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Integrated Policy Strategies and Regional Policy Coordination for Resilient, Green and Transformative Development: Supporting Selected Asian BRI Partner Countries to Achieve 2030 Sustainable Development Agenda

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Micro-sectoral analysis of Vegetable Oil and Ghee Industry

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Introduction

Pakistan is the world's 8th largest consumer of edible oil. An average Pakistani consumes 18 kilograms of ghee/cooking oil per year, which is 6 times higher than an average of 3 kilograms per capita across Europe (Bilal, 2022). As per the State Bank of Pakistan, the demand of Edible oil has been increasing due to growth in population and GDP and the consumer preference for vegetable oil consumption. In Pakistan, the per capita consumption of edible oil is even higher than India and Sri Lanka (SBP, 2022). At consumer level, the edible oil market is composed of two broad categories, vegetable oil and vegetable/Vanaspati ghee. As per the HEIS 2018-2019, the consumption of vegetable ghee is higher compared to vegetable oil. Nevertheless, the increasing demand for vegetable oil/ghee is not solely driven by dietary consumption trends. The multi-sectoral use and industry interlinkages of oil seeds and vegetable oil with poultry and soap industry also drive its demand.

2. Current Situation and Trend

Cooking oil & vegetable ghee industry is a large manufacturing sector in Pakistan. There are more than 150 manufacturers, which are the part of the Pakistan Vanaspati Manufacturers Association that produce vegetable ghee and cooking oil (PVMA, n.d.). In 2011, these companies had combined production capacity of 2.8 million tons, which increased to 3.9 Mln MT in 2022 (CCP 2011). Edible oil import bill is the highest in trade value of all the food commodities imported and fourth largest in terms of overall import bill of Pakistan (PBS 2024).

In 2024, the vegetable oil and Ghee Industry was amongst the top five revenue contributors as per the FBR (Table 1).

Table 1. Edible Oil Industry Economic Value. (Source: PVMA, n.d.)

Contribution of the Industry	***Amount***
Annual turn over	*2400 Billion PKR*
Duties, taxes and levies	*550 Billion PKR*

The Vegetable oil and Ghee industry is majorly based on Palm Oil and Soybean seeds. Given the domestic production of edible oil seeds is insufficient to meet demand, Palm oil offers the most affordable alternative. However, this reliance on imported Palm Oil has become economically unviable due to increasing share in import bill (Figure 1). Hence, the efforts are being made to increase cultivation and production of edible oil seeds. Pakistan also exported oil and ghee to a few countries. Overall Pakistan exported 92,407 USD worth oil and ghee in trade value to the world, out of which it exports 16,356 to the UAE and rest to the Korea, Kazakhstan and other countries.

Table 2. Edible Oil 2022-2023. Source: PACRA Sectoral Study, 2023

EDIBLE OIL CONSUMPTION (PALM OIL, SOYBEAN OIL, RAPESEED, COTTONSEED AND SUNFLOWER OIL)	**3.9 MLN MT**
PERCENTAGE OF PALM OIL IN DOMESTIC CONSUMPTION	**75%**
PERCENTAGE OF COTTONSEED OIL IN DOMESTIC CONSUMPTION	**24%**

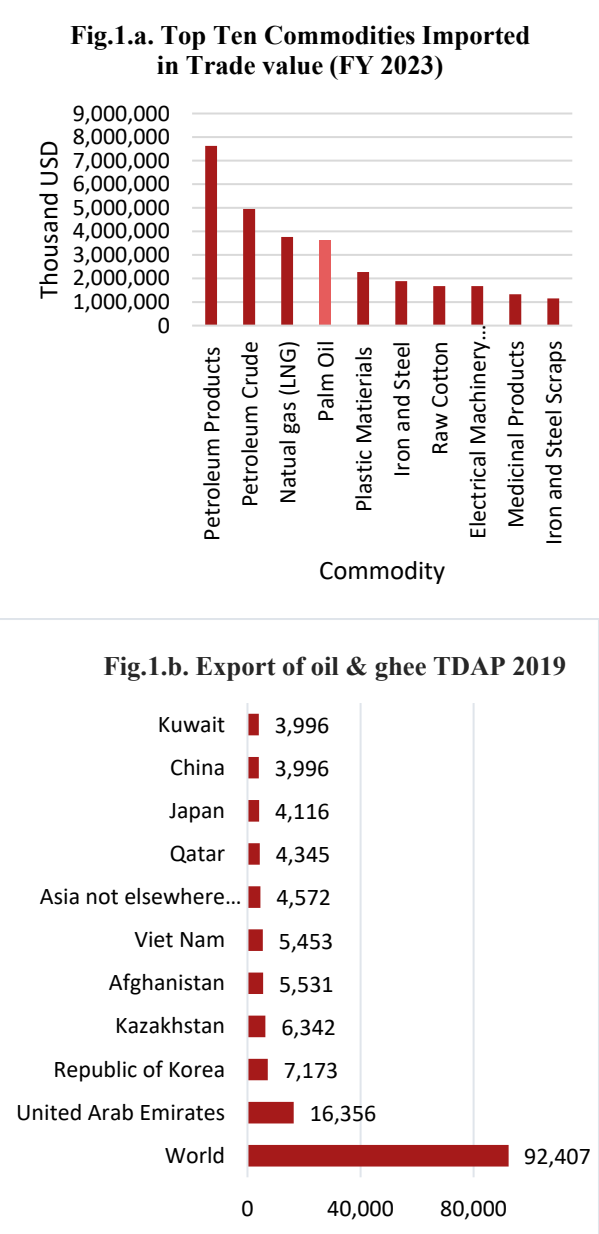

Figure 1. (a) Pakistan Bureau of Statistics (Import) (PBS, 2024) and (b) TDAP (Export) (Khalid, 2023).

