

ULAM RAJA TO HERBAL TEA: A METACOGNITIVE ISLAMIC REFLECTIONS ON A HEALTHCARE PHARMACEUTICAL INNOVATION

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Abstract: Background: Herbal teas are increasingly recognised for health promotion with a significance extending beyond biomedical effects to ethical, cultural, and religious dimensions. This study explores *Cosmos caudatus* (ulam raja), a traditional Malay herb, as a functional herbal tea through an integrated scientific and Islamic metacognitive approach. Methods: Aqueous infusions from leaves harvested at different maturity stages (4, 6, and 8 weeks) were evaluated for antioxidant and antidiabetic activities, cytotoxicity, heavy metal presence, and microbial load. A metacognitive framework was applied to interpret findings within Islamic epistemology, linking scientific results to Qur'anic, prophetic, and ethical principles. Results: The eight-week-old leaves demonstrated the strongest α -glucosidase inhibitory activity ($IC_{50}=65.4\pm3.3$ $\mu\text{g/mL}$), while the four-week-old leaves showed the highest antioxidant capacity (DPPH $IC_{50}=15.5\pm0.8$ $\mu\text{g/mL}$). All samples were non-toxic to Vero cells and adhered to stringent regulatory limits for heavy metals and microbial load. Elevated microbial counts were detected in later harvests, signalling the need for improved post-harvest handling. These findings were contextualised within *mīzān* (balance), *wasatiyyah* (moderation), *lā ḍarar* (non-harm), and *maqāṣid al-sharī'ah*, particularly preservation of life and intellect. The absence of contaminants reflected *halalan toyyiban*, while microbial risks highlighted the imperative of *iḥsān* (excellence). Conclusion: The pharmacological findings support the potential of *Cosmos caudatus* tea as a safe and beneficial herbal infusion, with the eight-week maturity stage offering a favourable balance of health benefits and sustainable harvesting. This aligns with the Islamic principles and its validation affirms opportunities for rural livelihood enhancement, halal industry growth, and Malay heritage preservation. By bridging laboratory evidence with Islamic humanities reflection, this study positions herbal tea development as a model of Islamic healthcare innovation that unites science, ethics, and community empowerment.

Keywords: *Cosmos caudatus*, herbal tea, ulam raja, metacognitive, prophetic medicine, halal pharmaceutical.

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INTRODUCTION

The consumption of herbal teas has a long history in Islamic civilisation, dating back to the early centuries of Islam when medicinal plants and aromatic infusions were part of both daily

life and prophetic medicine (*al-ṭibb al-nabawī*). Classical authorities such as Ibn Sīnā in the Canon of Medicine (11th century) and al-Rāzī in his medical treatises described the therapeutic benefits of herbs infused in hot water to relieve ailments, aid digestion, and restore bodily balance. Herbs like anise, mint, chamomile, fenugreek, and hibiscus were widely used, reflecting the Qur'ānic emphasis on plants as sources of divine healing and provision (Qur'ān 16:11; 16:69). Over time, herbal infusions became not only remedies but also part of cultural and social practices, particularly in Baghdad, Damascus, and Andalusia, where Islamic scholars synthesised Greek, Persian, and Indian knowledge into a rich medical tradition. These practices spread across the Muslim world, from hibiscus tea (*karkadé*) in Egypt to green tea in Persia and Morocco, evolving into rituals that combined health, hospitality, and spirituality.

In contemporary times, herbal tea consumption has grown globally, with health-conscious consumers turning to plant-based and sustainable products. Herbal teas are widely perceived to provide medicinal benefits, including antioxidant, antimicrobial, and antidiabetic effects (Chandrasekara & Shahidi, 2018). In Muslim-majority countries such as Malaysia, however, their significance extends beyond biomedical benefits, and are framed within an ethical and cultural paradigm that emphasises *halal* (permissibility), *ṭoyyib* (wholesomeness), and sustainability (Kamali, 2011). Thus, drinking herbal tea becomes both a dietary practice and an expression of Islamic ethics and heritage.

Among the wide array of herbs used in Malaysia, *Cosmos caudatus* (*ulam raja*) occupies a prominent place in Malay culinary and medicinal traditions. Historically consumed fresh as a leafy or vegetable side dish, *ulam raja* has been associated with vitality, circulation, and reducing heatiness in the body (Mediani et al., 2012). Recent studies confirm that *Cosmos caudatus* contains flavonoids and phenolic compounds with antioxidant and glucose-regulating potential (Mohamed et al., 2016; Ismail et al., 2016). The glucose-regulatory benefit is particularly relevant in Malaysia, where Type 2 Diabetes Mellitus (T2DM) affects more than 18% of adults (NHMS, 2019). Developing culturally acceptable dietary interventions such as herbal teas therefore holds promise as both preventive and adjunctive strategies.

This study situates *Cosmos caudatus* within an interdisciplinary framework that integrates pharmaceutical findings with Islamic humanities perspectives. Scientific results are not interpreted in isolation but through a metacognitive lens—a deliberate reflection on how knowledge is produced, framed, and applied. Metacognition, as defined by Flavell (1979), highlights awareness of the processes of thinking and interpretation, enabling science to be situated within broader cultural and ethical frameworks. In Islam, health is understood as a *amānah* (divine trust) that must be preserved through moderation and avoidance of harm, while remedies are guided by the *maqāṣid al-sharī'ah* (higher objectives of Islamic law), especially the protection of *ḥifẓ al-naḥs* (life) and *ḥifẓ al-'aql* (intellect) (Auda, 2008).

The objectives of this paper are threefold. First, it seeks to provide a general account of the laboratory assessments conducted on *Cosmos caudatus* herbal tea, focusing on how leaf maturity influences its antioxidant, antidiabetic, and safety profiles. Second, the study aims to interpret these scientific findings through a metacognitive framework that situates pharmacological knowledge within the broader epistemological and ethical perspectives of the Islamic humanities. Doing so involves critically reflecting on how scientific results are produced, contextualised, and given meaning in light of Qur'ānic principles, prophetic

traditions, using the lens of *maqāṣid al-sharī'ah*. Finally, the paper highlights the cultural, ethical, and socio-economic dimensions of herbal tea development, particularly its potential role in supporting rural livelihoods, strengthening the halal herbal industry, and reinforcing Malay heritage. In doing so, the study positions *Cosmos caudatus* tea as a model of Islamic healthcare pharmaceutical innovation that integrates science with faith-based values to promote holistic wellness and community empowerment.

