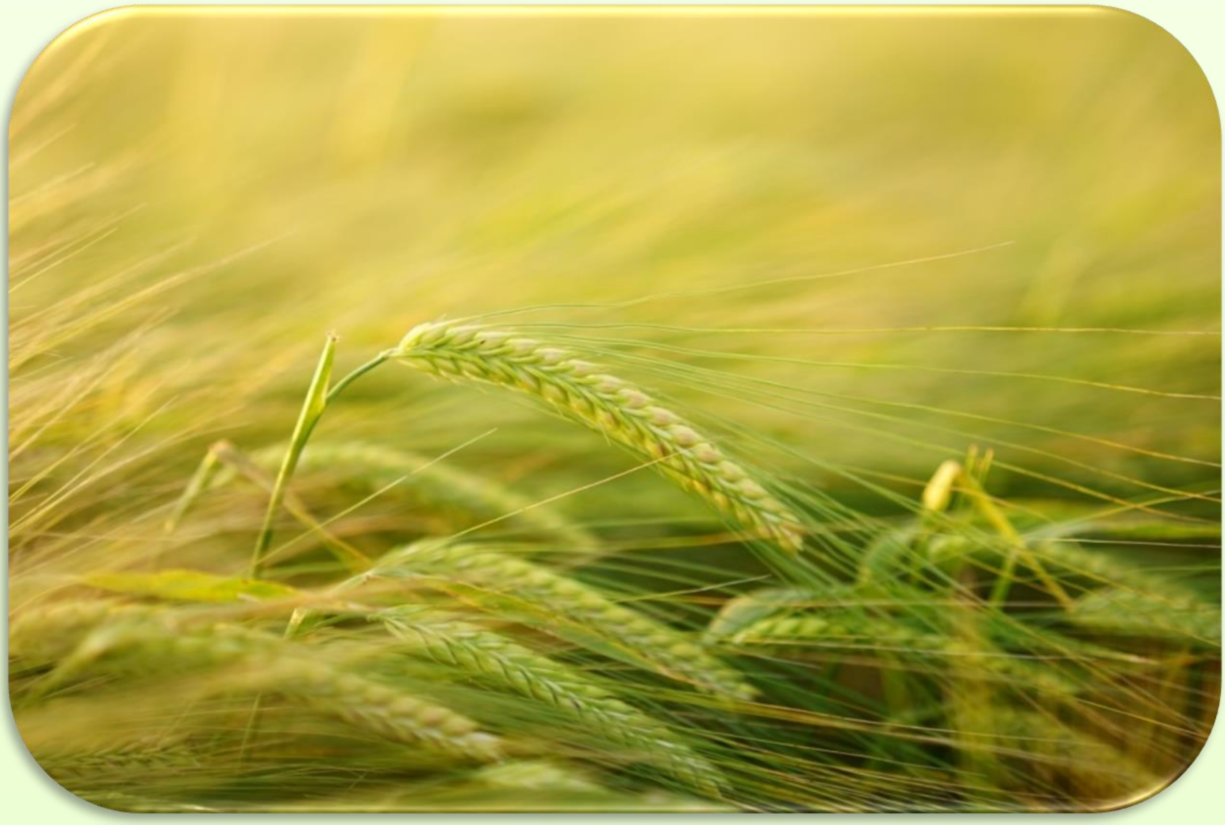

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CONTENTS

Assessment of Mushroom (*Pleurotus Ostreatus*) Production in Bohol, Philippines

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Abstract

The average farm size among Filipino farmers is less than two hectares. Therefore, an alternative crop that does not need a large land area must be considered. For the past years, mushroom production has been gaining recognition globally. Although its production does not require much space, Philippine production is behind compared to other Asian countries such as India, Korea, China, and Thailand. This study was conducted to assessed the mushroom production in Bohol province, including its demographic profile, gender role analysis of the growers, the status of mushroom adopters, and its cost-benefit analysis to depict its current condition. A complete enumeration of oyster mushroom producers in Bohol listed by the Agricultural Training Institute (ATI)-Central Visayas served as respondents for the study. Results revealed that mushroom production in Bohol is considered one of the profitable businesses with a benefit-cost ratio per peso investment of 1.10. The results suggest that mushroom production can be a profitable business venture that can be expanded throughout the province. Furthermore, additional knowledge on value-adding is also encouraged to increase the profit among producers.

Keywords: Cost-benefit, benefit-cost ratio, gender role analysis

Research article
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INTRODUCTION

Most of the poor are employed on family farms (Lowder et al., 2019; Celik and Peker, 2009). While family farms all over the world account for more than 90 percent (Lowder et al., 2019). Rural development objectives in developing countries often focus on increasing job opportunities through diversification of rural income and attaining a competitive structure for agriculture. Small family farmers are disadvantaged as they do not have the large tracts of land needed to produce large crops and raise significant quantities of animals (Celik & Peker 2009).

Likewise, existing agricultural lands are being converted into industrial areas or are owned by elite people, reducing the opportunities for impoverished farmers. Recent literature reviews conducted pointed out that there was a reduction in the average farm size in low and middle-income countries from 1960–2010 (Lowder et al., 2019; Lowder et al., 2016).

In the Philippines, a reduction in the average farm size has been reported from 1960-2000 (Lowder et al., 2019; FAO, 2015). Likewise, farmers in the country have been consistently registered as one of the primary sectors with the highest poverty incidence in the general population since 2006 (FAO, 2018). To ensure sustainable income among small landholder family farmers, mushroom production could be a potential opportunity for them.

Edible mushrooms have been harvested since ancient times. They were used for medicinal properties and have expanded with their current market for nutritional value such as protein, vitamins, and minerals (Khan et al., 2011; Manikandan, 2011). Globally the mushroom market size value was 12.74 million tons (MT) last 2018 and is projected to reach 20.84 million tons (MT) by 2026 with a compound annual growth rate (CAGR) of 6.41% (Fortune Business Insights, 2021.). In many developing and developed countries such as the USA, Great Britain, China, Japan, and Europe, production has become a profitable commercial agribusiness (Kortei et al., 2018). However, mushroom production in the country is relatively low compared to other neighboring countries such as India, Korea, China, and Thailand (Pathania et al., 2017).

Realizing the potential of mushroom production, the Philippine Department of Agriculture (DA) provides oyster mushrooms in the country through community-based programs; Bohol province is one of its recipients (Felisilda, 2014). Likewise, the Agricultural Training Institute (ATI) holds seminars and training on mushroom production for farmers. Despite the government initiative, there are few growers in Bohol, resulting in a limited supply of mushrooms and mushroom products for consumers.

Although mushroom consumption is increasing in the province, and lack of farmland and drought problem arises, the sector is not growing well. As the information on mushroom production in the Philippines is limited, nevertheless, information relating mushroom production to the gender role analysis is not documented.

Gender role analysis determines the concentration of women, men, and children's (boys and girls) activity profiles and the differences in access to and control over resources (FAO, 2014). In many developing countries, women comprise the largest percentage of the workforce in the agriculture sector. They play a predominant role and have an essential economic contribution to agricultural production (de Roo et al., 2016). However, these roles are often unrecognized and/or undervalued. For instance, in some countries, women are still considered subordinates to their husbands or male family members. Their roles in farming are seen as household chores and, therefore, remain unpaid. This, however, does not reflect the contribution of women to agriculture and the rural sector, where they play a significant role in food production and participate in the harvesting, processing, and marketing of agricultural produce (FAO 2018). Thus, closing the gender gap in agriculture is vital to ensure productivity and food security.