2.1. Palm Oil

The import of refined palm oil in Pakistan were reported as second largest globally at 2.9 Million MT (see Figure 2 a. and b.). The WITS data further shows that the import of crude palm oil in Pakistan stood at 71 Million KG, ranking eighteenth globally, worth US

$ 2.809 Billion. The Palm Oil constituted 94% of all edible oil imports of Pakistan in FY22. billion) was imported. Local edible oil production during 2023-24 is estimated to be 0.471 million tons.

Fig. 2.a. Top five Importers of refined Palm Oil HS Code 151190 (WITS - 2023)

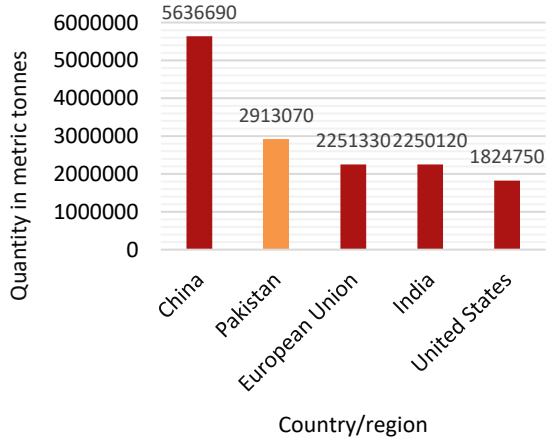

Fig. 2.b. Pakistan import Palm oil (excl. crude) | HS Code 151190 MT

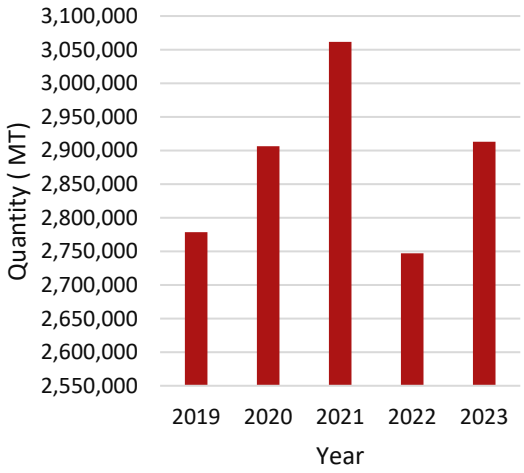

Figure 2. (a) and (b) Palm Oil import – Source: WITS 2023

2.2. Oil Seed

The production of oil seeds in Pakistan was 2.24 Mln MT in FY 2022-2023, whereas import of oil seeds in the same year was reported at 1.24 Million MT as per the USDA report on Oil Seeds. The decline in oilseed import was observed due to restrictions on Genetically Modified Organisms (GMO) Oilseeds in November 2022. The ban on GMO seeds however has been lifted in 2024 and it is expected that the import of oil seeds will increase to up to 2.1 Million MT in this fiscal year (USDA, 2024). The ban has been lifted at a time when GE seeds remain banned in France, Norway, Germany, Italy and Sri Lanka amongst others due to harmful effects on the environment. *The bio safety rules were amended to exclude requirement for local risk assessment of imported GMO seeds, recommended by article 15 of Cartagena protocol.*

Table 3. Statistics on import and domestic production of Oil Seeds in Million MT

OIL SEED CONSUMPTION (FY22-23)	QUANTITY IN MILLION MT
IMPORT OF OIL SEEDS (SOYBEAN, RAPESEED, SUNFLOWER) (USDA, 2024)	**1.24**
IMPORT OF SOYBEAN	0.942
IMPORT OF RAPE SEED	0.3
IMPORT OF SUNFLOWER	0.004
DOMESTIC PRODUCTION (CANOLA, RAPESEED, SUNFLOWER, COTTON SEED) (ECONOMIC SURVEY, 2024)	**2.24**
DOMESTIC COTTON SEED	1.29
DOMESTIC RAPESEED SEED	0.67
DOMESTIC SUNFLOWER SEED	0.13
DOMESTIC CANOLA SEED	0.14
EDIBLE OIL DOMESTIC PRODUCTION (BASED ON OILSEEDS CULTIVATED) (ECONOMIC SURVEY, 2024)	**0.5**

The production of domestic oil seeds is very low compared to the domestic edible oil demand. Amongst the oilseeds, on average cottonseed constituted 82% of domestic oil seed production from FY19-2022 (PACRA, 2024). Hence, despite governmental support to the domestic production of oilseeds, the increase in oil seed production is only marginal.

