Indian Journal of Ecology (2025) 52(5) (SI): 1386-1392
DOI: https://doi.org/10.55362/IJE/2025/4663

Manuscript Number: 4663
NAAS Rating: 5.38

Variation in *Sterculia foetida* Seed Oil Content among different Landscapes in South Gujarat *vis-a-vis* Oil Phytochemical and Fatty Acid Composition

M.R. Prajapati, N.S. Thakur*, A.A. Mehta and Y.A. Garde[1]

College of Forestry, Navsari Agricultural University, Navsari-396 450, Gujarat, India
[1]ICAR-Indian Agricultural Statistics Research Institute, Pusa New Delhi-110 012, India
**E-mail: drnsthakur74@gmail.com*

Abstract: The present study aimed to find out the variation in *Sterculia foetida* seed oil content across different landscapes (L_1 & L_8-arboreal; L_2-agricultural and L_3-L_7-city avenue plantations) of South Gujarat, India and its oil phytochemical and fatty acid composition. The sampling locations were comprised of eight landscapes falling in three districts namely Narmada (lies in the Satpura mountain ranges and the Narmada River basin), Navsari and Valsad (Arabian Sea coast). Findings deduced significant ($P \leq 0.05$) variation in *S. foetida* seed oil content among the landscapes and it ranged from 38.43 to 53.23% with overall average of 44.16%. Further, the gas-chromatography mass-spectrometry analysis revealed 11 volatile compounds in oil. Based on relative percentage most abundant were 9-Octadecanone (88.67), stigmasterol (78.74), 2-Decanone (78.02) and nonanoic acid (76.55). Gass chromatography analysis of Total Fatty Acid Methyl Esters (FAME) of *S. foetida* seed oil revealed 6 compounds. Among them maximum amount (57.06%) was of palmitoleic acid. The total saturated fatty acids, monounsaturated fatty acids and poly unsaturated acids were 19.48%, 18.37% and 62.13%, respectively. Corroboration of detected kernel oil phytochemicals and fatty acids, in the present study, with available literature expressed that these compounds have many biological properties indicating it beneficial for human being.

Keywords: Hazel sterculia, Oil content, Oil composition, Phytosterol, Fatty acid

Unveiling of the Planning Commission Government of India report on 'Pathways and Strategies for Accelerating Growth in Edible Oils Towards Self Reliance (*Atmanirbharta*), highlighted that over the past decades, per capita consumption of edible oil in the country has seen a dramatic rise, reaching 19.70 kg/year. This spate in demand has pointedly overtaken domestic production, leading to a substantial reliance on imports to meet both domestic and industrial needs. In 2022-23, India imported 16.50 million tonnes (MT) of edible oils, with domestic production fulfilling only 40-45% of the country's requirements. This situation presents a considerable challenge to the country's goal of achieving self-sufficiency in edible oils. Under a business-as-usual scenario, the national supply of edible oil is projected to increase to 16 MT by 2030 and 26.7 MT by 2047 (Patel et al., 2024). Oilseeds and edible oils are two of the most sensitive essential commodities. India is one of the largest producers of oilseeds in the world and this sector occupies an important position in the agricultural economy, accounting for the estimated production of 39.66 million tons of nine cultivated oilseeds during the year 2023-24 (November-October) as per Final Advance Estimates released by the Ministry of Agriculture at end of 2024. India contributes about 5-6% of the world oilseeds production. Export of oil meals, oilseeds and minor oils was about 5.44 million tons in the financial year 2023-24 valued at ₹ 29,587 crores (Patel et al., 2024). Vegetable oils are an integral part of producing manufactured food both domestically and on an industrial scale. The vegetable oil market is increasing upward with a compound annual growth rate (CAGR) of 3.25% during the forecast period 2019-2024 all around the world.

Therefore, it is necessary to find alternative sources of vegetable oil (Bose et al., 2021) and tree born edible oils (Hegde et al., 2019) to fulfil the insufficiency in the market. In addition to major oilseeds crops, 3 million tonnes of vegetable oil are being harnessed from secondary sources like cottonseed, rice bran, coconut, Tree Borne Oilseeds (TBOs) and oil palm which is categorized as secondary sources of oils should be included as primary source as it gives the highest per ha oil yield (4-5 t/ha). There are an array of plant species including perennial trees which have been evaluated for edible seed oil and after oil extraction cakes are used as a concentrate for livestock feeding or other purposes like manuring (Akande et al., 2016, Hegde et al., 2019).

