BioEnergy Research (2026) 19:107
https://doi.org/10.1007/s12155-026-11038-8

REVIEW

The Commercial Potential of High-Oil *Moringa oleifera*: A Competitive Analysis for the Biofuel and SAF Markets

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Received: 10 February 2026 / Accepted: 26 July 2026

Abstract

The accelerating global commitment to decarbonisation has intensified the search for sustainable, high-performance feedstocks capable of supporting the growing biofuel and Sustainable Aviation Fuel (SAF) sectors. Although conventional oilseed crops such as rapeseed, soybean, sunflower, and palm oil currently dominate biodiesel production, their long-term viability is constrained by issues including yield plateaus, competition with food-grade agriculture, extensive land requirements, and persistent sustainability concerns. These limitations underscore the need to explore alternative, climate-resilient crops with higher productivity and reduced environmental impact. In this context, high-oil-producing *Moringa oleifera* Lam. (drumstick tree) seed lines present a compelling opportunity. *M. Oleifera* combines strong agronomic resilience with favourable oil properties and significant potential for genetic enhancement, positioning it as a promising next-generation feedstock. This article evaluates the competitive position of *M. Oleifera* relative to established oilseeds through the application of Porter's Five Forces, SWOT analysis, and the Total Product Concept. The analysis suggests that *M. Oleifera* oil holds considerable commercial and strategic potential for both biodiesel and SAF markets but also highlights the importance of targeted investment in breeding programmes, supp-chain development, and regulatory alignment to support successful large-scale adoption.

Keywords *Moringa oleifera* · Biofuels · Sustainable aviation fuel (SAF) · Renewable energy feedstocks

Introduction

Global biofuel and Sustainable Aviation Fuel (SAF) markets have expanded rapidly over the last decade as international policy frameworks, including the EU Renewable Energy Directive (RED II), the U.S. Renewable Fuel Standard, and ICAO's CORSIA scheme, drive reductions in lifecycle greenhouse gas emissions [1, 2]. Biofuels encompass a broad range of energy carriers derived from biomass, including solid fuels (e.g., wood residues), gaseous fuels (e.g., biomethane), and liquid fuels (e.g., bioethanol, biodiesel, and hydro processed oils). In this study, biofuels refer to liquid hydrocarbon fuels produced from biomass that are rich in lipids and/or carbohydrates. These fuels may be used directly in transportation energy systems. Such fuels are currently playing an essential component in decarbonizing industries where electrification is either hard or too expensive, such as heavy-duty ground transport, maritime transport and aviation. SAF has gained strategic importance because aviation contributes approximately 2–3% of global CO_2 emissions and lacks viable, large-scale alternatives to liquid hydrocarbon fuels [3]. As airlines adopt net-zero commitments and governments introduce mandatory SAF blending targets, forecasts indicate substantial growth in SAF demand by 2030 [4]. Recent production data highlights this trajectory. Global biofuel output increased from roughly 105 billion litres in 2010 to approximately 165 billion litres in 2023, with only a temporary contraction during

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the COVID-19 pandemic [1]. SAF production, while still small in absolute terms rising from near zero in 2011 to approximately 700 million litres in 2023 have experienced rapid year-on-year expansion. Peer-reviewed assessments similarly document this pattern, noting that SAF production has grown exponentially over the last decade but remains severely constrained by feedstock availability and production capacity [5]. This divergence between a mature biofuel sector and an emerging, high-growth SAF market is illustrated in Fig. 1, which plots global production trends on dual axes. These trends together illustrate a significant as they have difficulty obtaining sufficient feedstock [5]. Scaling low-carbon fuels requires access to sustainable, high-performing oilseed sources that do not compete with food production, intensify land-use pressures, or drive deforestation [3]. For SAF, an additional constraint is the need to produce fuels compatible with existing aircraft engines, fuel distribution infrastructure and certification requirements, which in turn limits the range of feedstocks and conversion pathways that can be adopted at commercial scale [2].

Traditional oilseed crops, namely *Brassica napus* L. (rapeseed), *Glycine max* (L.) Merr. (soybean), *Helianthus annuus* L. (sunflower), and Elaeis guineensis Jacq. (African oil palm), continue to be the dominant feedstocks for biodiesel; however, each has limitations that impede long-term scaling. These include yield plateaus, high fertiliser and water demands, vulnerability to climate variability, and significant environmental concerns, particularly in the case of palm-oil-driven land conversion, as documented across major oilseed systems [6–9]. Though several alternative feedstocks such as *Camelina sativa* (L.) Crantz (camelina), *Jatropha curcas* L. (jatropha), *Millettia pinnata* (L.) *Panigrahi* (pongamia), and microalgae, have been proposed for biofuel and SAF production, limitations associated with yield performance, long maturation periods, or the economic and technical challenges of large-scale production have constrained their widespread adoption [7–9]. As sustainability expectations tighten, the search for alternative oilseeds with higher productivity, climate resilience, and favourable carbon footprints has become increasingly urgent. In this context, *M. oleifera* has emerged as a potential non-food oilseed alternative. *M. Oleifera* is a perennial, fast-growing woody tree native to the Himalayan foothills of northern India and widely cultivated throughout tropical and subtropical regions of Asia, Africa, and Latin America [10]. The species exhibits substantial genetic diversity across its global range and is adapted to a wide range of environments, particularly semi-arid and drought-prone regions [11, 12]. *M. oleifera* is predominantly outcrossing, although self-pollination can occur, and typically begins producing seeds within 6–12 months of planting, making it attractive for crop improvement and commercial cultivation programmes [10, 12].The seeds possess 35–40% oil, distinguished by strong oxidative stability and an advantageous fatty acid composition, leading to reduced processing expenses, enhanced fuel stability, and increased appropriateness for prolonged storage and blending. The species' capacity to flourish on marginal or degraded land enhances its sustainability potential [11, 13].