The industries in Pakistan mainly import soybean, which holds the highest share in oil seeds imported and used by the edible oil industry. The area under cultivation for soybeans in Pakistan decreased from 4.17 thousand hectares in 1995 to 0.12 thousand hectares in 2022. The production and cultivated area has decreased over the years however, the yield in terms of CAGR is positive at 1.86% (Khan et al., 2024).
Together with palm oil, soybean imports account for 7.1% of total import bill. As per a special report by State Bank of Pakistan, in terms of trade value soybean and palm constitute 90% of the oilseed import bill and 87% in terms of quantity (SBP, 2022). Apart from extraction of edible oil, soybean residue is also used as raw material in meals by poultry industry. Consequently, the ban on GMO soybean was protested both by poultry and vegetable oil associations (USDA, 2024).

Table 4. Ranking of Edible Oil/Seed in terms quantity imported, domestic production and consumption

Ranking of Edible Oil/Seed in terms quantity imported, domestic production and consumption		
Import	**Domestic Production**	**Consumption**
Palm oil	Cottonseed	Palm Oil
Soybean	Rapeseed	Soybean
Rapeseed	Sunflower	Canola
Canola	Canola	Cottonseed
Sunflower	--	Sunflower

Source: Developed by Author on the basis of Economic Survey of Pakistan and USDA statistics

The table above shows that vegetable oil and ghee industry is predominantly based on crude palm oil and soybean products. Therefore, in this study the analysis of green status focuses on palm oil and ghee manufacturing.

3. Policy landscape

3.1. Environmental Regulations

3.1.1. Recycling of waste cooking oil

In 2008, the Federal Government started National Biodiesel Programme to enhance the production of biodiesel. The government provided exemption on custom duty and GST for the procurement of biodiesel processing machinery to enable enough production to achieve the target of 10% blending of biodiesel in petrol diesel by 2025 (Ali et al., 2017). The promotion of biofuel production is also prescribed under the Alternative and Renewable Energy Policy 2011. There is an uptake now but still the production of biofuels (Biodiesel and Sustainable aviation fuel -SAF) in Pakistan remains very low, due to a poor infrastructure and mechanism for collection of cooking oil waste and proper municipal waste management. A close collaboration among the urban planners, waste management companies and bio-diesel producers is still not very well established. It is already a good progress that the Punjab Food Authority formulated Disposal of Waste Cooking Oil, Regulations 2017, to reduce the environmental and health impact from unsafe disposal and reuse of cooking oil. As mentioned above, many collectors now are active after getting the license from the Punjab Government for biodiesel production from waste oil to ensure that reuse of cooking oil and ghee in food supply chain is reduced.

3.1.2. Wastewater treatment from the industries

As the level of BOD and COD (key pollutants of edible oil industry) in dry season, far exceeds NEQ limitations, the waste water treatment has been made mandatory upon industries. The lack or poor treatment of industrial effluent is however not a universal problem in the industry. A large number of factories have installed the necessary machinery and adopted the processes to control/recycle it. During our visit to a large unit in Lahore, we would see such arrangements working and we were told that the regulatory agencies were now much more active than before. They however pointed out that many of the units find it hard to spend Rs. 80 million to install the machinery.

3.1.3. Health and Safety Regulations

The high consumption of Trans fatty acids (TFA) in Pakistan has been associated with high consumption of Vanaspati Ghee. The Federal and Provincial Food Regulatory Authorities and Quality Control Standards are devised to regulate concentration of TFAs in Vanaspati ghee (see table. 6). Apart from regulating the level of TFA in Ghee, studies recommend replacement Vanaspati with healthier fats and oil, and improved labeling on packaging (Tarar et al., 2020). The provincial and federal Food Authorities have also brought in mandatory legislation putting a ban on sale and production of loose and used oil. However, there are disparities in enforcement of these legislations amongst provinces (See table. 5). A study commission by the Food Fortification program in 2020 found that 28% of the oil consumed in Pakistan is from the informal sector and unregulated (See table 5) (E-Pact Consortium, 2021).

Table 5. Source: Nutrition International (2020). Rapid Market Assessment Study. Food Fortification Programme

Sectoral Market share as per degree of Formalization		*Production and Sale of Loose Oil*	
Degree of formalization	***Percentage share***	***Region***	***Percentage share***
Premium Brands	26%	Khyber Pakhtunkhwah	29.6%
Regional Brands	30.4%	Sindh (Excluding Karachi)	22.7%
Partially Refined & Packed	15.4%	Karachi	14.2%
Unrefined but Packed Oil	16.2%	South Punjab	13.5%
Loose Oil	12%	Balochistan	13.3%
		North and Central Punjab	6.69%

Table 6. Health and Safety Standards in Pakistan for Oil and Ghee

PSQCA Standards for Mandatory food Items				
Standard	**Oil/Ghee type**	**Limitation on Trans Fatty Acid**	**Concentration of Nickle**	**Reuse of Cooking Oil**
PS 2858 3rd Revision	Cooking Oil Blended		--	Banned for Cooking in entire Pakistan
PS 221 5th Revision	Banaspati	2g per 100g of total fat in conformity with WHO recommendation for TFA	0.2 mg/kg	
Provincial Regulations				
Sindh Food Authority Regulations (2018)	Banaspati	Less than 5% (Above WHO limit)		Banned for cooking.
Punjab Pure Food Regulations, 2018	Banaspati and Vegetable oil	Less than 0.5 % (Below WHO Limit)	0.025 Parts per million by weight	Banned for cooking. Licensing for Biodiesel production

Khyber Pakhtunkhwa (Food Standards) Regulations (2018).	Banaspati	Less than 5% Above WHO limit)		Banned for cooking.

