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Future Foresight of Halal in the Context of Sustainable Technologies with Focus to Animal Waste Index

Tharwat Mamdouh Al-Bataineh[1*], Jood Osama Quran[2], Jašić Midhat[3]

[1]*Ministry of Climate Change & Environment, United Arab Emirates. Dubai Al Ruwayyah 2 Area Beside Zayed University, Dubai – AlAin Road, Dubai, United Arab Emirates*
[2]*University of Maryland, Department of Neuroscience, Undergraduate Student, College Park*
[3]*University of Tuzla, Faculty of Pharmacy, Univerzitetska 8, 75000 Tuzla, Bosnia and Herzegovina*

[*]*Corresponding author: Tharwat Mamdouh Al-Bataineh*
E-mail address: dr_thrwat@yahoo.com

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ABSTRACT

The future of Halal sustainable technologies presents significant potential in addressing the growing demand for ethical, environmentally friendly solutions, particularly within Muslim communities and the global market. As the world becomes more aware of sustainability challenges, there is an opportunity to integrate Islamic principles of halal (permissible) and tayyib (pure, wholesome) into emerging technologies, especially in sectors like agriculture, pharmaceuticals, cosmetics, and finance. These sectors can benefit from innovations that adhere to sustainability standards while aligning with Halal practices. This paper focuses on evaluating the Animal Waste Index (AWI) as a tool to measure the management and impact of animal waste in agricultural settings. AWI aims to improve sustainability and waste management by tracking how animal waste is converted into compost, using efficient methods that align with Halal principles. The potential for real-time data collection and monitoring technologies would further enhance this process, leading to more sustainable and Halal-compliant agricultural practices. One solution in food waste management involves using bioreactors, which break down organic waste through controlled biological processes. These devices, which function both aerobically (with oxygen) and anaerobically (without oxygen), can convert food waste into compost, enriching soil and supporting agricultural production. The integration of bioreactors offers an efficient, scalable solution to waste management, reducing environmental impact and enhancing sustainability while meeting Halal standards. As Halal-certified products are increasingly in demand across various industries, the alignment of Halal practices with environmentally responsible solutions creates an opportunity to expand Halal standards into sustainable technologies. The growing application of Halal principles in new sectors such as animal welfare, cosmetics, and bio-based products suggests a broader potential for Halal sustainability efforts. The development of AWI as a tool for tracking animal waste conversion is vital in guiding agricultural practices toward more sustainable, ethical, and Halal-compliant methods. Composting food waste not only reduces environmental footprints but also turns waste into valuable resources, enriching soil and supporting food security. Looking ahead, technologies like bioreactors will play a crucial role in addressing global waste management challenges, sustainability goals, and the increasing demand for bio-based products. By fostering innovations that meet both ethical and environmental standards, the future of Halal sustainable technologies promises a more responsible and sustainable global market.

Keywords: *Halal technologies, sustainability, waste management, bioreactors, Animal Waste Index (AWI)*

Introduction

As the global population grows and environmental challenges intensify, the demand for ethical, sustainable, and health-conscious solutions continues to rise. (1) Within this evolving landscape, the integration of Islamic principles; particularly those related to Halal (permissible) and Tayyib (pure and wholesome), into technological and environmental frameworks offers an innovative and culturally rooted approach to sustainability. The Halal industry, traditionally associated with food, is now expanding its influence into diverse sectors such as agriculture, pharmaceuticals, cosmetics, and biotechnology, calling for robust systems that align with both religious compliance and environmental stewardship. (2)

One pressing issue in the sustainability discourse is the management of animal waste, especially in agricultural systems. Poor waste management contributes significantly to greenhouse gas emissions, water pollution, and soil degradation. To address these challenges, there is a growing need for tools that can effectively monitor and enhance the use of animal by-products in a way that supports environmental goals while adhering to Halal standards. (3)

This paper introduces the concept of the Animal Waste Index (AWI): a proposed metric for evaluating the sustainability and compliance of animal waste management systems within the Halal framework. AWI is typically refers to a measure or metric used to assess the amount and environmental impact of waste produced by livestock and other animals, particularly in agricultural settings. It's not a universally standardized term, so its meaning can vary depending on the context (e.g., academic research, environmental policy, or local regulations). It might include; waste management practices (e.g., composting, lagoon storage, runoff control), and it is more matters in regulatory compliance: used by environmental agencies to ensure farms meet waste disposal standards. (4)

By incorporating technologies such as bioreactors, precision agriculture, and real-time monitoring, AWI aims to serve as both an evaluative and operational tool to guide more responsible agricultural practices. (5) The use of bioreactors, in particular, offers a scalable and efficient solution for converting animal waste into high-quality compost, supporting circular economy principles and reducing environmental impact.

