1

Introduction

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 processes 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).

Good or bad diet is always associated with the intake of fat as it plays a mighty role in the onset of non-communicable diseases. Dietary oils and fats are vital components of food since they greatly influence the flavor, taste and overall quality of the dish while also being very beneficial to health. Oil is full of fatty acids, especially saturated and unsaturated fatty acids (Juric *et al*., 2022: Sura *et al*., 2020).

Fat/oils plays a major role in human health as it contains saturated fatty acids, monounsaturated fatty acids, polyunsaturated fatty acids and triglycerides. The essential fatty acids are not synthesized in our body, it can only be obtained from dietary sources (Nagy & Tiuca., 2017). Healthy fats, irrespective of their origin from animal or plant sources, have a major role to play in pathogenicity and etiology of both communicable and non-communicable diseases (Onishi *et al*., 2020).

As rightly pointed out by Ferraz *et al*., (2024) eating a diet heavy in trans fats, red or processed meat, sugar-sweetened drinks (SSB) and sodium combined with a diet deficient in whole grains, nuts, seeds, fruits, vegetables, fibers, legumes, omega-3 fatty acids, PUFA, milk and calcium are the potential dietary risk.

Appraisal of dietary practices is receiving more attention in recent years since, common risk factors for most non-communicable diseases (NCDs) are directly or indirectly linked to dietary consumption. According to Billingsley *et al*., (2018) eating a diet high in unsaturated fatty acids and good fats may help to avoid metabolic illness and lower the risk of cardiovascular diseases.

The human body utilizes dietary oils and fats for three main functions namely: as a source of energy, a structural component and as precursors for potent biological regulations (Chen *et al*., 2023). Edible oils, derived from plant based sources such as oilseeds, are rich in antioxidants and phenolic compounds, making them important components of our daily cooking.

Cooking oils play a crucial role in our daily nutrition as they are widely used in a variety of cooking methods, including frying, baking, sautéing, dressing, marinating and extrusion cooking. Indian culinary style uses oil from diverse sources, such as palm, peanut (also known as groundnut or arachis oil), coconut, avocado, 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 acids profiles, which balances saturated, monounsaturated and polyunsaturated fats and their natural antioxidants, including vitamins A, E and carotenoids (Lat, 2019)

The edible oil industry constantly strives hard to produce oils that are flavour-neutral, light coloured and both physically and oxidatively stable to meet consumer expectations and industry standards. Crude edible oils typically do not fulfill these criteria because they contain high amounts of non-glyceride compounds, with olive oil being an exception. These non-glycerides are typically eliminated through various processes collectively known as refining (Belur *et al*., 2017).

Numerous studies have shown that an imbalanced ratio of omega-3 to omega-6 Polyunsaturated Fatty Acids (PUFA) is linked to the onset of various health issues, including vascular diseases, cancer, osteoporosis, autoimmune diseases, cognitive decline and dementia (Wong *et al*., 2016). To address this, several countries have formulated dietary guidelines regarding fat consumption. The Food and Agriculture Organization

(FAO) recommended, total fat intake not surpassing 35% of daily caloric intake, with Saturated Fatty Acids (SFA) kept below 10%, Polyunsaturated Fatty Acids (PUFA) ranging from 6% to 11% and Monounsaturated Fatty Acids (MUFA) maintained between 14% and 19% (Nehdi *et al*., 2019).

Indian diet greatly uses plant based oils such as groundnut oil, gingelly oil, sunflower oil, safflower oil and palm oil as their main source of cooking medium. Researchers have constantly explored the health benefits of these oils, time and again for their functional and nutraceutical properties.

Groundnut oil is frequently utilized as a main cooking medium in Indian Cuisine, for varied cooking processes such as deep fat frying, shallow frying and pan frying because of its high smoke point (229.4^0 C), longer shelf life and high polyunsaturated fatty acids content, (Gunstone, 2011).

Up to 80% of groundnut oil is made up of two fatty acids: linoleic acid (PUFA) and oleic acid (monounsaturated fatty acids, MUFA). The remaining 20% is, made up of lignoceric, gadoleic, arachidic, behenic and palmitic acid. A lower incidence of diabetes, gallstones and coronary heart disease has been linked to consumption of groundnut oil (Ojiewo *et al*., 2020).

