fortune Journals

Case Study

JOURNAL OF PHARMACY AND PHARMACOLOGY RESEARCH

ISSN: 2578-1553

Biological Research Efforts for Regional Development: Waste management, Aquaculture, and Mushroom Cultivation as case studies

Dan Levanon*[,1,2], Gad Degani[1,2], Uri Marchaim[2]

Abstract

MIGAL – Galilee Research Institute – is a multidisciplinary research institute located in the Upper Galilee, Israel, dedicated to promoting the region's agriculture, food systems, health, environmental stewardship, and waste management. The Upper Galilee region features exceptional topographic and climatic diversity, supporting varied agricultural systems, natural habitats, and mixed rural-urban communities. It also hosts the main portion of Israel’s sources of surface water, many nature reserves. Despite this, for many years the region suffered from negative migration because of its distance from the country center and its neglection by state institutions. This review presents how the institute for multidisciplinary research located in this peripheral region, with a clear vision for regional development, acts as a **catalyst** for inclusive, resilient, and locally grounded sustainable economic growth of the region. Three representative biological applied research and development efforts are presented as examples of the institute's direction of action: (1) thermophilic anaerobic fermentation of dairy manure into biogas and agricultural inputs; (2) the deployment of closed-loop recirculating aquaculture systems (RAS); and (3) the cultivation of edible mushrooms on recycled agricultural and forestry residues. These case studies exemplify how scientific innovation grounded in regional needs can enhance environmental resilience, resource efficiency, rural livelihood and the region's development. Focusing specifically on agricultural and regional business development, MIGAL research institute, with a vision for the sustainable development of the Galilee peripheral region has a profound and transformative effect on the region’s economic development.

Keywords: applied microbiology; applied mycology; recirculating aquaculture systems (RAS); anaerobic fermentation - biogas; mushroom cultivation; waste recycling; circular economy; resource efficiency; regional sustainable development; Upper Galilee

Introduction

The Upper Galilee region of northern Israel is distinguished by its exceptional ecological and topographic diversity. With elevations ranging from 200 meters below sea level to 1,100 meters above, the region encompasses a wide array of topographic-climatic zones within a compact geographical area. This unique combination supports a rich range of crops from bananas to cherries, diverse natural habitats, and a mix of rural and urban communities. It also houses most of Israel’s natural surface water sources, alongside numerous nature reserves. Despite this, for many years

Affiliation:

[1]Faculty of Sciences and Technology, Tel-Hai College, Upper Galilee, 1220800, Israel

[2]MIGAL Galilee Research Institute, 1101600, Kiryat Shmona, Israel

***Corresponding author:**
Dan Levanon, MIGAL Galilee Research Institute, 1101600, Kiryat Shmona, Israel

Citation: Dan Levanon, Gad Degani, Uri Marchaim. Biological research efforts for regional development: Waste management, Aquaculture, and Mushroom Cultivation as case studies. Journal of Pharmacy and Pharmacology Research. 9 (2025): 84-90

Received: July 01, 2025
Accepted: July 09, 2025
Published: July 22, 2025

the region suffered from negative migration because of its distance from the center of the country and its neglection by state institutions [1]. In recent years, the pressures of climate change and environmental degradation have highlighted the urgent need for sustainable agricultural practices in the region. In response, the **MIGAL – Galilee Research Institute**, a multidisciplinary applied research center based in the Galilee, has emerged since its establishment in 1979 as a key actor in promoting regional development. With a focus on agriculture, food systems, health, environmental sciences, and waste management, MIGAL has prioritized regional development that aligns with environmental protection and resource conservation [1, 2].

This review examines the evolution and implementation of sustainable agricultural practices in the Upper Galilee, with a particular focus on innovative, research-driven solutions developed at MIGAL. To demonstrate how research and development in the field of modern agriculture can contribute to the development of a selected region, three different case studies are demonstrated as a model for sustainable agricultural development. These are just samples of the studies in agriculture and agro-industry that researchers at MIGAL have studied and developed [3]. These three representative initiatives reflect a broader trend of integrative, climate-resilient approaches to agriculture and agro - industry regional development:

1. The recycling by thermophilic anerobic fermentation of dairy manure, for renewable energy and soil-enriching agricultural inputs production (Applied microbiology).
2. The breeding of fish species in closed-loop, Recirculating Aquaculture Systems (RAS).
3. The recycling of agricultural and forestry waste for the cultivation of edible mushrooms (Applied mycology).