To contextualise these advantages relative to existing feedstocks, Fig. 2 presents a combined comparison of oil content, fuel quality, and key sustainability indicators across major oilseed crops. In this framework, higher values indicate more favourable economic and environmental performance, reflecting greater oil productivity per unit land area, improved fuel quality, and reduced resource and land-use

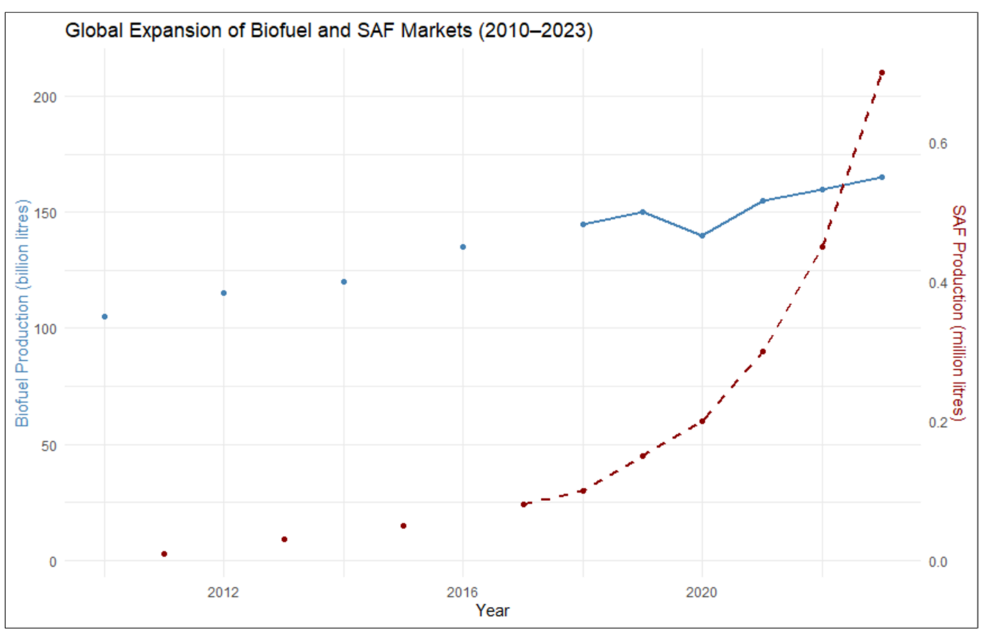

Fig. 1 Trends illustrate steady growth in global biofuel production and a rapid rise in SAF output from near-zero to over 200 million litres by 2023. Biofuel data are adapted from IEA and FAOSTAT datasets [1, 3], while SAF estimates draw on reports from IATA, ICAO, and IEA aviation analyses [1, 2, 4]. Image created on R studio