Sterculia foetida L., commonly known Hazel sterculia and wild almond. It is found from Eastern tropical Africa to North Australia, through Malaysia, Burma, Bangladesh, India, Sri Lanka and Malacca (Mujumdar et al., 2000). The generic name is based on the Latin word 'stercus', meaning 'manure', which refers to the smell of the flowers and leaves of some species. Fruits ripen in February, nearly 11 months after the 1^{st} appearance of the flowers. Mature trees produce approximately 200-350 kg of seed per year (Orwa et al., 2009). *S. foetida* seeds are safe to eat and contain significant amounts of carbohydrates, protein, lipids, minerals and macro and micronutrients (Galla 2013). Seeds yield a considerable amount an edible non-drying oil, is found in both the testa and the kernel and been found to be a good biofuel (Bose et al., 2021). Due to low moisture content, *S. foetida* seed have a prolonged shelf life. The oil has anti-diabetic, anti-dermatophytic, antimicrobial, anti-cancer, anti-obesity, antifertility, and antifeedant properties. On a small scale, oil from the seed is extracted and used in medicine to treat itches and other skin diseases internally and externally as a paste. The wood is boiled with seed oil and applied externally to treat rheumatism. By sensitizing receptors, seed oil may aid in the reduction of belly fat and insulin resistance. Based on all the tested parameters, oil may serve as an alternative, viable source of safe edible oil (Sarkar et al., 2021, Bose et al., 2021 Farsana et al., 2022). There is a dearth of information in India on its seed kernel and its oil nutritive value. Therefore, the present study was proposed to fulfil this lacking pertaining to physico-chemical, micro-macro nutrient, secondary metabolite, volatile phytochemical, oil content and oil composition of *S. foetida* across landscapes of south Gujarat extending from Arabian cost to Satpura mountain ranges India.

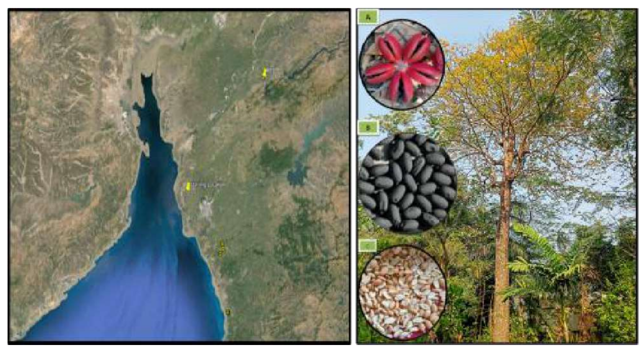
MATERIAL AND METHODS

Study area and fruit collection: *S. foetida* fruits were collected from distantly located eight different landscapes falling in three districts namely Narmada (falls in Satpura mountain ranges and Narmada River basin), Navsari and Valsad (along Arabian Sea coast) of south Gujarat, India.

Geographical location of landscapes and growth attributes of selected trees are given in Figure 1 and Table 1, respectively. In each landscape five trees were marked and height and diameter at breast height (DBH) was measured and average values are given in table 1. *S. foetida* fruits were collected in bulk (January 2024) from each landscape and brought to the laboratory and seeds were extracted.

Nut morpho-metric attributes: Under each replication (n=5) 100 nuts were taken and data on morph-metric attribute *i.e.* seed length and width, and seed weight was recorded.

Seed kernel oil content (%): The nuts were de-shelled manually to extract the kernel. The kernels were then dried in hot air oven at 65(±5)^{0}C for 72 hrs. The dried kernels were crushed and grounded fine using grinding mixer. Oil was extracted (using 25 g kernel powder) by using the Soxhlet



A B

Fig. 1. A) Geographic location of *S. foetida* landscapes and B) *S. foetida* tree in arboreal landscape (insight: fruit, seed and seed kernel from top to bottom, respectively)

Table 1. Geographical location, and average growth and seed morphometric attributes of *S. foetida* in different landscapes of south Gujarat

Land-scape (L)	Altitude (m)	Latitude (N)	Longitude (E)	Tree eight (m)	DBH (cm)	SL (mm)	SWdt. (mm)	SWt. (g)	MC (%)
RPL-L_1	67	21°85'81"	73°51'87"	22.50	45.06	19.23^{c}	12.46^{bcd}	1.85^{cd}	12.25^{de}
NVS-1-L_2	33	20°92'23"	72°90'52"	21.20	68.30	22.04^{a}	13.32^{a}	2.37^{a}	16.77^{a}
NVS-2-L_3	34	20°97'03"	72°93'42"	10.60	32.80	20.28^{b}	12.28^{cd}	1.91^{c}	13.41^{cd}
NVS-3-L_4	33	20°93'67"	72°94'01"	15.30	49.90	19.20^{c}	12.04^{cd}	1.73^{e}	15.80^{ab}
NVS-4-L_5	39	20°94'63"	72°93'49"	18.80	51.70	19.47^{c}	12.10^{cd}	1.76^{de}	16.45^{e}
VLD-1-L_6	30	20°60'42"	72°91'38"	12.40	46.60	21.94^{a}	11.97^{d}	1.89^{c}	15.43^{abc}
VLD-2-L_7	33	20°60'82"	72°90'83"	8.60	34.19	21.62^{a}	12.98^{ab}	2.28^{a}	14.06^{bcd}
VLD-3-L_8	32	20°60'46"	72°91'37"	21.50	36.00	20.26^{b}	12.68^{abc}	2.03^{b}	10.37^{a}
Mean	-	-	-	-	-	20.50	12.48	1.98	14.32
SEm (±)	-	-	-	-	-	0.18	0.22	0.03	0.77