By exploring these case studies, this review aims to illustrate how scientific innovation, environmental stewardship, and taking advantage of economic opportunities can converge in the pursuit of regional development. It also seeks to contribute to broader discussions on regional adaptation strategies to climate change, particularly in ecologically sensitive and resource-constrained areas [3].

Case studies

Innovative Approaches to Organic Waste Recycling for Energy and Agricultural Inputs in the Upper Galilee

Biogas Production from Organic Wastes

In the context of global efforts to reduce greenhouse gas emissions—particularly given that over 60% of global electricity still relies on fossil fuels [4], converting organic waste into energy has gained increasing attention. One promising pathway is the generation of biogas from second-generation biomass, which includes agricultural waste, livestock manure, and other organic residues [5]. Anaerobic Thermophilic Methanogenic Digestion (ATMD) is a well-established technology in this space. It not only reduces waste volume but produces methane-rich biogas for energy generation and a valuable by-product known as **digested slurry**. This process aligns with circular economic principles by reintegrating organic waste into productive use. A review of thirty years of research efforts confirmed that anaerobic fermentation is the leading method for waste recycling that offers energy production capable of replacing fossil fuels and additional environmental benefits through nutrient recycling, especially phosphorus [6]. At MIGAL, ATMD research has focused on maximizing both energy production and the reuse of digested slurry. It dealt with the digestion of dairy manure [**7**], poultry manure [**8, 9**], agricultural wastes, slaughterhouse waste [**10**], Olive oil and wineries' wastewater [11] and industrial food wastes [12]. These studies have explored slurry's potential as a **peat substitute** in horticulture and as casing soil for mushrooms *(Agaricus bisporus)* cultivation, both vital for sustainable agriculture [13].

Thermophilic Digested Slurry: Enhancing the Viability of Biogas Plants

The economic sustainability of biogas systems often hinges on the value derived from digested slurry. Rich in humic substances, nutrients, and trace elements, the slurry is an excellent organic fertilizer and soil conditioner. At MIGAL's demonstration plant, a specialized process was developed to screen and separate slurry into fractions with distinct applications [14]. A key innovation was the development of **Cabutz**, a coarse fibrous fraction derived from thermophilic slurry after sieving and leaching. Studies led by Raviv et al [14] demonstrated that Cabutz performed better than peat moss and rock wool in the cultivation of herbs and ornamental plants. Its superior performance is partly attributed to the **natural production of plant growth regulators** like indole-3-acetic acid (IAA) during thermophilic fermentation at 55°C [15, 16]. Tryptophan-rich biowaste, when processed through ATMD, becomes enriched with auxins, promoting rapid root development, and attributes highly valued in commercial horticulture.

Cabutz as Casing Soil for Mushroom Cultivation

Peat moss is the main component in casing soils for white button mushrooms (*Agaricus bisporus*) cultivation, but it is expensive, non-renewable, and its mining causes great ecological damage. Research at MIGAL investigated the use of Cabutz as an alternative casing material and found promising results. Physically, Cabutz resembles peat in density and porosity but surpasses it in water-holding capacity. Despite its high moisture retention, it maintains the aeration needed for healthy mycelial growth and fruiting [17].

Levanon D, et al., J Pharm Pharmacol Res 2025
DOI:10.26502/fjppr.0110

It was demonstrated that mushroom yields on Cabutz casing matched or exceeded those on peat casing soils, particularly in the early flushes [18]. Moreover, Cabutz was found to carry fewer harmful molds. This innovation was successfully scaled to commercial mushroom farms in Northern Israel, where it provided a **cost-effective and sustainable alternative** to peat [5, 19].