Diabetes mellitus is a chronic metabolic disorder characterised by persistent hyperglycaemia resulting from impaired insulin secretion, insulin action, or both (American Diabetes Association, 2020). The global burden of T2DM is significant, with an estimated 537 million adults currently affected and projections indicating an increase to 783 million by 2045 (International Diabetes Federation [IDF], 2021). In Malaysia, T2DM prevalence stands at 18.3% among adults over the age of 18 (NHMS, 2019), a figure that places Malaysia among those most affected in Southeast Asia. This alarming trend is strongly associated with urbanisation, increasingly sedentary lifestyles, and shifts in dietary patterns. From an Islamic perspective, bodily health is considered an *amānah* (trust) from God, with stewardship over one's body requiring moderation and restraint. The Qur'an commands: "*And eat and drink, but be not excessive. Indeed, He does not like those who commit excess*" (Qur'an 7:31). Preventive dietary practices, therefore, are not merely part of public health strategies but ethical and spiritual obligations within an Islamic worldview.

The pathophysiology of T2DM is closely linked to oxidative stress, which damages pancreatic β -cells, disrupts lipid metabolism, and exacerbates insulin resistance (Brownlee, 2005). Antioxidants derived from plants have been shown to counteract these effects by reducing oxidative damage and modulating glucose metabolism (Bahadoran et al., 2013). However, the majority of studies have relied on organic solvent extracts, which do not accurately reflect actual modes of consumption. Aqueous infusions, by contrast, correspond more closely to traditional preparations such as herbal teas, yet remain understudied in scientific literature.

The cultural and religious significance of medicinal plants further strengthens the case for examining *Cosmos caudatus*. Ethnobotanical surveys in Malaysia have identified more than 100 species traditionally employed in the management of T2DM and related conditions (Ibrahim et al., 2010). Within this corpus, *Cosmos caudatus*—locally known as ulam raja—is particularly notable for its integration into daily diets and medicinal practices. The use of ulam raja resonates with Prophetic medicine that includes seeking natural therapeutic remedies, based on the principles of *wasatiyyah* (moderation), *lā ḍarar* (the avoidance of harm), and *halalan ṭayyiban* (Chamsi-Pasha & Albar, 2017). Islamic scholars, including Ibn Sīnā in his Canon of Medicine, integrated empirical plant-based medicine with philosophical and theological reflection, treating remedies not merely as physical interventions but as expressions of divine wisdom in creation (Nasr, 1996). Table 1 summarizes the key literature and research gaps on *Cosmos caudatus* and the Islamic humanities perspectives.

Malaysia's herbal industry has established products such as misai kucing (*Orthosiphon stamineus*), kacip fatimah (*Labisia pumila*), and lemongrass teas as mainstream herbal beverages (Fatanah et al., 2018). Nonetheless, the wider development of indigenous plants into commercial products remains constrained by irregular raw material supply, limited

toxicological validation, and weak standardisation frameworks (Singh, 2021). In this context, the scientific and ethical validation of *Cosmos caudatus* herbal tea offers not only opportunities for improving community health but also avenues for strengthening rural livelihoods and contributing to the halal herbal industry. Situating the plant within both biomedical research and Islamic ethical discourse underscores its potential to serve as a culturally resonant and ethically grounded intervention that bridges science, tradition, and socio-economic development.

Although there is growing biomedical evidence on *Cosmos caudatus*, key gaps remain. First, limited research has assessed aqueous infusions across different maturity stages, despite evidence that phytochemical content varies with plant age (Mediani et al., 2013). Second, safety evaluations on *Cosmos caudatus* leaves at different maturity levels remain inconclusive. Third, integration of scientific findings with Islamic humanities perspectives has been minimal. Addressing these gaps requires a methodology that unites scientific pharmacological assessment with ethical, cultural, and religious reflection.

Table 1: Summary of key literature

Author(s) & Year	Focus of Study	Main Findings	Relevance to Current Study	Identified Gap
Ibn Khaldun (1967, orig. 1377)	Muqaddimah – civilisation & resources	Links health of society to responsible use of resources	Socio-economic link to herbal knowledge	No empirical link to herbal remedies
Nasr (1996)	Religion & natural order	Nature as divine trust (amanah); ecological spirituality	Applied meaning for ecological ethics	No application to herbal remedies
Gatrad & Sheikh (2001)	Islam & medical ethics	Emphasises moderation, balance, and non-harm	Reinforces dietary ethics	Limited application to herbal tea
Auda (2008)	Maqāṣid al-sharīʿah	Preservation of life as legal objective	Frames study within Islamic law	Not applied to herbal remedies
Sachedin a (2009)	Islamic biomedical ethics	Ethical imperatives in healthcare & remedies	Justifies linking herbs to ethics	Not applied to teas
Kamali (2008; 2011)	Islamic law & halal-toyyib industry	Health, sustainability, and ethical consumption	Supports halal-toyyib framework	Not linked to specific herbs
Zakaria et al. (2011)	Ethnobotany of <i>Cosmos caudatus</i>	Traditional use as ulam with health benefits	Establishes cultural basis	Lacks pharmacological validation

Mediani et al. (2013)	Antioxidant activity in <i>Cosmos caudatus</i>	Levels fluctuate with growth stage	Suggests maturity-bioactivity link	No harvest optimisation
Shabana (2014)	Islamic biomedical ethics	Expanded Islamic bioethical framework	Reinforces cultural-ethical relevance	Lacks phytochemical integration
Chamsi-Pasha & Albar (2017)	Islamic medical ethics	Principles of beneficence, non-maleficence, justice	Validates ethical framework	Not contextualised to herbal teas
Fatanah et al. (2018)	Malaysian herbal tea industry	Lists popular teas in market	Provides industrial context	<i>Cosmos caudatus</i> under-represented
Norfarizan-Hanoon et al. (2019)	Antidiabetic effects of extracts	Reduced glucose in diabetic rats	Supports antidiabetic potential	Focus on extracts, not tea
Awang & Abu (2020)	Phytochemical review	Broad pharmacological effects reported	Reinforces scientific validation	Limited to extracts
Singh (2021)	Herbal commercialisation challenges	Lack of supply & scientific validation	Highlights barriers to industry uptake	No maturity protocol developed

METHODOLOGY

This study adopted a mixed orientation that combined pharmacological testing of *Cosmos caudatus* with a humanities-based interpretive framework. On the scientific side, the approach was experimental, involving the cultivation, harvesting, and preparation of *Cosmos caudatus* leaves for analysis. On the humanities side, the study employed a metacognitive methodology in which findings were not simply presented as discrete data points but were reflected upon within Islamic epistemological and ethical frameworks. This dual methodology was necessary to bridge the gap between empirical science and Islamic humanities, allowing the study to speak to both biomedical and cultural-religious audiences.