This study explores how the convergence of Halal ethics and sustainable technology can shape future waste management strategies. (6) It emphasizes the potential of AWI to become a standard benchmark for Halal-compliant, eco-friendly agricultural operations, ultimately contributing to broader goals such as food security, soil health, and ethical environmental practices.

Materials and Methods

This study proposes the development and application of the Animal Waste Index (AWI) as a framework for evaluating and managing animal waste in alignment with Halal and sustainability principles. (12) The methodology combines technological, environmental, and religious dimensions to establish a practical and ethical waste management approach.

The primary material used in this study was raw animal waste, including manure and organic by-products collected from livestock farms. The waste was free from non-organic contaminants and stored in sealed containers before processing. The treatment system used was a closed-loop **bioreactor unit**, equipped with temperature regulation, aeration controls, and compost collection chambers.

Additional materials included:

- Water is needed in old fashion windrows as well as for other technologies, for moisture control. With Bioreactors this is absolutely avoided. A very big advantage of the Bioreactor is that there is no need for water at all, saving lot of water and costs. In addition to this, the Bioreactor generates water vapor that can be captured and re-used for irrigation of greenhouses of for any other water needs (for example, the mod size Bioreactor generates about 100L of H2O a day that can be reused for many different needs).
- Temperature sensors (to monitor internal conditions).
- Aeration system (to maintain aerobic microbial activity); as well as to control temperature levels and appropriate internal moisture levels generated as heat and water vapor during the composting process.
- pH meter (to monitor acidity during composting): pH is measured for the organic waste to be composted as well as from the produced compost. The Bioreactor does not measure the pH during the composting process unless set-up for a specific and customized study for specific testing and analysis.

Conceptual Framework of the Animal Waste Index (AWI)

The AWI is designed as a composite index that measures the efficiency, compliance, and environmental impact of animal waste management systems. It integrates indicators from three main dimensions:

Halal Compliance: Assesses whether waste handling, transformation, and byproduct usage adhere to Islamic principles (e.g., cleanliness, animal welfare, and the avoidance of najis materials in contamination).

Environmental Sustainability: Evaluates reduction of greenhouse gas emissions, soil and water conservation, and minimization of harmful runoff.

Technological Efficiency: Measures the operational effectiveness of applied technologies such as bioreactors, including waste conversion rates, compost quality, and system scalability.

UN Data on Animal Waste Consumption

The United Nations provides data on animal waste consumption by households and other sectors across different countries. (17)

- Bangladesh: Household consumption of animal waste has been consistently high, with figures around 99,863 terajoules in 2021.
- Armenia: Household consumption has fluctuated, reaching 2,863 terajoules in 2020. (17)

Global Residue and Manure Data

Research consolidating global residue data from agriculture, fisheries, and forestry provides insights into livestock manure: (15 and 16)

- Slaughterhouse By-products: The inedible parts of slaughtered animals vary by species, e.g., 22% for turkeys, 37% for broilers, 38–40% for pigs, 47% for sheep and goats, and 49% for cattle.
- Fish Processing By-products: These include trimmings like heads, frames, skin, and tails, constituting up to 70% of fish and shellfish after processing. (15 and 16)

This data aids in understanding the volume and potential utilization of animal waste.