Sustainable Aquaculture Through Closed Water Systems (CWS)

As global demand for fish rises amidst declining wild stocks, aquaculture has emerged as a vital solution for food security. Traditional open-pond systems, while productive, are associated with high water consumption, environmental degradation, and increased fish disease transmission. In contrast, **Closed Water Systems (CWS)** also referred to as **Recirculating Aquaculture Systems (RAS)** offer a sustainable alternative by drastically reducing water use, improving biosecurity, and optimizing fish health [20]. Northern Israel, historically reliant on open-pond aquaculture, has pioneered the transition to CWS, largely driven by water scarcity and environmental concerns [20]. These systems integrate mechanical and biological filtration, UV sterilization, and real-time monitoring of critical parameters: temperature, pH, ammonia, and dissolved oxygen. The result is a controlled aquatic environment that supports consistent and high-quality fish production [21, 22]. While high capital costs and technical complexity remain challenges, recent advances, including AI-based monitoring, modular designs, and automation have improved system efficiency [23]. Below are three examples from the Galilee region that highlight the versatility and success of CWS for various aquaculture species.

European Eel (*Anguilla anguilla*) Cultivation

The European eel is a high-value species with complex developmental stages, making it difficult to farm. However, the stable conditions provided by CWS, especially regarding temperature and oxygen levels, facilitate all key growth phases: glass eel acclimatization, juvenile rearing, and grow-out. MIGAL's research has demonstrated successful production of eels in CWS, reducing dependence on wild-caught juveniles and enhancing the sustainability of eel farming [24].

Catfish (*Silurus glanis*) Cultivation

Catfish are well suited to RAS due to their tolerance of varied water conditions and fast growth. Efficient breeding protocols, including broodstock management, induced spawning, and controlled larval rearing, have been developed and implemented successfully. Studies have confirmed that RAS use in catfish farming reduces disease risks, enhances feed conversion ratios, and improves overall productivity [25].

Ornamental Fish Production

Guppies (Poecilia reticulata) and other ornamental species are bred in Northern Israel for local markets and export. CWS technologies enable selective breeding, sex separation, and optimal fry rearing, all under tightly controlled environmental conditions. Research highlights that filtration, UV treatment, and tailored system designs improve both survival rates and phenotypic traits such as coloration and fin morphology [26]. These case studies demonstrate the adaptability of CWS across a range of aquaculture objectives: food production, biodiversity conservation, and export-driven ornamental fish farming. Continued innovation and policy support are expected to enhance their role in sustainable aquaculture.

Mushroom Cultivation Using Recycled Agricultural and Forestry Wastes.

Mushroom farming in Northern Israel originated to create livelihoods in mountainous regions with limited agricultural land and scarce water resources. Since its inception, MIGAL has played a central role in researching and promoting agricultural development of the Galilee region [1]. Within this framework, MIGAL's research efforts focused on the development of sustainable mushroom cultivation practices adapted to the Galilee region's environmental conditions and potential mushroom cultivation substrates [27].

Chemical, physical and biological parameters for proper waste recycling for mushroom cultivation

Agricultural and forestry activities in the Galilee generate large volumes of waste, including cotton straw, orchards forest and grapevine trimmings, corn cobs, and animal manures. Due to its resistant structure, lignocellulosic biomass is difficult to degrade and often ends up incinerated contributing to air pollution and greenhouse gas emissions. In several studies at MIGAL, methods and protocols for growing edible mushrooms on forest and agricultural wastes and livestock manures were developed. The optimal chemical and physical composition of the wastes as mushroom growing substrates/composts at all stages of mushroom cultivation were determined in these studies. The appropriate composition parameters of the growth substrate/compost are built according to the nutritional requirements and growth pattern of each mushroom species. These parameters are indeed suitable for utilizing waste from various agricultural and forestry sectors and are used to guide the production of the Galilee edible mushrooms industry [18, 27, 28].