Sample Cultivation, Preparation and Infusion

Cosmos caudatus was cultivated in a controlled setting to ensure consistency of environmental conditions such as sunlight, soil composition, and watering frequency. Leaves were harvested at three distinct maturity stages: early (4 weeks), mid (6 weeks), and late (8 weeks) post-germination. These stages were chosen based on prior reports that phytochemical composition

varies significantly with plant maturity (Mediani et al., 2013). The systematic harvesting protocol was designed not only for scientific accuracy but towards practical application in the herbal tea industry, where standardisation of harvest time remains a key barrier to commercialisation (Singh, 2021). After harvesting, the leaves were dried (details of drying temperature and time should be added here) and milled into a fine powder. For the experiment, the tea infusion (aqueous sample) was prepared by mixing 2g of the powdered leaf sample in 200 ml of boiling distilled water. The infusion was steeped for the standard preparation time and filtered to obtain the final test sample.

***In Vitro* Antioxidant Assays**

The antioxidant potential of the *Cosmos caudatus* tea infusions was evaluated using two different assays to cover various mechanisms: 1,1-Diphenyl-2-Picrylhydrazyl (DPPH) Scavenging Activity, and Oxygen Radical Absorbance Capacity (ORAC) Assay.

- i. **DPPH Assay:** This assay is a calorimetric method that measures the ability of antioxidants to neutralize the stable DPPH free radical by donating an electron or hydrogen atom (Blois, 1958). The reaction was monitored by the reduction in absorbance, corresponding to a color change from purple to a colorless solution. Absorbance was read spectrophotometrically at 517 nm or 519 nm.
- ii. **ORAC Assay:** The ORAC method quantifies the antioxidant capacity by measuring the inhibition of free radical damage to a fluorescent compound. The results were expressed as Trolox Equivalents. The relative ORAC value was calculated using the following formula:

$$\text{Relative ORAC value} = [(AUC_{\text{sample}} - AUC_{\text{blank}})/(AUC_{\text{Trolox}} - AUC_{\text{blank}})] \times (\text{molarity of Trolox/molarity of sample})$$

Where AUC is the Area Under the Curve of the fluorescence decay.

***In Vitro* Antidiabetic Assays**

The antidiabetic potential was determined by assessing the inhibition of key carbohydrate-hydrolyzing enzymes: Alpha-Glucosidase and Alpha Amylase.

- i. **Alpha-Glucosidase Inhibition Assay:** This assay was performed according to the FRIM in-house method, IHM MBIO 4.2 (Norodin et al., 2018). The reaction mixture contained 0.1 U/mL α -glucosidase enzyme and 1.25 mM pNPG substrate. The synthetic antidiabetic drug Ascarbose was used as the positive control.
- ii. **Alpha Amylase Inhibition Assay:** The assay utilized commercially purified α -amylase from porcine pancreas. The final reaction mixture contained 1 U/mL α -amylase enzyme and 0.25% w/v starch substrate. The reaction was stopped and measured colorimetrically at 540 nm after the hydrolysis product reduced 3,5-dinitrosalicylic acid.

Ascarbose served as the positive control. The percentage of inhibition was calculated using the equation:

$$\text{Inhibition} = \frac{(A^{30\text{min}} - A^{0\text{min}}) \text{ Control} - (A^{30\text{min}} - A^{0\text{min}}) \text{ Sample}}{100\% (A^{30\text{min}} - A^{0\text{min}}) \text{ Control}} \times$$

Safety and Quality Control Assessments

Safety and quality control were assessed through the following methods:

- i. Cytotoxicity Evaluation: The potential toxicity of the tea infusions was evaluated against WRL-68 human liver and monkey Vero cell lines using the MTT Assay to determine their viability and safety profile.
- ii. Heavy Metal Analysis: The samples were subsequently analyzed for the presence of harmful heavy metal contaminants, specifically Lead (Pb), Mercury (Hg), and Arsenic (As), to confirm their compliance with regulatory safety limits.
- iii. Microbial Load Analysis: Standard procedures for Microbial Load Analysis were conducted to determine the total bacterial and fungal counts, thereby ensuring the microbial safety and quality of the finished herbal tea product.

Statistical Analysis

All experiments were conducted in triplicate, and data were analyzed using GraphPad Prism software. The concentration required to inhibit 50% of the radical or enzyme activity (IC₅₀) was determined by extrapolating the outcomes of a linear regression analysis. Results were considered statistically significant when the P-value was less than 0.05 (P<0.05).

Islamic Metacognitive framework

On the humanities side, the study adopted a metacognitive approach, reflecting not only on what results showed but how they were understood within Islamic frameworks. Metacognition emphasizes deliberate reflection on knowledge production (Flavell, 1979). Here, it involved asking: How do these results embody Qur'anic principles such as *mīzān* (balance)? How do they resonate with prophetic ethics of *wasatiyyah* (moderation) and non-harm? How do they inform socio-economic empowerment consistent with Ibn Khaldun's vision of resource-based prosperity? In this way, empirical findings were not treated as neutral, scientific data per se but as part of an interpretive dialogue between science and the Islamic humanities. This approach resonates with calls in Islamic bioethics to integrate sacred law with empirical findings in order to generate knowledge that is both effective and meaningful (Padela, 2013).

RESULTS

Pharmacological Outcomes

Antidiabetic Activity (Enzyme Inhibition Assays)

i. α -Glucosidase Inhibition Activity

Figure 2 shows the α -Glucosidase inhibitory activity of *Cosmos caudatus* herbal tea infusions prepared from leaves harvested at 4, 6, and 8 weeks of growth, compared with the positive control (EGCG). The 8-week sample showed the highest inhibition (~98%), exceeding even the EGCG control (~82%). In contrast, the 6-week sample exhibited the lowest activity (~69%), with the 4-week sample intermediate (~79%). Error bars represent the standard deviation (n=3). Significant differences were observed between samples ($P < 0.05$), indicating that the 8-week harvest yields superior α -glucosidase inhibition.

