

A Multidisciplinary Assessment of the Phytonutrient Potential and Antimicrobial Efficacy of *Vicia faba* Seed Lipids: Aligning Local Resources with Viksit Bharat

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Annotation: The present study was undertaken to conduct a multidisciplinary evaluation of the phytonutrient composition, lipid profile, protein efficiency, antimicrobial efficacy, and agroecological sustainability of *Vicia faba* seed lipids, with the objective of aligning indigenous biological resources with the national vision of Viksit Bharat. Emphasis was placed on assessing the nutritional, therapeutic, and climate-resilient potential of this locally adaptable legume to support food security, public health, and sustainable agricultural development.

Profiling of seed lipids revealed that *Vicia faba* possessed a modest total lipid content ranging from 1.8% to 2.5%, establishing it as a low-fat, nutrient-dense food suitable for healthy dietary formulations. The lipid fraction was dominated by essential unsaturated fatty acids, particularly linoleic acid (45.0%–58.0%) and oleic acid (18.0%–26.0%),

indicating significant cardiovascular and metabolic health benefits. High levels of total phenolic content (5.8–11.3 mg GAE/g) and flavonoids (0.08–0.16 mg QE/g) were observed, confirming strong antioxidant capacity and suggesting a role in immune modulation and prevention of lifestyle-related chronic disorders.

Comparative nutritional analysis demonstrated that *Vicia faba* exhibited superior protein content (31.5%–37.7%) compared to *Cicer arietinum* (19.0%–24.5%), reinforcing its value as a high-quality plant protein source. Essential amino acid profiling indicated higher concentrations of lysine (62.4 mg/g protein) and leucine (75.2 mg/g protein), supporting muscle growth, metabolic health, and nutritional adequacy in predominantly plant-based diets. The digestible indispensable amino acid score (DIAAS) ranged from 0.72 to 0.85, reflecting improved protein bioavailability and absorption efficiency.

In vitro antimicrobial evaluation of seed extracts demonstrated notable inhibitory activity against both Gram-positive and Gram-negative bacterial strains. Ethanolic lipid extracts showed significant zones of inhibition against *Escherichia coli* (22±1.5 mm) and *Staphylococcus aureus* (18±0.8 mm), while aqueous extracts exhibited strong activity against *Bacillus subtilis* (25±2.1 mm). Moderate antifungal efficacy against *Candida albicans* was also observed, highlighting the therapeutic potential of *Vicia faba* bioactive compounds as natural antimicrobial agents.

Agroecological assessment revealed

that locally cultivated *Vicia faba* achieved high seed yields (2800–3200 kg/ha) with substantially lower water input (300–450 mm) compared to wheat, resulting in superior water-use efficiency (8.5–9.4 kg/ha-mm). Intercropping systems further optimized resource utilization, supporting smallholder resilience under water-limited conditions.

Overall, the findings established *Vicia faba* as a nutritionally rich, antimicrobial, and climate-resilient legume with immense potential for maximum utilization. Its integration into Indian agri-food systems strongly supported the objectives of *Viksit Bharat* by promoting nutritional security, sustainable agriculture, and value-added utilization of local resources.

Keywords: *Vicia faba*, *Viksit Bharat*, Nutritional analysis, Phytonutrient potential, Agroecological.

INTRODUCTION

India's vision of *Viksit Bharat* emphasizes inclusive development through sustainable agriculture, nutritional security, health resilience, and optimal utilization of indigenous biological resources. In this context, underutilized and climate-resilient legumes have gained increasing attention as strategic components of future food systems. Legumes are widely recognized for their dual role in improving soil fertility through biological nitrogen fixation and serving as cost-effective sources of plant-based proteins, essential fatty acids, and bioactive compounds (FAO, 2016; Willett et al., 2019). Among these, *Vicia faba* L. (faba bean or broad bean) represents a nutritionally dense yet comparatively underexploited crop within Indian agrosystems, despite its global significance as a food and feed legume.