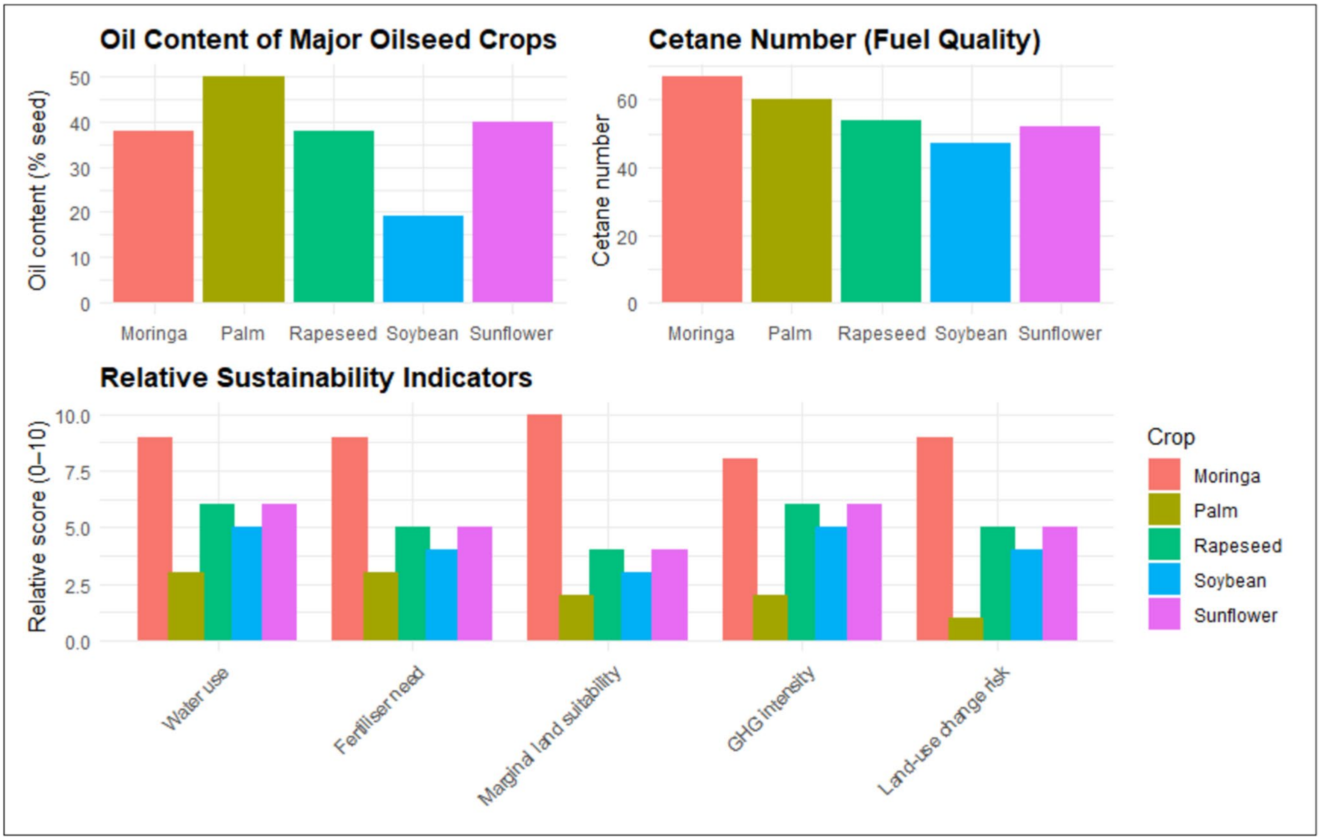

Fig. 2 Oil content and cetane number values are adapted from peer-reviewed assessments of biodiesel feedstocks [14–17]. Sustainability indicators (water and fertiliser use, marginal land suitability, GHG intensity, land-use change risk) are based on comparative agricultural and environmental studies [11, 18–20]. Created on R studio

intensity. The relative sustainability score is therefore constructed such that a higher score represents a more desirable outcome, integrating agronomic efficiency and fuel-relevant traits that are critical for large-scale, cost-effective biofuel deployment.

Given these dynamics, the objective of this article is to evaluate the commercial and strategic potential of high oil *M. oleifera* seed lines relative to established oilseed crops. Incorporating Porter's Five Forces, SWOT analysis, and the Total Product Concept, this study offers a systematic evaluation of *M. oleifera's* competitiveness in the developing biodiesel and SAF markets. This integrated approach facilitates a thorough comprehension of the potential and limitations related to promoting *M. oleifera* as a next-generation feedstock that can aid in decarbonization and sustainable market growth.

Geopolitical Developments in Global Vegetable Oil Markets

The increasing reliance on vegetable oils as feedstocks for biodiesel and Sustainable Aviation Fuel (SAF) has heightened the need to understand the economic, political and environmental factors that influence their availability, cost, and long-term sustainability. Although agronomic performance determines the biological potential of oilseed crops, global vegetable oil markets are governed by a much wider set of interacting factors including trade policies, geopolitical events, supply-chain disruptions, and changing patterns of agricultural production [3, 21]. These factors can directly affect feedstock security along with price stability, creating challenges for fuel producers attempting to scale low-carbon fuel production while meeting environmental and economic objectives [1, 22]. As a result, geopolitical developments in vegetable oil markets have become an important consideration in evaluating both conventional and emerging biofuel feedstocks particularly those intended for SAF pathways where supply reliability and certification compliance are essential. Market analysis highlights a widening gap between projected SAF demand and the availability of sustainable feedstocks capable of supporting commercial-scale production. The International Energy Agency estimates that SAF deployment must increase by at least thirty-fold by 2030 to align with global net-zero trajectories, yet current volumes remain below 0.1% of total aviation fuel consumption [1]. Meanwhile, demand for biofuels more broadly continues to rise, driven by net-zero strategies, national energy security priorities, and volatility in fossil fuel markets [5]. This intensifying demand places significant strain on traditional oilseed crops, which already face structural constraints Including land-use competition with food crops, yield stagnation, and high input requirements that limit their ability to sustain biofuel expansion [17, 23]. In addition, palm oil production has been widely associated with deforestation, biodiversity loss, and emissions-intensive land-use change, prompting regulatory scrutiny and consumer resistance in key markets [19, 20].

Geopolitical dynamics further exacerbate supply risks and price volatility. Trade disruptions including U.S.-EU tariff disputes, export restrictions in major producing countries, and climate-induced yield losses have introduced substantial uncertainty in vegetable oil markets [3, 21]. Rising fertiliser prices and supply chain disruptions following global events such as the Russia–Ukraine conflict has amplified these pressures, highlighting the vulnerability of biofuel production pathways that rely heavily on agricultural inputs [21]. As a result, both academic and industry literature increasingly emphasise the need to diversify feedstock portfolios to enhance resilience, reduce exposure to commodity price swings, and meet sustainability obligations [1, 22] (Fig. 3).

Within this context, *M. oleifera* is attracting growing interest as a non-traditional but commercially relevant oilseed that could contribute to feedstock diversification in biodiesel and SAF markets. *M. oleifera* is highly drought-tolerant, thrives on marginal or degraded land, and requires significantly lower fertiliser and water inputs than conventional oilseed species [10, 11]. Its seeds contain 35–40% oil with a favourable fatty acid composition and high oxidative stability, characteristics that translate into superior biodiesel quality and potentially advantageous properties for SAF precursor production [13, 14] Despite these advantages, *M.oleifera* remains underexplored in global commodity markets, and its competitive position relative to established oilseed crops has not been systematically assessed. A strategic evaluation grounded in market analysis frameworks is therefore needed to determine whether *M. oleifera* can viably contribute to emerging low-carbon fuel economies.