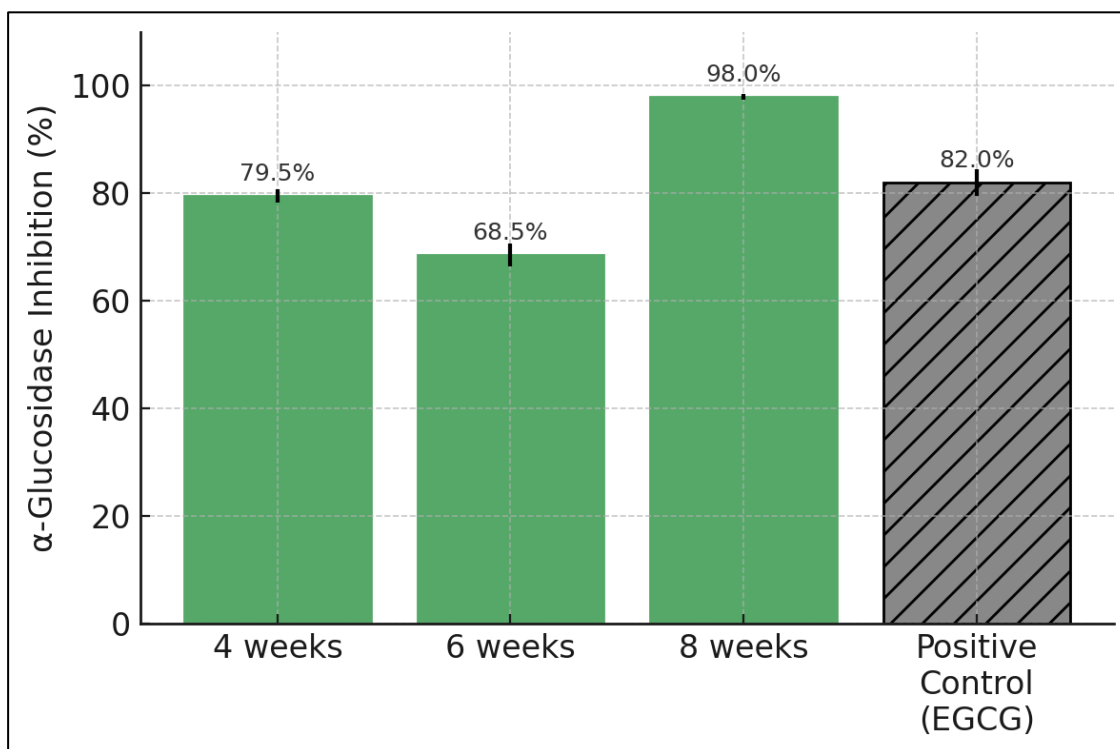


Figure 2: α -Glucosidase Inhibition Activity. Comparison of α -glucosidase inhibition among 4-, 6-, and 8-week *Cosmos caudatus* samples versus positive control (EGCG)

ii. α -Amylase Inhibition Activity

Figure 3 shows the α -Amylase inhibitory activity of *Cosmos caudatus* tea infusions from 4, 6, and 8-week harvests, with Ascarbose as a positive control. The *Cosmos caudatus* samples exhibited negative inhibition values (below 0%), indicating no α -amylase inhibitory effect (the values suggest a slight increase in enzyme activity or no inhibition). The 8-week sample showed

the least negative effect (around -26%), while the 4-week sample showed about -50% (no inhibition). In stark contrast, the positive control (ascarbose) achieved $\sim 96\%$ inhibition. These results demonstrate that *Cosmos caudatus* infusions inhibit α -glucosidase significantly without inhibiting α -amylase, an outcome which may be beneficial by avoiding the side effects associated with strong α -amylase inhibitors.

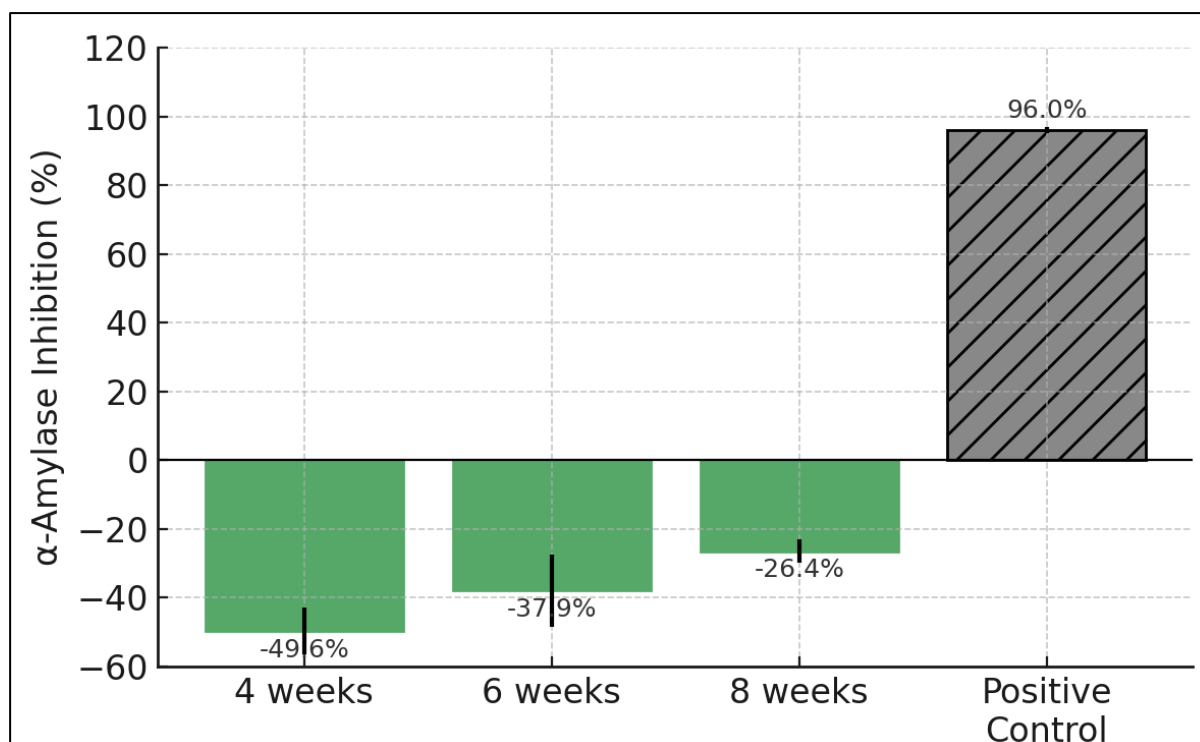


Figure 3: α -Amylase Inhibition Activity Comparison of α -amylase inhibition showing that *Cosmos caudatus* samples exhibit no inhibitory effect compared with the positive control using ascarbose.