Similarly, in India, the market for gingelly oil has experienced significant growth in recent years, a trend expected to continue from 2022 to 2032. Its widespread consumption is driven by its numerous health benefits (Oboulbiga *et al*., 2023).

Gingelly oil primarily contains linoleic acid (37-40%), oleic acid (35-43%), palmitic acid (9-11%) and stearic acid (5-10%), together with trace amounts of linolenic acid. Antioxidants and bioactive substances such as phenolics, phytosterols and phytates are also found in good amounts in sesame seeds. They are also high in short-chain peptides and Polyunsaturated Fatty Acids (PUFA). Because gingelly oil contains a high concentration of sulfur containing amino acids and phytosterols, it also has specific significance in lowering cholesterol levels (Pathak *et al*., 2014).

Sesamin in gingelly oil demonstrates not just anti-hypertensive qualities but also anti-atherogenic, anti-thrombotic, anti-obesity and lipolytic effects (Dalibalta *et al*., 2020).

Sesame seeds possess bioactive components such as phytosterols and lignans, which contribute to their therapeutic advantages (Mohammed *et al*., 2022).

Sunflower is considered as a functional food or nutraceutical because of its oleic acid (30%) and linoleic acid (59%) content. Pharmacological studies have shown that sunflower possesses therapeutic properties for various ailments (Adeleke *et al*., 2020).

Sunflower oil is a good source of manganese, vitamins, tocopherols, phytosterols, triterpene glycosides, glutathione reductase, carotenoids, phenolic acids, flavonoids, peptides, alkaloids, tannins and saponins.

India leads the world in producing safflower oil, alongside other minor oilseeds such as sesame. The composition of safflower oil varies globally due to differences in varieties, soil and climatic conditions. Consequently, when introducing a new crop like safflower to a regional cropping system, it is crucial to understand how it performs under specific local environmental conditions. Because of its chemical composition, Safflower oil demonstrates significant neutraceutical properties, such as anti-diabetic, thermogenic, cardio-protective, anti-inflammatory , antioxidant and cytotoxic activity for particular tumor cells. These attributes make Safflower oil a promising ingredient in Indian cooking (Ergonul *et al*., 2020).

The lignans and flavonoids present in safflower oil act as phytoestrogens, a plant derived compounds with effects similar to estrogen that are anti-carcinogenic and hypocholesterolemic in nature (Ergonul *et al*., 2020).

The FSSAI and ICMR have recently recommended using flaxseed oil in cooking due to its high lignin content, which functions as an antioxidant (Grover *et al*., 2021). Flaxseed a rich source of omega-3 PUFA (ALA), lignans, proteins and dietary fibers, is a highly valued food ingredient. Alpha – linolenic acid in flaxseed positively affects blood lipids, leading to notable reductions in plasma total cholesterol, LDA cholesterol and VLDL cholesterol (Dzuvor *et al*., 2018: Nowak *et al*., 2023 and Tang *et al*., 2023).

Though oils are loaded with salient functional properties, most Vegetable Oils do not confirm to the Fatty Acid (FA) profile recommended by the World Health Organization (WHO), although they are high in Polyunsaturated Fatty Acids (PUFAs), as

they are prone to lipid oxidation. This oxidation leads to rancidity, diminishing the nutritional profile of the oil. Consequently, vegetable oils can be tailored to produce antioxidant rich Blended Oil (BO) with enhanced Oxidative Stability (OS) during storage (Rabail *et al*., 2021).

Dietary intake of saturated fats has been linked to increased levels of Low Density Lipoprotein (LDL) , which in turn is associated with a higher risk of Cardiovascular Disease (CVD). This connection, along with findings from epidemiological studies and clinical trials, has shaped long standing public health guidelines recommending a reduction in saturated fat consumption to help prevent CVD. However, the relationship between saturated fat and CVD risk is still debated, partly due to the inherent limitations of the clinical studies that have investigated this issue (Valk *et al*., 2022).

Replacing saturated fat with monounsaturated fat has been linked to lower total and LDL cholesterol levels. However, the degree of the reduction is slightly lower than when replacing it with polyunsaturated fats (Borges *et al.,* 2020).

