetable oils derived from different plant seeds. These oils have a limited range of technical applications because of their unique chemical and physical characteristics. Blending of oil improves texture, oxidative and nutritional qualities at a reasonable prize and promotes health and wellbeing (Pattnaik *et al*., 2022).

According to Rabail *et al*., 2021, Sesame seed oil is more refined oil as apolyunsaturated, with approximately 82 percent unsaturated fatty acid and roughly equal quanity of oleic and linolenic acids. It is highly resistant to oxidative deterioriation when compared to other vegetable oils.

An unblended vegetable oil may exhibit inferior physical, chemical and nutritional properties, as well as reduced oxidative stability. Blending vegetable oils with differing properties is a straightforward method to develop new products that posses desired physiochemical and oxidative characteristics, as well as balanced compositions (Orsavova *et al*., 2015: Baltork *et al*., 2016).

Fatty Acid Profile of the Formulated Blended Vegetable Oils

Fatty acid profiles of the formulated blended vegetable oils is given in table XXV and discussed below.

TableXXV

Fatty Acid Profile of the Formulated Blended Vegetable Oils

Fatty acid Peak area %	BOGN-1	BOGO-II	BOSF-III	BOSFO-IV	BOFO-V	BOEP-VI	Groundnut Oil	Gingelly Oil	Sunflower Oil	Safflower Oil	Flaxseed Oil
Saturated fatty acid											
Methyl palmitate (C16:0)	11.963	9.482	6.293	7.556	8.375	8.425	13.675	9.992	6.293	6.102	5.831
Methyl stearate (C18:0)	4.336	5.520	3.633	3.960	4.963	5.013	3.967	6.712	3.633	2.716	6.410
Methyl arachidate (C20:0)	1.032	0.663	0.301	0.476	0.446	0.415	1.489	0.874	0.301	0.272	0.230
Methyl behenate (C22:0)	1.807	0.560	0.839	0.665	0.591	0.000	3.102	Nd	Nd	Nd	0.253
Methyl lignocerate (C24:0)	0.684	0.288	0.000	0.000	0.304	0.207	1.077	Nd	Nd	Nd	Nd
Monounsaturated Fatty acid											
Methyl oleate (C18:1 [cis-9])	35.303	35.470	29.486	24.600	26.942	25.741	41.632	44.568	29.486	13.438	21.188
Methyl eicosenate (C20:1 [cis-11]	5.019	7.239	0.150	6.931	22.450	0.000	0.702	0.239	0.150	Nd	0.703
Polyunsaturated fatty acid											
Methyl linoleate (C18:2 [trans-9,12])	39.208	40.340	59.299	55.812	35.928	29.877	34.356	37.615	59.299	77.471	52.407

Note: BOGN-I – Groundnut oil-50 ml + gingelly oil-12.5ml + sunflower oil-12.5ml + safflower oil-12.5ml +flaxseed oil-12.5 ml, BOGO-II- Gingelly oil-50 ml + groundnut oil-12.5ml + sunflower oil-12.5ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOSF-III- Sunflower oil-50 ml + groundnut oil-12.5ml + gingelly oil-12.5ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOSFO-IV – Safflower oil-50 ml + groundnut oil-12.5ml + gingelly oil-12.5ml + sunflower oil-12.5 ml + flaxseed oil-12.5 ml, BOFO-V-Flaxseed oil-50 ml + groundnut oil-12.5 ml + gingelly oil-12.5 ml + sunflower oil-12.5 ml + safflower oil-12.5 ml, BOEP-VI- Groundnut oil-20 ml + gingelly oil-20 ml + sunflower oil-20 ml + safflower oil-20 ml and flaxseed oil-20 ml.

The results are consistent with the study conducted by Sharayei*et al*., (2016), in which canola oil, palm oilein oil and olive oil were blended in the ratio of 75:15:10 and the largest amounts of monounsaturated fatty acids C16:0 methyl palmitate

(14.12%) and polyunsaturated fatty acids C18:2 methyl lenoleate (21.02%) were found.

The presence of saturated fatty acid in all the blended vegetable oils was found to be low in comparison withthat of groundnut oil.