The objective of the present study was to determine the demographic profile, gender role analysis of the growers, the status of mushroom producers, and the cost-benefit analysis of mushroom producers in Bohol. With this, the researchers are hopeful that the results would be utilized as a basis for encouraging more Boholano farmers to venture into mushroom production and would serve as a guide in implementing programs by the policymakers, donors, researchers, and extension agents for its success.

MATERIALS and METHODS

A complete enumeration of the 12 mushroom producers in Bohol listed by the ATI-Central Visayas served as the study's respondents. A total of eight (8) municipalities in Bohol served as study sites. This includes the municipalities of Bilar, Guindulman, Tubigon, Tagbilaran, Mabini, Antequera, Balilihan, and Maribojoc (Figure 1). Surveys were conducted from July through October 2019.

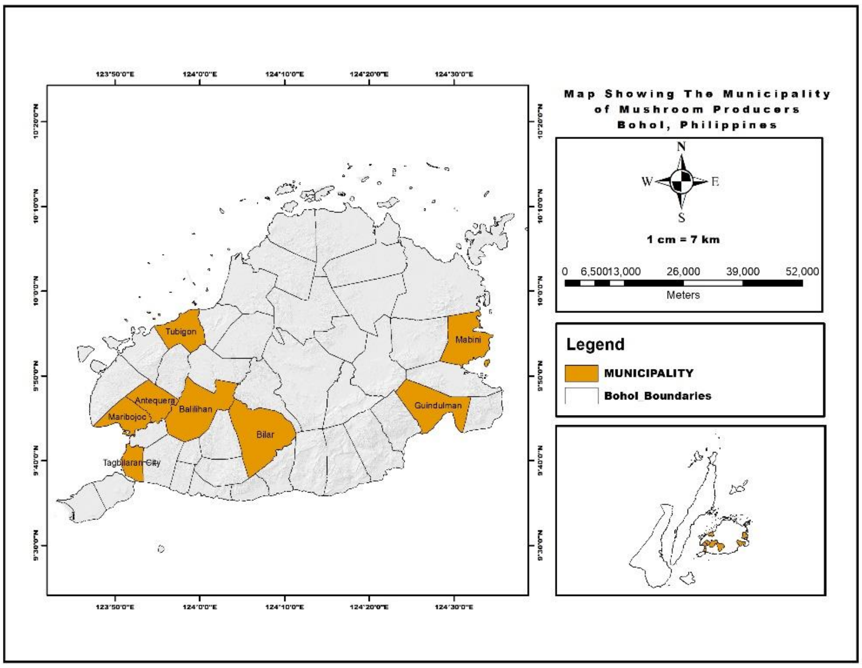

Figure 1. Map showing the mushroom producers in Bohol, Philippines

A pilot test of the questionnaire on two mushroom growers for small-scale and commercial-type production was first employed to test its validity. The semi-structured questionnaire was modified from the methods of Celik and Peker (2009) and Singh et al. (2010) for the cost-benefit analysis and Abadingo and Macalolot (2015) for gender role analysis**.** The questionnaire assessed demographic profile, gender role analysis, the current status of mushroom adopters, and cost-benefit analysis of mushroom producers in Bohol. Following the pilot test, the assessment tool was finalized, and one-on-one interviews with the respondents were conducted.

The data gathered on the demographic profile and status of mushroom producers were tallied, collated, tabulated, and analyzed using simple percentages. In identifying the gender role analysis, the frequency of response among the mushroom producers–respondents were used as a basis. On the other hand, the cost-return analysis comprising the total variable cost, total production cost, average selling price (Php/kg), gross returns, net returns, returns over variable cost, benefit-cost ratio, cost of production (Php/kg) and net returns (Php/kg) were calculated following the formulas of Singh et al. (2010).

RESULTS and DISCUSSION

Demographic Profile of Mushroom Growers/ Respondents

A total of 12 mushroom growers were interviewed, seven men and five women. Of those interviewed, one was from Antequera, Maribojoc, Tagbilaran, Tubigon, and Bilar; two from Balilihan and Guindulman; and three from Mabini. Most (91.87%) of the mushroom producers in Bohol were married. Twenty-five (25) percent of respondents were housewives with 0-3 years of experience in mushroom production. Housewives participating in mushroom production is a good contributing factor to increase the socio-economic status per household. Government employees, businessmen/women, and farmers are also involved in the production (16.67% equally). This denotes that mushroom production in Bohol has been gaining recognition not only from the local farmers but from the professionals as well.

Table 1. Demographic Profile of the Mushroom Grower-Respondents

Item	Frequency	Percentage (%)
Civil status		
Single	1	8.33
Married	11	91.67
Occupation		
Government Employee	2	16.67
OFW	1	8.33
Housewife	3	25.00
Businessman/Woman	2	16.67
Farmer	2	16.67
Seaman	1	8.33
Instrumental Engineer	1	8.33
Educational Attainment		
Elem. Level	0	0.00
Elem. Graduate	0	0.00
Secondary Level	0	0.00
Secondary Graduate	2	16.67
College Level	1	8.33
College Graduate	9	75.00
Training/seminars		
Mushroom Growing and Harvesting	11	91.66
Business Aspect, Mushroom Marketing	1	8.33
Mushroom Substrate	12	100.00
Food Processing	7	58.33
Experience in Mushroom Production		
0-1 years	4	33.33
2-3 years	4	33.33
4-5 years	3	25.00
6-7 years	1	8.33

All respondents participated in substrate preparation, and almost all (91.66%) attended the topics on mushroom growing and harvesting. Additionally, a majority (58.33%) had attended food processing.

This suggests that while initial trainings are successful, there is a need to conduct subsequent trainings, such as marketing strategy for the producers. Considering their length of experience in mushroom production, there are also indications of a need to conduct more seminars and training, which would broaden the producers' expertise.

Gender Role Analysis

The gender role analysis of mushroom producers in Bohol reveals that, except for harvesting, all operation decisions are made by males. Similar results were observed in actual operations in that only harvesting and marketing were the domains of the women. Male dominance in the growth stages of mushroom production should be considered when conducting seminars and training. However, this also emphasizes the need to expand these skills to women in production. Conversely, harvesting and marketing are currently dominated by women. Gender roles are important considerations so that the seminars to be given will fit their actual roles in the operation but also be used as a platform to expand roles. Children are rarely involved in the decision-making and actual operation of mushroom production. There is a need for them to be trained or developed to ensure the sustainability of mushroom producers within the household.

Table 2. Gender Role Analysis in Mushroom Production in Bohol

Farm Operation	**Decision Making**				**Actual Operation**			
	Men	**Women**	**Boys**	**Girls**	**Men**	**Women**	**Boys**	**Girls**
Spawn/Seed Selection	√		√		√		√	
Substrate Preparation	√		√		√		√	
Fruiting bag Preparation	√		√		√		√	
Incubation	√		√		√		√	
Fruiting	√		√	√	√		√	
Harvesting		√	√			√	√	
Marketing	√		√			√	√	

Status of Mushroom Producers

A majority (58.33%) of mushroom producers have conducted a market survey for price demand, indicating that producers in Bohol had prior knowledge of the market survey. It also indicates that they have further plans to develop a business venture. Furthermore, almost all (91.67%) producers have less than 500 pieces of fruiting bags during production. As such, most (41.67%) of them had an abundant quantity with very good quality on the first production. An equal number of growers consumed mushrooms on a daily/weekly basis depending on their food menu and the availability of their harvest. This correlates with the mode of product utilization in which all respondents reported consuming their produce at home as part of their food menu.