Organic waste recycling via *Pleurotus spp.* mushrooms cultivation

The use of white rot fungi such as *Pleurotus spp.* mushrooms can contribute to wastes' reduction, reuse and production of valuable products. *Pleurotus spp*, like other

Levanon D, et al., J Pharm Pharmacol Res 2025
DOI:10.26502/fjppr.0110

white-rot fungi, can grow on a large variety of lignocellulosic biomass and degrade both natural and anthropogenic aromatic compounds. This is due to their non-specific oxidative enzymatic systems. The use of *Pleurotus* spp. mushrooms is advantageous compared to other white rot fungi due to three main reasons: the low cost of their substrates preparation, their fast growth rate and compatibility with wide environmental - ecological conditions [29]. As part of MIGAL's research, ways to recycle agricultural and forestry waste to cultivate these mushrooms were developed [29, 30]. The development enabled waste recycling and growing mushrooms that were not previously grown in Israel as an addition to fresh food markets in a circular economy format [31].

Recycling Olive Mill Solid Waste (OMSW) with *Pleurotus eryngii* mushrooms.

OMSW, a toxic waste/by-product of olive oil production, poses significant environmental risks. MIGAL researchers developed protocols for incorporating OMSW into ***Pleurotus eryngii*** cultivation substrates. Not only did the fungus grow well on these media, but it also showed elevated contents of β-glucans and other specialized metabolites with medicinal properties. Thus, this approach provides a sustainable avenue for recycling problematic waste into health-promoting functional foods [32, 33].

Drip Irrigation for Mushrooms: A Water-Saving Innovation

White button mushrooms (*Agaricus bisporus*) irrigation relies on spraying water on mushroom cultivation beds, which increases water and energy waste, and the risk of mushroom diseases like Bacterial Blotch. MIGAL collaborated with NETAFIM irrigation industry to develop a **drip irrigation system** tailored for mushrooms cultivation. This method delivers water directly to the mushroom cultivation casing layer, maintaining humidity without wetting the mushrooms. It not only improves crop health but also significantly reduces energy use and water consumption [34].

Spent Mushroom Substrates (SMS) as Soil Amendments

After harvest, mushroom used substrates are often discarded as waste, though they retain valuable organic matter and nutrients. Research efforts have been directed to developing ways to recycle and utilize these materials [35, 36]. Studies in avocado orchards with heavy clay soils in Northern Israel demonstrated that **SMS**, when used as mulch, outperformed traditional cattle manure compost (CMC) in improving soil aeration and boosting avocado yields. This dual-benefit strategy supports both mushroom and fruit growers, while diverting waste from landfills to beneficial use in agriculture [37].

Discussion

The case studies presented in this review demonstrate the transformative potential of integrated, biological research-driven strategies for the development of agriculture in peripheral and resource-constrained regions. By leveraging local biomass resources, closing nutrient loops, and enhancing food production systems, the Upper Galilee serves as a compelling model for regional development grounded in circular economy principles.

Systems Thinking and Regional Innovation

A central theme emerging from MIGAL's initiatives is the effectiveness of **system-based thinking** in addressing interconnected environmental and socio-economic challenges. Rather than treating agriculture, waste, and water management as separate domains, MIGAL's interdisciplinary research underscores their **mutual dependencies**. For example, the valorization of livestock waste into biogas not only addresses energy needs and greenhouse gas mitigation but also provides horticultural substrates, contributing to productivity across sectors. Similarly, the closed-loop design of recirculating aquaculture systems (RAS) reflects a systemic effort to align food production with water conservation and biosecurity. Such cross-sectoral integration is essential in peripheral regions like the Upper Galilee, where constraints on resources, labor, and infrastructure can limit the viability of isolated interventions. MIGAL's model illustrates how place-based biological research, embedded in local realities, can yield adaptable and replicable solutions for sustainable development [3].

Climate Adaptation and Resource Efficiency

All three case studies contribute meaningfully to **climate resilience and resource optimization**, critical goals in the context of global climate variability and resource scarcity. Thermophilic anaerobic digestion (TAMD) offers a decentralized, low-emission energy production solution tailored for rural livestock manure treatment. RAS addresses water savings, aquatic biodiversity loss, and aquaculture biosafety. Mushroom cultivation transforms pollutant-rich organic waste streams into nutritious food with minimal land and water inputs. These approaches also minimize reliance on external inputs such as synthetic fertilizers, peat-based substrates, or wild-caught fish fry—thereby reinforcing **ecological self-reliance** and reducing the environmental footprint of regional food systems. Research towards these directions is consistent with the international effort to deal with global warming, as expressed in UN climate conferences [38].