Marangoni *et al*., (2020) claim methyl linolate a n-6 fatty acid is an oxidative stress marker, with functional properties to decrease blood cholesterol, blood pressure, and inflammation and was found to be high in blended vegetable oils III and IV.

Also presence of methyl eicosenate in monounsaturated fatty acids was found to be high in blended vegetable oils compared to stand-alone oil. Fatty acid profile of formulated blended vegetable oils (BOGN-I to BOEP-VI) and stand- alone oils – Chromotogram (Annexure – XIX-XXIII).

Phase IV: Fatty Acid Profile of Cooked Products Using Blended Vegetable Oil

The investigator was curious to study the fatty acid profile of foods cooked using the formulated blended vegetable oil to understands its dietary contribution. Three commonly consumed recipes namely vada (deep fat frying), chapatti (pan frying), and potato poriyal (sautéing) were selected for this purpose and their fatty acid profile of oil in the cooked products was analyzed using GC-FID. The observations are tabulated and projected below.

Oil absorption and Overall Fatty acid composition of the Cooked Products for Deep Fat Frying (Vadai)

The quantum of oil absorption and overall fatty acid composition of the cooked product using the deep frying method (Vadai) is shown in Table-XXVI and discussed below.

Table XXVI

Oil absorption and Overall Fatty acid composition of the Cooked Products for Deep fat Frying (Vadai)

Oils	Blended vegetable oils						Stand - Alone Oil		
	BOGN-I	BOGO-II	BOSF-III	BOSFO-IV	BOFO-V	BOEP-VI	Groundnut oil	Gingelly oil	Sunflower oil
Oil Absorption(g/100g)	24.20	9.97	17.23	10.08	12.74	34.87	24.83	18.67	12.53
Saturated fatty acid (g/100g)	**4.57**	1.46	2.19	1.29	1.87	6.13	**6.50**	3.70	1.91
Monounsaturated fatty acid (g/100g)	9.61	3.88	6.26	3.23	6.29	12.90	10.88	8.47	4.39
Polyunsaturated fatty acid (g/100g)	**10.02**	4.63	8.79	5.53	4.58	15.84	**7.44**	6.50	6.22
Trans fat (g/100g)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

Note: BOGN-I – Groundnut oil-50 ml + gingelly oil-12.5 ml +sunflower oil-12.5 ml+ safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOGO-II- Gingelly oil-50 ml + groundnut oil-12.5 ml + sunflower oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOSF-III- Sunflower oil-50 ml + groundnut oil-12.5 ml + gingelly oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOSFO-IV – Safflower oil-50 ml + groundnut oil-12.5 ml + gingelly oil-12.5 ml + sunflower oil-12.5 ml + flaxseed oil-12.5 ml, BOFO-V-Flaxseed oil-50 ml + groundnut oil-12.5 ml + gingelly oil-12.5 ml + sunflower oil-12.5 ml + safflower oil-12.5 ml, BOEP-VI- Groundnut oil-20 ml + gingelly oil-20 ml + sunflower oil-20 ml + safflower oil-20 ml and flaxseed oil-20 ml.

It is observed that although the presence of oil absorption of BOGN-I (24.20g) was similar to that of groundnut oil (24.83g), the quantum of saturated fatty acid (4.57g) was less than

the saturated fat of groundnut oil (6.50g), and the PUFA content was found to be greater (10.02g) than groundnut oil (7.44g). On comparing the rate of oil obsorption of blended oil BOSF-III with stand-alone sunflower oil, the obsorptionwas found to be higher in blended oil, and a proportionate increase in polyunsaturated fatty acids was observed. Maximum oil absorption was observed in BOEP-VI. The quantum of trans fat was found to be less than 0.1g/100g.

Fatty acid Profile of the Formulated Blended Vegetable Oils – Deep Fat Frying (Vadai)

Table XXVII shows the fatty acid profile of the formulated blended vegetable oils- for deep fat frying (Vadai).