Despite the high reported consumption levels within the home, producers are all motivated by pricing and marketability to sell their products outside the home. Two of the areas indicated for sale were the local market and restaurants, implying profitability in expanding the production within the province.

Table 3. The status of mushroom producers

Item	Frequency	Percentage (%)
Market Survey		
Yes	7	58.33
No	5	41.67
No. of Fruiting Bags		
0-500 pcs	11	91.67
501- 1,000 pcs	0	0.00
1,001-1,500 pcs	0	0.00
1,501- 2,000 pcs	0	0.00
2,001- 2,500 pcs	0	0.00
2,501- 3,000 pcs	1	8.33
Quality of produced		
Excellent	3	25.00
Very good	5	41.67
Good	4	33.33
Fair	0	0.00
Quantity of first produced		
Few	5	41.67
Abundant	7	58.33
Frequency of mushroom consumption		
Daily	5	41.67
Weekly	2	16.66
Bi-weekly	5	41.67
Monthly	0	0.00
Motivation for continuing mushroom production		
Better marketability	11	91.66
Better price	12	100.00
The possible market for mushroom		
Hotel	2	16.66
Market	7	58.33
Restaurant	7	58.33
Co-growers	5	41.67

Cost and Returns from Mushroom Production

Fixed costs were the incubation room and growing area, while the variable costs were labor, electricity, compost, and spawn. These costs resulted in an average of PhP 11,676.70 per 100 fruiting bags. The average mushroom production in the province per 100 fruiting bags is PhP 54.65 per kilogram, with an average selling price of PhP 235.45 per kilogram, creating a net return of mushroom per kilogram of PhP 21.78. Therefore, the benefit-cost ratio of mushroom production per peso investment is 1.10. Similar profitability findings have been observed in Turkey, Tanzania, and Thailand (Celik and Peker, 2009; Marshal and Nair, 2009), further supporting the stability and potential of the industry. The results imply that mushroom production can be an alternative and or supplementary source of income among small landholders in the province whose average annual income is PhP 110, 000.00 (or 9,166.67 per month).

Table 4.a. Break-up of Cost of Mushroom Production in Bohol Per 100 fruiting bags (size: 6 x 12 x 0.002)

Particulars	
A. Fixed Cost	
i. Depreciation on Incubation room	5740.56
ii. Depreciation on Growing area	33.33
Total	PhP 5773.89
B. Variable Cost	
i. Labor Charges	5290.38
ii. Electricity Charges	147.59
iii. Compost	101.50
iv. Spawn	363.33
Total	PhP 5902.80
Total (A+B)	PhP 11,676.70

Table 4.b. Cost (Php) and Returns of Mushroom Production in Bohol per 100 fruiting bags (size: 6 x 12 x 0.002)

Particulars	
Total variable cost	5902.80
Total production cost	11676.70
Mushroom production (kg)	54.65
Average selling price (Php/kg)	235.45
Gross returns	12867.19
Net returns	1190.49
Returns over variable cost	6964.38
Benefit-cost ratio	1.10
Cost of production (Php/kg)	213.67
Net returns (Php/kg)	21.78

CONCLUSION

The results of the study show that most of the mushroom growers are married and housewives, which is an excellent contributing factor to increase their socio-economic status per household. Furthermore, mushroom producers are not only local farmers, but some are professional as well, creating a diverse population with differing networking opportunities. Basic seminars and training appear to be well attended by growers, but additional opportunities must be present to expand the sector. When considering the mushroom production gender roles in the present study, gender should be considered when hosting such educational opportunities.

Mushroom production in Bohol was a profitable business venture in the province with a net return of Php 21.78 per kilogram and a benefit cost-ratio per peso investment of 1.10. It has been shown to be successful, even as a secondary business venture. Additionally, the government scheme appears to be working as citizens are engaged in the production of mushrooms. However, there are indicators that additional educational opportunities and consideration of gender roles would help expand production within Bohol.

ACKNOWLEDGMENT

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Fungal Remediation of Nematocide with Fluopyram Active Ingredient in Different Concentrations with *P. Jensenii*

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Abstract

The use of chemicals such as insecticides, herbicides, fungicides and nematocides is common in agriculture and farmers nedd to use them to protect crops from pests, weeds and fungi. While these agents are necessary to control pests and weeds, they have often had undesirable consequences, such as harming non-target organisms, including aquatic species. Bioremediation is one of an usefulI method for eliminating negative effects of these kind of chemicals in receiving environments such as soil and water. In this study *Pencillium jensenii* soil fungi used as a bioremediator tool for bioremediate a fluopyram nematocide with important environmental parameters such as Chemical Oxygen Demand (COD) and Total Organic Carbon (TOC) in agiated culture conditions in certain time periods. According to the results of the study, *P. jensenii* performed high COD and TOC removal efficiencies against fluopyron nematocide as 88% for both parameters in 6 and 7 days respectively. This means, *P. jensenii* is a suitable tool for bioremdiate this kind of nematocides in agricultural activities.

Keywords: Bioremediation, Chemical oxygen demand, Nematocide, *P. jensenii*, Total organic carbon.

Research article
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INTRODUCTION

Pesticides represent a global economic problem and an element of increasing human health concern due to adverse health and environmental problems that occur worldwide, especially affecting end consumers and producers. Pesticides are also important for consumers' acute risk assessment due to the variability of their residues (Prodhan et al., 2023). However, the use of pesticides can also cause environmental and health problems. Pesticides are chemicals, usually synthetic, that are toxic to their biological targets. There are various classes of pesticides, and they are generally classified according to the type of target pest and the way they are used. These classes include insecticides, nematocides, herbicides, fungicides, and rodenticides often used in the home and garden (Casida and Durkin, 2013).

In addition to all these, the effects of pesticides on the ecosystems of aquatic environments, which are the ultimate reservoir, have become a wide area of interest (Tan et al., 2021). These organic-based pollutants can enter receiving aquatic environments through different pathways. It is an undoubted fact that once pesticides enter aquatic environments, they will have a negative impact on aquatic organisms (Huang et al., 2022). Additionally, the use of pesticides may cause target pests to become resistant to pesticides (Tabashnik et al., 2010). Overuse or misuse of pesticides can have significant impacts on natural ecosystems. This can lead to loss of plant and animal species, groundwater pollution, decreased soil quality, and increased adverse effects on human health (Aktar et al., 2009). Today, many pesticide mitigation strategies, such as integrated pest and low input management, have been implemented at the farmland level. Such management strategies both reduce the amount of pesticides applied and aim to minimize the human and environmental health effects of pesticide use (Möhring et al., 2020).

Nematodes are thin, cylindrical parasitic worms that are known pests of plants. These worms can damage plant roots, inhibiting plant growth and causing yield loss. It can also be applied to some plant leaves. In this way, it protects the root system of plants and improves plant health.