The enforcement is also picking up, as according to the press reports, in January 2024, the Khyber Pakhtunkhwa Food Department sealed 21 mills and imposed heavy fines for selling unprocessed cooking oil that was harmful for the human health. KPK is introducing a new district system to better enforce governmental regulations, indicating the growing awareness in the bureaucracy to address the concerns of climate change and environmental pollution.

The newly introduced "National Hazardous Waste Management Policy, 2022" pledges to introduce environmental taxes for industry by incorporating the "Polluter Pays" in its Guiding Principles. This offers an opportunity to reduce industrial waste specially one polluting water bodies in Pakistan. Strengthening such policy frameworks will facilitate green transformation in production and design in manufacturing sector.

4. Diagnostic analysis

Pakistan faces major challenges in the way of imagining and practicing the greening of its ghee and cooking oil industry. Given the National Seed Policy 2024 and National Oilseed Enhancement Proramme both aim to reduce the import of oilseed, through domestic cultivation and production, our analysis also sheds light on the greening challenges with respect to cultivation enhancement, while primarily focusing on the processing, refining and packaging industry of this sector.
Sectoral greening challenges in this sector include land use in the cultivation phase, oil production processes, high consumption of ghee/oil and disposal and recycling of ghee/oil waste. Soybean, palm, sunflower, and canola oils emit 1.2 billion metric tons of carbon every year, which is double the emissions of all cars in the United States (Nobbs, 2023). In developing countries, the challenges are confounded due to poor regulatory systems, making the transition to towards greening much more difficult.

4.1. Domestic Cultivation of Vegetable Oil Seeds and Palm Kernel

A five year "National Oilseed Enhancement Proramme" was launched in Pakistan in 2023 to promote cultivation of canola, sunflower and sesame seeds through subsidy on seeds and inputs (Khan et al., 2024) with the aim of import substitution and self-sufficiency. At present, about 32% of the total oilseed consumption is domestically produced in Pakistan. There has been a decline in cultivation of oil seeds due to the comparative advantage of competing crops in cultivation (Anjum and Naz, 2024). The IUCN report on "The Future of Oil Seeds" highlights that edible oil crops constitute 37% of agricultural cultivation land use,

In the longer run, cultivation of oil seeds and palm should not be devoid of their environmental and ecological context. The land use changes associated with Edible oilseeds cultivation can lead to deforestation and loss of biodiversity if the system of production is not aligned with the principles of sustainable productivity (Figure 3).

impacting environment significantly when produced at industrial scale in poor regulatory environments (Meijaard et al., 2024).

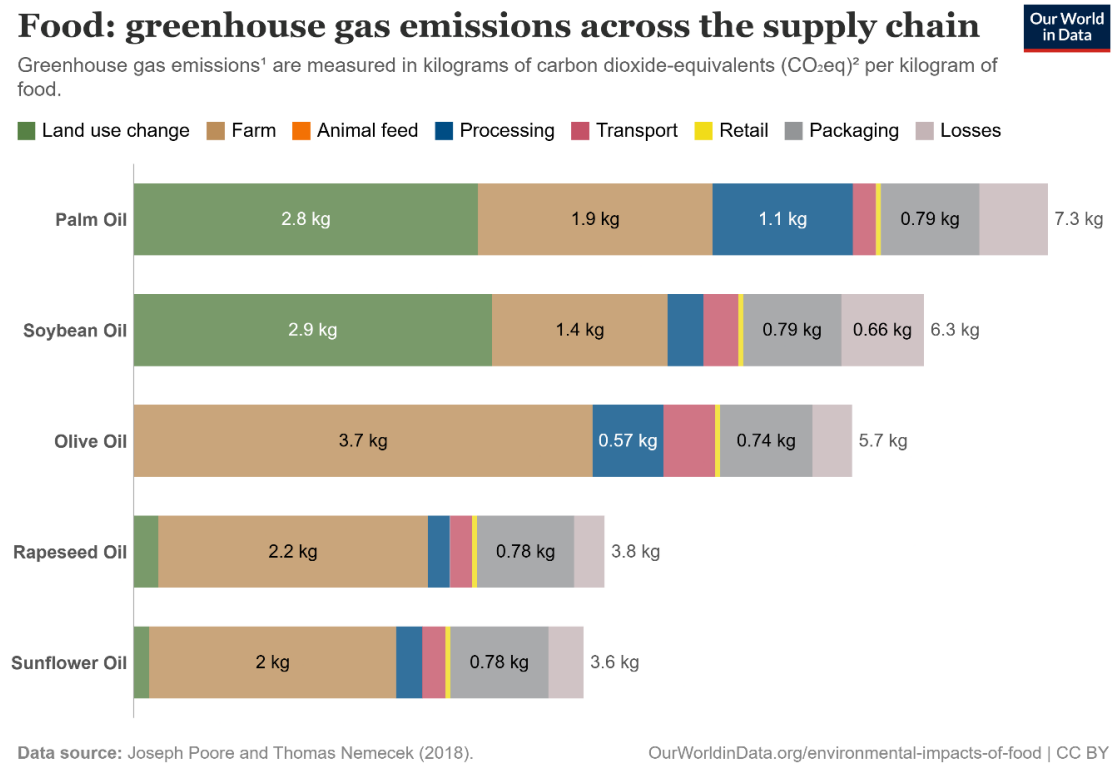

Figure 3. Vegetable Oil greenhouse gas emissions across the supply chain.
Source: Our World in Data