Analytical Framework for Assessing the Commercial Potential of *Moringa oleifera*

This study evaluates the competitive and commercial potential of *M. oleifera* as an emerging oilseed feedstock for biodiesel and Sustainable Aviation Fuel (SAF) production by integrating three complementary analytical frameworks: Porter's Five Forces, SWOT analysis, and the Total Product Concept. These frameworks are widely employed in strategic management, technology adoption research, and market competitiveness assessments, and together they provide a multi-layered understanding of *M. oleifera's* positioning within the global biofuel and SAF value chains [24, 25].

The first framework uses five forces introduced by Michael E Porter in 1979 [24], providing a structured approach for assessing the competitive pressures that shape market attractiveness and long-term profitability. The framework examines five key forces: (1) competitive

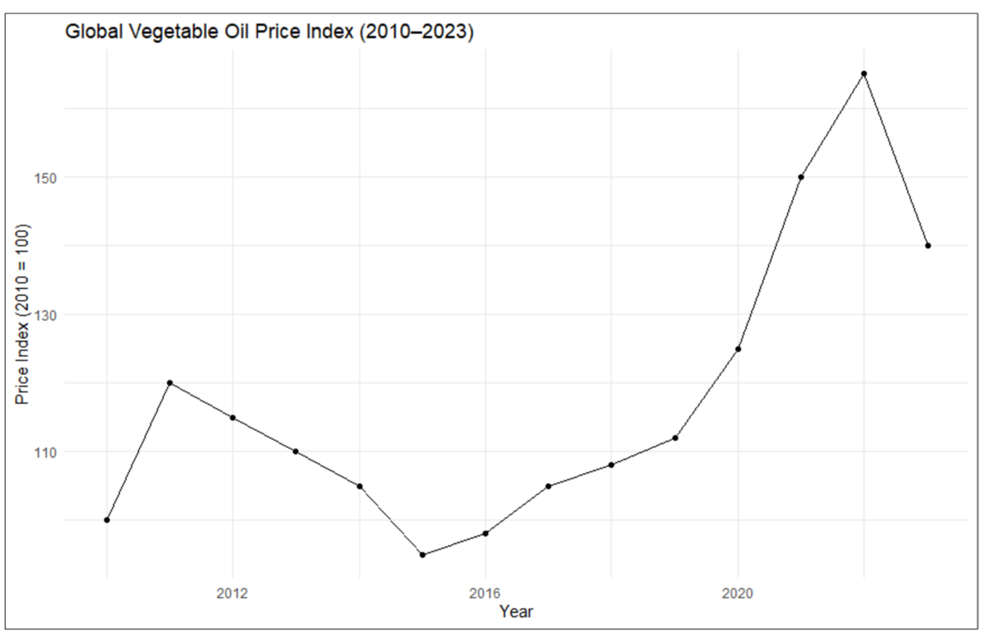

Fig. 3 Annual changes in the global vegetable oil price index (2010 = 100), showing volatility driven by shifts in supply, demand, and global commodity markets. Data adapted from the FAO Vegetable Oil Price Index [3] supported by broader commodity price analyses [21]. (made using R)

rivalry among existing firms, (2) the threat of new entrants, (3) the bargaining power of suppliers, (4) the bargaining power of buyers and (5) the threat of substitute products [24]. This framework facilitates the systematic evaluation of *M. oleifera's* competitive position relative to established oilseed crops such as rapeseed, soybean, sunflower, and palm oil, while also emphasizing broader industry challenges, including feedstock scarcity, regulatory uncertainties, and technological path dependence that impact the viability of emerging feedstock alternatives [24]. By applying this tool, the analysis situates *M. oleifera* within the strategic landscape of an industry undergoing rapid transition and facing increasing pressure to diversify sustainable feedstock sources (Fig. 4).

The second framework, SWOT analysis, examines *M. oleifera's* internal strengths and weaknesses alongside external opportunities and threats. Originally developed during strategic planning research at Harvard Business School, SWOT was designed to help organisations diagnose their internal capabilities while systematically evaluating the external environment [26]. This dual perspective renders the framework especially appropriate for emerging feedstocks such as *M. oleifera*, which occupy a position at the convergence of agronomic performance and swiftly evolving biofuel markets. Strengths identified for *M. oleifera* include its high oil content, advantageous fuel-quality characteristics, and robust sustainability profile, aligned with feedstock attributes that SWOT analysis was traditionally designed

Fig. 4 Porter's Five Forces framework used to analyse the competitive structure of the biofuel and SAF feedstock industry. (Adapted from Porter's Five Forces model [24]

to highlight those that are providing a "distinctive competence" in competitive settings [2, 27].

Conversely, weaknesses reflect challenges such as underdeveloped supply chains, limited commercial production experience, and potential variability in agronomic performance. Opportunities relate to expanding SAF mandates, demand for low-input non-food oilseeds, and rising global interest in resilient feedstocks suitable for degraded lands. Threats include competition from other next-generation oils, volatile policy environments, and uncertainty in scaling agricultural production [26, 27]. The SWOT framework thus supports a nuanced understanding of *M. oleifera's* strategic potential and constraints.