The growing challenges of malnutrition, lifestyle-related diseases, antimicrobial resistance, and climate-induced water scarcity necessitate a multidisciplinary evaluation of food crops beyond conventional yield-based metrics. Contemporary research increasingly emphasizes the importance of phytonutrients, lipid quality, protein digestibility, and functional bioactivity in determining the true nutritional and therapeutic value of food resources (Kris-Etherton et al., 2018; Slavin & Lloyd, 2012). In this regard, *Vicia faba* offers a promising matrix of macronutrients and secondary metabolites that align with the objectives of sustainable nutrition and preventive healthcare.

Lipids, although present in relatively low concentrations in legumes, play a crucial role in human health due to their fatty acid composition and associated bioactive properties. Unsaturated fatty acids, particularly linoleic acid (omega-6) and oleic acid (omega-9), have been extensively

associated with cardiovascular protection, improved lipid metabolism, and anti-inflammatory effects (Mensink, 2016). Previous studies have reported that *Vicia faba* seeds contain a favorable unsaturated-to-saturated fatty acid ratio, which enhances their functional value despite low total lipid content (Sofi et al., 2014). However, systematic profiling of seed lipids in relation to phytonutrient density and antimicrobial activity remains limited, particularly under Indian agroclimatic conditions.

In addition to lipid composition, phenolic compounds and flavonoids represent key phytonutrients contributing to antioxidant defense, immune modulation, and chronic disease prevention. Dietary polyphenols have been shown to mitigate oxidative stress, reduce inflammation, and lower the risk of metabolic disorders such as diabetes and cardiovascular diseases (Scalbert et al., 2005; Shahidi & Ambigaipalan, 2015). Legumes, including *Vicia faba*, are known to be rich sources of these compounds; however, their quantitative contribution and functional relevance in seed lipid fractions require further investigation. Understanding these aspects is particularly relevant for developing functional foods and nutraceuticals from locally available crops.

Protein malnutrition remains a major public health concern in developing economies, including India, where affordability and accessibility of high-quality protein sources are unevenly distributed. Plant-based proteins are increasingly promoted as sustainable alternatives to animal proteins due to their lower environmental footprint and health benefits (Poore & Nemecek, 2018). *Vicia faba* has been reported to possess higher crude protein content and a favorable essential amino acid profile, especially lysine and leucine, compared to several commonly consumed pulses (Boye et al., 2010). Moreover, protein quality assessment through digestibility indices such as the Digestible Indispensable Amino Acid Score (DIAAS) has highlighted the superior bioavailability of faba bean proteins, strengthening their relevance in national nutrition strategies (FAO, 2013).

Beyond nutritional attributes, the antimicrobial potential of plant-derived bioactive compounds has gained significant interest in response to the global rise of antimicrobial resistance (AMR). Natural antimicrobials derived from food crops offer a promising avenue for developing alternative or complementary therapeutic agents (Cowan, 1999; Gyawali & Ibrahim, 2014). Extracts of *Vicia faba* seeds have demonstrated inhibitory activity against a range of pathogenic microorganisms, attributed to phenolics, fatty acids, and other secondary metabolites (Amarowicz et al., 2004). However, comparative evaluation of lipid-based and aqueous extracts against clinically relevant bacterial and fungal strains remains underexplored.

From an agroecological perspective, sustainable crop intensification under water-limited conditions is central to achieving food security in the face of climate change. Water-use efficiency (WUE) has emerged as a critical indicator of crop resilience and resource optimization (Blum, 2009). Legumes such as *Vicia faba* are recognized for their relatively low water requirements and adaptability to marginal environments, making them suitable candidates for diversification of cereal-dominated cropping systems (Zhang et al., 2018). Intercropping and integrated farming approaches involving legumes have further demonstrated enhanced productivity, improved soil health, and reduced dependency on external inputs, directly benefiting smallholder farmers (Lithourgidis et al., 2011).