Palm oil crop produces the highest GHG emissions along its supply chain. [Figure 3] Hence, the domestic cultivation of Palm, if considered in the future should rather be based on sustainable models, such as Agroforestry. According to IUCN, if cultivation of vegetable crops consistently grows at good pace, they may have a critical impact on biodiversity (IUCN, 2024). The life-cycle assessment studies show that the highest environmental impact of vegetable oil comes from the cultivation phase (Avraamides and Fatta, 2008 for olive oil; Schmidt, 2010 for rapeseed and palm oil; Mattsson et al., 2000; Simone et al., 2009; Spinelli et al., 2012 for sunflower oil). In the case of Pakistan, where cultivation is on a very small scale it is currently not a major concern. We should be however, very agile to the growing negative environmental impact of refining and packaging, particularly, bleaching and wastewater, which could be very high, now and in the coming years given size of the sector (Nucci et al., 2014).

4.2. Green Status of vegetable oil refining and packaging industry

The supply chain of vegetable oil and ghee begins with extraction of oil from seeds or processing imported crude or refined vegetable oil. The production process of Palm Oil mainly involves refining, deodorizing, fortification and packaging. However, these processes involve multiple manufacturing processes and machineries resulting in waste and other byproducts.

The sourcing of raw material i.e. palm, soybean, canola and other seeds and oil is either through commercial importers or domestic grain market. The middleman in the case of locally produced seeds is involved in price exploitation in domestic grain market which disincentives farmer with low prices for their produce, according to a report by the State

Bank of Pakistan (SBP 2022). The role played by unfair trade practices across the supply chain has the potential of compromising the greening and SDG goals. It is likely that up until the farm gate, the production process is clean but the hoarding, price gouging, corruption and manipulation renders the supply chain un-green. The commercial practice artificially jacking up the cost of raw materials, which we discuss in detail in our Study on Wheat, forces other economic actors across the supply chain to cut corners by adulteration, counterfeits, omission of processes etc.

4.2.1. Environmental status: Emissions and Waste

The refining process of vegetable oils utilizes water at different stages of production. This results in generation of wastewater containing chemical compounds like phenol, heavy metals, catalysts used in the hydrogenation process, oxidizable substances, fats and oils. The Industrial Affluent and emissions are regulated as per the National and Provincial Environmental Quality Standards.

A study on industrial effluents from edible oil industries in Islamabad found that the concentration of Nickle in wastewater is well above the NEQ standard of 1.0 mg/L at the proportion of 13.67 mg/L. The same study finds that proportion of oil and grease also accedes the NEQ limit of 10 mg/L at 36 to 76 mg/L. The chemical oxygen demand (COD) of the effluent is very high and above the NEQ standards at 1012 to 2105 mg/L, whereas the NEQ standard is 150 mg/L (Afzal et al., 2016). The untreated effluent water from the industry in Islamabad/Rawalpindi region is dumped in Nallah Layi, from where it flows to the Indus river tributaries. Another study from Haripur district on vegetable ghee industries also found concentration of Nickle, total dissolved substance (TDS), total suspended substance (TSS) and COD and BOD levels in industrial waste to be above NEQ limits with per day 174 Kg of suspended load at 155.5 m3/day (Hussain, 2014). The high levels of COD and organic waste is harmful for the aquatic life and leads to eutrophication and anaerobic conditions.