Fluopyram is an active ingredient in an pesticide that is effective against nematodes. It affects the nervous system of nematodes and disrupts their vital functions. It can affect the movement and feeding abilities of nematodes by blocking the communication of nerve cells. Thus, fluopyram-containing nematocytes can exert a lethal effect against nematodes or suppress their ability to reproduce.
Its chemical name is 4-(2,6-difluorobenzyl)-1-(1-methyl-1H-pyrazol-4-yl)-5-oxymethyl-1H-pyrazol-3-carboxamide. This compound was developed to be effective against agricultural pests such as nematodes. Bioremediation is the use of specific microorganisms, plants or microbial enzymes to reduce or eliminate environmental pollution. This process uses biological mechanisms to metabolize or transform the pollutant. Various types of pollution involve a wide range of substances, including oil and petroleum products, heavy metals, and agricultural chemicals (such as pesticides and herbicides). The bioremediation methods explained were an effective and environmentally friendly technique because they result in the complete transformation of pesticides into a non-toxic product. Many of the researchers suggests that the bioremediation process can overcome the challenges and limitations of physical and chemical treatment for pesticide removal (Femina et al., 2023).

In this study, one of a soil fungi *P. jensenii* used as a new bioremediator tool for remediate COD and TOC value of the fluopyrom prepared for suggested agricultural using dosage in agiated culture conditions. The difference of this study from previous studies is that it is aimed at monitoring the bioremediation effect of *P. jensenii* soil fungus on fluopyram nematocide in agiated culture conditions daily with COD and TOC which are two important environmental pollution indicator parameters.

MATERIAL and METHOD

Preparing *Penicillium jensenii*

P. jensenii pure microorganism cultures used in the study were obtained from Munzur University Environmental Engineering laboratory. These fungi collected from agricultural soil and isolated and identified before. Pure cultures were propagated to carry out bioremediation activities. For this purpose, the cultures transferred to solid agar media in petri dishes were placed in a 27°C incubator. Then, they were enriched in Saboraud dextrose broth medium at the same temperature for bioremediation activities in liquid media (Cruikshank, 1972).

Preparing pesticide solutions

Fluopyram was prepared in 250 ml conical flasks as 250, 500, 750 and 1000 mg/L, based on the application dose of farmers and recommended in the usage recipe.

Removal of Fluopyram by Bioremediation Process

In the study, firstly, COD and TOC values of the environment that includes enriched *P. jensenii* fungi were monitored every 24 hours. When these values were equal to the concentration of the pesticide, 1 ml of enriched fungal samples taken from these environments (each 1 ml contains approximately 10^6 colony-forming individuals) were inoculated into fluopyrome media prepared at 250, 500, 750 and 1000 mg/L. Then, these pesticide-fungus mixtures were taken into a incubator and shaken at 160 rpm at 27^0C. The samples taken every 24 hours were filtered through a 0.45µm filter and the bioremediation activities of the *P. jensenii* fungus were followed by COD and TOC analyses. In the study, COD analyzes were performed with the open relux method as specified in standard method 5220B. HACH DRB 200 thermoreactor using Hach COD kits that measured in the range 0–1500 mg/l (Cat number: 23459-52) used for COD analysis while Shimadzu TOC-V device was used for TOC analyses. Standard Method 5310B High emperature burning method prefered for TOC analysis. In order to inhibit the activity of fungal colonies, one drop of 1N H_2SO_4 was added to the filtrates. experiments lasted 14 days in total. All of the COD and TOC analysis were performed three times and average value of these replications taken for consideration.

RESULTS AND DISCUSSION

Bioremediation Studies Results on the basis of COD and TOC

In the study, the bioremediation activity results based on COD and TOC shown by *P. jensenii* fungus on Fluopyram nematocytes at different concentrations are shown in Figures 1 and 3 on a concentration basis; on the basis of removal efficiency, it is shown in Figures 2 and 4.