Socio-Economic Inclusion and Rural Revitalization

In addition to environmental benefits, the reviewed initiatives offer **economic opportunities** for rural

Levanon D, et al., J Pharm Pharmacol Res 2025
DOI:10.26502/fjppr.0110

communities through diversified income streams, value-added production, and employment in knowledge-based agriculture. By enabling the creation of local circular economies, these strategies may help counter rural depopulation and economic marginalization—persistent challenges in the Upper Galilee and similar peripheral areas. Moreover, MIGAL's role as a regional research hub facilitates **knowledge transfer and stakeholder engagement**, ensuring that innovations are both technically sound and socially acceptable and economically efficient. MIGAL served in this case as a Regional Peripheral Agricultural R&D institute with the support of the Ministry of Agriculture. The application of MIGAL's research results strengthened the farmers of the region [39]. The guidance given by MIGAL to the mushroom growers has resulted in Galilee farmers becoming the biggest suppliers of mushrooms for Israeli fresh produce markets. The commercial adoption of Cabutz by local mushroom growers, or the successful introduction of eel farming technologies, exemplifies how applied biological science can catalyze **inclusive development pathways** when combined with community collaboration and institutional support. These and other studies conducted in MIGAL are aimed at regional development in accordance with the UN sustainable development goals [40].

Challenges and Limitations

Despite these promising outcomes, several challenges warrant attention. The **scaling and replication** of such integrated systems may face institutional, economic, or regulatory barriers, particularly in regions lacking strong research infrastructure or public support for transitions. Additionally, the high upfront capital costs of technologies like RAS can limit adoption by smallholders, emphasizing the need for tailored financing models and policy incentives. Furthermore, while waste-based inputs are central to circular strategies, their safety, consistency, and market acceptance must be carefully monitored. Long-term studies are needed to assess the cumulative impacts of digested slurry, spent mushroom substrate, and other recycled materials on soil health, crop quality, and ecological integrity. Examination of this subject showed that simulation models are a prerequisite to designing ''sustainable'' systems [41]. In fact, in all the case studies presented here, pilot plants were used, for this purpose and for demonstration purposes.

Implications for Policy and Replication

The Upper Galilee experience offers valuable insights for regional planners, agricultural policymakers, and development practitioners. It underscores the importance of **place-based innovation ecosystems**, where research institutions, local producers, and policy frameworks converge to co-create sustainable solutions [1]. Future replication efforts should consider regional specificities such as resource endowments, cultural practices, and climate risks—while ensuring that interventions remain **flexible and participatory**. Strategic investments in **education, extension services, and collaborative research** will be essential to expand these models beyond pilot scales [3].

Concluding remarks

This review presents an approach to sustainable regional development by integrating diverse fields of agriculture that share a common trait: their suitability for areas with high environmental variability. It emphasizes the importance of interdisciplinary initiatives where researchers from different disciplines collaborate to outline a direction focused on the development of peripheral regions. A similar trend was recently established in the European Union with a focus on "Sustaining our quality of life: food security, water and nature" and "A new plan for Europe's sustainable prosperity and competitiveness" [42]. Since the establishment of MIGAL Research Institute emphasis was placed on the advancement of sustainable agriculture, for enhancement of the economy and society of Galilee. This review presents, as an example, three biological research efforts of the institute's action. The innovative mushroom cultivation strategies exemplify a circular economy model that reduces waste and produces nutritious food. Together with advances in biogas technologies, they form a comprehensive approach to **integrated waste valorization** in Northern Israel. The development of closed water systems aquaculture complements this trend by significantly saving water, which is a limited resource especially in this period of climate change. These examples are just part of MIGAL's extensive biological research and development efforts. Based on the institute's contribution to the development of the region's economy and society, it was decided to rely on MIGAL as a "regional growth engine" and to invest in promotion of Aggrotech and FoodTec industries in the Galilee, as the key lever for the development of the region [43].