TableXXVII

Fatty acid Profile of the Formulated Blended Vegetable Oils – Deep fat Frying (Vadai)

Fatty acid Peak area %	BOGN-1	BOGO-II	BOSF-III	BOSFO-IV	BOFO-V	BOEP-VI	Groundnut Oil	Gingelly Oil	Sunflower Oil
Saturated fatty acid									
Methyl palmitate (C16:0)	14.017	8.375	8.687	9.762	8.375	10.122	15.148	11.293	9.264
Methyl stearate (C18:0)	3.975	4.963	3.886	4.604	4.963	5.136	4.243	6.887	4.454
Methyl arachidate (C20:0)	0.714	0.446	0.000	0.000	0.446	0.590	1.907	1.201	0.699
Methyl behenate (C22:0)	0.000	0.591	0.000	0.000	0.591	1.096	3.631	0.439	0.841
Methyl lignocerate (C24:0)	0.000	0.304	0.000	0.000	0.304	0.635	1.269	0.000	0.000
Monounsaturated Fatty acid									
Methyl oleate (C18:1 [cis-9])	33.813	26.942	29.873	32.794	26.942	34.074	42.940	45.371	35.066
Methyl eicosenate (C20:1 [cis-11]	5.916	22.450	6.449	6.027	22.450	2.916	0.885	0.000	0.000
Polyunsaturated fatty acid									
Methyl linoleate (C18:2 [trans-9,12])	39.110	35.928	49.714	44.845	35.928	40.751	29.649	0.000	49.234

Note: BOGN-I – Groundnut oil-50 ml+ gingelly oil-12.5ml + sunflower oil-12.5 ml+ safflower oil-12.5 ml +flaxseed oil-12.5 ml, BOGO-II - Gingelly oil-50 ml + groundnut oil-12.5 ml + sunflower oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOSF-III - Sunflower oil-50 ml + groundnut oil-12.5 ml + gingelly oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOSFOV – Safflower oil-50 ml + groundnut oil-12.5 ml + gingelly oil-12.5 ml + sunflower oil-12.5 ml + flaxseed oil-12.5 ml, BOFOV - Flaxseed oil-50 ml + groundnut oil-12.5 ml + gingelly oil-12.5ml + sunflower oil-12.5 ml + safflower oil-12.5 ml, BOEPVI - Groundnut oil-20 ml + gingelly oil-20 ml + sunflower oil-20 ml + safflower oil-20 ml and flaxseed oil-20 ml.

Compared to gingelly oil (0.00) and groundnut oil (29.649%), the presence of methyl linolate was found to be high in all the blended vegetable oils. The percentage

of peak areas of BOSF-III for methyl linolate (49.714%) was found to be similar to that of sunflower oil (49.234%). The BOGO-II reported a higher percentage of peak area for methyl eicosenate (22.450%).Except for BOGN-I (14.017) and BOEP-VI (10.122%), all the other blended vegetable oils (BOGN-II 8.375%, BOSF-III 8.687%, BOSFO-IV 9.762%, BOEP-V 8.375%) reported a lesser percentage of methyl palmitate. Fatty acid Profile of the Formulated Blended Vegetable Oils (BOGN-I and BOGO-VI) and Stand Alone Oils - Deep Fat Frying (Vadai) (Annexure- XXIV-XXVII)

Oil absorption and Overall Fatty acid Profile of the Cooked Products for Pan Frying (Chapatti)

The oil absorption and overall fatty acid profile of the cooked products for pan frying (Chapatti) is given in the tableXXVIII and discussed below.

Table XXVIII

Oil absorption and Overall Fatty Acid composition of the Cooked Products for Pan Frying (Chapatti)

Oils	Blended vegetable oils						Stand- Alone Oils		
	BOGN-I	BOGO-II	BOSF-III	BOSFO-IV	BOFO-V	BOEP-VI	Groundnut oil	Gingelly oil	Sunflower oil
Oil Absorption (g/100g)	6.13	9.44	4.08	5.15	5.77	12.56	8.51	11.63	12.58
Saturated fatty acid(g/100g)	1.22	1.56	0.93	1.06	1.30	3.59	2.90	3.17	3.96
Monounsaturated fatty acid(g/100g)	2.47	4.07	1.91	2.07	2.30	6.61	3.67	5.50	6.33
Polyunsaturated fatty acid (g/100g)	2.44	3.81	1.21	2.02	1.95	5.37	1.95	2.96	2.29
Trans fat (g/100g)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