UAE Animal Waste Statistics

In the United Arab Emirates, specifically in Abu Dhabi Emirate, the volume of non-hazardous solid animal waste generated was approximately 386,440 tons in 2018. (10) This statistic highlights the scale of animal waste management challenges in urban settings. (11)

Bioreactor Integration

The bioreactor is a controlled, thermophilic composting unit designed to accelerate the decomposition of organic animal waste. (Figure 1) The reactor is made of corrosion-resistant material; it is made from pipes used for drinking water and coated for anti-corrosion and anti-rust, following corresponding regulations, insulated to retain heat, and sealed to prevent odor emissions. The internal mixing and uniformity of the organic matrix being composted is ensured thanks to the continuous, non-stop gentile low pace rotation of 10 rotations per hour, which is a real competitive advantage of this technology. This approach avoids the constant and repeated intermittent mechanical disruption of the natural and biological occurring composting process and all the negative impact that this type of interruptions generates; to ensure even distribution of heat and microbial activity. (6) Halal process compliance (as reviewed by Sharia auditors).

Figure 1: Bioreactor Device

Discussion

The integration of Halal principles into modern sustainability technologies presents a promising avenue for addressing global environmental challenges while respecting cultural and religious values. The findings and observations from applying the Animal Waste Index (AWI) framework highlight several key insights into how Islamic ethics and technological innovation can jointly shape the future of sustainable agriculture. (12)

Alignment of Halal and Sustainability Objectives

One of the most compelling outcomes of this study is the clear compatibility between Halal requirements and sustainable practices. Islamic teachings emphasize cleanliness, resource conservation, and humane treatment of animals all of which align with global sustainability goals. By embedding Halal compliance into waste management systems, the AWI helps ensure that both spiritual and ecological integrity are maintained. (13)

The bioreactor system, for instance, fulfils multiple objectives: it minimizes environmental impact, transforms waste into beneficial compost, and operates under conditions that are transparent and controllable important aspects for Halal certification. The monitoring of inputs and processes reduces the risk of contamination and supports traceability, which are critical in Halal assurance systems. (14)

Efficiency and Impact of Bioreactor Technology

Bioreactors have proven to be effective in managing animal waste with minimal environmental harm. The transformation of raw manure into nutrient-rich compost within a relatively short time frame (less than 20 days) supports their suitability for both small-scale and industrial farming operations. (Figure 2) In the pilot case, the compost output showed significant improvement in soil nutrient levels and reduced odor and pathogenic risks key concerns in both sustainable agriculture and Halal practices. (18)

Furthermore, the ability to control oxygen levels, temperature, and microbial activity allows for greater standardization and reproducibility, which is critical for scaling the technology across regions with varying climates and agricultural needs. (19 and 20)

Figure 2: The input to the Bioreactor device (animal manure, waste)

Challenges and Limitations

Despite its promise, the implementation of AWI and bioreactor technology faces several challenges:

Regulatory and Certification Gaps: Current Halal certification systems are not universally equipped to evaluate sustainability-oriented technologies, particularly in waste processing. There is a need for updated guidelines that integrate environmental metrics with Halal verification.

Cost and Accessibility: Initial investment in bioreactor systems and real-time monitoring tools may be prohibitive for smallholder farmers, particularly in developing countries.

Knowledge and Training: Adoption of the AWI framework requires training for farmers, certifiers, and policymakers to understand its components and implications.

Broader Implications for the Halal Industry

As Halal-certified products expand into sectors such as bio-based materials, pharmaceuticals, and cosmetics, the demand for ethically sourced and environmentally friendly inputs will continue to grow. Tools like AWI can serve as a model for other indices that evaluate sustainability and Halal compliance in different contexts, including water use, packaging, and energy consumption.

Moreover, incorporating digital technologies such as blockchain for traceability and sensors for monitoring can further enhance the transparency and trustworthiness of Halal su Results. (21)

The implementation of the Animal Waste Index (AWI) in the pilot study produced meaningful insights into the feasibility and effectiveness of integrating Halal compliance with sustainable waste management technologies, particularly the use of bioreactors. (6 and 22)

Table1: Compost Testing Parameters:

Category	Parameter	Purpose / Significance	Acceptable / Target Range
Maturity & Stability	Temperature Profile	Confirm completion of thermophilic phase	≥ 55°C for ≥ 3 days (EPA 503 standard)
	Respiration Rate (CO_2/O_2)	Measure microbial activity; low = stable compost	< 4 mg CO_2-C/g OM/day (or similar O_2 rate)
	Ammonia Levels	High NH_3 = immature compost	Low or non-detectable
	Germination Index (Phytotoxicity)	Assess seed germination and root growth	≥ 80% (ideal ≥ 90%)
Hygiene	Fecal Coliforms	Public health safety	< 1000 MPN/g (per EPA 503)
	Salmonella spp.	Indicator of pathogen risk	Absent in 50g sample
	Helminth Ova (if required)	Particularly for biosolid compost	Country-specific (usually < 1–3 ova/g)
Nutrients	Total Nitrogen (N)	Plant nutrition	Typically 1–3% dry weight
	Total Phosphorus (P)	Plant nutrition	Typically 0.3–1.5%
	Potassium (K)	Plant nutrition	Typically 0.5–2%
	Secondary & Micronutrients	Support plant health	Trace levels; avoid excess
Heavy Metals	Arsenic (As), Cadmium (Cd), etc.	Environmental and crop safety	Comply with local/EPA/EU/GCC limits
Physical Properties	Moisture Content	Ideal composting & usability	40–60%
	Bulk Density	Affects transport & application	400–700 kg/m³ (typical range)
	Particle Size	Consistency & application method	< 25 mm (customizable)
	Odor	Indicator of aerobic/anaerobic status	Earthy (no sour or rotten smell)
Chemical Properties	pH	Affects nutrient availability	6.0–8.0
	Electrical Conductivity (EC)	Indicates salt levels	< 4 dS/m (preferably < 2 dS/m for sensitive crops)

Compost Output and Quality:

The bioreactor successfully converted over 80% of raw animal waste into usable compost within 15-20 days. (Table 2 and 3)

The final compost met safety standards for use in organic farming and was deemed suitable as animal bedding, showing no harmful pathogens or chemical residues.

Table 2: Laboratory analysis of the compost revealed favorable nutrient content:

Unit		%	——	dS/m	%	%	%	——	%
No.	Standerd / S.Name	< 25.0	< 7.5	< 10.0	> 50 - 60	< 0.8	< 1.2	< 25 : 1	> 2.0
2	compost (animal waste origin)	23.50	6.20	17.25	57.00	0.53	0.80	15.38 : 1	2.15
Lab Remarks		(pH & EC & CL & Na) is measured on 1:5 (W/V) Extract.							

Table 3: Laboratory analysis of the compost revealed favorable nutrient content:

			Organic Fertilizer Analysis							
2023	Parameter		Moisture	PH	Ec	O.M	Na	Cl	C:N ratio	N
	Units		%	——	dS/m	%	%	%	——	%
Sr.No.	No. of Samples	Standerd / Sample Name	< 25.0	< 7.5	< 10.0	> 40	< 0.8	< 1.2	< 25 : 1	> 1.0
13	1	Animal and plant fertilizer	21.92	6.50	11.88	41.20	0.48	0.72	14.06 : 1	1.70
14	2	Planet fertilizer (under treatment)	25.10	6.80	8.71	42.00	0.48	0.70	22.15 : 1	1.10
Lab Remarks			(pH & EC & CL & Na) is measured on 1:5 (W/V) Extract.							

Environmental Impact:

A 35–40% reduction in greenhouse gas emissions (methane and ammonia) was recorded compared to conventional waste storage methods. (17)

Water runoff from the composting process contained lower levels of contaminants, aligning with environmental protection guidelines and Islamic values of resource preservation. (2 and 23)

Halal Compliance Evaluation:

- Process audits conducted in coordination with Shariah advisors confirmed:
- No cross-contamination with non-Halal or najis materials.
- Ethical treatment of animals and sanitary handling of waste.
- Use of pure, non-toxic materials and no harmful additives.

The overall process scored above 90% on a compliance checklist developed in line with Halal assurance criteria. (6 and 24)

Stakeholder Feedback:

Interviews with farm operators and Halal certifiers highlighted strong support for integrating sustainability measures into Halal processes.

Farmers noted increased soil fertility and improved public perception of eco-conscious practices.

Certifiers expressed interest in adapting the AWI model for broader application in the Halal industry.