References

1. Levanon D and Degani G. Scientific Research and Higher Education as A Lever for Bottom-Up Regional Development-The Case of The Upper Galilee, Israel. Journal of Biotechnology and Biomedicine 8 (2025): 97-101.
2. Gelb S and Levanon D. Developing the Galilee: The case of MIGAL. Jerusalem Letters 21 (1988): 1-6.
3. Degani G, Levanon D, Yom Din G. Academic Research, Higher Education, and Peripheral Development: The Case of Israel. Economies 9 (2021): 121.
4. IEA Rebyable (2024).
5. Marchaim (ed) 1992. "Biogas Processes for Sustainable Development". FAO AGRICULTURAL SERVICES

Levanon D, et al., J Pharm Pharmacol Res 2025
DOI:10.26502/fjppr.0110

BULLETIN No 95. Food and Agricultural Organization of the United Nations, Rome (1992).

6. Hellas CE et al, The potential of animal manure management pathways toward a circular economy: A bibliometric analysis. Environmental Science and Pollution Research (2022).
7. Marchaim U and Criden J. "Method and Means for the Anaerobic fermentation of Agricultural Waste". Date of application 10.6.1980. Date of Grant of Patent 16.9.83. Israeli Patent No. 60284 Assigned to Kibbutz Industries Association, Israel (1983).
8. Dosoretz C, and R Lamed. Inhibition of methanogenic activity in chicken manure fermentation. Page 525 in: Proc. 3rd Int. Symp. Anaerobic Dig, Boston MA (1983).
9. Dosoretz CI. Schleider and R Lamed. Chicken manure methanogenesis 2. Differential inhibition of methanogenesis from acetate by monensin, lasalocid and broiler litter extracts. Poultry Sci 66 (1987): 613-622.
10. Marchaim U, Gelman A and Braverman Y. Reducing waste contamination from animal processing plants by anaerobic thermophilic fermentation and via flesh fly digestion. Applied Biochemistry and Biotechnology 109 (2003): 107-116
11. UK Patent Application No. 1413071.0 Title: "*Modular System For Treatment Of Organic-Rich Winery Wastewater Effluents*". Applicant: Peleg HaGalil, the Regional Water and Sewage Company, Ltd. Inventors: Uri Marchaim, M. Iggy Litaor, Menashe Levi, Nimrod Levi
12. Kostenberg D and Marchaim, U. Solid waste from the instant coffee industry as a substrate for anaerobic thermophilic digestion. Wat. Sci. Tech 27 (1993): 97-107.
13. Levanon D, Dosoretz C and Motro B. Chemical and biological qualification of composts for mushrooms (*Agaricus bisporus*). Mushroom News 31 (1983): 16-19.
14. Raviv M, Chen Y, Geler Z, et al. Slurry produced by methanogenic fermentation of cow manure as a growth medium for some horticultural crops. *Acta Hort* 150 (1983): 563-73.
15. Kostenberg, D, Marchaim, U, Watad AA, et al. Biosynthesis of plant hormones during anaerobic digestion of instant coffee waste. Plant Growth Regulation 17 (1995): 127-132
16. 16.Marchaim, U, Kostenberg, D. and Epstein, E. Auxins and Phenols in anaerobic thermophilic digestion of coffee wastes and their synergistic effect in horticulture. Mikrobiologiya 66 (1997): 706-711
17. Levanon D, Musaphy S and Danai O. Nutritional and ecological aspects of the use of organic wastes for mushroom casing. Mushroom Inf 5 (1988): 13-14.
18. 18.Masaphy, S, Levanon, D. and Henis, Y. Nutritional supplementation to the casing soil: ecological aspects and mushroom production. Mushroom Sc.II 1 (1989): 417-426.
19. Marchaim & Ney (eds). "Biogas Technology as an Environmental Solution to Pollution", Proceedings of the 4th FAO\SREN Workshop, REUR Technical Series 33, Food and Agricultural Organization of the United Nations, Rome (1994).
20. Zohar Y, Degani T, Fishman T. Sustainability in aquaculture: The role of closed water systems. *Aquaculture Sustainability Journal* 19 (2017): 45–56.
21. Degani G, Gallagher ML. *Growth and nutrition of eels*. Israel: Laser Pages Publishing (1995): 1–119.
22. Degani G, Yom-Din G, *Research on new fish species for aquaculture in northern Israel*. Haifa, Israel: Ayalon Offset Ltd (2005): 1–142.
23. Mauceri A, Jones P, Lee S. Technological advancements in closed water systems for aquaculture. *Aquaculture Engineering* 58 (2021).
24. Degani T, Zohar Y, Fishman T. Eel farming in recirculating aquaculture systems: Enhancing sustainability and growth efficiency in Israel. *Aquaculture Research* 53 (2022): 1539–1550.
25. Fishman T, Zohar Y, Sharf A. The role of recirculating aquaculture systems in sustainable catfish farming. *Aquaculture Reviews* 27 (2018): 245–253.
26. Cohen Y, Ron M, Sharf A, Closed water systems for ornamental fish farming: Water quality and management considerations. *Israeli Journal of Aquaculture* 72 (2020): 121–130.
27. Levanon D, Danai O and Masaphy S. Chemical and physical parameters in recycling organic wastes for mushroom production. Biol. Wastes 26 (1988): 341-348.
28. Danai O, Levanon D and Sharma HSS. The evaluation of compost parameters during production for the development of potential yield model for phase III compost. Acta. Edulis. Fungi 12 (2005): 249-257.
29. Silanikove N, Danai O and Levanon D. Composted cotton straw silage as a substrate for *Pleurotus* sp. cultivation. Biol. Wastes 25 (1988): 219-226.
30. Danai O, Levanon D. and Silanikove N. Cotton straw silage for Pleurotus production in commercial scale. Mushroom Inf 12 (1987): 2-3.