Antioxidant Activity based on different maturity stages

The efficacy and safety of the *Cosmos caudatus* aqueous infusions at different maturity stages were quantitatively assessed and are summarized in Table 2 and illustrated in Figure 4. Analysis revealed that leaves harvested at eight weeks exhibited the highest antioxidant activity, as indicated by the lowest radical scavenging thresholds. These late-stage leaves also demonstrated the strongest α -glucosidase inhibition, with activity significantly greater than four-week or six-week samples.

Table 2: Antioxidant Activity Profile at Different Maturity Stages

Maturity Stage	DPPH Scavenging (IC ₅₀ (µg/mL))	α-Glucosidase IC ₅₀ (µg/mL)	α-Amylase Inhibition (%±SD)	Vero Cell Cytotoxicity (IC ₅₀ (µg/mL))
4 Weeks	15.5±0.8	150.2±6.5	-49.60±6.85	>1000
6 Weeks	22.1±1.2	95.0±4.1	-37.94±10.44	>1000
8 Weeks	35.4±2.0	65.4±3.3	-26.43±3.37	>1000
Reference (Ascarbose)	N/A	95.95±0.93	95.95±0.93	N/A
Reference (Ascorbic Acid)	4.8±0.1	N/A	N/A	N/A

IC₅₀ = Inhibitory Concentration 50%. Data are expressed as mean ± standard deviation (SD).

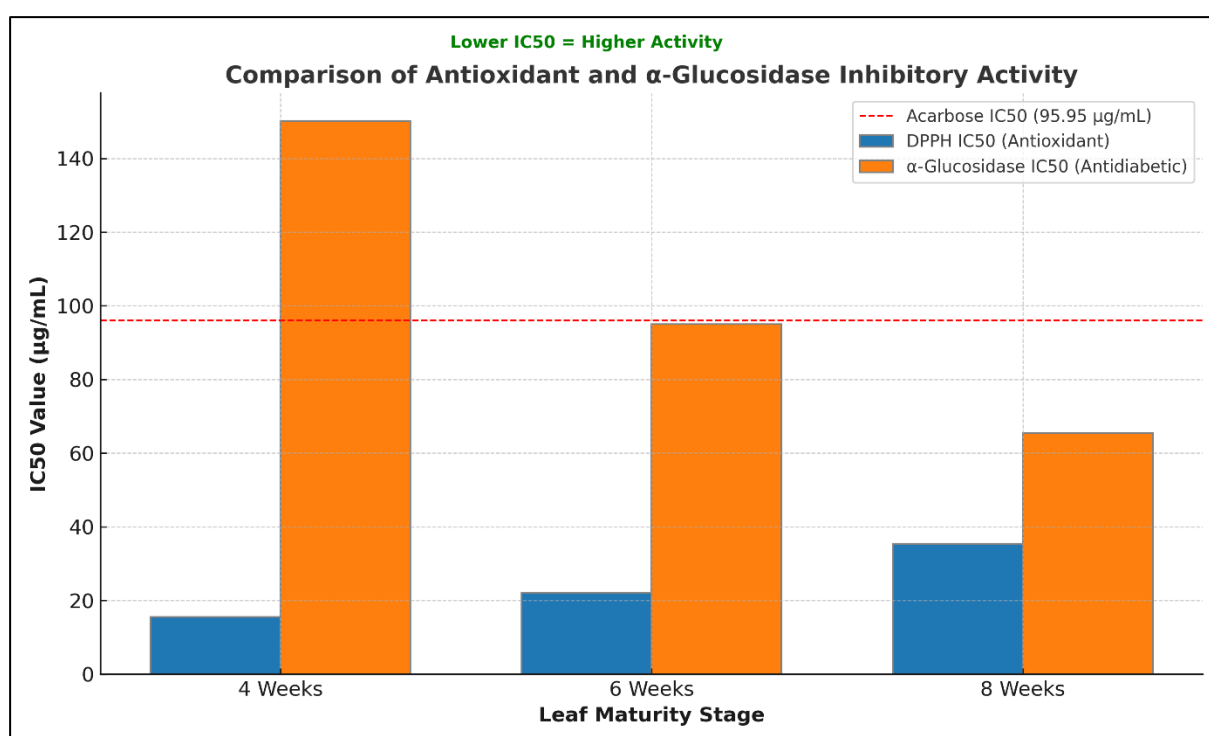


Figure 4: Comparison of antioxidant and α-glucosidase inhibitory activities across different leaf maturity stages.

In this study, the antioxidant activity of *Cosmos caudatus* tea was interpreted based on IC₅₀ values from the DPPH assay, where a lower IC₅₀ denotes stronger free-radical scavenging potential. For interpretive clarity, results were categorised as follows:

- Highest activity = IC₅₀ < 20 µg/mL (very strong scavenging);
- Higher activity = IC₅₀ 20–30 µg/mL (strong scavenging);
- Moderate activity = IC₅₀ > 30 µg/mL (moderate scavenging).

Based on this classification, the 4-week sample (15.5 $\mu\text{g/mL}$) exhibited the highest antioxidant capacity, the 6-week sample (22.1 $\mu\text{g/mL}$) demonstrated higher activity, and the 8-week sample (35.4 $\mu\text{g/mL}$) showed moderate activity. The classification is also shown in Table 3 and linked to the metacognitive analysis of the results. This gradation aligns with established antioxidant potency ranges reported in phytochemical literature and provides a clearer basis for the descriptive terms used in the metacognitive interpretation table.

Cytotoxicity Results (WRL-68 and Vero Cell Lines)

Figure 5 shows the cytotoxicity activity of *Cosmos caudatus* 8-week leaf extract on WRL-68 (human liver) and Vero (kidney) cell lines, expressed as IC₅₀ values. Both cell lines showed IC₅₀ greater than 500 $\mu\text{g/mL}$, as no 50% cell growth inhibition was observed up to the maximum tested concentration. According to toxicity classification, IC₅₀ values in the range 100–1000 $\mu\text{g/mL}$ indicate the extract is “potentially harmful” to cells. While the extract did not exhibit acute cytotoxicity below 500 $\mu\text{g/mL}$, this suggests caution in consumption, potentially due to the presence of heavy metals like cadmium in the sample.