Note: BOGN-I – Groundnut oil-50 ml+ gingelly oil-12.5 ml + sunflower oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOGO-II- Gingelly oil-50 ml+ groundnut oil-12.5 ml + sunflower oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOSF-III-Sunflower oil-50 ml+ groundnut oil-12.5 ml+ gingelly oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOSFO-IV – Safflower oil-50 ml + groundnut oil-12.5 ml + gingelly oil-12.5 ml+ sunflower oil-12.5 ml+ flaxseed oil-12.5 ml, BOFO-V-Flaxseed oil-50 ml + groundnut oil-12.5 ml + gingelly oil-12.5ml + sunflower oil-12.5 ml + safflower oil-12.5 ml, BOEP-VI- Groundnut oil-20 ml + gingelly oil-20 ml + sunflower oil-20 ml + safflower oil-20 ml and flaxseed oil-20 ml.

From the above table it is evident that for pan frying, the oil absorption of blended vegetable oil ranged between 4.08g to12.56g. 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). The blended oil BOSF-III reported the least PUFA content 1.21gm/100gm. The percentage of trans fat was found to be <0.1. It can be inferred that BOEP-VI had better PUFA and MUFA content than other blends.

Fatty Acid Composition of the Formulated Blended Vegetable Oils – Pan Frying (Chapatti)

The fatty acid composition of the formulated blended vegetableoil for – pan frying (Chapatti) is given in Table XXIX and discussed below.

Table XXIX

Fatty Acid Composition of the Formulated Blended Vegetable Oils – Pan Frying (Chapatti)

	Blended Vegetable Oils						Stand-Alone Oils		
Fatty acid Peak area %	**BOGN-1**	**BOGO-II**	**BOSF-III**	**BOSFO-IV**	**BOFO-V**	**BOEP-VI**	**Groundnut Oil**	**Gingelly Oil**	**Sunflower Oil**
Saturated fatty acid									
Methyl palmitate (C16:0)	11.963	11.963	15.314	14.608	12.805	13.497	18.661	18.691	15.824
Methylstearate (C18:0)	0.266	0.266	6.857	6.071	6.889	6.862	5.104	7.412	6.728
Methyl arachidate (C20:0)	1.032	1.032	0.000	0.000	2.002	0.754	2.822	1.004	1.282
Methylbehenate (C22:0)	1.807	1.807	0.000	0.000	0.000	1.282	4.543	2.287	1.714
Methyl lignocerate(C24:0)	0.684	0.684	0.000	0.000	0.000	0.395	2.162	0.767	0.758
Monounsaturated Fatty acid									
Methyloleat(C 18:1 [cis-9])	35.303	35.303	45.147	37.996	34.096	39.733	42.321	50.350	47.320
Methyleicosenate (C20:1 [cis-11]	5.019	5.019	1.362	2.175	5.704	2.461	0.757	0.000	0.000
Polyunsaturated fatty acid									
Methyllinoleate (C18:2 [trans-9,12])	39.208	39.208	27.300	37.385	26.226	31.733	22.142	18.200	25.438

Note: BOGN-I – Groundnut oil-50 ml+ gingelly oil-12.5 ml+sunflower oil-12.5 ml+ safflower oil-12.5 ml +flaxseed oil-12.5 ml, BOGO-II- Gingelly oil-50 ml+ groundnut oil-12.5 ml + sunflower oil-12.5 ml + safflower oil-12.5 ml+flaxseed oil-12.5 ml, BOSF-III-Sunflower oil-50 ml+ groundnut oil-12.5 ml+ gingelly oil-12.5 ml+safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOSFO-IV – Safflower oil-50 ml+ groundnut oil-12.5 ml+gingelly oil-12.5 ml+ sunflower oil-12.5 ml+ flaxseed oil-12.5 ml, BOFO-V-Flaxseed oil-50 ml + groundnut oil-12.5 ml+ gingelly oil-12.5ml+ sunflower oil-12.5 ml+ safflower oil-12.5 ml BOEP-VI-Groundnut oil-20 ml + gingelly oil-20 ml + sunflower oil-20 ml + safflower oil-20 ml and flaxseed oil-20 ml.