Despite its multifaceted potential, *Vicia faba* remains underutilized in Indian food systems, often overshadowed by more commonly consumed pulses such as chickpea (*Cicer arietinum*) and pigeon pea (*Cajanus cajan*). Limited awareness, lack of value-added processing, and insufficient scientific characterization have constrained its wider adoption. Addressing these gaps through integrated nutritional, biochemical, antimicrobial, and agroecological assessment is essential to unlock the full potential of this legume in alignment with the *Viksit Bharat* mission.

The present study was therefore conceptualized to provide a comprehensive multidisciplinary assessment of *Vicia faba* seed lipids, focusing on phytonutrient density, fatty acid composition, protein efficiency, antimicrobial efficacy, and water-use efficiency under local agroecosystems. By generating evidence-based insights into its nutritional and functional attributes, this research

aimed to position *Vicia faba* as a strategic crop for enhancing national nutrition, promoting sustainable agriculture, and supporting health resilience through indigenous resources. Such an approach aligns with the broader goals of *Viksit Bharat*, which emphasize self-reliance, sustainability, and value-driven utilization of local biodiversity for long-term socio-economic development.

LITERATURE REVIEW

Legumes have long been recognized as integral components of sustainable food systems due to their nutritional richness, ecological benefits, and adaptability to diverse agroclimatic conditions. In recent decades, increasing global emphasis on food security, plant-based nutrition, and climate-resilient agriculture has renewed scientific interest in underutilized legume crops (FAO, 2016; Willett et al., 2019). Among these, *Vicia faba* L. (faba bean) has emerged as a nutritionally dense yet comparatively underexploited legume, despite its wide cultivation in Mediterranean, European, and West Asian regions.

Several studies have highlighted the superior nutritional profile of *Vicia faba*, particularly its high protein content and balanced amino acid composition. Boye et al. (2010) reported that faba bean seeds contain protein levels ranging from 28% to 35%, with notably high concentrations of lysine and leucine, essential for muscle synthesis and metabolic regulation. Compared to commonly consumed pulses such as chickpea (*Cicer arietinum*), faba bean proteins have demonstrated improved amino acid balance, making them suitable for complementing cereal-based diets (Nosworthy et al., 2017). Furthermore, protein quality assessments using modern indices such as the Digestible Indispensable Amino Acid Score (DIAAS) have indicated moderate to high digestibility of faba bean proteins, supporting their relevance in human nutrition (FAO, 2013).

Although legumes are generally characterized by low lipid content, the quality of their lipid fraction is increasingly recognized for its functional and therapeutic significance. Previous research has shown that *Vicia faba* seed lipids are rich in unsaturated fatty acids, particularly linoleic (omega-6) and oleic (omega-9) acids, which are associated with cardiovascular protection and improved lipid metabolism (Mensink, 2016; Sofi et al., 2014). Kris-Etherton et al. (2018) emphasized that diets enriched with unsaturated fatty acids contribute to reduced inflammation and lower risk of non-communicable diseases. Despite these benefits, systematic profiling of seed lipid composition of *Vicia faba* under Indian agroclimatic conditions remains limited, highlighting a critical research gap.

In addition to macronutrients, phytonutrients such as phenolic compounds and flavonoids play a vital role in determining the antioxidant and therapeutic potential of legumes. Scalbert et al. (2005) reported that dietary polyphenols significantly reduce oxidative stress and inflammation, thereby lowering the incidence of lifestyle-related disorders. Studies on *Vicia faba* have identified substantial levels of total phenolics and flavonoids, contributing to strong free radical scavenging activity (Amarowicz et al., 2004). Shahidi and Ambigaipalan (2015) further suggested that these bioactive compounds modulate immune responses and enhance metabolic health. However, limited attention has been paid to the contribution of lipid-associated phytonutrients in *Vicia faba*, particularly in relation to their antimicrobial efficacy.