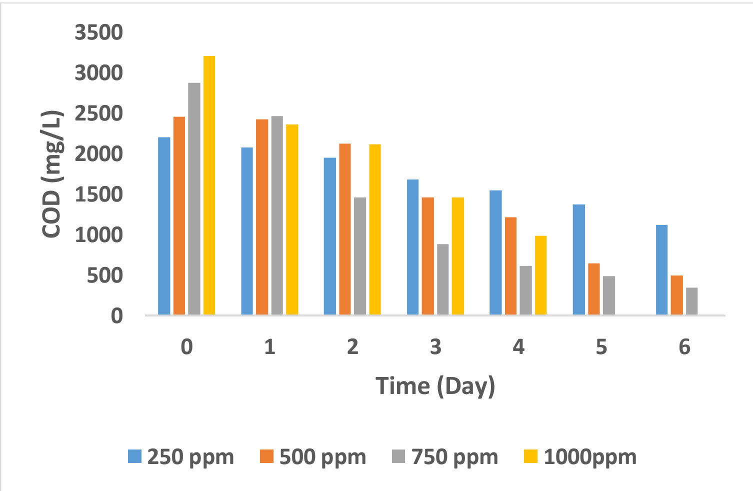

Figure 1. COD decrease based on concentration shown by *P. jensenii*

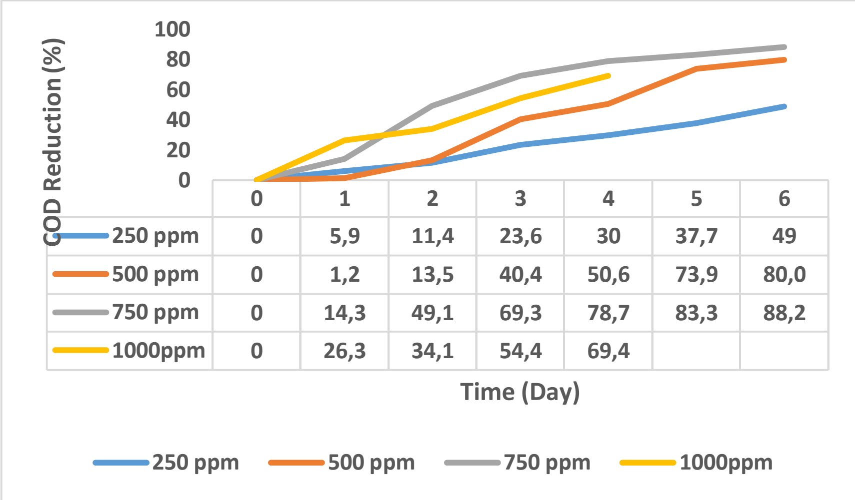

Figure 2. COD reduction efficiency (%) shown by *P. jensenii*

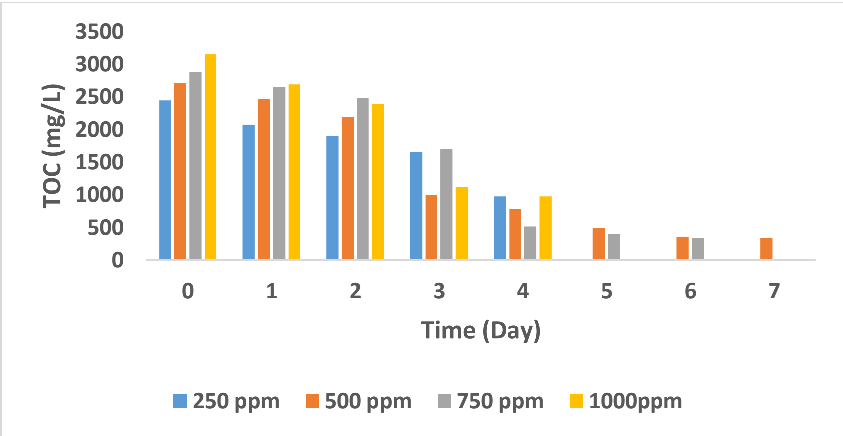

Figure 3. TOC decrease based on concentration shown by *P. jensenii*

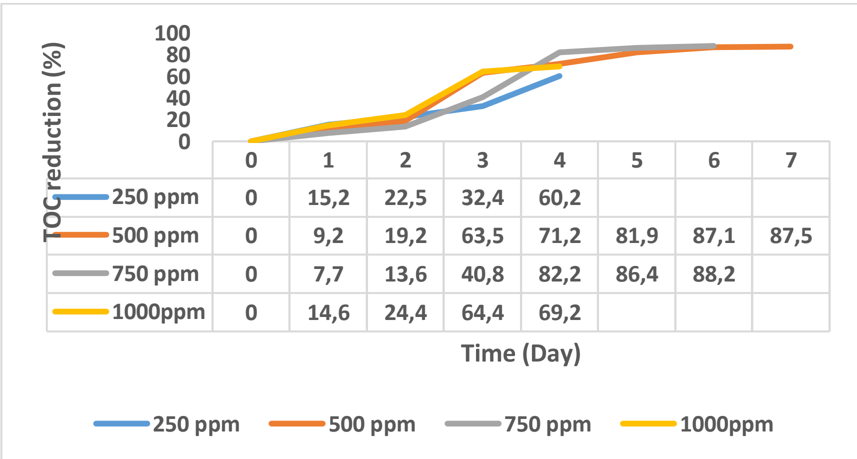

Figure 4. TOC reduction efficiency (%) shown by *P. jensenii*

When the results of the bioremediation activity of the *P. jensenii* fungus on the Fluopyram nematocyte are examined, it is seen that the removal efficiency on a COD basis at the end of the 6th day is 49, 80 and 88.2%, respectively, in 250, 500 and 750 mg/L fluopyram environments. At the end of the 4th day, the removal efficiency in the 1000 mg/L environment was found to be 69.4%. Since increases in the amount of COD were noticeable at the end of these days, the experiment was completed at the end of the 6th day for the 250, 500 and 750 mg/L environments, and at the end of the 4th day for the 1000 mg/L environment. As can be seen from Figure 1, the removal amounts on a COD basis increased from 2200 mg/L to 1120 mg/L at the end of the 6th day in a 250 mg/L environment; In environments of 500 and 750 mg/L, there is a decrease from 2450 and 2870 mg/L to 490 and 340 mg/L, respectively, during the same period. The removal amount in the 1000 mg/L environment is from 3200 mg/L to 980 mg/L at the end of the 4th day (Figure 1 and 2).

When the removal results of the study based on the TOC parameter were examined, the removal in the medium containing 250 mg/L fluopyrome increased from 2440 mg/L to 970 mg/L with an efficiency of 60.2% at the end of the 4th day; In a 500 mg/L environment, from 2710 mg/L to 340 mg/L at the end of the 7th day, with a removal efficiency of 87.5%; At the end of the 6th day in an environment of 750 mg/L, it increased from 2870 mg/L to 340 mg/L with an efficiency of 88.2%; Finally, in the 1000 mg/L environment, it decreased from 3150 mg/L to 970 mg/L at the end of the 4th day, with an efficiency of 69.2%. The reason why the study was terminated on days 4, 7, 6 and 4, respectively, in environments of 250, 500, 750 and 1000 mg/L is that there is an increase in the TOC value at the end of these days, as well as in the COD parameter (Figure 3 and 4).

The reason for these increases seen in both COD and TOC values after certain days is thought to be that after the fungus breaks down the pesticide in its environment, it competes with its own intracellular activities and dead fungal cells increase the COD and TOC values in the environment.

Considering the decrease in the TOC parameter, striking differences with COD are observed in terms of both timing and removal efficiencies. This key difference is that COD is greater than TOC. It is generally known that COD determines the amount of energy required to chemically decompose organic material (in this case it represents the organic load from both pesticides and the medium). TOC, on the other hand, covers all carbon-containing substances originating from the medium containing pesticides and microorganisms in the system.

This study is about the use of *P. jensenii* fungus obtained from agricultural soils in the bioremediation of Fluopyram nematocyte. In many studies in the past, microorganisms isolated from activated sludge of pesticide producing companies were used. However, this study, unlike others, involves isolating the *P. jensenii* fungus directly from agricultural fields and using it in bioremediation studies. This may mean that the resistance of these microorganisms to pesticides and their bioremediation capacity may be naturally higher, given the fact that agricultural environments are exposed to pesticides. Therefore, this study may be an important step to better understand the bioremediation potential of microorganisms obtained from agricultural fields.

It has been understood that microorganisms in bioremediation systems can remain active throughout the duration of bioremediation activities (Lin et al., 2015). This shows that bioremediation can be an effective and alternative method to reduce environmental pollution.

It is recommended to use microorganisms to reduce the toxic effects of pesticides. After pesticides are released into the receiving environment, their negative effects on contaminated areas can also be investigated with environmental parameters such as COD, TOC and Biological Oxygen Demand (BOD_5).

Biodegradation of pesticides is related to pesticide residues, application time and the activities of microorganisms. Erguven and Yıldırım (2019) stated that *Methylobacterium radiotolerans* and *Microbacterium arthrosphaerae* strains completed Imidacloprid bioremediation after 18 days. While the COD parameter was determined as 52, 96 and 99%, respectively, with 20, 40 and 80 ml bacterial consortia, the BOD_5 rates were 88, 79 and 50%, respectively, in the same period. has been recorded.

Many researchers argue that certain microorganisms can develop tolerance to pesticides. In another study, *B. cereus, B. subtilis, B. melitensis, P. aeroginosa, P. fuorescence* and *S. marcescens* consumed 46-72% of chlorpyrifos as the sole carbon source in a sedimentary environment after three weeks. It has been found that they can decompose (Lakshmi et al., 2008).

The removal of herbicide residues in the bioremediation process depends on the activities and nutritional needs of the microorganism (Field et al., 1995; Erguven and Yıldırım, 2016). Penicillium species have been shown to exhibit metabolic activity on herbicides and similar micropollutants and alleviate the toxic effects of these chemicals by lignin degradation by 76% in 15 days and 94% in 30 days (Siripong et al., 2009). In the literature, it has been documented that endosulfan has a biodegradation capacity of up to 96% in studies in aerobic and anaerobic facilities using mixed bacterial populations (Kumar and Philip, 2006).

Góngora-Echeverría et al. (2020) examined the biodegradation of glyphosate in pure strains and microbial consortia. These studies have shown that the inoculation method is effective for the bioremediation of polluted agricultural soils. *Pseudomonas nitroreducens*, *Ochrobactrum sp*., their consortium and *Pseudomonas citronellolis* strain ADA-23B, showed more than 90% removal of glyphosate herbicide in agricultural fields. Erguven and Yildirim (2016) investigated the bioremediation rate of chlorsulfuron herbicide and evaluated its capacity to reduce COD. It has been determined that *B. simplex, B. muralis, M. luteus, M. yunnanensis* and *C. tetani* strains provide 70% to 93% removal within 4.5 days. Belal and Elkhateeb (2014) conducted a study on the bioremediation of pendimethalin and examined this process with the bacterial species *Pseudomonas putida*. It was determined that this bacterium eliminated all pendimethalin at a concentration of 100 µg/ml within one month. Later, in another study conducted with *Phanerochaete chrysosporium*, Belal and Elkhateeb (2014) determined that pendimethalin at a concentration of 100 mg/L was removed by 56%. This process achieved a removal success rate of 75% after 7 days, and 85% and 95% after 14, 21 and 28 days.