All six blended vegetable 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 by BOEP-VI (39.733%), it was found to be lesser compared to all stand-alone oils. The percentage of peak area for methyl linolate(BOGN-I- 39.208%, BOGO-II- 39.208%, BOSF-III – 27.300%, BOSFO-IV -37.385%, BOFO-V-26.226% and BOEP-VI- 31.733%)was found to be comparatively higher than the stand-alone oil.

Thus it can be inferred that blended vegetable oils are a healthier alternative for stand-alone oils for pan frying. Fatty acid Profile of the Formulated Blended Vegetable Oils (BOGN-I and BOGO-VI) and Stand Alone Oils Pan Frying (Chapatti) (Annexure- XXVIII-XXX).

Oil absorption and Overall Fatty acid composition of the Cooked Products for Sauteing (Potato Poriyal)

The oil absorption and overall fatty acid composition of the cooked products for sauteing (Potato poriyal) is given in table XXX and discussed below.

Table XXX

Oil Absorption and Overall Fatty Acid Composition of the Cooked Products for Sauteing (Potato Poriyal)

Oils	Blended vegetable oils						Stand-alone oils		
	BOGN-I	BOGO-II	BOSF-III	BOSFO-IV	BOFO-V	BOEP-VI	Groundnut oil	Gingelly oil	Sunflower oil
Oil Absorption(g/100g)	4.72	5.61	22.56	26.33	8.76	16.03	21.72	22.41	17.86
Saturated fatty acid (g/100g)	0.89	0.81	2.96	3.33	1.38	2.78	5.21	4.09	2.05
Monounsaturated fatty acid (g/100g)	1.89	2.19	7.28	8.30	4.51	5.35	9.09	9.81	5.58
Polyunsaturated fatty acid (g/100g)	1.94	2.61	12.32	14.70	2.87	7.90	7.42	8.51	10.22
Trans fat (g/100g)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

Note: BOGN-I – Groundnut oil-50 ml + gingelly oil-12.5 ml+sunflower oil-12.5 ml + safflower oil-12.5 ml +flaxseed oil-12.5 ml, BOGO-II- Gingelly oil-50 ml + groundnut oil-12.5 ml + sunflower oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOSF-III- Sunflower oil-50 ml + groundnut oil-12.5 ml+ gingelly oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOSFO-IV –Safflower oil-50 ml + groundnut oil-12.5 ml+gingelly oil-12.5 ml+ sunflower oil-12.5 ml+ flaxseed oil-12.5 ml, BOFO-V- Flaxseed oil-50 ml + groundnut oil-12.5 ml + gingelly oil-12.5ml + sunflower oil-12.5 ml+ safflower oil-12.5 ml , BOEP-VI- Groundnut oil-20 ml + gingelly oil-20 ml + sunflower oil-20 ml + safflower oil-20 ml and flaxseed oil-20 ml.

Although the percentage of oil absorption of BOSF-III (25.56g) and BOSFO-IV (26.33g) were in par with groundnut (21.72g) and gingelly oil (22.41g), the percentage of absorption of saturated fat (BOSF-III -2.96g and BOFO-IV- 3.33g) was

found to be lesser.The percentage of PUFA in cooked potato poriyal was found to be greater in BOSF-III (12.32g) and IV (14.70g) compared to the stand-alone oils.

Fatty acid Composition of the Formulated Blended Vegetable Oils - Sautéing (Potato Poriyal)

The fatty acid composition of the formulated blended vegetable oils for - sauteing (Potato poriyal) is given in table XXXI and discussed below.