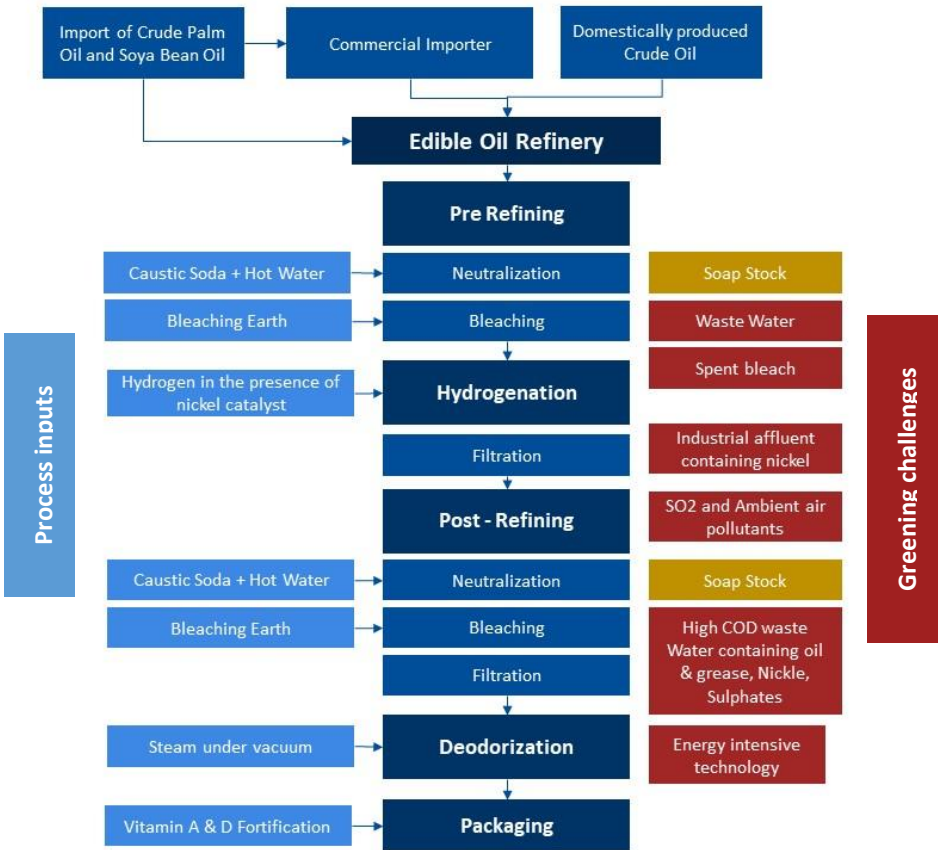

Figure 4. Vegetable Oil Refining Process (Author's Adaptation)

In Pakistan, only 1% of wastewater is treated, as reported by the Pakistan Council of Research in Water Resources (PCRWR), which monitors the quality of surface and ground water as well as impact of pollution on biota. As per PCRWR Report 2022, the quality of surface water is deteriorating due to untreated affluent from domestic, industrial and agricultural sources. The level of dissolved oxygen in Ravi River, feeding Lahore, is approximately zero the in dry reason and below permissible limits in river Soan, feeding Islamabad.

The deodorization process utilizes high energy due to use of inefficient technologies. Although some industries such as the IFFC are shifting towards alkaline closed loop vacuum system to reduce consumption of both water and energy. Besides the liquid waste, they also generated air emissions and solid waste. Solid waste generation is mainly in the form of spent earth, filter cloth and spent catalyst. In general, vegetable oil refining processes does not have significant air emissions. The air emissions are mainly generated from the boiler in boiler in production process, including chemical released during bleaching and deodorization.

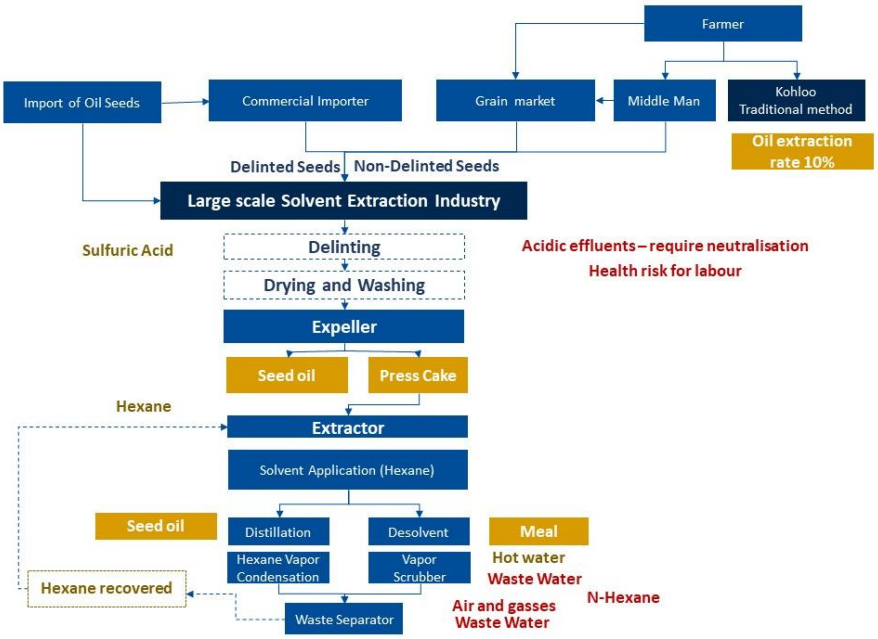

Figure 5. Seed Oil extraction Process in Pakistan (Author's Adaptation)

As for seed oil extraction, mainly conventional methods and technologies of solvent extraction and expeller methods are utilized in Pakistan. The Large Scale Solvent Extraction Industry mainly relies on Hexane solvent extraction methods due to high recovery rate. However, the process has a high environmental impact as illustrated in fig 5 and table 7.