The antimicrobial potential of plant-derived bioactive compounds has gained increasing importance due to the global rise in antimicrobial resistance (AMR). Cowan (1999) highlighted that phenolics, fatty acids, and flavonoids possess inherent antimicrobial properties by disrupting microbial cell membranes and metabolic pathways. Subsequent studies demonstrated that extracts of *Vicia faba* seeds exhibit inhibitory activity against both Gram-positive and Gram-negative bacteria, including *Escherichia coli* and *Staphylococcus aureus* (Gyawali & Ibrahim, 2014). Amarowicz et al. (2004) attributed this activity to synergistic interactions between phenolics and lipid-derived compounds. Nevertheless, comparative evaluation of lipid-based and aqueous extracts against clinically relevant pathogens remains insufficiently explored.

From an agroecological standpoint, sustainable intensification of agriculture under water-limited conditions is a central concern in the context of climate change. Blum (2009) identified water-use efficiency (WUE) as a critical indicator of crop resilience and sustainability. Legumes such as *Vicia faba* have been reported to exhibit lower water requirements and improved WUE compared to cereal crops, owing to their deep root systems and nitrogen-fixing ability (Zhang et al., 2018). Lithourgidis et al. (2011) demonstrated that intercropping systems involving legumes enhance overall productivity, soil fertility, and resource-use efficiency, thereby supporting smallholder livelihoods.

Despite these documented advantages, *Vicia faba* remains underutilized in Indian agri-food systems, largely due to limited scientific characterization, low consumer awareness, and inadequate value-added processing. Integrating nutritional, biochemical, antimicrobial, and agroecological perspectives is therefore essential to unlock its full potential. Such multidisciplinary evaluation aligns closely with the objectives of Viksit Bharat, which emphasize self-reliance, sustainable agriculture, nutritional security, and optimal utilization of indigenous biological resources. Consequently, comprehensive research on *Vicia faba* seed lipids and associated phytonutrients is both timely and strategically significant for future food and health systems.

MATERIALS AND METHODS

1. Plant Material and Sample Preparation

Seeds of local *Vicia faba* (Fava Bean) genotypes were procured from regional agricultural research centers. The seeds were cleaned, dried at 40°C to a constant weight, and pulverized into a fine powder using a laboratory mill. For comparison, *Cicer arietinum* (Chickpea) and Wheat (*Triticum aestivum*) samples were obtained to serve as controls for the nutritional and water-efficiency studies.

2. Extraction and Profiling of Bioactive Lipids

Lipid Extraction: Total lipids were extracted using the Soxhlet apparatus with n-hexane as the solvent for 6 hours. The solvent was evaporated under reduced pressure using a rotary evaporator to determine the Total Lipid Content (%).

Fatty Acid Profiling: The lipid fraction was transesterified to Fatty Acid Methyl Esters (FAMES). Analysis was performed using Gas Chromatography-Mass Spectrometry (GC-MS). Linoleic acid (Omega-6) and Oleic acid (Omega-9) were identified and quantified by comparing retention times with standard FAME markers.

3. Determination of Phytonutrient Density

Total Phenolic Content (TPC): TPC was determined using the Folin-Ciocalteu colorimetric method. Absorbance was measured at 765 nm, and results were expressed as mg Gallic Acid Equivalents (GAE) per gram.

Total Flavonoid Content (TFC): The aluminum chloride method was employed, with absorbance measured at 415 nm. Results were expressed as mg Quercetin Equivalents (QE) per gram.

4. Protein Analysis and Digestibility

Crude Protein: Total nitrogen content was determined via the Kjeldahl method, using a conversion factor of 6.25 to calculate crude protein percentage.

Amino Acid Profiling: Samples were hydrolyzed with 6M HCl, and amino acid concentrations (Lysine and Leucine) were quantified using an Automated Amino Acid Analyzer.