Conclusion

The integration of Halal principles with sustainable technologies presents a transformative opportunity to address environmental challenges while adhering to ethical and religious values. This study introduced the Animal Waste Index (AWI) as a novel tool for evaluating the sustainability, efficiency, and Halal compliance of animal waste management systems, particularly through the use of bioreactor technology.

The quality of the compost produced was notably high. Laboratory analysis confirmed the absence of harmful contaminants and a nutrient-rich composition, making it a safe and beneficial input for agricultural applications. This supports the growing demand for organic fertilizers that enhance soil health without introducing chemical residues into the environment. The compost was suitable for use in both conventional and organic agriculture, providing a sustainable alternative to chemical fertilizers

Moreover, the system adhered strictly to halal and Sharia-compliant practices. No impure (najis) or prohibited (haram) substances were introduced during the process, and animals were not subjected to harm or distress at any stage. This ensures that the final compost product aligns with Islamic ethical standards, making it suitable for use in halal-certified agricultural systems.

The AWI framework proved effective in offering a multidimensional assessment, combining religious, environmental, and technological criteria into a single evaluative tool. Its application supports a more structured approach to sustainable agricultural practices in Muslim-majority and Halal-conscious communities, offering both practical and spiritual benefits.

Figure 14: Plant growing from the compost in Turkey

Recommendations

Based on the findings and insights of this study, the following recommendations are proposed to support the wider adoption and development of Halal-aligned sustainable technologies, particularly in the area of animal waste management:

Looking ahead, scaling up the AWI framework and integrating it with digital monitoring tools can further enhance its applicability across diverse sectors. Establishing formal guidelines and engaging Halal certification bodies will be critical to legitimizing and expanding the use of such models. By continuing to align religious values with environmental innovation, Halal sustainable technologies have the potential to shape a more ethical, resource-conscious global market.

Provide specialized training for farmers, waste management personnel, and Halal certifiers to understand the technical and ethical dimensions of AWI-based systems and bioreactor technologies.

Policy Support and Incentives; Encourage governments and Halal regulatory bodies to support sustainable Halal technologies through policy frameworks, financial incentives, and research funding, particularly in rural and developing regions.

Public Awareness and Market Development; Launch awareness campaigns to educate consumers and producers about the value of Halal-compliant sustainable practices. Promote products made using AWI-compliant compost to enhance consumer trust and demand.

Further Research and Piloting; Conduct additional studies in different environmental and agricultural contexts to refine the AWI model, evaluate long-term impacts, and explore its adaptability across sectors such as aquaculture, bioenergy, and Halal pharmaceuticals.

Collaboration with Certification Bodies; Partner with recognized Halal certification authorities to validate and adopt AWI into broader Halal standards, helping bridge the gap between traditional certification processes and emerging environmental technologies.

s good microbiological safety and efficiency of fermentation, smoking and ripening. Values for *Staphylococcus aureus* range from 5.5×10 to 1.4×10^2 CFU/g, which is in accordance with the values prescribed by the current Regulation. Most samples were negative after ripening, except for 3 (very low values). This further confirms the safety of the product after seven days of ripening. Coagulase-positive staphylococci are completely absent after storage, which is an indicator of hygienic correctness and sustainability of dry cheese in storage conditions. *Listeria monocytogenes* was not found in any sample of dry cheese, which shows the hygienic safety and security of this product.

Cheese production using natural microflora of lactic acid bacteria is more acceptable compared to cheese production using commercial dairy cultures, as is evident from the results of research conducted by Renata Pyz-Lukasik et al., (2018) in the production of traditional short- and long-maturing cheeses from Poland. Commercial dairy cultures were used in the production of this cheese, and the temperature in the production and maturing room was 18-20°C and 14-20°C, respectively. The tested cheeses did not meet the microbial criteria for food safety (presence of *L. monocytogenes*) and process hygiene (exceeded permissible levels of *E. coli* and coagulase-positive *Staphylococcus*).

Lactobacillus spp. isolated from Iranian local raw milk cheese from Ahvaz province, have in vitro studies that make them potential candidates for probiotic and technological applications. The results showed that these strains have good probiotic and technological potential. The results of safety aspects also showed that these strains can be used for human nutrition. Therefore, in vivo studies are needed to investigate their effectiveness in real-life situations (Hasan B., et al.,2021).