Table 7. Seed Oil Extraction Methods Analysis

Seed Oil Extraction Methods Analysis						
Method	**GHG**	**Energy Consumption**	**Environmental Impact**	**Criteria Pollutants**	**Clean Production**	**Oil Recovery**
Expelling mechanical	Low	low	Low	low	High	Low
Hexane Solvent Extraction	Low	Low	High	Low	Low	High

4.2.2. Resource use: Energy efficiency and water consumption

There are many challenges in the refining process, excessive heat is needed to roast seeds and press under high temperature, while chemicals are added to retain aroma/fragrance of raw seeds during roasting, and next refining phase uses a lot of chemicals to reduce its acidic value while. Moreover refining process also often removes the substances which are beneficial for health and can be used in medicines and other industries, such as tocopherols, phospholipids, squalene, polyphenols and phytosterols. The excessive use of water in the refining process is also a matter of concern. Some industries have installed water treatment plants to reuse the same water in the same plant but such cases are very few.

Oil Seeds-based vegetable oils deliver less than 0.01% of the world's important nutrients, even though it covers 30% of global cropland (Our World in Data). This makes it necessary that micronutrients are added through fortification. The Food Authorities in Pakistan have started implementing the Standards in this regard much more aggressively than before, particularly in Punjab.

4.2.3. Recycling, reuse and disposal

The presence of used cooking oil and ghee in wastewater can harm aquatic life, as it forms a thin layer of oil and grease on the water's surface, blocking sunlight which is needed for photosynthesis and affects plant growth. Moreover, this oil layer also prevents oxygen from being absorbed in the water which threatens the aquatic life. A lot of used oil is unintentionally released into water bodies from the kitchens, including the restaurants, while washing dishes. A small amount of used cooking oil can contaminate large amount of water. According to some studies, 1 litre of waste cooking oil can pollute up to 25,000 litres of fresh water (Cargill, 2016).

At present, the used cooking oil is reused [a kind of recycling] to prepare inferior bakery items or restaurant food. In recent years, numerus regulatory actions have been undertaken by federal and provincial government to curb this menace. Reuse of once used oil at home is also a problem as the used oil e.g. after deep frying is then used to cook different dishes. Using the used oil once may not be problematic but reusing it too many times can be fatal for health as reheating cooking oil increase the production of harmful substances like polycyclic aromatic hydrocarbons (PAH) and 4-hydroxy-2-nonenal (HNE), that can increase the risk of heart diseases and cancer.

The recycling of used cooking oil by producing biofuels is also picking up in Pakistan. There are around ten biodiesel companies with a license from Punjab Food Authority to collect used cooking Oil to produce biodiesel (Business Recorder, 2023). Some of the large-scale industries engaged in biodiesel production are Bio Tech Energy Ltd (BTE), Total Parco, Mitsubishi and Euro Company. The BTE is pioneer in biodiesel production in Pakistan with a production capacity of 50,000 tons per annum (TPA) of biodiesel, entirely exported to Europe. The company has recently secured funding from Asian Development Bank (ADB) and International Financing Corporation (IFC) for expanding its biofuel production to Sustainable Aviation Fuel (SAF), up to a capacity to produce 200,000 TPA SAF through extended collection of both Used Cooking Oil (UCO), Soap Stock Acid oil from Vegetable oil refineries and other waste from edible oil refineries (Bio Tech, 2024). The BTE has an extended collection network across Pakistan. This model of circular economy principles is offering significant opportunities in greening of the vegetable oil and ghee industry of Pakistan.

However, the high cost of the technology required for recycling of Edible Oil Industry Wastes and Used Cooking Oil for biofuel production poses a challenge to upscaling this kind of recycling. Hence, as an alternative to domestic production of bio-fuels, some companies are exploring opportunities to export these wastes as bio feedstock. The United Limited Company has obtained certification from ISCC EU to export bio feedstock as bio-circular feedstock.

4.2.4. Social concerns for health risks

During the manufacturing of vegetable oil, undesirable compound could be formed such as glycidyl ester, 3-MCPD-esters, harmful trans-fatty acids, and polymeric triacylglycerols (Gharby, 2022). Some refined cooking oils might contain Erucic Acid, which is bad for heart, can cause lung cancer and may irritate skin (Thangavel, 2023).

The consumption of Palm oil has globally increased due to it being more affordable of the edible oils and high resource use efficiency of oil extraction per hectare of crop cultivation. However, it is the least healthy of edible oils due to the highest proportion of unsaturated fatty acids. Palm is used in margarine and vanaspati ghee production as well apart from vegetable oil. With the help of an analysis of five popular brands for the presence of trans-fatty acids [TFAs] in Vanaspati and Margarine, a study found that the margarine samples showed TFA levels from 1.56% to 23.99% while for Vanaspati ghee all samples had a TFA level above 5%, with values ranging from 5.36% to 33.03% (Tarar et al., 2020) way beyond the limit of 5 % set by PSQCA PS 221 for Vanaspati.

4.2.5. Challenges for lean practices in the sector

The government has become quite active on the quality and hygiene of the ghee and cooking oil industries but the enforcement of environmental regulations to transition towards green and clean industry is minimal. Same is the case with the industry. Pakistan Vanaspati Manufacturer's Association (PVMA) is seeking support from the government to grow oil seed crops at a larger scale and expand oil extraction to meet the domestic demand. However, the reduction of the overall environmental footprint of the industry is not yet very high on the political agenda. Another key challenge towards lean practices is the absence of large scale waste cooking oil collection systems. Also numerous small and medium sized industries have entered this sector, importing palm oil from different sources, refining and packaging it to sell in the domestic market.