In this study, a bioremediation process was carried out on nematocytes with the active ingredient fluopyram under shaking culture conditions using *P. jensenii* fungus. In the study, we focused on the removal of two important environmental parameters such as COD and TOC, as much as possible. According to the results obtained from the study, it is recommended that *P. jensenii* fungus can effectively remove the herbicide containing the active ingredient Fluopyram on the basis of COD and TOC and that this fungus can be used in bioremediation activities on such nematocytes.

CONCLUSION

This study is about the bioremediation activities of *P. jensenii* fungus on fluopyram nematocides at concentrations recommended for use in agricultural areas, based on COD and TOC parameters.

In the light of the data obtained from the study, it offers a biological treatment method recommendation to eliminate nematocyte residues to farmers who frequently use or are considering using fluopyram in the agricultural sector. Additionally, bioremediation activities were examined with COD and TOC parameters instead of high-cost chromatographic methods to monitor this bioremediation process.

The findings reveal that the *P. jensenii* fungus has the capacity to successfully eliminate nematocysts. Therefore, the use of this mushroom is recommended.

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Effects of Global Warming on the Glacial Melts in North Polar

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Abstract

Global warming has become familiar to many people as one of the most important environmental issues of our time. This review will describe the effects of global warming on the glacial melt at the North Pole. On the land, glaciers are melting and retreating in places like Antarctica, Greenland, and Alaska. At sea, the area of floating ice, which we call sea-ice Floating ice is formed by the freezing of the sea surface. Is becoming smaller each year. The cold region (north polar) is home to a variety of creatures, which, with the melting of natural glaciers, are under threat. Therefore, these are the clearest threats of the current climate change effects of global warming on the glacial melts in the North Polar, which have effects on mercury (Hg), marine systems, sea level rise, public health, and economies.

Keywords: Global Warming, Glacial Melts, North Polar, Mercury (Hg), Marine systems

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INTRODUCTION

Global warming is one of the most important environmental issues that many people are aware of currently (Davarcioglu, 2017; Moser, 2010; Lorenzoni et al., 2006). The expanding global population, changing climate conditions, and economic activity make it more vital than water (Bagdatli and Belliturk, 2016a). Climate change and global warming are diminishing accessible water resources practically everywhere on the planet (Ucak and Bagdatli, 2017).Increasing or decreasing changes in climatic values affect living things negatively and cause a decrease in productivity, especially in agricultural production (İstanbulluoğlu et al., 2013). As well as being known as global pollution because greenhouse gases such as carbon dioxide (CO_2) have a long life in the atmosphere, their effects impact everyone in the world (Jacobson, 2012; Gibbons et al., 2000; Abbasi and Abbasi, 2012; Solomon et al., 2010; Smith et al., 2009; Shine et al., 2005; Montzka et al., 2011). One of the fundamental ideas behind global warming can be figured out by considering two energies: the surface of the Earth is warmed by solar radiation, and the other is the thermal radiation from the Earth and the atmosphere that is radiated out into space (Hansen, 2004).

Therefore, these two radiation streams must generally be in balance because the atmosphere contains greenhouse gases, which act as a blanket over the Earth's surface by absorbing the thermal radiation they emit, causing the greenhouse effect (Hansen, 2004).

In addition, this effect causes climate change to influence the long-term climate everywhere on our planet. such as drought, rising sea levels, melting glaciers, warming oceans, floods, storms, and heat waves, can directly and indirectly affect plants and have a disastrous impact on people's way of life and communities (Taloor et al., 2022; David and Odenigbo, 2022).

Todays, one of the basic problems that worries people is the melting of natural glaciers. In fact, glaciers are ancient rivers of compressed snow that creep through the landscape, shaping the planet's surface and forming freshwater reservoirs (Haq et al., 2012; Singh and Dhir, 2014; Adhikari and Huybrechts, 2009). According to the information abstained, over 68 percent of fresh water is stored in the Antarctic and Greenland Ice Sheets (Bamber et al. 2018; Windnagel et al. 2023). Today, around 10 percent of the earth is covered with natural glaciers; 90 percent are located in Antarctica, and the remaining 10 percent are in Greenland. Therefore, approximately 200,000 glaciers are distinct from the ice sheets (Huss and Farinotti, 2012; Windnagel et al., 2023). The world's largest glaciers by area are found in Antarctica and the North Pole. Since time immemorial, nearly all of the Arctic Ocean has been covered by ice all year (Windnagel et al., 2023). The northernmost point on Earth is the North Pole, which is located in the middle of the Arctic Ocean and is usually blanketed with ice. The ice sheets that cover the North Pole are about two to three meters thick and more than 4,000 meters deep (Nelson, V., 1997). This cold region is home to a wide variety of creatures, including Arctic foxes, polar bears, seals, fish, birds, and even some people. Some plants and animals even depend on the ice to thrive, so they have learned to coexist with it (Osborne & Boyce, 2012). Additionally, ice functions as a shield to preserve the Earth and our oceans. The globe stays colder because of these brilliant white areas, which reflect extra heat into space. Unfortunately, because of the increasing effects of global warming on glacial melt in the North Polar Region, it is possible that the giant ice sheets of Greenland and Antarctica won't remain stable. The extent to which enhanced melting as the climate warms somewhat offsets heavier snowfall during the colder seasons is also unknown. Because of weather change, a combination of rising ocean temperatures and ice sheet melting could systematically inundate the world's coasts by raising sea levels for centuries. Dramatic environmental shifts are occurring throughout the North Polar Region due to global warming (Karl & Trenberth 2003).

As well as everywhere we look, we notice more intense or uncommon weather, such as storms, floods, or droughts. Some places may get colder, while others may get warmer. However, the Arctic and North Polar Glaciers are the places where climate change is occurring the quickest. According to recent estimates and studies, the clearest evidence of current climate change effects of global warming is on the glacial melts in the North Polar, which have effects on mercury (Hg), marine systems, sea level rise, public health, and economies. the purpose of this review is Effects of Global Warming on the Glacial Melts in North Polar

How has climate change affected the physical and biogeochemical characteristics of Arctic (North Polar) environments?

Climate change and mercury (Hg) in the North Pole:

Climate change has affected the physical and biogeochemical characteristics of Arctic environments (Prowse et al., 2006). Probably the largest driver of change for physical and biogeochemical changes in the Arctic ecosystem is warmer air temperatures. In the Arctic, recent temperature increases are more than twice as great as those observed at lower latitudes. Additionally, there are regional variations in the most recent atmospheric climatic patterns seen throughout the Arctic (AMAP, 2017). These wide changes to the meteorological environment may have implications for the long-range transport of mercury (Hg) to the Arctic and exchange with terrestrial and marine environments. According to recent estimations, the Arctic permafrost contains a significant amount of mercury and is subject to damage because of climate change (Chetelat et al., 2022; Dastoor et al., 2022; Chetelat et al., 2022).