(DBH= Diameter at Breast Height); RPL=Rajpipla; NVS=Navsari; VLD=Valsad; DBH=Diameter at breast height; SL=Seed length; SWdt.=Seed width; SWt.=Seed weight; MC=Moisture content; Letter different in same vertical column are significantly different according to Duncan's multiple range test ($P \leq 0.05$)

method with hexane as per the standard procedure followed for the estimation of oil in oilseeds and TBOs (Bose et al., 2021).

Oil phytochemical and oil fatty acid profile: *S. foetida* seed oil phytochemicals were detected through Gas Chromatography-Mass Spectrometry (GC-MS) partly following Sukhadiya et al., (2021) whereas fatty acids were estimated following standard method of AOAC (2000).

Statistical analysis: All respective data sets were analyzed as per standard statistical procedure using Complete Randomized Design (CRD) and F-test was done and ANOVA was constructed with following model Yij = μ + ti + eij, where Yij = an observation, μ = overall mean effect, ti = true effect of the (Ti) treatment, eij = error term of the (Yj) unit receiving (i) treatment, i = a particular treatment, j = a particular replicate as described by Snedecor and Cochran (1980). Treatment means were compared at $P \le 0.05$. Further, Duncan's multiple range test (DMRT) was adopted to compare the sets of means of each factor (Sheoran et al., 1998).

RESULTS AND DISCUSSION

Seed morpho-metric and biomass attributes: *S. foetida* seed morpho-metric attributes namely seed length, width and weight varied significantly ($P \le 0.05$) among the eight studied landscapes (Table 1). Maximum seed length (22.04 mm), width (13.32 mm) and weight (2.37 g/seed) was recorded for seeds of L_2 landscape (NVS-1-L_2). Shortest seed length (19.20 mm) and least seed weight (1.73 g/seed) was found in seed of NVS-3-L_4. The minimum seed width (11.97 mm) was of seeds from L_6 landscape (VLD-1-L_6). Overall, seed length, width and seed weight had average values of 20.50 cm, 12.48 cm and 1.98 g, respectively.

Oil content: The perusal of data (Fig. 2) expressed that percentage of *S. foetida* seed oil content varied significantly ($P \le 0.05$) among eight different landscapes. Maximum oil content (53.23%) was found in VLD-3-L_8 landscape seeds, which was statistically at par with RPL-L_1 landscape having 47.51% oil. NVS-3-L_4 landscape seeds kernel yielded minimum oil content (38.43. Overall, in all the landscapes an average of 44.16% oil content was obtained.

Oil phytochemicals: The phytochemicals detected through gas-chromatography mass-spectrometry (GC-MS) in SFSK and kernel are presented in table 2. The chromatograms showing retention time and relative abundance of volatile phytochemical compounds detected in kernel oil are depicted in Figure 3. In total, 11 phytochemicals could be identified extracted kernel oil. Among them phytochemicals *viz.,* 1-Decyne, Cyclopropane pentyl, Nonanal, 2-Decanone, Nonanoic acid, n-Hexadecanoic acid, 9-Octadecanone, 12-Tricosanone, Squalene, Stigmasterol and β-Sitosterol were detected with relative area 14.29, 39.61, 53.18, 78.02, 76.55, 48.11, 88.67, 19.28, 57.43, 78.74 and 48.43%, respectively (Table 2).

Oil fatty acid composition: Fatty acids are composed of a hydrocarbon chain with a methyl group and a terminal carboxyl group. Fatty acids are major components of triacylglycerols, phospholipids and other complex lipids. Triacylglycerols and hence fatty acids are the main contributors to dietary fat in humans. The properties of dietary fat are primarily determined by the composition of its fatty acids, which may be SFA (no double bonds), MUFA (one double bond) or PUFA (greater than one double bond).