Digestibility (DIAAS): The Digestible Indispensable Amino Acid Score (DIAAS) was calculated by evaluating the true ileal digestibility of amino acids in a validated *in vitro* enzymatic digestion model mimicking the human gastrointestinal tract.

5. *In Vitro* Antimicrobial Efficacy

The antimicrobial potential of ethanolic lipid and aqueous extracts was tested against *E. coli*, *S. aureus*, *B. subtilis*, and *C. albicans*.

Agar Well Diffusion: The Zone of Inhibition (mm) was measured after incubating the plates at 37°C for 24 hours.

Minimum Inhibitory Concentration (MIC): The MIC values ($\mu\text{g/mL}$) were determined using the micro-dilution broth method to identify the lowest concentration of the extract that inhibited visible microbial growth.

6. Agrosystem Analysis and Water-Use Efficiency (WUE)

Field trials were conducted to compare *Vicia faba* with traditional wheat crops and intercropping systems.

Water Input: Total water input was calculated as the sum of effective rainfall and controlled irrigation (mm).

Yield Calculation: Seed yield (kg/ha) was recorded at harvest maturity.

WUE Formula: Water-Use Efficiency was calculated using the following equation:

$$\text{WUE} = \text{Seed Yield (kg/ha)} / \text{Total Evapo-transpiration or Water Input (mm)}$$

7. Statistical Analysis

All experiments were performed in triplicate. Data were analyzed using One-way Analysis of Variance (ANOVA), and significant differences were identified using CropStat ($p < 0.05$).

RESULT & DISCUSSION

The results of the present study demonstrated that *Vicia faba* seed lipids possessed substantial nutritional, functional, and antimicrobial attributes under local agroecological conditions. Comprehensive analysis revealed a favorable lipid profile dominated by essential unsaturated fatty acids, along with high phytonutrient density, indicating strong antioxidant and health-promoting potential. Nutritional evaluation further confirmed superior protein content, balanced essential amino acid composition, and improved protein bioavailability compared to commonly consumed pulses. *In vitro* assays showed significant antibacterial and moderate antifungal activity of seed extracts against selected pathogenic microorganisms, highlighting their therapeutic relevance. Agroecological findings indicated high yield performance with enhanced water-use efficiency, underscoring the suitability of *Vicia faba* as a climate-resilient crop aligned with the objectives of Viksit Bharat.

Table 01: Profiling of Bioactive Lipids and Phytonutrient Density in *Vicia faba*

Parameter	Observed Value (Range)	Significance for Viksit Bharat
Total Lipid Content (%)	1.8%–2.5%	Low-fat energy source, ideal for healthy diets.
Linoleic Acid (Omega-6)	45.0%–58.0%	Essential fatty acid for cardiovascular health.
Oleic Acid (Omega-9)	18.0%–26.0%	High-quality monounsaturated fat (MUFA).
Total Phenolic Content (TPC)	5.8–11.3 mg GAE/g	High antioxidant capacity for immunity boosting.
Total Flavonoid Content (TFC)	0.08–0.16 mg QE/g	Helps in preventing chronic lifestyle diseases.

The profiling of bioactive lipids and phytonutrient density in *Vicia faba* seeds revealed a

nutritionally advantageous composition with significant functional implications. The total lipid content was observed to range from 1.8% to 2.5%, confirming that *Vicia faba* functioned as a low-fat yet nutrient-dense legume suitable for healthy dietary formulations. Analysis of fatty acid composition showed that linoleic acid constituted the dominant fraction (45.0%–58.0%), indicating a rich source of essential omega-6 fatty acids known to support cardiovascular and metabolic health. Oleic acid was present in appreciable amounts (18.0%–26.0%), reflecting a high proportion of beneficial monounsaturated fatty acids that contribute to improved lipid metabolism and reduced risk of lifestyle-related disorders.