Finally, the Total Product Concept is employed to evaluate how *M. oleifera* oil can evolve from a raw agricultural commodity into a differentiated market offering with added value for biofuel and SAF producers. This model distinguishes between the core product (raw *M. oleifera* oil), the actual product (refined biodiesel or SAF precursors), and the augmented product, which includes certified sustainability attributes, low-carbon intensity scoring, and compliance with emerging fuel specifications. Levitt's [28] foundational argument that "there is no such thing as a commodity" underscores the relevance of this model for *M. oleifera* even basic agricultural inputs can be strategically differentiated through performance, reliability, sustainability, and service dimensions. In line with Levitt's emphasis on exceeding customer expectations and creating augmented value, the differentiation of *M. oleifera* can be enhanced through targeted breeding for increased oil yields, advancements in processing efficiency, sustainability certification programs, and the establishment of traceable, vertically integrated supply chains. These enhancements facilitate the transition of *M. oleifera* from a basic feedstock to a high-value, strategically significant product that can fulfil the increasing demands of biofuel and SAF markets for dependability, environmental sustainability, and secure long-term supply [25, 28] (Fig. 5).

By integrating these three frameworks, the conceptual approach employed in this study provides a comprehensive basis for evaluating *M. oleifera's* market positioning, competitive advantages, and potential role in supporting the future expansion of biodiesel and SAF sectors. This layered analysis moves beyond technical feasibility to address structural, strategic, and value-chain considerations that determine the adoption of new biofuel feedstocks.

Data Sources and Analysis

All quantitative analyses in this study were conducted using reproducible workflows implemented in **R version 4.3.1** (R Core Team, 2023). Data were sourced from internationally standardised, annually updated databases to ensure comparability across years and regions (Supplementary material). Raw datasets for global biofuel and SAF production (Fig. 1) were retrieved from the International Energy Agency

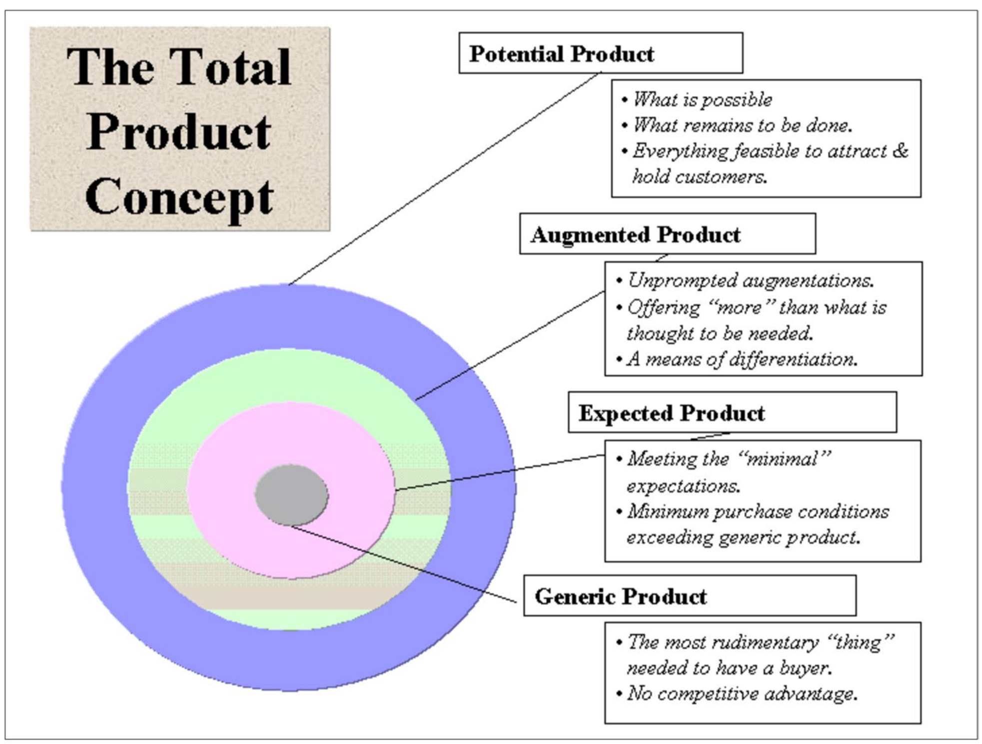

Fig. 5 The total product concept illustrating the four layers of value offered by a product. Adapted from classical representations of the Total Product Concept [25, 28]

[1]. Food and Agriculture Organization FAOSTAT databases [3]. International Civil Aviation Organization [2], and International Air Transport Association [4]. SAF production volumes were cross-checked with values reported in recent peer-reviewed meta-analyses to mitigate discrepancies between agency reporting methodologies [5, 29]. Data cleaning involved type harmonisation, removal of missing entries, and the conversion of heterogeneous reporting units into standardised volumetric units (million litres per year). Time-series smoothing for visual clarity employed a LOESS regression with span parameters set between 0.25 and 0.35.

Comparative oilseed traits (Fig. 2) were compiled through a systematic extraction of oil content, cetane number, and sustainability metrics from peer-reviewed agronomic, biochemical, and LCA literature [11, 14–16, 18, 19]. Reported ranges were harmonised by calculating mid-point or representative mean values when necessary. To enable cross-feedstock comparison, variables with differing measurement scales were normalised using min–max scaling to a [0,1] range. Data visualisation was performed using ggplot2, with additional geometric layers constructed manually for categorical sustainability indicators.