Therefore, one of the most obvious signs of present climate change effects is mercury (Hg) movement from terrestrial catchments, where widespread permafrost thaw, glacier melt, and coastal erosion are boosting the export of Hg to downstream ecosystems (Chetelat et al., 2022). According to Goodsite et al.'s 2012 study, mercury is a gaseous element whose reaction kinetics depend on atmospheric temperature. Therefore, climate affects how mercury is distributed between the atmosphere and land surfaces. So, warmer temperatures appear to promote the formation of methylmercury in lake and ocean sediments as well as tundra soils, according to experimental data (Chételat et al. 2015).

Improved geographic coverage of measurements and modeling approaches are needed to better evaluate the net effects of climate change and its long-term implications for Hg contamination in the Arctic. The other critical issue is how climate change is affecting terrestrial and marine systems.

The effect of climate change on the North Polar's terrestrial and marine systems:

According to research from the past ten years, either increased export owing to a change in circulation or local melting has caused the multi-year ice field in the Arctic to thin out since the 1970s (Macdonald et al., 2003; Smetacek and Nicol, 2005). Sea ice drastically lowers the quantity of sunlight that reaches the ocean. indicates that for the first time in many thousands of years, some oceanic regions are seeing summertime sunlight. As a result, when polar marine habitats warm more due to global warming, sea ice thickness and extent will be affected in a cascading manner. The productivity of species and the relative significance of various energy channels via food webs might be influenced (Meredith et al., 2019; Trebilco et al., 2020; IPCC, 2021; Thorson et al., 2021). Therefore, over the past 50 years, scientists have observed some zooplankton and fish species moving toward the poles as the oceans become warmer (Kortsch et al., 2015).

As mentioned in the article and research, that is why the Arctic has large populations of marine birds and exceptionally large stocks of fish, benthos, and mammals (seals, walrus, and whales) (Smetacek and Nicol 2005). In addition, another reason is that the light increases the productivity of the North Pole by allowing phytoplankton to flourish and photosynthesize in formerly arid regions. It is possible to view the rise in phytoplankton as a positive development because it will enhance marine life and provide more food for zooplankton, benthos, and eventually fish, polar bears, whales, birds, and seals (Darnis et al. 2012).

Additionally, the majority of fish species are now more frequently hunted due to climate change and the melting of pole glaciers. Some Arctic animals, though, have changed over time to rely on the existence of ice. Seals and walruses can exit the ocean thanks to the sea ice, which they need to relax, reproduce, and avoid other marine predators like killer whales (Heath et al., 2021). On the other side, in order to hunt for seals, other species, including polar bears, depend on their ability to cross the frozen sea. So with weather changes and melting ice getting more common, travel is made more challenging by melting ice since bear weight cannot be supported by thin ice. On the other hand, ice presents a challenge to whale species since they need access to the atmosphere to breathe. Overall, it is unclear which predators in the food chain will benefit from melting sea ice and which ones will suffer from it. (Heath et al., 2021). Growing Population is also an important reason for climate variation will raise several issues for worldwide food supply due to which numerous nutritional complications could arise in the upcoming future. Production of food is a major concern that could be effected by climatic variations (Bagdatliet al., 2023), like an upsurge in sea-level due to climate change, leads to the devastation of forests which are key source of food in many regions (Afreen et al., 2022).

Arctic glaciers as important contributors to global sea level rise (Lakes):

Rapid glacial melt in the North Pole influences ocean currents and enormous amounts of cold. Extremely cold glacial melt water entering warmer oceans means ocean currents are being slowed by cold water. These changes in nature caused by glaciers will cause sea levels to rise as land-based ice continues to melt. According to Lindsey (2021), Rahmstorf (2010), and Walsh et al. (2012) studies, rising sea levels are a result of melted glaciers, which increase coastal erosion and raise the storm surge because coastal storms like hurricanes and typhoons become more common and severe as air and ocean temperatures warm. As previously mentioned, the ice sheets in Antarctica and Greenland (North Polar) are the main causes of sea level rise on a worldwide scale (Hock et al., 2009; Radić, & Hock, 2011).

As Vasskog et al. (2015) mentioned, the Greenland ice sheet is already melting four times faster than it did in 2003, and it is already responsible for 20% of the current rise in sea level. The extent to which ocean levels rise in the future will be greatly influenced by how quickly and how much these Greenland and Antarctic ice sheets melt. By the end of the century, the Greenland ice sheet's current pace of melting is predicted to have doubled if emissions keep rising. Alarmingly, if all of Greenland's ice disappeared, sea levels would rise by 20 feet.

The effect of climate change on Arctic public health, and economies:

According to the theories and research of researchers, the possible impact on human health will vary from location to location depending on regional climate variances, variations in health conditions, and the capacity of various populations to adapt (Séguin et al., 2008; Parkinson and Evengård, 2009). In particular, the most vulnerable people may be those living in isolated villages in the Arctic with weak support systems, scant infrastructure, and weak or nonexistent public health systems (Parkinson & Berner, 2009). Therefore, people who rely on subsistence fishing and hunting will be more susceptible to changes that influence the targeted species. As well as certain infectious diseases that may transmit from animals to people because of climate stress and shifting animal populations (Parkinson and Berner, J. 2009).

According to Revich et al. (2022), changes in the climate cause significant issues. Beyond the Polar Circle, in West Siberia, there have been more than 70 significant outbreaks of Siberian anthrax since 1760. One of the other reasons to show climatic change's impact on animals in this part of West Siberia According to literature sources (Revich et al., 2022), an extensive outbreak of Siberian anthrax among deer, followed by a 2 meter deep seasonal thawing of permafrost and possible Siberian anthrax bacterial vegetation, and movement from the active permafrost layer to the top soil, were all triggered by a very hot summer of 2016. There are also signs that global warming causes permafrost to thaw, which could facilitate the release of diseases and other germs. In permafrost soils that are between a few thousand and two million years old, prokaryote and eukaryote microorganisms may be able to survive the year-round negative temperatures. These bacteria may migrate to the surface with groundwater due to permafrost deterioration. This discovery supported the idea that infectious disease vectors that had been dormant in permafrost for a very long time could become active again and be discharged into the ecosystem because of climate change (Streletskiy et al., 2019).

Increasing patient wait times, the inaccessibility of healthcare services, and the emergence of contagious diseases mean that while some risks and direct economic losses may be identified, forecasted, and assessed, many indirect effects and the ensuing economic costs are much harder to predict. There are reasons to think that indirect economic costs brought on by permafrost degradation may far outweigh direct losses.

Future projections of climate change in the North Polar:

There is massive research and study about future expectations of climate change in the northern Arctic or the Atlantic Ocean. In this part, we review a small part of these studies, which reflect the most important risks expected in the future. The researchers and experts focused on projected changes in North Polar temperature, precipitation, sea ice, and glacier melt. Precipitation increases in the North Polar are predicted to vary from 5 to 10% in the Atlantic sector to as much as 35% in some high North Polar areas by the late 21st century (Kattsov et al. 2005).

As well, Overland et al. (2014) found a significant difference in Arctic surface air temperatures at the end of the 21st century based on two radiative forcing scenarios (mitigation and business-as-usual) in the CMIP5 (Coupled Model Intercomparison Project Phase 5) collection of GCMs (General Circulation Models), which strongly supports starting greenhouse gas mitigation operations. According to Chen et al.'s 2021 climate projections, by 2100, arctic surface air temperatures could increase by 7 degrees Celsius because of an increase in atmospheric carbon dioxide. Therefore, sea ice cover varies significantly throughout the year. As Arthun et al. (2021) mentioned, around 2050, the Arctic will lose its ice cover in late summer. Therefore, the rise in temperature at the North Pole will cause more rainfall in the region and the beginning of the melting of the natural glaciers. According to Bintanja's 2018 research, local, seasonal, and temporal variability in precipitation is larger than local temperature. Increases in Arctic rainfall could lead to impacts from projected strong increases in Arctic rainfall (such as permafrost thawing, ecosystem shifts, sea ice retreat, and glacier melt).