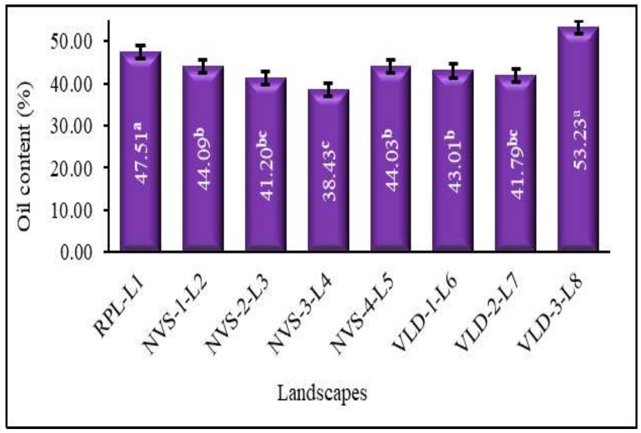


Fig. 2. Variation in *S. foetida* seed oil content (%; SEm=±1.023) among different landscapes of south Gujarat; L=Landscape; RPL=Rajpipla; NVS=Navsari; VLD=Valsad; Letter different in vertical bar are significantly different according to Duncan's multiple range test ($P \le 0.05$)

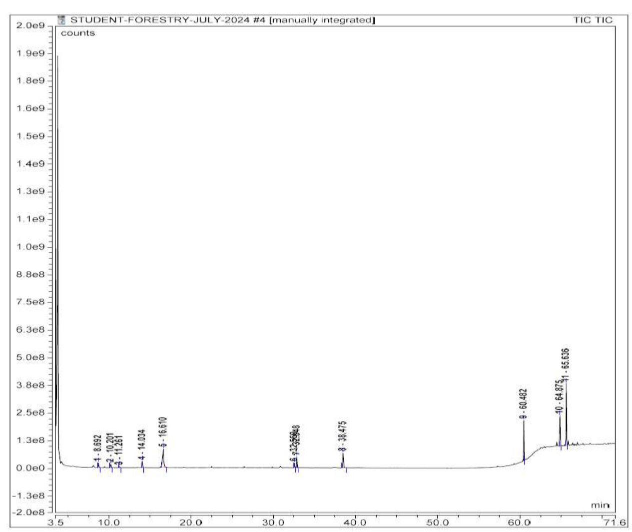


Fig. 3. GC-MS chromatogram showing retention time and relative abundance of volatile phytochemical compounds detected in *S. foetida* kernel oil

Different foods contain different amounts of fat and different types of fatty acids and these may be affected by processing, storage, and cooking methods. Its widespread distribution in dietary fats and oils, palmitic acid is the most common fatty acid in many diets. The optimal fatty acid composition of the diet is an important factor which can play an important role in disease prevention and promote health. The Joint Food and Agriculture Organization/WHO expert consultation on fats and oils in human nutrition (FAO/WHO 1994) concluded that 'Adequate amounts of dietary fat are essential for health'. Fatty acids also can affect the expression of genes encoding for enzymes which are involved in lipid metabolism and to interact with nuclear receptor proteins that bind to DNA, therefore fatty acids can alter the transcription of regulatory genes (Calder 2015).

Based on FAME chromatogram (Figure 4a, b) and Table 3 data demonstrated in that *S. foetida* seed oil exhibited 6 compounds. Among them maximum percentage (57.06%) was of palmitoleic acid. Others were 1.22% palmitic acid, 5.07% oleic acid, 15.41% linoleic acid, 18.26% arachidic acid and 2.96% eicosadienoic acid. The current investigation demonstrated that total saturated fatty acids, monounsaturated fatty acids and poly unsaturated acids were 19.48, 62.13 and 18.37%, respectively. The results deduced that maximum monounsaturated fatty acids were detected in different landscapes of south Gujarat selected in present study.