Global vegetable oil price data (Fig. 3) were obtained from the FAO Vegetable Oil Price Index for the period 2010–2023 [3]. Values were reindexed such that 2010 = 100 for internal consistency. Year-on-year volatility was quantified using both absolute differences and standard deviation of first differences. Findings were contextualised using commodity price interaction analyses from [21], which were not plotted directly but informed market interpretation.

Conceptual diagrams (Porter's Five Forces, SWOT, Total Product Concept) were produced using vector-based illustration software (Canva v3.0), informed by theoretical frameworks from [25, 27] While these diagrams do not originate from quantitative datasets, their content reflects the results of the structured market analyses conducted in this study.

All computational scripts, including data preprocessing, scaling, and figure generation, were written in R using tidyverse, patchwork, and scales packages. The analytical workflow emphasises methodological transparency, reproducibility, and alignment with internationally recognised data standards in biofuel market research.

Results and Integrated Discussion: Strategic Market Evaluation of *M. oleifera*

Using the integrated analytical framework outlined in Sect. 3, the data on oil content, cetane number, sustainability indicators, and market characteristics, compiled from peer-reviewed agronomic, biochemical, environmental, and market literature, were combined to assess the competitive positioning of *M. oleifera* within biodiesel and Sustainable Aviation Fuel (SAF) markets. Reported values were harmonised using representative means or midpoint estimates and standardised to enable cross-feedstock comparison. This data, together with evidence from policy documents, industry reports, and commodity market analyses, informed the Porter's Five Forces, SWOT, and Total Product Concept evaluations presented in this study, revealing that *M. oleifera* occupies a strategically promising yet underdeveloped position within the global feedstock landscape, with its potential constrained primarily by structural, infrastructural, and market-awareness limitations.

Porter's Five Forces

Porter's Five Forces analysis highlights that rivalry in the existing feedstock market remains intense due to the dominance of established commodities such as rapeseed, soybean, sunflower, and palm oil, each of which benefits from entrenched production systems, global trading networks, and decades of agronomic optimisation [17]. *M. oleifera* is differentiated by its low input requirements, high cetane number of the derived biofuel, and ability to grow on marginal land, features that align strongly with emerging sustainability-driven purchasing behaviours in the fuel sector [11]. Nevertheless, barriers to entry remain moderately high due to the capital intensity of refining infrastructure, the need for standardised oil quality, and the stringency of SAF certification frameworks [2].Supplier power is presently high because *M. oleifera* production is geographically dispersed among smallholders with limited mechanisation, creating challenges in volume consistency and traceability key requirements for both biodiesel and SAF procurement [3, 30]. Buyer power is also strong: refiners, airlines, and blenders can select from a wide portfolio of established feedstocks, including waste-derived oils and fats, which currently enjoy favourable carbon-intensity scoring and market subsidies [5, 31]. The threat of substitutes remains significant, as *M. oleifera* competes not only with other plant oils but also with waste lipids, tallow, and algae, many of which are already integrated into certified SAF pathways and shown to deliver competitive lifecycle emissions performance [32, 33] (Fig. 6).

SWOT Analysis

The SWOT analysis further contextualises *M. oleifera's* strategic potential. Key strengths include high seed oil content (35–40%), superior oxidative stability, and a cetane number of ~ 67 properties that exceed those of major oilseed