In the chains of saturated fatty acids, there are no double bonds (Zhou *et al*., 2022). According to recent UK National Institute for Health and Care Excellence (NICE) recommendations, individuals who are at high risk of developing or already have CVD should "eat a diet in which total fat intake is 30% or less, total energy intake from saturated fats is 7% or less and intake of dietary cholesterol is less than 300 mg/day where possible saturated fats are modified by monounsaturated and polyunsaturated fats" (Wright *et al*., 2022).

Monounsaturated Fatty Acids (MUFAs) and Polyunsaturated Fatty Acids (PUFAs) are abundant in vegetable oils derived from different plant seeds. The unique physical and chemical characteristics of the oils have limited the range of technical applications. Therefore, the most common modifications are hydrogenation, fractionation, intersterification and blending. One of the precise ways to create novel, targeted products with the required texture, nutritional and oxidative qualities at a reasonable prize and better industrial use is to blend vegetable fats and oils with diverse compositions and capabilities (Pattnaik *et al*., 2022).

There are two major groups of PUFAs that are important to human health: omega-6 and omega-3 PUFA. Linoleic acid (LA, 18:2ω-6) and α-linolenic acid (ALA, 18:3ω-3) are the most common PUFAs found in diets. Animals cannot produce LA or ALA; hence they are considered necessary fatty acids. LA and ALA are abundant in plant based meals due to their synthesis. Many seeds, nuts and plant oils, such as safflower, sunflower, pumpkin seeds; walnuts, and flaxseed oil contain LA (Borasio *et al*., 2022).

Polyunsaturated fatty acids have a crucial role in brain and heart development, as well as tissue and organ stability. Numerous research groups throughout the world are focusing on studies into the dietary deficiency of omega-3 fatty acids, as well as the specific roles of omega-6 and omega-3 (Arnoldussen *et al*., 2014). High omega-3 PUFA content is associated with fewer morning stiffness, swelling joints, discomfort and disease activity. (Brouwers *et al*., 2015).

Healthy fats, particularly Polyunsaturated Fatty Acids (PUFAs), play a pivotal role in modulating immune cell activity by altering the Fatty Acid (FA) content of these cells. Polyunsaturated fats are essential in managing inflammation within the body (Khalaifah *et al*., 2020). Low intake of essential fatty acids has been linked to a variety of health issues, including dermatitis, renal hypertension, mitochondrial activity abnormalities, CVDs, type 2 diabetes, delayed brain development, arthritis, depression and lower immunity to infections (Djuricic *et al*., 2021).

There's growing global interest in exploring the potential health benefits of edible fats and oils, particularly in relation to chronic diseases, given the close connection between diet and inflammatory response. Polyunsaturated Fatty Acids (PUFAs) such as Eicosapentaenoic Acid (EPA) and Docosahexaenoic Acid (DHA) found in flaxseed oil, can be transformed into oxygenated bioactive lipids that exhibit anti-inflammatory and/or pro-resolving properties. Additionally, the combination of phenolic compounds and vitamins present in edible oils may help prevent chronic diseases by exerting anti-inflammatory, antioxidant, neuroprotective and immune modulatory effects (Mazzocchi *et al*., 2021).

Grover *et al*. (2021) observed that the fatty acid compositions of commonly used vegetable oils often deviate from recommended standard specifications. Achieving the

ideal combination of fatty acids in the triacylglycerol (TG) of oils and fats in a single oil is a challenge.

According to nutritionists, single oil would not be sufficient to provide the ideal blend of fatty acids in triacylglcerol (TG) oils and fats. The fatty acid contents of several widely used vegetable oils show an imbalance and do not align with the recommended dietary intake of essential fatty acids. It was observed that blending edible oils can improve the vegetable oil's physicochemical and sensory attributes as well as their oxidative stability (Kiralan *et al*., 2017). Vegetable oil and fat varieties differ in composition and are crucial to the functional, sensory and financial aspects of food and food products (Wen *et al*., 2023). To obtain vegetable oils with the best fatty acid content and storage stability and to create the desired quality, the blending of oil was approved by the Government of India in 2006. The peroxide, free fatty acid and acid values of the oils are all reduced during this process (Prathibha *et al*., 2018).