In response to edaphoclimatic factors plant organs tend

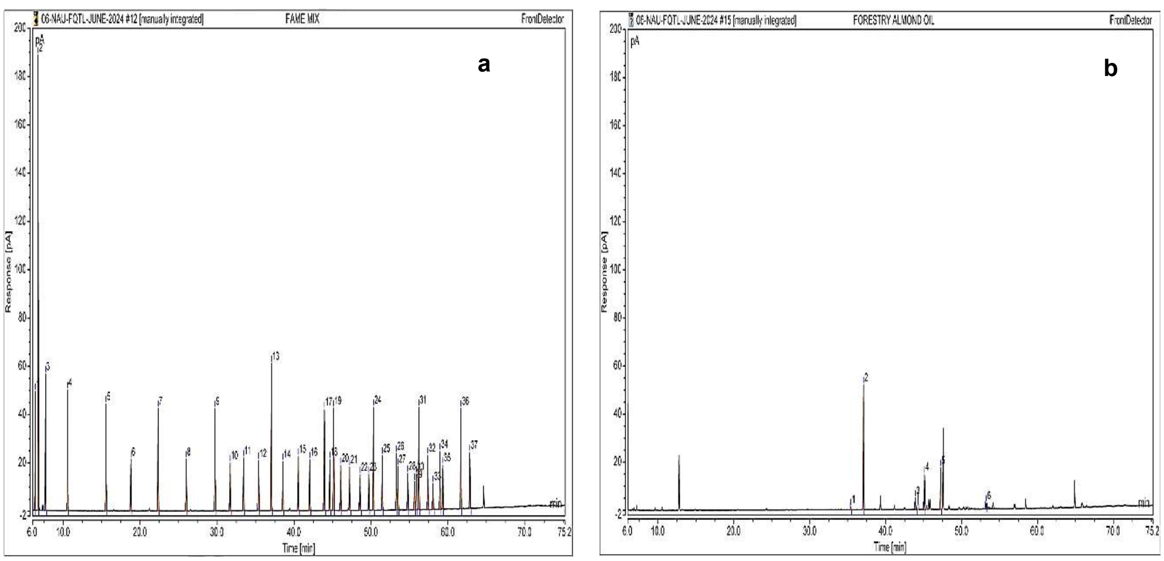


Fig. 4. a) Chromatogram of fatty acid methyl ester (FAME) for standard and b) chromatogram of fatty acid methyl esters (FAME) of *S. foetida* seed kernel oil

Table 2. *S. foetida* kernel oil phytochemicals detected through Gas chromatography-mass spectrometry (GC-MS)

Compound	Chemical formula	Molecular weight (g/mol)	Retention time (min)	Relative area (%)
1-Decyne	$C_{10}H_{18}$	138.25	8.692	14.29
Cyclopropane, pentyl-	C_8H_{16}	112.21	10.201	39.61
Nonanal	$C_9H_{18}O$	142.24	11.261	53.18
2-Decanone	$C_{10}H_{20}O$	156.27	14.034	78.02
Nonanoic acid	$C_9H_{18}O_2$	158.24	16.610	76.55
n-Hexadecanoic acid	$C_{16}H_{32}O_2$	256.42	32.560	48.11
9-Octadecanone	$C_{18}H_{36}O$	268.48	32.848	88.67
12-Tricosanone	$C_{23}H_{46}O$	338.61	38.475	19.28
Squalene	$C_{30}H_{50}$	410.73	60.482	57.43
Stigmasterol	$C_{29}H_{48}O$	412.70	64.875	78.74
β-Sitosterol	$C_{29}H_{50}O$	414.70	65.636	48.43

Table 3. Fatty acid composition of *S. foetida* kernel oil

Fatty acid	Retention time (min)	Relative area (%)
Palmitic acid (C16:0)	35.40	1.22
Palmitoleic acid (C16:1 [cis-9])	37.08	57.06
Oleic acid (C18:1)	43.92	5.07
Linoleic acid (C18:2)	45.13	15.41
Arachidic acid (C20:0)	47.24	18.26
Eicosadienoic acid (C20:2)	53.26	2.96
SFA		19.48%
MUFA		62.13%
PUFA		18.37%

SFA=Saturated fatty acids; MUFA=Monounsaturated fatty acids; PUFA=Polyunsaturated fatty acid

to change their morphometric attributes (Zobel and Talbert 1984, Sukhadiya et al., 2021). The study indicated that overall, seed length, width and seed weight had average values varied significantly. These variations in morpho-metric attributes among the studied landscapes reflects prevailing influence of both genetic and environmental factors on the individuals of these landscapes (Elmagboul et al., 2014, Finch-Savage and Bassel 2016, Malek et al., 2024).

The SFSKs contain golden yellow oil (Habib et al., 2013). Oil from seed kernels have been reported to show high quality and oxidative stability during storage. Thus, seed kernels could be used as a potential source of edible oil in the food industry (Chanyawiwatkul et al., 2018). The oil content obtained in the present study is in conformity with earlier studies (Chanyawiwatkul et al., 2018, Devarajan et al., 2022) in this species. However, Bose et al. (2021) reported higher oil content (58.70%) whereas, Farsana et al. (2022) have reported lower oil content (34%) compared to our findings.