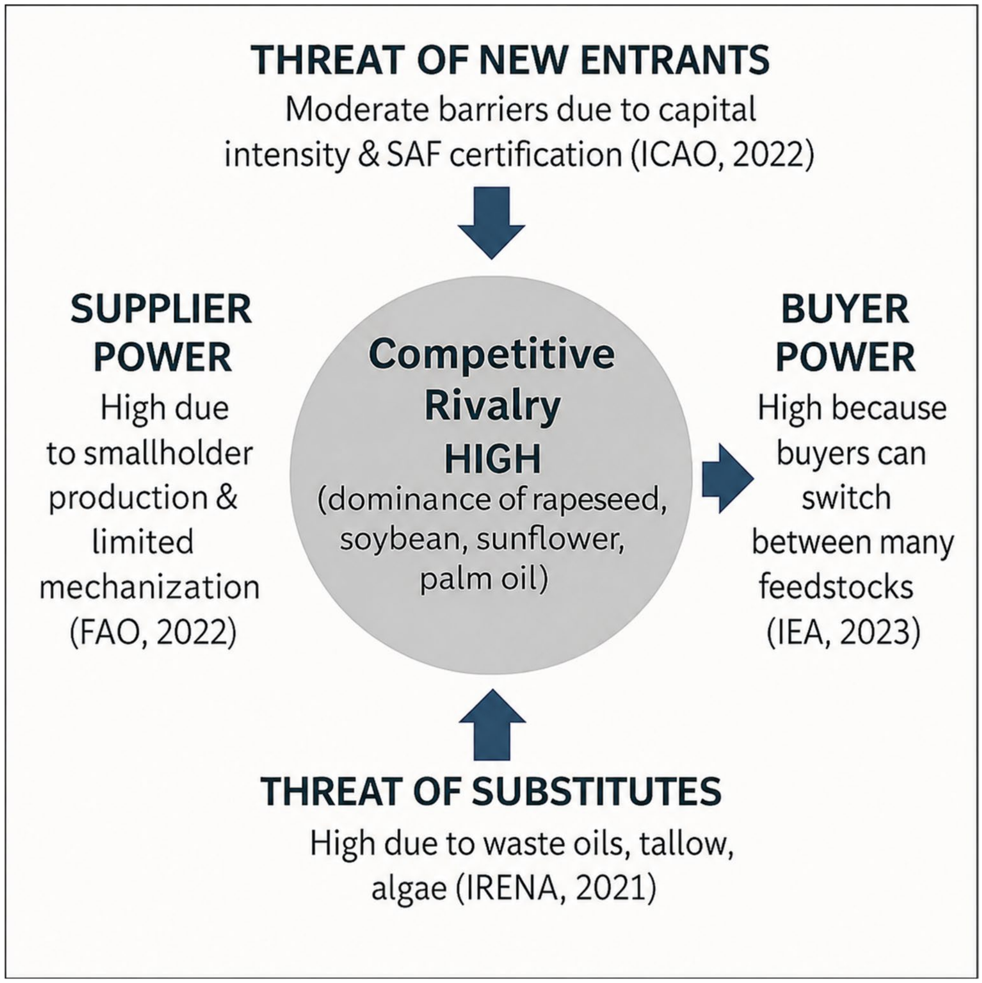

Fig. 6 Porter's Five Forces analysis of *M. oleifera* as a biofuel and SAF feedstock [2, 3, 22]. (Made using Canva)

competitors and translate well into high-quality biodiesel and hydro processed SAF precursors [13, 14]. Agronomically, *M. oleifera's* drought tolerance and suitability for marginal, degraded, or semi-arid land position it as a feedstock with minimal competition against food crops and low indirect land-use change (ILUC) risk, a critical metric under emerging sustainability certification schemes [23]. However, weaknesses are substantial: global *M. oleifera* cultivation remains small-scale, with production dominated by dispersed smallholders and limited adoption of commercial agronomic practices [11, 34]. Harvest mechanisation is minimal, as *M. oleifera* seed production is still largely manual and lacks crop-specific mechanised harvesting technologies [35]. Opportunities arise from rising SAF blending obligations, climate-resilient agriculture strategies, the need for diversification beyond overburdened oilseed systems, and increasing investor interest in non-food perennial crops. Threats include policy uncertainty surrounding renewable fuel mandates [36], competition from heavily subsidised waste oils that dominate current SAF and renewable diesel markets [31], and the rapid advancement of alternative next-generation oils such as algae and camelina, both of which are progressing through certified SAF pathways and receive significant research and commercial investment [7–9].

Total Product Concept

The Total Product Concept provides a comprehensive framework through which *M. oleifera* can be positioned not merely as a raw agricultural commodity but as a differentiated, multi-layered market offering within the biodiesel and Sustainable Aviation Fuel (SAF) sectors. At the generic product level, *M. oleifera* offers crude seed oil that is readily convertible through transesterification or hydro processing into biodiesel or HEFA–SAF intermediates, like other vegetable oils traditionally used in renewable fuel production [15, 16]. At the expected product level, *M. oleifera* exceeds baseline performance metrics typically sought by fuel producers: its oil exhibits a high cetane number (~ 67), superior oxidative stability, and a favourable fatty-acid composition dominated by oleic acid traits that collectively enhance combustion efficiency and storage stability while reducing NOx emissions [13, 14, 31] These characteristics position *M. oleifera* above many conventional feedstocks, including