One straightforward and different approach to accomplish this is to create Structural Lipids (SLs) from various oils or create a physical mixture of various oils in the appropriate ratio.

In general, diverse vegetable oils are combined to create edible blended oils, which vary in price and nutritive value. It's critical to precisely quantify the amount of vegetable oils included in blended oils since the right proportions of vegetable oils in the diet can deliver the right nourishment (Xu *et al*., 2016).

Blending oils can lower blood levels of triacylglycerol and cholesterol, in addition to providing a balanced fatty acid profile (Li *et al*., 2020). Blending is a straightforward, practical and cost- effective strategy to improve the physiochemical and nutritional qualities of oil (Dhyani *et al*., 2018). Blending oils to create a new vegetable oil with desired health advantages is a popular procedure. Many studies have shown that using the right oil mixes can lower cholesterol and triacylglycerol levels in the blood and liver (Jan *et al*., 2016).

It also regulates omega-3 and omega-6 polyunsaturated fatty acids ratio and high oleic acid content (Saini *et al*., 2021).

Improved physiochemical properties are another advantage of oil blending leading to greater oxidative stability, better suitability for frying and more neutral flavours that are widely accepted. Additionally, blending oils makes it easier to achieve the right combination and proportion of oils compared to rotating different oils in a home setting (FSSAI, 2011). The Dietary Guidelines for Indians by National Institute of Nutrition (NIN) (2011) suggest mixing different oils to achieve a healthier omega-6 to omega-3 ratio. Recommended combinations include blending groundnut, sesame or rice bran oil with canola oil or with soybean oil. Another suggested combination is palmolein oil with soybean oil. Additionally, blending safflower or sunflower oil with palmolein oil is also recommended. These combinations are designed to balance fatty acids in the diet, improving nutritional intake (Misra *et al*., 2011).

Consumption of Blended Oils (BO), particularly those in Oleic Acid (OA) and omega-3 Polyunsaturated Fatty Acids (PUFAs), may help rectify the fatty acid imbalances commonly observed in modern diets, which tend to be high in omega-6 to omega-3 FA ratios and Saturated Fats (SFAs) (Kaseke *et al*., 2021 and Uriho *et al*., 2019).

Blending oils can enhance their natural antioxidants, Monounsaturated fatty Acids (MUFA), and Polyunsaturated Fatty Acids (PUFA), which in turn could have positive impact on health of individuals (Ramroudi *et al*., 2022).

Objectives

Primary Objectives

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

Secondary objectives

The secondary objectives is to

- study the consumption of fats and oils in selected households of Coimbatore.
- survey the market availability of blended vegetable oils.
- formulate blended vegetable oils and to assess their quality attributes.

- analyze the fatty acids profile of the formulated blended vegetable oils and
- to investigate the fatty acids profile of products cooked using the formulated blended vegetable oils.

Null Hypotheses

- Hypothesis$_{01}$ There is no significant difference in the refractive index of the formulated blended vegetable oils with that of stand-alone oils
- Hypothesis$_{02}$ There is no significant difference in the density of the formulated blended vegetable oils with that of stand-alone oils
- Hypothesis$_{03}$There is no significant difference in the viscosity of the formulated blended vegetable oils with that of stand-alone oils
- Hypothesis$_{04}$There is no significant difference in the organoleptic acceptability level of the formulated blended vegetable oils with that of stand-alone oils.
- Hypothesis$_{05}$ There is no significant difference in the peroxide value of the formulated blended vegetable oils with that of stand-alone oils
- Hypothesis$_{06}$There is no significant difference in the iodine value of the formulated blended vegetable oils with that of stand-alone oils
- Hypothesis$_{07}$ There is no significant difference in the saponification value of the formulated blended vegetable oils with that of stand-alone oils
- Hypothesis$_{08}$ There is no significant difference in the acid value of the formulated blended vegetable oils with that of stand-alone oils
- Hypothesis$_{09}$ There is no significant difference in the free fatty acid profile of the formulated blended vegetable oils with that of stand-alone oils