These variations may be ascribed to varied climatic and geological conditions, and genetic variability in *S. foetida* trees growing in different landscapes in present study (Sukhadiya et al., 2021, Malek et al., 2024). Further, oil yield in many oil-yielding species use to be seed moisture content driven. The higher oil content of VLD-3-L_8 is apparent from the fact that this landscape seed source showed lower moisture content and conversely oil content was less in seeds from NVS-1-L_2 landscape which exhibited higher MC. These findings are in congruence with earlier similar inferences made by Orhevba et al. (2013).

Different compounds extracted from the plants possess various properties that which have significant effects on the health and nutrition of humans and livestock (Almodaifer et al., 2017). *S. foetida* seed and oil has anti-diabetic, antidermatophytic, antifungal, antifungal, insecticide, anticancer, anti-obesity, antibiotic, antiviral, hormonal, carcinogenic and antitumoral properties (Kale et al., 2011, Jafri et al., 2019, Subashini et al., 2020, Farsana et al., 2022). Seeds are safe to eat raw or cooked without any toxicity in humans or animals (Alam et al., 2021). A number of flavonoids, phenolics, steroids, coumarins, phenylpropanoids and cerebrosides have been found in the roots, leaves, seeds and barks of this species (Cuong et al., 2019) and triterpenoids, steroids, and fatty acids have also reported (Pham et al., 2021). Phytosterols (stigmasterol, β-sitosterol and squalene) exhibit various beneficial properties, including analgesic, immune-regulating, anti-inflammatory, antioxidant, anticancer, and anti-aging effects, as well as the ability to prevent cardiovascular diseases (Zhao 2016, Chen et al., 2017, Zhang et al., 2022, Luana et al., 2024). β–Sitosterol is one of the main dietary phytosterols belonging to the class of organic compounds known as stigmastanes (Sharma et al., 2021). The provenances studied in the present study could be source for further improvement to get kernel oil with higher beneficial volatile compounds.

Vegetable or tree born oil fatty acids are important compositional attributes as they have antioxidant, antibiotic, antifungal, insecticide anti-tumor activity *etc.* (Subashini et al., 2020, Farsana et al., 2022). Palmitic acid was reported as dominant fatty acid (52%) in this species seed oil (Vipunngeun and Palanuvej 2009). However, in Indian seed oil it was found 11.87% (Kale et al., 2011) comparatively, it was lowest (1.22%) in the current research. In same species the total saturated fatty acids and unsaturated fatty acids amounted up to 15.80% and 33.35% (Kale et al., 2011). Total 27.32% saturated fatty acids and 5.30% mono-unsaturated fatty acids, 55.95% poly-unsaturated fatty acids reported in *S. foetida* seed oil (Chanyawiwatkul et al., 2018), which is comparatively different from the present study. Ghazani et al. (2014) indicated that the extraction methods and solvent used also had the impact on fatty acid composition in oil. *S. foetida* oil fatty acids have been found to have antioxidant, antibiotic, antifungal, insecticide and anti-tumor activity (Kavitha et al., 2015, Subashini et al., 2020, Farsana et al., 2022).

CONCLUSION

The present findings deduced significant variations in *S. foetida* seed morpho-metric varied significantly across the landscapes. The kernel oil content was in good percentage and gas-chromatography mass-spectrometry revealed 11 volatile compounds in extracted oil, which have been reported to have many beneficial biological properties particularly stigmasterol and β-sitosterol. Total Fatty Acid Methyl Esters (FAME) analysis of oil revealed 6 compounds with maximum percentage of palmitoleic acid and these have been reported to have antioxidant, antibiotic, antifungal, insecticide and anti-tumor activity.

ACKNOWLEDGEMENT

Authors extend sincere thanks to Deans, College of Forestry, Navsari Agricultural University, Navsari, and College of Veterinary Science & Animal Husbandry (Kamdhenu University, Gandhinagar), Navsari Campus, Gujarat, India for providing necessary support to accomplish this study.

AUTHOR'S CONTRIBUTION

M.R. Prajapati: sample collection, laboratory analysis, data arrangement and manuscript draft preparation; N.S. Thakur: research conceptualization, data interpretation, table and figure construction, reviewing and editing manuscript; A.A. Mehta: laboratory sample analysis, oil extraction, data interpretation; manuscript reviewing; Y.A. Garde: data tabulation and statistical interpretation.

REFERENCES

Akande TO, Odunsi AA and Akinfala EO 2016. A review of nutritional and toxicological implications of castor bean (*Ricinus communis* L.) meal in animal feeding systems. *Journal of Animal Physiology and Animal Nutrition* 100(2): 201-210.

Alam N, Banu N, Aziz MAI, Barua N, Ruman U, Jahan I and Simal-Gandara J 2021. Chemical profiling, pharmacological insights, and in silico studies of methanol seed extract of *Sterculia foetida*. *Plants* **10**(6): 1135.