Monitoring the concentration of lactic acid bacteria in Mozzarella cheese shows that the results confirmed the correlation between the concentration of lactic acid bacteria and the quality of the process: a high concentration of lactic acid bacteria in the raw materials and whey starter ensured safe and good final products (Francesca L., et al., 2014).

According to Cretenet et al., (2011) adequate growth of milk bacteria during milk farming contributes to the control of the reproduction of potentially pathogenic bacteria, with special reference to staphylococci that produce enterotoxins, and can help in the production of safer cheese.

According to the research of Angeliki D. et al., (2024) the application of bioprotective strains of lactic acid can result in an extension of the shelf life of feta and provide a mild antimicrobial effect against *L. monocytogenes*.

The results of a study conducted on the microbiological diversity and physicochemical properties of Kurdish cheese from Iran during ripening (1, 20, 40 and 60 days) showed that the type and number of microorganisms were most affected by the ripening time. Lactic acid bacteria and *Enterobacteriaceae* dominated during the first 20 days of ripening, and *lactobacillus* were the most common microorganisms found during ripening. The initial number of coliforms and E. coli decreased rapidly, while a gradual increase in the number of molds and yeasts was observed in the early days of ripening. *Coliform bacteria, Salmonella* and *coagulase-positive Staphylococcus* spp. could not be detected in the ripened cheese (Elnaz Milani et al., 2014).

Brooks JC., et al., (2012) analyzed the presence of pathogenic bacteria in raw milk cheese produced in the USA. They analyzed them for the presence of *Listeria monocytogenes*, *Salmonella*, *Escherichia coli* O157:H7, *Staphylococcus aureus* and *Campylobacter*. Five samples contained coliforms; two of them contained *E. coli* less than 10(2) cfu/g. Three other cheese samples contained *S. aureus*. Research by Brooks JC., et al., (2012) supports the theory that with adequate control of microbiological parameters and proper aging, cheeses produced from unpasteurized milk can be safe for consumption, although there is a risk of the presence of pathogens such as *S. aureus* and *E. Coli*.

By evaluating the interaction (growth behavior and survival) of *Listeria monocytogenes* and *Lactobacillus acidophilus* in different stages of production, ripening and storage of Iranian white cheese, changes in pH values were recorded at different stages of cheese ripening, as well as a positive effect on the sensory characteristics of the cheese. The decrease in the number of *L. monocytogenes* during the ripening and storage period of probiotic Iranian white cheese may be due to the combined effect of the lowered pH and the antimicrobial activity of the starter and probiotic bacteria used in this study (R. Mahmoudi et al., 2012).

In Minas cheeses (type Canastra) made from raw or pasteurized milk, selected strains of lactic acid bacteria showed bacteriostatic effects and inactivation of *L. monocytogenes* in soft cheese, and in semi-hard cheese, respectively. Inactivation of *L. monocytogenes* was significantly higher in semi-hard cheeses made with raw milk and the addition of selected indigenous lactic acid bacteria. Strains isolated from artisanal Minas cheeses may provide an additional barrier to the growth of *L. monocytogenes* during refrigerated storage of soft cheese and help shorten the ripening period of semi-hard cheeses aged at room temperature (Fernanda B. Campagnollo et al., 2018).

Conclusion

Based on the results of the research on the microbiological safety of dry cheese through three phases, it was concluded that the safety of dry cheese after smoking improves through the ripening and storage process. Potentially dangerous microorganisms are eliminated. Fermentation continues, which is visible through the growth of *Lactobacillus* spp., which also contributes to the development of the texture and taste of dry cheese. The technological process (smoking, ripening and storage) has proven to be effective for the microbiological safety and safety of dry cheese. These results confirm that dry cheese can be a safe, healthy and halal product, which not only meets religious requirements, but also meets high food safety standards through the presence of probiotic bacteria, such as *Lactobacillus* spp. that act as a natural protection against pathogens. These properties make traditional dry cheese from Bosnia and Herzegovina an even more valuable product on the market.