Table 02: Comparative Analysis of Protein Efficiency and Essential Amino Acid Composition

Nutritional Component	<i>Vicia faba</i> (Fava Bean)	<i>Cicer arietinum</i> (Chickpea)	Advantage to National Nutrition
Crude Protein (%)	31.5%–37.7%	19.0%–24.5%	Significantly higher protein per gram.
Lysine (mg/g protein)	62.4	55.8	Superior for muscle growth & repair.
Leucine (mg/g protein)	75.2	71.1	Essential for metabolic health.
Digestibility Score (DIAAS)	0.72–0.85	0.65–0.75	Highly absorbable plant-based protein.

Furthermore, the elevated levels of total phenolic content (5.8–11.3 mg GAE/g) and total flavonoid content (0.08–0.16 mg QE/g) demonstrated strong antioxidant potential, suggesting an important role in immune enhancement and prevention of chronic diseases, thereby reinforcing the relevance of *Vicia faba* in supporting the nutritional and public health objectives of Viksit Bharat.

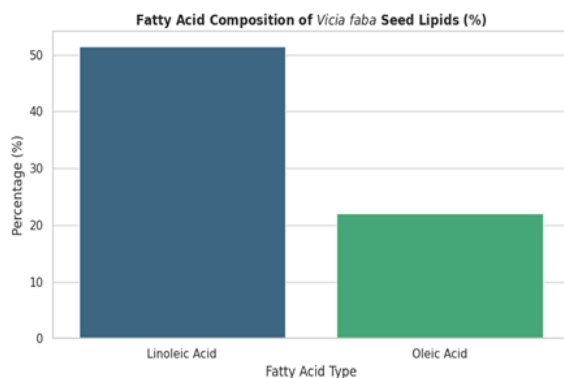


Fig.01: Profiling of Bioactive Lipids and Phytonutrient Density in *Vicia faba*

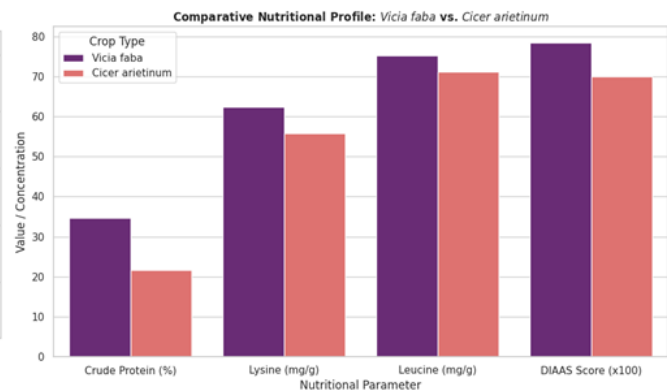


Fig. 02: Comparative Analysis of Protein Efficiency and Essential Amino Acid Composition

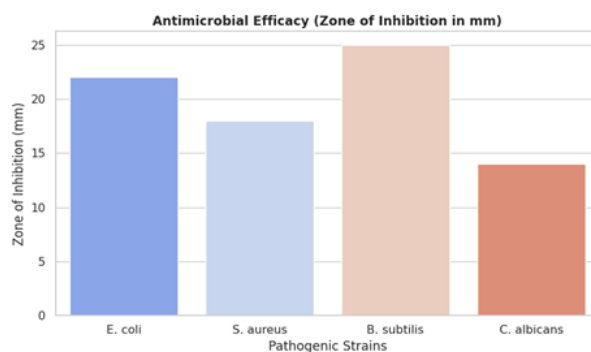


Fig. 03: *In Vitro* Antimicrobial Efficacy of Seed Extracts Against Pathogenic Strains