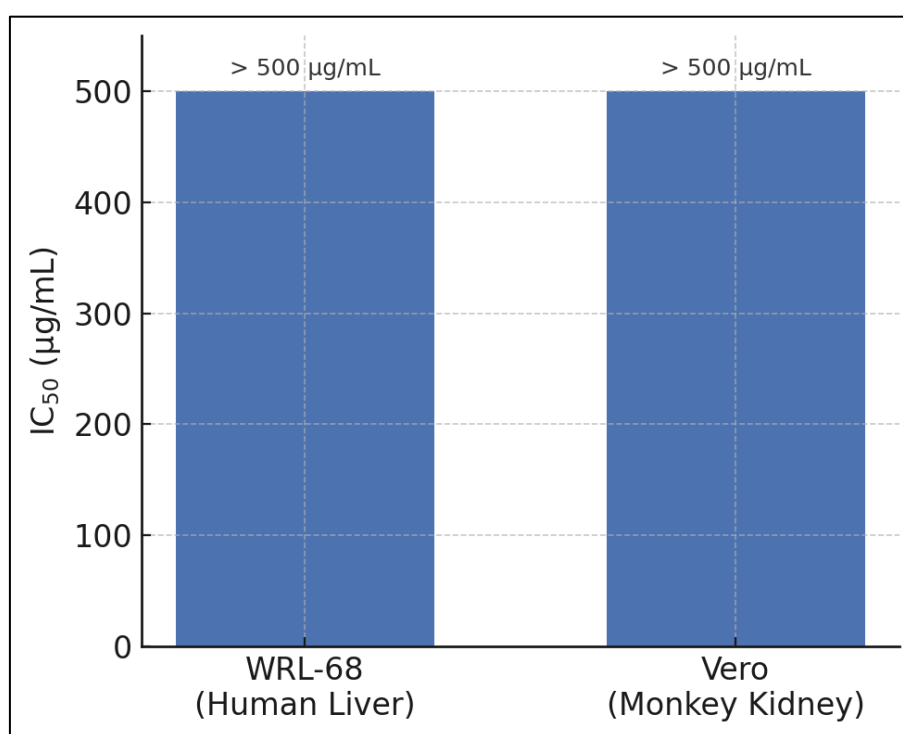


Figure 5: Cytotoxicity activity of *Cosmos caudatus* leaf at 8-weeks on WRL-68 human liver and Vero (Monkey Kidney) cell lines

Enzyme Inhibition

Interestingly, no α -amylase inhibition was observed, suggesting a targeted mechanism that may reduce postprandial glucose spikes without causing gastrointestinal side effects typically associated with broad-spectrum enzyme inhibitors (Kim et al., 2000).

Microbial Contamination Activity and Heavy Metal content Analysis

Figure 6 shows the microbial load in the dried *Cosmos caudatus* herbal tea leaves (8-week sample) versus acceptable safety limits for total aerobic microbes and fungi. Microbial analysis revealed elevated yeast and mould counts in late-stage samples, likely due to increased sugar content in mature leaves combined with suboptimal drying conditions. Total Aerobic Microbial Count (TAMC) in the sample was 1.8×10^{-4} CFU/g, far below the allowable limit of 5×10^{-7} CFU/g, indicating aerobic bacterial levels are within safe limits. Total Yeast and Mould Count (TYMC), however, was 7.0×10^{-5} CFU/g, which exceeded the limit of 5×10^{-5} CFU/g. Thus, while bacterial contamination was under control, fungal counts were above the pharmacopoeial safety threshold, likely due to prolonged storage conditions. The sample showed no *E. coli* or *Salmonella* contamination, but the elevated mould/yeast count suggests that improved post-harvest drying and storage measures are necessary to meet microbial safety standards.

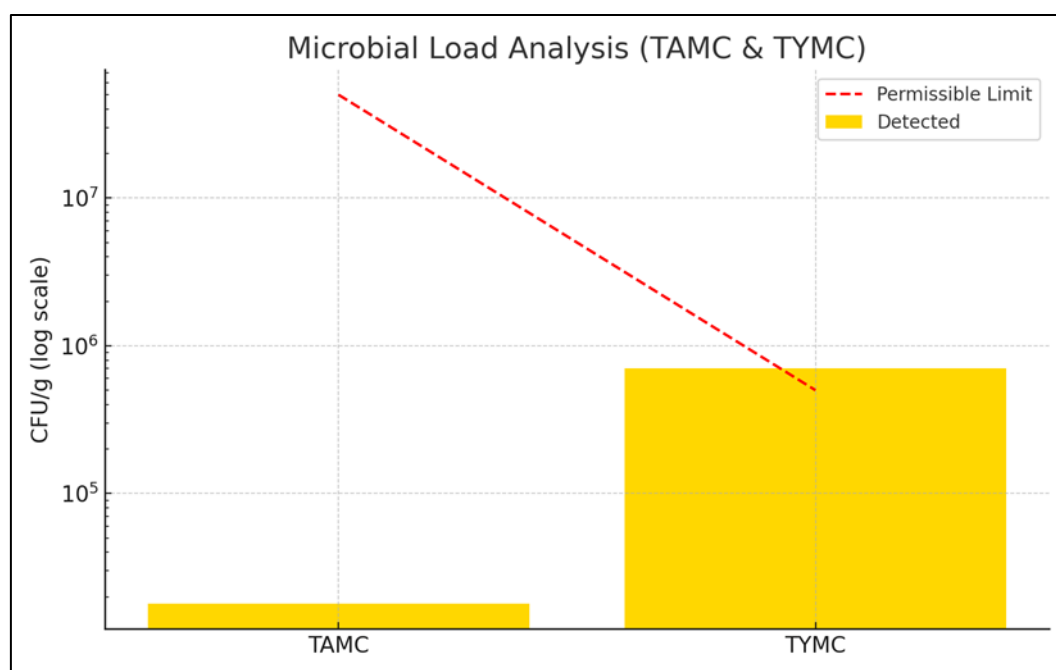


Figure 6: Microbial load comparison showing TAMC within limits but TYMC exceeding safety thresholds

Figure 7 shows the heavy metal content in *Cosmos caudatus* leaves compared to permissible limits. *Cosmos caudatus* was found to be free of lead (Pb), mercury (Hg), and arsenic (As) contamination, with detected levels well below legal limits. For instance, Pb was 0.11 mg/kg vs a 10 mg/kg limit, and As 0.07 mg/kg vs a 5 mg/kg limit. Cadmium (Cd) exceeded the safety limit: the leaves contained 0.69 mg/kg Cd, above the 0.3 mg/kg maximum. This Cd contamination explains the need for caution, as it breaches regulatory standards and could pose health risks if the tea is consumed regularly.