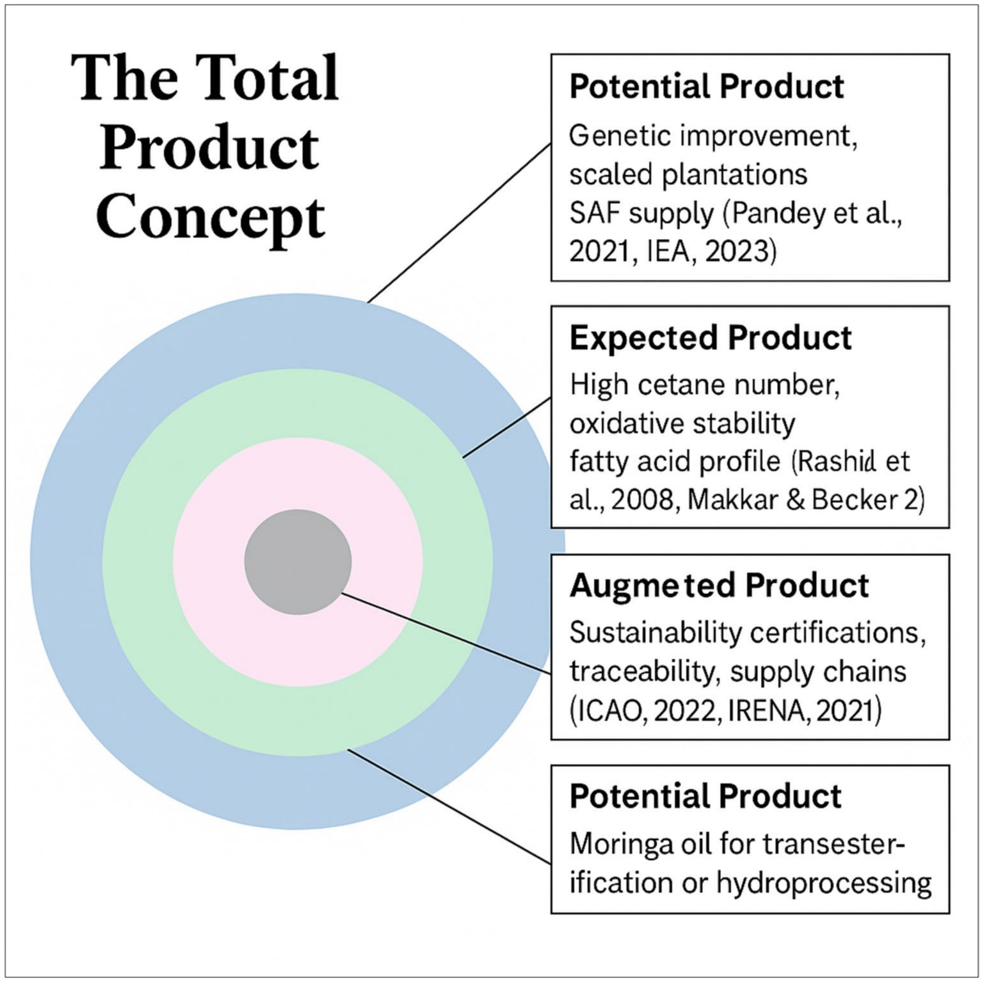

Fig. 7 Total Product Concept applied to *M. oleifera* as a biodiesel and SAF feedstock. (Created on Canva)

soybean and sunflower oil, whose cetane values and oxidation stability are comparatively lower.

At the augmented product level, *M. oleifera's* value proposition expands beyond inherent oil properties. Opportunities for differentiation include certifiable sustainability attributes such as low indirect land-use change (ILUC) risk, drought resilience, and suitability for cultivation on degraded or marginal lands factors increasingly prioritised under regulatory frameworks such as the EU Renewable Energy Directive (RED II) and ICAO's CORSIA sustainability criteria [2, 37]. Additional augmentations include the development of traceability-enabled supply chains, digital monitoring systems for smallholder integration, and vertically coordinated cultivation, processing models that ensure quality consistency, volume reliability, and compliance with SAF feedstock documentation requirements [3, 22].

Finally, the potential product level encompasses future innovations and strategic expansions that significantly enhance *M. oleifera's* commercial and environmental value. These include the development of genetically improved, high-oil-yielding *M. oleifera* varieties through breeding, tissue culture, and metabolic engineering; large-scale plantations optimised for semi-arid regions impacted by climate change; and integrated *M. oleifera*-based SAF value chains capable of supplying dedicated regional aviation hubs [1, 11, 12]. As global SAF demand accelerates and feedstock scarcity intensifies, the potential for *M. oleifera* to contribute to low-carbon aviation pathways become increasingly evident. By conceptualising *M. oleifera* across the generic, expected, augmented, and potential product layers, the Total Product Concept reveals a progressive trajectory through which this emerging oilseed could develop into a strategically significant feedstock aligned with long-term decarbonisation and sustainability imperatives (Fig. 7).

Integrating these results, the strategic assessment indicates that *M. oleifera* possesses many features that closely align with the future demands of the biodiesel and SAF markets: climate resilience, non-food designation, adaptability to marginal land, and high-quality oil. Nonetheless, the Discussion emphasizes that achieving this potential necessitates specific and targeted interventions. These encompass investments in breeding programs aimed at enhancing oil yield and uniformity; the development of mechanized harvesting and processing infrastructure; the establishment of contract farming and aggregation systems to mitigate supplier power; and collaboration with SAF producers to integrate *M. oleifera* into initial certification pathways. Without these enabling conditions, *M. oleifera* risks being overshadowed by feedstocks with more mature supply chains or by waste-derived lipids that presently dominate the low carbon-intensity segment of the market [1]. Nonetheless, the combination of agronomic advantages, sustainability alignment, and favourable fuel properties positions *M. oleifera* as a strategically important candidate for feedstock diversification, especially under global pressure to expand SAF production and reduce reliance on high-ILUC oils.

Conclusion

This analysis shows that *M. oleifera* offers strong potential as a sustainable biofuel and SAF feedstock due to its high-quality oil, low input requirements, and suitability for marginal land. Strategic frameworks indicate that while *M. oleifera* holds notable advantages over conventional oilseeds, its market impact is currently limited by supply-chain fragmentation, smallholder-dominated production, and competition from established and subsidised feedstocks. Targeted investment in breeding high-oil varieties, developing scalable cultivation systems, and integrating *M. oleifera* into certified low-carbon fuel pathways will be essential for unlocking its commercial viability. Efforts to improve the species are already underway in universities, research institutes, and commercial breeding programmes, with a focus on increasing oil yield, improving seed productivity, and enhancing agronomic performance [12]. As demand for renewable fuels continues to grow, *M. oleifera* has the potential to become an important component of a more diverse and resilient feedstock portfolio.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s12155-026-11038-8.

Author Contributions A.G and K.J conceptualised the manuscript, carried out data analysis and primary writing. R.C, R.W, B. Q and V.M provided supervision, funding acquisition and contributed to writing and editing the manuscript. All authors reviewed the manuscript and approved the final draft.

Data Availability The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Competing interests The authors declare no competing interests.

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