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Summary and Conclusion

Dietary patterns are changing globally, with a noticeable decline in the composition of coarse grains, staple cereals, pulses, alongside an increase in the intake of animal-based foods, sugars, salts, Fats/ oils, refined grains, and processed products, while these changes are unfolding at varying rates across regions and populations, they are progressing most rapidly in the developing world. The consumption of salt, sugar and fats especially from processed foods is skyrocketing in middle income countries including India. Whereas it is staple in high income countries. The Global Panel on Agriculture and Food Systems for Nutrition has emphasized the need for high- quality diets across populations. Despite advancements in the dietary habits of the global population there is still an existence of low quality diets in several regions. Diets deficient in essential nutrients and overloaded with harmful components are now recognized as the leading risk factor for the global burden of disease (Tufford *et al*., 2023).

Cooking oils take a crucial part in our daily nutrition as they are widely used in a variety of cooking methods, including baking, sauteing, marinating, frying, dressing and extrusion cooking. These oils come from diverse sources, such as palm, peanut (also known as groundnut oil), coconut, avocado, fish, flax, soybean, canola, sunflower, olive, corn, sesame, and other vegetables. Essential for a balanced diet, cooking oils are key sources of lipids, which provide energy, contribute to cell membrane integrity, and are fundamental in hormone production. Additionally, the nutritional value and health benefits of these oils are significant, largely due to their fatty acid profiles, which balance saturated, monounsaturated, and polyunsaturated fats, and their natural antioxidants, including vitamins A, E, and carotenoids. These antioxidants help shield cells and tissues from oxidative damage caused by free radicals (Lat., 2019).

Numerous studies have shown that an imbalanced ratio of omega-3 (ω-3) to omega-6 (ω-6) polyunsaturated fatty acids (PUFAs) is linked to the onset of various health issues, including vascular diseases, cancer, osteoporosis, autoimmune diseases, cognitive decline, and dementia (Wong *et al*., 2016).

According to nutritionists, a single oil would not be sufficient to provide the ideal blend of fatty acids in triacylglycerol (TG) oils and fats. So the best way to create healthy vegetable oil that can help prevent and treat diseases brought on by FA imbalances is to combine various types of oils. The use of Blending Oils (BO), which are high in oleic acid and omega-3 Polyunsaturated and low in omega-6/omega -3 FA ratios and SFAs, may assist to address the fatty acid imbalances seen in modern civilization diets (Uriho *et al*., 2019). Hence the primary objective the primary objective of the study is to "Formulate Blended Vegetable Oils and Investigate their Fatty Acid Profile in Cooked Products"

The study was conducted in four phases:

In phase I, a fats and oil consumption survey was carried out. The city of Coimbatore was selected using convenience sampling. Using Cochran's formula; 272 households were selected to study the consumption of fats and oils using convenient sampling. Since this phase was carried out during the COVID-19 outbreak, data on the consumption of fats and oils was collected only from 196 households. Female members from the selected household were taken as respondents. An interview schedule was pre-tested and validated to collect the background information on age, sex, type of family, number of family members, education, and occupational status. Using a modified Kuppuswamy scale (2022) the socio-economic status of the selected family was assessed. The information on the quantity of fats and oils purchased and consumed per month was collected using the inventory method. The average consumption of oil per day per household was calculated.

To elicit information on the availability of different types of oil, with particular reference to the availability of blended vegetable oils, a market survey was conducted in all four geographical regions of Coimbatore. Eight commercial and wholesale outlets comprising two outlets from each region were selected using purposive sampling techniques. An observation checklist was constructed, and information on the availability of different oil types and brands of oils, their product and nutrition labeling, and the market availability were elicited.

In phase II, five vegetable oils, three oils namely groundnut, gingelly, and sunflower oil, that are commonly consumed, and two oils, safflower, and flaxseed, with high polyunsaturated fatty acids and health benefits, were selected for blending. A total of six blended oils were formulated. The blended oils were then tested for their sensory

(9 point hedonic scale), physical properties namely colour (Gowegroup Multitesters digital food colour card reader), Refractive Index (AOAC 17th ED, 2000), Density (AOAC 17th ED, 2000), Solubility, Viscosity (AOAC-2000) Smoking point (Thermopro), viscosity (AOAC-2000) and chemical properties namely peroxide value (Peroxide value (FSSAI 02.042:2021), Iodine value (FSSAI 02.010:2021), Saponification value (FSSAI 02.042:2021), Acid value (FSSAI- 02.009:2021), Free fatty acids (FSSAI 02.042:2021).