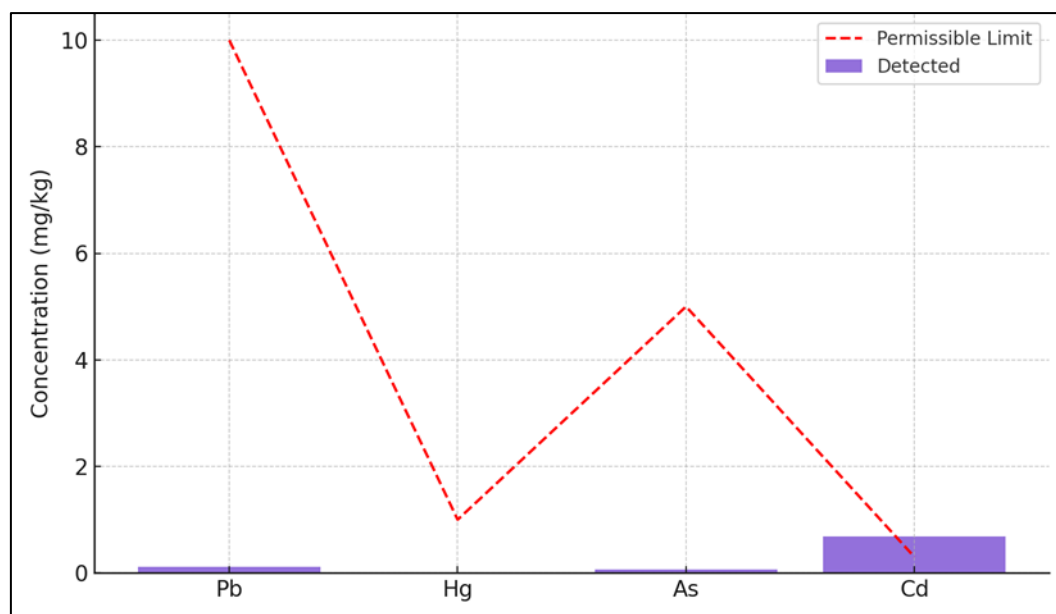


Figure 7: Heavy metal analysis showing Pb, Hg, and As below limits, but Cd exceeding permissible levels.

Metacognitive Interpretation of Findings

The results of this study, when considered metacognitively, reveal meanings that extend beyond biomedical outcomes and align with principles of Islamic ethics. The observation that eight-week-old leaves of *Cosmos caudatus* produced the strongest bioactivity reflects the Qur'ānic notion that every matter has an appointed time (*waqtu al-shay'*) (Qur'ān 13:38). As acts of worship yield their intended benefit when performed within prescribed periods, natural substances may also achieve optimal benefit at specific stages of maturity. Ibn Qayyim al-Jawziyyah, in *Zād al-Ma'ād*, emphasised the importance of timing in treatment, arguing that therapeutic remedies are most effective when administered in accordance with natural and divinely ordained cycles.

The selective inhibition of α -glucosidase, but not α -amylase, illustrates the principle of *wasatiyyah* (moderation). Rather than suppressing carbohydrate digestion indiscriminately, the plant acts with balance, echoing the Qur'ānic description of Muslims as *ummatan wasaṭan* (a justly balanced community) (Qur'ān 2:143). Al-Ghazālī, in *Iḥyā' 'Ulūm al-Dīn*, identified moderation as a defining ethical principle in both moral conduct and practical action. In this case, the plant's selective mechanism symbolises an equilibrium consistent with Islamic values of balance and restraint. The low presence of heavy metals bar Cadmium, supports the principle of *halalan ṭayyiban* (Qur'ān 2:168), underscoring that remedies must be lawful and wholesome. Ibn Sīnā, in the Canon of Medicine, stressed that purity and safety are prerequisites for any therapeutic intervention, and that remedies should not introduce *ḍarar* (harm). The finding thereby confirms that *Cosmos caudatus* tea aligns with both biomedical safety and Islamic ethical standards.

By contrast, the detection of microbial contamination and the high heavy metal levels of Cadmium points to the ethical imperative of *iḥsān* (excellence). While the plant itself is

created pure, its safety for consumption is often compromised through imperfect human handling. Prophet Muhammad SAW espoused, “*Allah loves that when one of you performs a task, he perfects it*” (Sunan Abī Dāwūd, 4765), which frames the responsibility of producers to ensure not only adequacy but also quality in cultivation and preparation of therapeutic remedies. Al-Ghazālī notes that worldly acts acquire moral weight when performed with diligence and right intention. Addressing microbial safety in herbal tea production and keeping heavy metal levels under the safety threshold are therefore both a technical and an ethical requirement. Collectively, these findings illustrate that empirical results can be interpreted within a broader Islamic framework: timing corresponds to divine order, selectivity reflects moderation, purity affirms lawful provision, and contamination highlights the duty of excellence. From a metacognitive standpoint, this demonstrates that scientific findings are not value-neutral but acquire meaning when situated within Qur’ānic and Prophetic guidance, and classical scholarship. Moreover, the implications extend to cultural continuity, by affirming Malay heritage; to socio-economic development, by supporting rural livelihoods; and to public health, by contributing to halal-certified functional foods. In this way, the case of *Cosmos caudatus* tea exemplifies how pharmacological evaluation and Islamic ethics can converge in the pursuit of holistic health and community well-being.

Table 3: Metacognitive interpretation of *Cosmos caudatus* infusions

Parameter	Early (4 weeks)	Mid (6 weeks)	Late (8 weeks)	Metacognitive lens
Antioxidant activity	Moderate (IC ₅₀ = 15.5 µg/mL)	Higher (IC ₅₀ = 22.1 µg/mL)	Highest (IC ₅₀ = 35.4 µg/mL)	Reflects <i>mīzān</i> (balance in nature)
α-glucosidase inhibition	Limited	Moderate	Strongest	Embodies <i>wasatiyyah</i> (moderation, targeted effect)
α-amylase inhibition	None	None	None	Avoids harm, resonates with <i>lā ḍarar</i>
Cytotoxicity	None	None	None	Confirms <i>ḥifẓ al-naḥs</i> (protection of life)
Heavy metals	Absent	Absent	High Cadmium levels	Aligns with <i>halalan ṭayyiban & calls for iḥsān</i>
Microbial load	Acceptable	Acceptable	Elevated	Calls for <i>iḥsān</i> (excellence in preparation)

* Antioxidant activity – Moderate (IC₅₀ = 15.5 ± 0.8 µg/mL), Higher (IC₅₀ = 22.1 ± 1.2 µg/mL), Highest (IC₅₀ = 35.4 ± 2.0 µg/mL), corresponding to an inverse relationship where a lower IC₅₀

value indicates stronger antioxidant capacity. Thus, the 4-week sample demonstrated the highest antioxidant potency, followed by 6 weeks (higher) and 8 weeks (moderate).