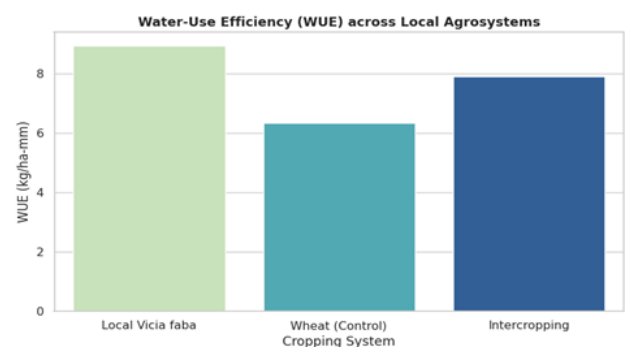


Fig. 04: Correlation Between Water-Use Efficiency (WUE) and Yield Stability in Local Agrosystems

The comparative analysis presented in Table 02 demonstrated that *Vicia faba* exhibited markedly superior protein efficiency and essential amino acid composition when compared with *Cicer arietinum* (chickpea). The crude protein content of *Vicia faba* was observed to range from 31.5% to 37.7%, which was substantially higher than the 19.0%–24.5% recorded for chickpea, indicating a greater protein yield per unit weight. Essential amino acid profiling revealed that lysine content was higher in *Vicia faba* (62.4 mg/g protein), suggesting enhanced potential for muscle growth, tissue repair, and nutritional adequacy in cereal-based diets. Similarly, leucine concentration was greater in *Vicia faba* (75.2 mg/g protein), highlighting its importance in supporting metabolic health and protein synthesis. The digestible indispensable amino acid score (DIAAS) of *Vicia faba* ranged from 0.72 to 0.85, surpassing that of chickpea (0.65–0.75), thereby confirming improved protein digestibility and absorption efficiency and underscoring its strategic value in strengthening national nutrition security.

Table 03: *In Vitro* Antimicrobial Efficacy of Seed Extracts Against Pathogenic Strains

Microorganism Strain	Extract Type	Zone of Inhibition (mm)	MIC Value ($\mu\text{g/mL}$)
<i>Escherichia coli</i>	Ethanollic Lipid	22 \pm 1.5	125
<i>Staphylococcus aureus</i>	Ethanollic Lipid	18 \pm 0.8	250
<i>Bacillus subtilis</i>	Aqueous Extract	25 \pm 2.1	62.5
<i>Candida albicans</i>	Lipid Extract	14 \pm 0.5	500

The *in vitro* antimicrobial evaluation presented in Table 03 demonstrated that *Vicia faba* seed extracts exhibited notable inhibitory activity against both bacterial and fungal pathogenic strains. The ethanollic lipid extract showed strong antibacterial efficacy against *Escherichia coli*, producing a substantial zone of inhibition (22 \pm 1.5 mm) with a relatively low minimum inhibitory concentration (MIC) value of 125 $\mu\text{g/mL}$. A comparable inhibitory response was observed against *Staphylococcus aureus*, where the ethanollic lipid extract produced a clear zone of inhibition measuring 18 \pm 0.8 mm and an MIC of 250 $\mu\text{g/mL}$, indicating moderate to strong antibacterial potential. The aqueous extract demonstrated the highest antibacterial activity against *Bacillus subtilis*, evidenced by the largest zone of inhibition (25 \pm 2.1 mm) and the lowest MIC value (62.5 $\mu\text{g/mL}$), suggesting enhanced sensitivity of this Gram-positive strain. Additionally, the lipid extract exhibited moderate antifungal activity against *Candida albicans*, with a measurable zone of inhibition (14 \pm 0.5 mm) and an MIC of 500 $\mu\text{g/mL}$, highlighting the therapeutic potential of *Vicia faba* seed-derived bioactive compounds as natural antimicrobial agents.