Almodaifer S, Alsibaie N, Alhoumendan G, Alammari G and Kavita MS 2017. Role of phytochemicals in health and nutrition. *BAOJ Nutrition* **3**(1): 28-34.

AOAC Official Methods 2000. *Oils and Fats*, US Food and Drug Administration, 10th edi, 41.1.28, 19.

Bose R, Bhattacharya E, Pramanik A, Thomas AH and Biswas SM 2021. Potential oil resources from underutilized seeds of *Sterculia foetida*, L. - Quality assessment and chemical profiling with other edible vegetable oils based on fatty acid composition, oxidative stability, antioxidant activity and cytotoxicity. *Biocatalysis and Agricultural Biotechnology* **33**: 1-7.

Calder PC 2015. Functional roles of fatty acids and their effects on human health. *Journal of Parenteral and Enteral Nutrition* **39**: 18-32.

Chanyawiwatkul J, Supapavnich S and Takeungwongtrakul S 2018. Physicochemical properties and oxidative stability of oils from samrong (*Sterculia foetida*) seed. *International Journal of Agricultural Technology* **14**(7): 1097-1106.

Chen S, Bi Y, Sun S and Chen J 2017. The content and composition of total, free, and esterified sterols of Lotus Plumule oil by GC–MS/FID. *Journal of the American Oil Chemists' Society* **94**(3): 363-373.

Cuong DTD, Dat HT, Duan NT, Hoa NT, Tuyen PNK, Duan NT, Thuong PD, Phat NT, Tri M D, Son DV and Phung NKP 2019. Isolation and characterization of six flavonoids from the leaves of *Sterculia foetida* Linn. *Vietnam Journal of Chemistry* **57**(4): 438-442.

Devarajan Y, Munuswamy DB, Nalla BT, Choubey G, Mishra R and Vellaiyan S 2022. Experimental analysis of *Sterculia foetida* biodiesel and butanol blends as a renewable and eco-friendly fuel. *Industrial Crops and Products* **178**: 114612.

Elmagboul H, Mahgoup S and Eldoma A 2014. Variation in seed morphometric characteristic and germination of *Acacia tortilis* subspecies raddiana and subspecies spirocarpa among three provinces in Sudan. *Global Journal of Bio-science and Biotechnology* **3**(2): 191-196.

FAO 1994. Fats and oils in human nutrition. Report of a joint expert consultation. Food and Agriculture Organization of the United Nations and the World Health Organization. FAO *Food and Nutrition Papers* **57**: i-xix, 1-147.

Farsana S, Sandra S, Ansil PN and Soumya S 2022. *Pharmacological Importance of Sterculia foetida Traditional Medicinal Plants* (Vol. 6), AkiNik Publications, New Delhi, pp: 85-108.

Finch-Savage WE and Bassel GW 2016. Seed vigour and crop establishment: Extending performance beyond adaptation. *Journal of experimental botany* **67**(3): 567-591.

Galla NR 2013. Physico-chemical, mineral, amino acid composition, antioxidant activity and sorption isotherm of *Sterculia foetida* L. seed protein flour. *American Journal of Pharmatech Research* **3**(1): 346-361.

Ghazani SM, Garcia - Llatas G and Marangoni AG 2014. Micronutrient content of cold - pressed, hot - pressed, solvent extracted and RBD canola oil: Implications for nutrition and quality. *European Journal of Lipid Science and Technology* **116**(4): 380-387.

Habib HM, Kamal H, Ibrahim WH and Al Dhaheri AS 2013. Carotenoids, fat soluble vitamins and fatty acid profiles of 18 varieties of date seed oil. *Industrial Crops and Products* **42**: 567-572.

Hegde HT, Gunaga RP, Thakur NS, Bhusara JB and Soundarva RL 2019. Utilization of mahua resources: traditional knowledge as a tool for sustainable management. *Current Science* **17**(10): 1727-1730.

Jafri A, Bano S, Rais J, Khan F, Shivnath N, Sharma A and Arshad M 2019. Phytochemical screening of Sterculia foetida seed extract for anti-oxidant, anti-microbial activity, and detection of apoptosis through reactive oxygen species (ROS) generation, mitochondrial membrane potential (MMP) decrease, and nuclear fragmentation in human osteosarcoma cells. *Journal of Histotechnology* **42**(2): 68-79.

Kale SS, Darade V and Thakur HA 2011. Analysis of fixed oil from *Sterculia foetida* Linn. *International Journal of Pharmaceutical Sciences and Research* **2**(11): 2908.

Kavitha M, Vadivu R and Radha R 2015. A review on *Sterculia foetida* Linn. *Research Journal of Pharmacognosy and Phytochemistry* **7**(4): 239.