In phase III the fatty acid profile of all six formulations of blended vegetable oil was studied using the Gas Chromatography – Flame Ionization Detection method adhering to the standard procedure. The sample was injected into GC-FID. The presence of fatty acids was identified in a chromatogram by comparing their retention time to that of the corresponding peak. The samples were analyzed in triplicate.

To investigate the fatty acid profile of blended oils in cooked products, common cooking methods, namely deep frying, pan frying, and sauteing, were chosen. Three recipes, namely vadai, chapatti and potato poriyal were standardized, and the products were cooked in measured quantity of oils. Fat from cooked products was extracted (Soxhlet extraction) and the fatty acid profile of the absorbed fat was analyzed (GC-FID).

The salient findings are

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

A) Survey on Household Consumption of Fats and Oils

- The age of the selected female respondents was between 25-55 years.
- Fifty-three percent of the respondents were found to have completed their undergraduate level of education.
- The monthly income of 37% of households ranged between Rs.18, 953 to Rs. 31,590.
- Out of 196 households, 48% of households belonged to upper lower socio-economic status. None of the selected households belonged to the upper class.
- Consumption of groundnut oil was found to be maximum (108 ml/d), followed by sunflower oil (87 ml/d). However, palm oil consumption was seen in 50 households.

- The quantum of monthly purchase of oil was found to be high in upper-middle income and lower-middle income class. Also a higher quantum of consumption of palm oil among lower-income households was observed.
- Per day consumption of groundnut oil (80 ml/d) and gingelly oil (6 ml/d) was found to be low among the lower income group, at the same time consumption of palm oil (375 ml) was found to be high in the lower income group.

B) Market Survey on Availability of Blended Vegetable Oils

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

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

- The refractive index of blended vegetable oils ranged between 1.45 and 1.46. No significant difference between the six blended oils and stand-alone oils was observed.
- The density of blended vegetable oils ranged between 0.92 g/ml and 0.98 g/ml. The BOSFO-IV (0.92 ± 0.11g/ml) with 50 ml of safflower oil had a lower density than other blended vegetable oils.
- On the whole the viscosity of all the formulated blended oil ranged between 48.67 ± 1.15 to 69.33 ± 9.81. The viscosity of blended oil BOFO-V (52.00 ± 1.73) and BOEP-VI (53.00 ± 1.73) was reported to be similar indicating a uniform thermal behavior while heating.
- All the stand-alone oil and formulated blended vegetable oils were observed to be soluble in water, chloroform, petroleum ether and ethanol.
- The smoking temperature of blended vegetable oils ranged between 157ºC and 194.4ºC. The lowest smoking temperature was observed for BOFO-V (157^0C) with 50 ml of flaxseed oil and 12.5 ml each of groundnut, gingelly, sunflower and safflower oil and the highest smoking temperature was observed for BOGN-

I (194.4ºC) with 50 ml of groundnut oil and 12.5 ml each of gingelly, sunflower, safflower and flaxseed oil.

- All six blended oils were tasteless, and the BOFO-V with the 50 ml of flaxseed oil and 12.5 ml each of groundnut, gingelly, sunflower and safflower had a fish odor which intensified while heating. The texture of all blended vegetable oils was light and non greasy.
- The colour of the BOGN-I and BOSFO-IV was found to be dark yellow and BOSF-III and BOFO-V were found to be light yellow.
- On the whole the peroxide value of all the formulated blended oil was observed to be more or less similar with the values ranging between 0.003 ± 0.05Meq/kg to 0.06 ± 0.05 Meq/kg). A significance difference in the peroxide value between the blended vegetable oil and stand-alone oil was observed at 1% level of significance indicating a better oxidative stability.
- The iodine value of stand-alone oils ranged between 84 mg KOH/g and 150 mg KOH/g. The highest iodine value was observed for safflower oil (150.33 ± 0.58 mg KOH/g). A significant increase in iodine value was observed between the formulated blended vegetable oils and stand-alone oils at a one percent level of significance.
- The saponification value of blended vegetable oil ranged between (190.67 ± 0.58 mg/KOH to 261.67 ± 0.58 mg/KOH).
- The acid value of blended vegetable oil ranged between 1.36 ± 0.00 and 2.21 ± 2.02mg KOH/g. The lowest acid value was reported in BOFO-V (1.36 ± 0.00 mgKOH/g), followed by BOSFO-IV (1.92 ± 0.017 mgKOH/g).
- The free fatty acid level of blended vegetable oil ranged between 0.66±0.05 % to 1.11 ± 0.01% and stand-alone oil ranged between (0.33± 0.00% to 5.52 ± 0.00%).
- In general, the overall acceptability level of the formulated blended vegetable oils was on par with the acceptability levels of the stand-alone oils.
- Also, out of the six formulations, BOFO-V comparatively obtained the lowest acceptability score (37.50 ± 0.23), which can be attributed to a distinct fish odor during deep fat frying.