TableXXXI

Fatty acid Composition of the Formulated Blended Vegetable Oils - Sautéing (Potato Poriyal)

	Blended Vegetable Oils						Stand- Alone Oils		
Fatty acid Peak area %	**BOGN-1**	**BOGO-II**	**BOSF-III**	**BOSFO-IV**	**BOFO-V**	**BOEP-VI**	**Groundnut Oil**	**Gingelly Oil**	**Sunflower Oil**
Saturated fatty acid									
Methyl palmitate (C16:0)	ND	9.461	7.403	7.556	9.461	9.475	14.230	10.105	7.420
Methyl stearate (C18:0)	14.362	4.447	4.021	3.960	4.447	5.587	3.382	7.336	3.286
Methyl arachidate (C20:0)	0.000	0.501	0.547	0.476	0.501	0.422	1.871	0.821	0.000
Methyl behenate (C22:0)	0.000	ND	0.862	0.665	0.000	0.000	3.106	0.000	0.782
Methyl lignocerate (C24:0)	0.000	ND	0.282	0.000	0.000	0.000	1.403	0.000	0.000
Monounsaturated Fatty acid									
Methyl oleate (C18:1 [cis-9])	33.938	9.461	32.066	24.600	32.932	29.104	41.311	43.754	31.264
Methyl eicosenate (C20:1 [cis-11]	6.137	4.447	0.192	6.931	6.123	22.359	0.547	0.000	0.000
Polyunsaturated fatty acid									
Methyl linoleate (C18:2 [trans-9,12])	38.470	45.352	47.860	55.812	45.352	31.264	34.151	37.983	57.248

Note: BOGN-I – Groundnut oil-50 ml+ gingelly oil-12.5 ml + sunflower oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOGO-II- Gingelly oil-50 ml + groundnut oil-12.5 ml + sunflower oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOSF-III-Sunflower oil-50 ml + groundnut oil-12.5 ml + gingelly oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOSFO-IV – Safflower oil-50 ml+ groundnut oil-12.5ml + gingelly oil-12.5 ml + sunflower oil-12.5 ml + flaxseed oil-12.5 ml, BOFO-V-Flaxseed oil-50 ml + groundnut oil-12.5 ml+ gingelly oil-12.5ml+ sunflower oil-12.5 ml + safflower oil-12.5 ml BOEP-VI- Groundnut oil-20 ml + gingelly oil-20 ml + sunflower oil-20 ml + safflower oil-20 ml and flaxseed oil-20 ml.

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 oils (34.151%) in general.

Also the presence of methyl oleate in all blended vegetable oils was found to be less compared to the gingelly (43.754%), groundnut oils (31.264%). Saturated fats namely methyl palmitate and methyl behenate were not detected in BOGN-I and BOGO-II respectively. Fatty acid Profile of the Formulated Blended Vegetable Oils (BOGN-I and BOGO-VI) and Stand Alone Oils- Sauteing (Potato Poriyal) (Annexure- XXXI-XXXIII).

Shelf Life of the Blended vegetable oils without Antioxidant

The oxidative stability is a critical measure of oil quality and its ability to resist deterioration over time.The shelf lives of the blended vegetable oils without antioxidants is given in the TableXXXII and discussed below.

Table XXXII

Shelf Life of the Blended Vegetable Oils without Antioxidant

Days	BOGN-I	BOGO-II	BOSF-III	BOSFO-IV	BOFO-V	BOEP-VI
0th	0.57	0	0	1.93	2.67	1.15
7th	2.66	0.76	1	5.21	5.26	3.37
14th	6.52	1.71	3.38	6.88	7.64	8.74
21st	10.28	3.99	6.20	11.07	11.75	11.74
28th	12.18	6.98	8.45	15.29	15.19	15.21
35th	14.80	9.51	9.55	15.81	-	-
42th	15.25	11.89	14.33	-	-	-
49th	-	14.37	15.18	-	-	-
56th	-	16.07	-	-	-	-

Note: BOGN-I – Groundnut oil-50 ml + gingelly oil-12.5 ml + sunflower oil-12.5 ml + safflower oil-12.5 ml +flaxseed oil-12.5 ml, BOGO-II- Gingelly oil-50 ml + groundnut oil-12.5 ml + sunflower oil-12.5 ml + safflower oil-12.5 ml+flaxseed oil-12.5 ml, BOSF-III-Sunflower oil-50 ml + groundnut oil-12.5 ml+ gingelly oil-12.5 ml+safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOSFO-IV – Safflower oil-50 ml+ groundnut oil-12.5 ml+gingelly oil-12.5 ml+ sunflower oil-12.5 ml+ flaxseed oil-12.5 ml, BOFO-V-Flaxseed oil-50 ml, groundnut oil-12.5 ml+ gingelly oil-12.5ml+ sunflower oil-12.5 ml+ safflower oil-12.5 ml, BOEP-VI- Groundnut oil-20 ml, gingelly oil-20 ml, sunflower oil-20 ml, safflower oil-20 ml and flaxseed oil-20 ml.