Luana C. dos Santos, Renata G. Broco e Silva, Eupidio Scopel, Tahmasb Hatami, Camila A. Rezende and Julian Martinez 2024. Concentration of stigmasterol, β-sitosterol and squalene from passion fruit (*Passiflora edulis* Sims.) by-products by supercritical CO2 adsorption in zeolite 13-X. *The Journal of Supercritical Fluids* **209**: 106250.

Malek SS, Thakur NS, Patel VR, Gunaga RP, Hegde HT and Garde YA 2024. Provenance and seasonal variations in proximate and cell wall composition of *Melia dubia* leaf fodder from Satpura and Sahyadri mountain ranges, India. *Agroforestry Systems* **98**: 1859-1872

Mujumdar AM, Naik DG, Waghole RJ, Kulkarni DK and Kumbhojkar MS 2000. Pharmacological studies on *Sterculia foetida* leaves. *Pharmaceutical biology* **38**(1): 13-17.

Orhevba BA, Chukwu O, Osunde ZD and Ogwuagwu V 2013. Influence of Moisture Content on the Yield of Mechanically Expressed Neem Seed Kernel Oil. *Academic Research International* **5**: 252-257.

Orwa C, Mutua A, Kindt R, Jamnadass R and Anthony S 2009. *Agroforestry Database: A tree reference and selection guide version 4.0*. Retrieved from http://www.wo rldagroforestry.org/sites/treedbs/treedatabases.asp [Accessed 12 March 2025].

Oyeleke GO, Salam MA and Adetoro RO 2012. Some aspects of nutrient analysis of seed, pulp, and oil of baobab (*Adansonia digitata* L.). *Journal of Environmental Science, Toxicology and Food Technology* **1**(4): 32-35.

Patel N, Choudhary H and Goswami S 2024. NITI Aayog (2024): Pathways and strategy for accelerating growth in edible oil towards goal of *Atmanirbharta*. GoI, pp: 214. https://www.niti.gov.in

Pham NKT, Nguyen TD, Doan TDC, Ha TD, Tran NMA, Tran TD and Nguyen TP 2021. Stercufoetin A, new oleanane-type triterpenoid from the leaves of *Sterculia foetida* L. *Natural Product Research* **35**(7): 1226-1231.

Sarkar N, Chakraborty D, Dutta R, Agrahari P, Bharathi SD, Singh AA and Jacob S 2021. A comprehensive review on oilseed cakes and their potential as a feedstock for integrated biorefinery. *Journal of Advanced Biotechnology and Experimental Therapeutics* **4**(3): 376-387.

Sharma N, Tan MA and An SSA 2021. Phytosterols: potential metabolic modulators in neurodegenerative diseases. *International Journal of Molecular Sciences* **22**(22): 12255.

Sheoran OP, Tonk DS, Kaushik, LS, Hasija RC and Pannu RS 1998. Statistical software package for agricultural research workers. In: "*Recent advances in information theory, statistics and computer applications*". Department of Mathematics Statistics, CCS HAU, Hisar, India, pp: 139-143.

Snedecor GW and Cochran WG 1980. "*Statistical methods*", (7th edn.), Iowa State University Press, Ames. USA, pp: 292.

Subashini K, Prakash S and Sujatha V 2020. Polymer nanocomposite prepared using copper oxide nanoparticles derived from *Sterculia foetida* leaf extract with biological applications. *Materials Research Express* **7**(11): 115-308.

Sukhadiya ML, Thakur NS, Patel VR, Gunaga RP, Kharadi VB, Tyagi KK and Singh S 2021. Provenance variations in proximate principles, mineral matter, total phenols and phytochemicals of *Melia dubia* drupes: an unexplored alternate livestock feed stock. *Journal of Forestry Research* **32**(1): 119-131.

Vipunngeun N and Palanuvej C 2009. Fatty acids of *Sterculia foetida* seed oil. *Journal of Health Research* **23**(3): 157.

Zhang R, Han Y, McClements DJ, Xu D and Chen S 2022. Production, characterization, delivery, and cholesterol-lowering mechanism of phytosterols: A review. *Journal of agricultural and food chemistry* **70**: 2483–2494.

Zhao Q 2016. *Research on the extraction, purification, composition analysis and antimicrobial active of physterol from seed kernel oil of shiny-leaved yellowhorn*. M.Sc. Thesis, Shaanxi Normal University, Xi'an.

Zobel BJ and Talbert J 1984. *Applied Forest Tree Improvement*, John Wiley, New York, USA, pp 505.

Received 25 August, 2025; Accepted 10 November, 2025