- No significant difference in the overall acceptability score was observed at 1% level of significance for pan frying for BOGN-I (37.62 ± 0.5) and BOGO-II (38.08 ± 0.075), with that of the stand-alone oil namely groundnut oil (37.34 ± 0.24), gingelly (37.32 ± 0.26), sunflower oil (37.44 ± 0.42).
- The alpha-tocopherol content of BOSF- III (36.80mg/g) was higher, followed by BOSFO-IV (32.93mg/g) and BOGN-I (23.53mg/g). The least alpha-tocopherol content was observed in BOFO- V (2.80mg/g).

Phase III: Fatty Acids Profile of Blended Vegetable Oil

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

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

- For deep fat frying (Vadai), although the percentage of oil absorption of BOGN-I (24.20g) was similar to that of groundnut oil (24.83g), the quantum of absorption of saturated fatty acids was less (4.57g) than the groundnut oil (6.50g).Similarly the quantum of absorption of polyunsaturated fatty acids was found to be greater (10.02g) than groundnut oil (7.44g).
- For deep fat frying compared to groundnut oil (29.649%), the presence of methyl linoleate was found to be high in all the blended vegetable oils. The percentage of peak areas of BOSF-III (49.714%) for methyl linoleate was found to be similar to that of sunflower oil (49.234%). BOGO-II (22.450%) reported a higher percentage of peak area for methyl eicosenate. Also the blended vegetable oils BOSFO-IV (1.29g) and BOGN-II (1.46g) reported a lesser percentage of saturated fats.

- For pan frying (Chapatti), the oil absorption of blended vegetable oils ranged between 4.08g to 12.56g. The least oil absorption was noted in BOSF-III (4.08g), followed by BOSFO-IV (5.15g) and BOFO-V (5.77g). The highest absorption was noted in BOEP–VI (12.56g). BOSF-III reported the least PUFA (1.21g) content. The percentage of trans fat was found to be <0.1g in all blended and stand-alone oils.

- For pan frying (Chapatti), all the six blended oils in this study reported a lesser percentage of peak area for all the saturated fat. Though methyl oleate was found to be higher in BOSF-III (45.147%) followed BOEP-VI (39.733), it was found to be lesser compared to all stand- alone oils.

- For sautéing (potato poriyal), the oil absorption of blended vegetable oils ranged between 4.72g to 26.33g. The least oil absorption was noted in BOGN-I (4.72g), followed by BOGO-II (5.61g) and BOFO-V (8.76g). The highest absorption was noted in BOSFO–IV (26.33g). BOGN-I reported the least PUFA (1.94g) content. The percentage of trans fat was found to be <0.1g in all blended and stand-alone oils.

- For sautéing (potato poriyal), the presence of methyl linoleate was found to be higher in BOSFO-IV (55.812%) followed by BOSF-III (47.860%) compared to gingelly oil (37.983%) and groundnut oil (34.151%).

- The shelf life of formulated blended vegetable oil (BOGN-I) without antioxidant reported 49 days of shelf life.

- The shelf life of formulated blended vegetable oil with antioxidants also reported 35-50 days of shelf life in general blended oil BOFO-II reported maximum shelf life of 49 days.

Conclusion

The chemical properties of the blended vegetable oils reported better oxidative stability compared to stand-alone oils. The sensory attributes of all the blended vegetable oils were in par with the stand-alone oils and hence can serve as an alternate cooking medium. The BOSF-III and BOSFO-IV were found to be superior in physical and chemical properties. Also, the above two blends reported the least oil absorption in

cooked products and were found to be low in saturated fats, and high in MUFA and PUFA. Hence it can be recommended as healthier oils compared to stand-alone oils.

Limitations

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

Recommendations

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