5. Policy Recommendations

The demand of vegetable oil and ghee in Pakistan is consistently increasing calling for greening of oil refining and extraction processes as well as the supply chain of various vegetable oil sources. Moreover, for achieving the SDG 12 policy and regulatory action must address both unsustainable production as well as unsustainable consumption. This study highlights an increasing demand and consumption of vegetable oils, which is not only incurring a heavy price on the import bill but also impacting the health of people. In addition to promoting cleaner production processes this study also recommends policies that address and promote shift towards sustainable and healthy consumption patterns.

The government and nongovernment stakeholders need to build a support for reducing carbon emissions in the ghee and cooking oil industry and promote greening practices. The industries need to develop eco-friendly practices at every step from cultivating and sourcing vegetable oil and crops to safe disposal of industrial waste and recycling of waste cooking oil. It is also important to focus on greening the refining process of oils by removing undesirable compounds, generating less harmful compounds like 3-MCD-esters and avoiding least damage to desirable compounds like tocopherols, phospholipids. The key policy recommendations proposed under this study are as follows:

a) **Recycling:** Incentivize investment in biofuel production by introducing feed-in-Tariff renewable Energy Policy for biofuels and tax relief on technologies (Khan et al., 2021). Invest in bio-feedstock storage and formulate standards and regulations for bio-feed stock storage tanks and facilities.

b) **Waste management:** There is a need to develop a proper waste management system for the disposal of used cooking oil, from industries to households, in an environmentally friendly way.

In households, used cooking oil can be reused for cooking 2–3 times before disposal. For disposal, it should be sealed in a non-recyclable container and discarded with routine garbage. In cases where large quantities of used cooking oil are generated, such as in restaurants, it should be stored properly and sold to industries that use it for biodiesel production. The recycling of used oil into biodiesel can also help greening the transport, power generation, and construction. A number of cities in the world are already using biodiesel made of waste cooking oil collected from the restaurants to run buses and shuttles. The study found that converting waste cooking oil into biodiesel not only helps the country achieve a 10% biofuel share in the petroleum sector but also reduces the import of edible and crude oil (Qamar et al., 2020).

c) **Packaging**: The packing of cooking oil is an important part of greening the cooking oil industry. The plastic materials used to make bottles and plastic packing are extremely harmful to the environment. The greening of packing requires adoption of biodegradable plastics, biopolymers, or edible packages.

d) **Waste Water treatment**:The treatment of wastewater from vegetable oil refineries through coagulation and adsorption needs to be made mandatory upon the vegetable oil industries (Hussain, 2014).

In Pakistan, the voluntary reporting on NEQ limits has not worked well and there is a need to strengthen the local Environmental Protection offices for better enforcement and making the reporting on NEQs and PEQs mandatory. Other advanced methods of waste water treatment are also recommended in table below:

Table 8. Industrial waste treatment investment opportunities for greening

Technology	***Process***	***Advantages***	***Study***
Microbial fuel cell (mfc) treatment	Conversion of chemical energy to electrical energy in an mfc reactor	High cod removal and electricity production	Firdous et al. 2018
Integrated treatment system consisting of ic bioreactor and macrophytes	Biological treatment involving internal circulation anaerobic bioreactor and constructed wetland for industrial waste treatment	The process is low cost and highly ecological	Gulzar et al. 2018

e) **Regulation of sub-standard oils and ghee:** Finalize the proposed environmental taxation framework as proposed under National Hazardous Substance Policy, as a priority. We do not recommend putting a ban on harmful varieties of Vanaspati ghee, which is often used either by the poor or the restaurants, street food entrepreneurs and bakeries, but a more stringent enforcement of standards in the geographies which are more associated with low standards should go a long way in alleviating the problem.

f) **Energy efficiency and sustainable water consumption:** Some large-scale manufacturers have installed **waste heat recovery from boilers** and **alkaline closed loop vacuum system** and **waste water treatment plants** to reduce energy and water consumption. Government needs to support transitioning of

both large and small scale industries to facilitate adoption of such greening processes and technologies.

g) **Modernizing Solvent Extraction:** The edible oil extraction technology in Pakistan utilizes conventional methods of solvent extraction and expeller methods. The hazard created due to the location of large-scale extraction industries away from the farms and near import points or in big cities close to consumption, being reliant on imports, (Rana, Gill & Akram, 2022) can be mitigated to an extent with green investment in better solvent extraction technologies, in the case of new units, which will not only help elevate extraction rates and increase efficiency but also reduce environmental impact. Climate finance is proposed to promote cold-pressed method of producing cooking oil as it uses less energy, does not involve any harmful chemicals and also no desired nutrients are lost in this process.

h) **ESG Reporting and Compliance:** The Securities and Exchange Commission has mandated voluntary report of ESG compliance, which is a big step forward. However, till date the reporting level is abysmally low. Similarly, the submission of Annual Communication of Progress [ACOP] report to Roundtable on Sustainable Palm Oil [RSPO] for being in compliance of RSPO Supply chain is almost non-existent nor has the Pakistan Vanaspati Manufacturers Association made much headway in introducing such green practices among its members.

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