The shelf life of formulated blended vegetable oil without antioxidant was observed to be35-49 days. The maximum shelflife was reported in blended oil BOGO-II indicating a better oxidative stability against rancidity. We also observed a least shelf life of 14 days for BOSFO-IV, BOFO-V and BOEP-VI.Formulas blended with gingelly and groundnut oil showed better shelflife compared to oils blended with sunflower, safflower and flaxseed oils.

A study by Mohammed *et al.,* (2023) investigated the changes in acid value, peroxide value and density of sunflower oil over a 16- week storage period. On prolonged storage of sunflower oil at ambient temperatures (25-33ºC) oxidative degradation was observed. Initially, the oil samples exhibited acceptable acid values but significantly decreased on storage. Additionally, the inclusion of antioxidant vitamins in the stored samples leads to a higher reduction in acid and peroxide value compared to samples without antioxidents. Moreever, the addition of vitamins also diminished the formation of free fatty acids in sunflower oil.

The storage properties of oils are influenced by several factors, including the degree of unsaturation, carbon chain length and type, quanity and distribution of Fatty

Acids (FA) on the triglyceride molecule, as well as their isomeric forms. Sunflower oils, which are high in unsaturated fatty acids, are particularly prone to oxidative rancidity. This form of rancidity can develop over extended storage periods and is exacerbated under unsuitable storage conditions, adversely affecting the quality of sunflower seed oil (Badawi *et al*., 2020).

Shelf Life of the Blended Vegetable Oils with Antioxidant

The shelf lives of the blended vegetable oils with antioxidants is given in the table XXIII and discussed below.

Table XXXIII

Shelf Life of the Blended Vegetable Oils with Antioxidant

Days	BOGN-I	BOGO-II	BOSF-III	BOSFO-IV	BOFO-V	BOEP-VI
0th	0.57	0	0	1.85	2.67	1.13
7th	3.39	0.76	0.95	5.30	4.95	3.06
14th	7.01	2.01	3.40	7.12	7.26	7.31
21st	11.09	4.12	6.43	11.11	10.92	11.10
28th	13.52	7.14	8.87	15.36	14.98	14.27
35th	15.19	10.32	10.71	16.10	-	-
42th	16.54	14.72	11.41	-	-	-

49th	-	14.72	15.97	-	-	-
56th	-	16.21	-	-	-	-

Note: BOGN-I – Groundnut oil-50 ml + gingelly oil-12.5 ml + sunflower oil-12.5 ml+ safflower oil-12.5 ml +flaxseed oil-12.5 ml, BOGO-II- Gingelly oil-50 ml + groundnut oil-12.5 ml + sunflower oil-12.5 ml + safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOSF-III-Sunflower oil-50 ml + groundnut oil-12.5 ml+ gingelly oil-12.5 ml+safflower oil-12.5 ml + flaxseed oil-12.5 ml, BOSFO-IV – Safflower oil-50 ml+ groundnut oil-12.5 ml+gingelly oil-12.5 ml+ sunflower oil-12.5 ml+ flaxseed oil-12.5 ml, BOFO-V-Flaxseed oil-50 ml, groundnut oil-12.5 ml+ gingelly oil-12.5ml+ sunflower oil-12.5 ml+ safflower oil-12.5 ml, BOEP-VI- Groundnut oil-20 ml + gingelly oil-20 ml + sunflower oil-20 ml + safflower oil-20 ml and flaxseed oil-20 ml.

The shelf life of formulated blended vegetable oil with antioxidants was observed to be35-49 days for BOFO-IIindicating a better oxidative stability against rancidity. Through addition of antioxidants showed varioation in the peroxide levels, it did not greatly influence the keeping quality of oil. Oxidative stability of the blended oil treated with antioxidents was found to be better in blends of groundnut and gingelly oil compared to sunflower, safflower and flaxseed oil.