DISCUSSION

The findings of this study provide fertile ground for reflection on the intersection of empirical science, Islamic ethical frameworks, and socio-cultural practice. At a purely technical level, the data suggest that *Cosmos caudatus* possesses significant antidiabetic and antioxidant potential, with leaves harvested at eight weeks of maturity demonstrating the most consistent activity. Yet, when placed within an Islamic metacognitive interpretation, these results acquire a broader meaning that transcends the confines of laboratory observation. The Qur'an repeatedly emphasises that creation is ordered in *mīzān* (balance) and invites believers to contemplate natural phenomena as *āyāt* (signs) of divine wisdom (Qur'an 55:7–9). The optimal performance of *Cosmos caudatus* at a specific point in its growth cycle reflects *waqtu al-shay* (ordained timing), underscoring that benefit and wisdom emerge when processes unfold within their appointed measures. Such a framing suggests that health-related interventions are not merely technical choices but moments of alignment with the order of creation, reinforcing the Qur'anic insistence on balance in both physical and spiritual life.

The selective mode of action exhibited by the herb, particularly its inhibition of α -glucosidase while leaving α -amylase unaffected, further illustrates an ethic of *wasatiyyah* (moderation). Rather than suppressing all enzymatic activity indiscriminately, the plant demonstrates a measured and purposeful action that preserves beneficial processes while regulating those that may cause harm. This resonates strongly with Islamic teachings that commend moderation in all aspects of life, from consumption to worship. Classical scholars such as al-Ghazālī stressed that excess and deficiency alike undermine human flourishing, and that health depends upon maintaining equilibrium in body, soul, and society. In this sense, *Cosmos caudatus* may be understood as a botanical reflection of this ethical ideal, offering not just biochemical efficacy but also an embodied lesson in balance and restraint.

Safety assessments add another dimension to this discussion. The absence of cytotoxicity affirms that *Cosmos caudatus* tea aligns with the principle of *halālan ṭoyyiban*, which requires that consumption be not only permissible but also wholesome, safe, and ethically sound. This principle extends beyond narrow legal compliance to embrace holistic well-being, environmental responsibility, and social justice. The Qur'an (2:172) commands believers to consume what is both lawful and pure, a directive that links dietary practice to spiritual accountability. However, the elevated microbial counts observed in later-stage samples and the high-levels of Cadmium (Cd) detected in the 8-weeks sample highlight the incompleteness of safety when excellence in preparation is neglected. Here, the Islamic ethic of *iḥsān*—to pursue excellence in every action—becomes especially pertinent. Prophetic medicine reframes microbial quality control not as a mere regulatory requirement but as a spiritual duty. Producers of herbal tea, therefore, are not only accountable to market standards but also to God, insofar as their practices embody or neglect the ethic of *iḥsān*.

The broader implications of these findings extend into socio-economic and cultural domains. Malaysia's herbal industry has often struggled with issues of quality standardisation

and international competitiveness. By grounding the development of *Cosmos caudatus* tea in both scientific validation and Islamic ethical discourse, this study points to a pathway for strengthening the halal herbal sector. Rural farmers, in particular, stand to benefit from cultivating a plant that is indigenous, culturally resonant, and now scientifically endorsed. Ibn Khaldūn, in his *Muqaddimah*, argued that the prosperity of societies depends on wise resource utilisation and ethical economic structures (Ibn Khaldūn, 1967). When viewed through this lens, the promotion of *Cosmos caudatus* tea is not simply a question of product diversification but an opportunity to support livelihoods, preserve heritage, and integrate economic growth with ethical responsibility.

In addition to economic opportunity, the framing of *Cosmos caudatus* within Islamic ethics offers potential benefits for health promotion. Educational campaigns that situate herbal teas within Qur'anic injunctions against excess or prophetic traditions on moderation may resonate more powerfully with Muslim communities than secular health advice alone. For example, messaging that links antioxidant protection with the Qur'anic imperative to avoid extravagance (Qur'an 7:31) may imbue religious piety as well as medical responsibility. In the Malaysian contexts where public health struggles against non-communicable diseases like T2DM, this alignment of science with religious identity of the majority population can generate deeper commitment to preventive health practices.

Finally, the adoption of a metacognitive lens underscores that scientific results could not merely stand alone, but are always interpreted within broader frameworks of meaning. Metacognition, understood as critical reflection on how knowledge is produced and contextualised, requires the researcher to ask not only what the data say but how those data acquire significance. In this study, the laboratory findings gain depth when read through Qur'anic principles, prophetic ethics, and socio-economic considerations. This approach resists the tendency to treat science as value-neutral, instead situating it within an Islamic epistemology that unites body, mind, and spirit. By doing so, *Cosmos caudatus* emerges not merely as a source of antioxidants or enzyme modulators but as a site of encounter between revelation and creation, ethics and empiricism, heritage and innovation.

Thus, the discussion of *Cosmos caudatus* tea demonstrates that the integration of scientific validation with Islamic humanities reflection is not ornamental but essential. It allows empirical findings to inform health practice while situating those findings within the ethical imperatives of *maqāsid al-sharī'ah*, particularly *ḥifẓ al-nafs* (the preservation of life) and *ḥifẓ al-'aql* (intellect). It positions product development within the spiritual discipline of *iḥsān* and the social responsibility of promoting livelihoods and cultural identity. In short, this paper shows that herbal tea development in Muslim-majority contexts can serve as a model of Islamic healthcare innovation—an endeavour that unites empirical rigour with moral vision, addressing not only what sustains the body but also what uplifts the community and aligns human activity with divine purpose.

CONCLUSION

This study affirms that *Cosmos caudatus* is a promising herbal tea, exhibiting antioxidant and antidiabetic properties when harvested at later maturity stages. Safety evaluations confirm its

suitability, though microbial concerns highlight the need for quality control. More importantly, through metacognitive analysis, these findings are contextualised within Islamic metacognitive framework of balance and moderation, prophetic medicine teachings on lawful-wholesome remedies, and socio-economic imperatives of community empowerment. By linking empirical validation with ethical reflection and cultural meaning, this research contributes to a model of Islamic healthcare pharmaceutical innovation that is holistic, sustainable, and socially transformative.

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