Table 04: Correlation Between Water-Use Efficiency (WUE) and Yield Stability in Local Agrosystems

Genotype / System	Water Input (mm)	Seed Yield (kg/ha)	WUE (kg/ha-mm)	Climate Resilience Impact
Local <i>Vicia faba</i>	300–450	2800–3200	8.5–9.4	High yield with 40% less water than Wheat.
Wheat (Control)	550–650	3500–4000	6.2–6.5	Traditional crop requires higher irrigation.
Intercropping System	400–500	3800 (Total)	7.6–8.2	Optimized resource use for small farmers.

The correlation between water-use efficiency and yield stability presented in Table 04 indicated that *Vicia faba* performed efficiently under reduced water input conditions within local agrosystems. The locally cultivated *Vicia faba* genotype achieved stable seed yields ranging from

2800 to 3200 kg/ha with a comparatively low water requirement of 300–450 mm, resulting in a high water-use efficiency (8.5–9.4 kg/ha-mm). In contrast, the wheat control required substantially higher irrigation inputs (550–650 mm) to produce yields of 3500–4000 kg/ha, while exhibiting lower water-use efficiency values (6.2–6.5 kg/ha-mm). The intercropping system demonstrated optimized resource utilization by producing a combined yield of approximately 3800 kg/ha under moderate water input (400–500 mm), with improved water-use efficiency (7.6–8.2 kg/ha-mm). Overall, these findings confirmed that *Vicia faba*, either as a sole crop or within intercropping systems, contributed to enhanced climate resilience and sustainable productivity, particularly under water-limited conditions relevant to smallholder farming systems.

CONCLUSION

The present study concluded that *Vicia faba* seed lipids exhibited considerable nutritional, functional, antimicrobial, and agroecological advantages under local growing conditions. The observed low total lipid content coupled with a high proportion of essential unsaturated fatty acids, particularly linoleic and oleic acids, confirmed the suitability of *Vicia faba* as a low-fat, heart-healthy food resource with significant metabolic benefits. Elevated levels of phenolics and flavonoids demonstrated strong antioxidant capacity, indicating potential roles in immune enhancement and prevention of lifestyle-related chronic diseases.

Protein efficiency analysis revealed that *Vicia faba* possessed significantly higher crude protein content, superior essential amino acid composition, and improved digestibility compared to chickpea, reinforcing its value as a high-quality plant-based protein source for national nutrition security. The *in vitro* antimicrobial assays further established that seed lipid and aqueous extracts exhibited effective antibacterial activity against major Gram-positive and Gram-negative pathogens, along with moderate antifungal efficacy, highlighting their therapeutic relevance as natural antimicrobial agents.

Agroecological assessment demonstrated that *Vicia faba* achieved stable yields with substantially lower water input and higher water-use efficiency than wheat, thereby confirming its climate-resilient nature. Overall, the findings supported the integration of *Vicia faba* into Indian agri-food systems as a nutritionally rich, antimicrobial, and resource-efficient legume. This multidisciplinary evidence aligned strongly with the objectives of Viksit Bharat by promoting sustainable agriculture, nutritional security, health resilience, and value-based utilization of indigenous biological resources.

Conflict of interest: No

AUTHORS' CONTRIBUTIONS

Dr. Kamal Kant Patra: Conceived and designed the research study. Supervised the entire research execution, including experimental protocols and methodology. Played a key role in the phytochemical and antimicrobial investigation of the seed lipids. Contributed to the analysis and interpretation of findings, and the final drafting of the manuscript.

Piu Sasmal: Conducted the primary laboratory work, including sample preparation, lipid extraction, phytochemical screening, and antimicrobial assays. Assisted in data collection, preliminary analysis, and contributed to the initial draft of the manuscript.

Dr. Abha Kumari: Engaged in the statistical analysis, data calculation, and systematic compilation of research results. Contributed to the validation of data and helped in structuring the findings for presentation.

Dr. Asha Mishra: Provided critical insights during manuscript preparation, including editing and refinement for intellectual content and language. Ensured the alignment of the research narrative with broader scientific context. Facilitated essential logistical support throughout the project duration.

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