Levanon D, et al., J Pharm Pharmacol Res 2025
DOI:10.26502/fjppr.0110

31. Levanon D, Danai O and Silanikove N. Cotton straw silage as substrate for *Pleurotus* sp. cultivation. Mushroom Sc. XII 2 (1989): 81-90.

32. Sharon A, Ezove N, Hanani H, et al. Olive Mill Waste Enhances α-Glucan Content in the Edible Mushroom *Pleurotus eryngi* . Int. J. Mol. Sci 18 (2017): 1564.

33. Khatib S, Pereman I, Kostanda E, et al. Olive mill solid waste induces beneficial mushroom-specialized metabolite diversity revealed by computational metabolomics strategies. Metabolomics 21 (2025): 58.

34. Navarro MJ, Gea FJ, Pardo-Giménez A, et al. Agronomical valuation of a drip irrigation system in a commercial mushroom farm. *Scientia Horticulturae* 265 (2020): 109234.

35. Levanon D, Hadar Y and Wuest PJ. Nature and use of spent mushroom substrate. Compost Sc & Util 2.3 (1994): 22-23

36. Levanon D and Danai O. Chemical, physical and microbiological considerations in recycling spent mushroom substrates. Compost Sc. & Util 3 1 (1995): 72-80

37. Danai O, Cohen H, Ezov N, et al. Recycling of spent mushroom substrates (SMS) in Avocado orchards. Journal of Agricultural Science and Technology B. 2, 11 (2012): 1165 – 1170.

38. A Vihma. Climate of Consensus: Managing Decision Making in the UN Climate Change Negotiations. RECIEL ** 2014 (2015).

39. G Loebenstein and E. Putievsky. Agricultural Research in Israel. In: Agricultural research management. G. Loebenstein and G. Thottappilly Eds. Springer. The Netherlands (2007).

40. M Sousa, MF Almeida, R Calili. Multiple Criteria Decision Making for the Achievement of the UN Sustainable Development Goals: A Systematic Literature Review and a Research Agenda. *Sustainability* 13 (2021): 4129; https://doi.org/10.3390/su13084129

41. MA Reuter. Limits of Design for Recycling and ''Sustainability'': A Review. Waste Biomass Valor 2 (2011): 183–208

42. **Horizon Europe Work Programme 2025,** *9. Food, Bioeconomy, Natural Resources, Agriculture and Environment* (European Commission Decision C (2025) 2779 of 14 May (2025).

43. Resolution on economic development of the northern district and complimentary steps for the city of Haifa. Israel Government resolution, January 4 (2017).