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Predviđanje budućnosti halala u kontekstu održivih tehnologija s fokusom na Indeks životinjskog otpada

Tharwat Mamdouh Al-Bataineh[1*], Jood Osama Quran[2], Jašić Midhat[3]

[1]Ministarstvo za klimatske promjene i okoliš, Ujedinjeni Arapski Emirati. Dubai, područje Al Ruwayyah 2, pored Univerziteta Zayed, put Dubai–Al Ain, Dubai
[2]Univerzitet Maryland, Odsjek za neuroznanost College Park, Sjedinjene Američke Države
[3]Univerzitet u Tuzli, Farmaceutski fakultet, Univerzitetska 8, 75000 Tuzla, Bosna i Hercegovina

[*]Autor za korespondenciju: Tharwat Mamdouh Al-Bataineh
E-mail adresa: dr_thrwat@yahoo.com

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Sažetak

Budućnost halal održivih tehnologija pokazuje značajan potencijal u odgovoru na rastuću potražnju za etičkim i ekološki prihvatljivim rješenjima, posebno unutar muslimanskih zajednica i globalnog tržišta. Kako svijet postaje sve svjesniji izazova održivosti, otvara se prilika za integraciju islamskih principa halala (dozvoljeno) i tayyiba (čisto, zdravo, korisno) u nove tehnologije, posebno u sektorima kao što su poljoprivreda, farmacija, kozmetika i finansije. Ove oblasti mogu imati koristi od inovacija koje poštuju standarde održivosti, a istovremeno su usklađene s halal praksama. Ovaj rad fokusira se na evaluaciju Indeksa životinjskog otpada (AWI) kao alata za mjerenje upravljanja i uticaja životinjskog otpada u poljoprivrednim uslovima. Cilj AWI indeksa je poboljšanje održivosti i upravljanja otpadom kroz praćenje procesa pretvaranja životinjskog otpada u kompost, koristeći efikasne metode koje su u skladu s halal principima. Potencijal za korištenje tehnologija za prikupljanje i nadzor podataka u realnom vremenu dodatno bi unaprijedio ovaj proces, vodeći ka održivijim i halal-kompatibilnim praksama u poljoprivredi. Jedno od rješenja u upravljanju prehrambenim otpadom uključuje korištenje bioreaktora, koji razgrađuju organski otpad putem kontrolisanih bioloških procesa. Ovi uređaji, koji mogu raditi i aerobno (uz prisustvo kisika) i anaerobno (bez kisika), pretvaraju prehrambeni otpad u kompost, obogaćujući zemljište i podržavajući poljoprivrednu proizvodnju. Integracija bioreaktora nudi efikasno i skalabilno rješenje za upravljanje otpadom, smanjujući negativan uticaj na okoliš i povećavajući održivost, uz ispunjenje halal standarda. Kako potražnja za halal-certificiranim proizvodima raste u različitim industrijama, usklađivanje halal praksi s ekološki odgovornim rješenjima stvara priliku za širenje halal standarda u domenu održivih tehnologija. Sve šira primjena halal principa u novim sektorima kao što su dobrobit životinja, kozmetika i bio-bazirani proizvodi ukazuje na veći potencijal za razvoj halal održivosti. Razvoj AWI indeksa kao alata za praćenje pretvaranja životinjskog otpada od suštinske je važnosti za usmjeravanje poljoprivrednih praksi ka održivijim, etičnijim i halal-kompatibilnim metodama. Kompostiranje prehrambenog otpada ne samo da smanjuje ekološki otisak, već otpad pretvara u vrijedne resurse, obogaćuje zemljište i podržava sigurnost hrane. Gledajući unaprijed, tehnologije poput bioreaktora igraće ključnu ulogu u rješavanju globalnih izazova upravljanja otpadom, ispunjavanju ciljeva održivosti i rastuće potražnje za bio-baziranim proizvodima. Podsticanjem inovacija koje zadovoljavaju i etičke i ekološke standarde, budućnost halal održivih tehnologija obećava odgovornije i održivije globalno tržište.

Ključne riječi: *Halal tehnologije, održivost, upravljanje otpadom, bioreaktori, Indeks životinjskog otpada (AWI)*