CONCLUSION

Numerous detrimental effects on agricultural crop productivity are caused by the increase in greenhouse gas emissions into the atmosphere, global warming, changes in temperature and precipitation patterns, and other factors (Bağdatlı et al., 2015). Precipitation carries greenhouse gasses and carbon dioxide from the atmosphere down to Earth. We refer to this phenomenon as acid rain. Acid showers alter the water's pH and have an impact on aquatic life. Plants lose their natural structure as a result of it (Bagdatli and Can, 2019). The life of living organisms is badly impacted by extreme temperature changes. In the future, finding clean water will be challenging since rising temperatures would cause more evaporation (Bağdatlı and Can, 2020). Global efforts should be directed at expanding the required research and implementing carbon emission reduction strategies, as reducing greenhouse gas emissions will be a major factor in mitigating the effects of global warming (Bagdatlı and Arıkan, 2020). Conferring to scientists, climate change is a condition where atmospheric air have been changed and retain for centuries. Climate change known as collection of several atmospheric changes which can be happened by human activities or could be natural (Elsheikh et al., 2022b).

The reduction in the surface changes of the water reservoir over time is noticeable. This manifests itself as the result of disorder in the evaporation and current precipitation regime in water sources that are affected by global climate change (Albut at al., 2018). Water, is an important element, for existence of living lives. Precipitation and Rainfall both are sources of water and various activities of living beings depends on both these aspects like life survival, Agricultural productivity, migration of living beings and urbanization (Bagdatli and Arslan, 2019; Elsheikh et al., 2022a). Global climate change, the industrial revolution of the then-human atmosphere to release CO_2 , CH_4, O_3, and NO_2 as gases are very quickly heat the earth by the greenhouse effect that occurred as a result of an increase above normal (Bagdatli and Belliturk, 2016b). The influence of the global climate will have an effect on the changing of seasons, particularly in the observation of substantial fluctuations in temperature and precipitation (Bagdatli and Arslan, 2020).

According to scientific theory and empirical data, the Earth's climate has been warming, and greenhouse gases produced by human activity are mostly to blame for these changes. On the other hand, human activity is largely responsible for climate warming. Climate change affects the long-term climate, causing the melting of natural glaciers in the North Polar Region. In fact, these natural glaciers are freshwater reservoirs. As well, these cold regions are home to a wide variety of creatures, including Arctic foxes, polar bears, seals, fish, birds, and people. Some plants and animals even depend on the ice to thrive, so they have learned to coexist with it. Therefore, this is a vital issue for the survival of the planet because it provides the clearest evidence of the current climate change effects of global warming on the glacial melts in the North Polar, where wide changes in meteorology lead to mercury transport to the Arctic. The other critical issue is the effects of climate change on terrestrial and marine systems. Rapid glacial melt in the north polar will cause sea levels to rise as land-based ice continues to melt. As well as these meteorological chances effects on animals and plants, in particular, people living in isolated villages in the Arctic with weak support systems, scant infrastructure, and no public health systems are most vulnerable to climate change and infectious diseases. People relying on subsistence, fishing, and hunting are more vulnerable to species changes.

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The Challenges and Prospects of South Sudan Agriculture

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Abstract

The South Sudanese agricultural sector is characterized by a subsistence-based approach, low productivity, a lack of infrastructure and market institutions, low levels of technology and inputs, and a high degree of rainfall sensitivity. Specifically, rain-fed subsistence agriculture and complete reliance on forests as a source of energy and other environmental goods and services are two factors that contribute to 95% of the population's dependence on climate-sensitive natural resources. In order to increase South Sudan's overall economic well-being, the agricultural sector's productivity performance is crucial. In the past, there have been several factors that have limited agricultural productivity, including a lack of improved or hybrid seed availability, a lack of seed multiplication capacity, low fertilizer profitability and efficiency, a lack of irrigation infrastructure development, a lack of transportation infrastructure, market accessibility issues, and a high prevalence of soil degradation and infertile soil. The aim of this review is to examine the challenges and risks facing the agriculture sector and the future prospects in South Sudan.

Keywords: South Sudan, Challenges, Prospects, Agricultural Production

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INTRODUCTION

Agriculture is the main source of income for the majority of the population in Africa, with 75% of them living in rural areas. Thankfully, during the past few years, agriculture in Africa has continued to expand. However, area growth rather than advances in land productivity have been the main drivers of growth. In most nations, future sustainable agricultural growth will necessitate a larger focus on productivity increase as available space for new agriculture shrinks, especially in light of mounting worries about deforestation and climate change (Bekabil, 2014; Bağdatlı and Bellitürk, 2016a).

One of the most impoverished regions is Sub-Saharan Africa. It is about three times as big as the USA, both in terms of population and land area. Agriculture, which employs two-thirds of the labor force, generates 35% of the region's gross domestic product, and generates 40% of its foreign exchange profits, is crucial to the region's economies. Thus, increasing general economic well-being in Sub-Saharan Africa depends on improving productivity performance in the agriculture sector (Fulginiti et al., 2004).

Agricultural production and proximity to urban markets are substantially associated in Sub-Saharan Africa SSA, even after taking into account agro ecology. Inadequate resource endowments, insufficient input use (fertilizer, improved seeds, and irrigation), and unfavorable policies that persisted for a long time have been recognized as the main factors in the agricultural sector's poor and falling performance in SSA. Agriculture in Africa faces resource constraints due to ongoing environmental degradation, rapid population growth, and low levels of infrastructure investment (Dorosh et al., 2012). According to Moyo et al. (2015), Africa's low irrigation use and disproportionate reliance on rain-fed agriculture are to blame for the region's low agricultural production. Unirrigated crops like maize, cassava, millets, sorghum, yams, sweet potatoes, plantains, and rice serve as the region's principal food sources. Additionally, the lack of proper institutional support and a favorable business environment due to the agricultural sector's low public funding has made it difficult for the private sector to participate in and invest in agriculture. According to the Comprehensive Africa Agriculture Development Program (CAADP) of the New Partnership for Africa's Development (NEPAD), governments should allot 10% of their national budgets to agriculture in order to support water management, intensify irrigation, lessen the reliance of the continent on rain-fed agriculture, and boost climate change resilience. Public spending on agriculture, however, is significantly below the 10% target, ranging, for instance, from a low of 0.15% in Guinea-Bissau to 3.61% in Malawi (Shimeles et al., 2018).

After being founded on July 9, 2011, South Sudan is the world's newest nation. A January 2011 referendum that declared secession from Sudan resulted in the declaration of independence. The country is divided into six agro-ecological zones from a geo-morphological perspective, each of which offers a variety of agricultural possibilities (maize, sorghum, wheat, and so forth), as well as an abundance of water resources, including rainfall, lakes, and rivers. The production of cereal rarely fulfills demand, despite this potential. A severe output limit and decreased yield are caused by the low quality of productive inputs and support services, outdated and inefficient technology, and eventually the lack of infrastructure (Caruso et al., 2017).

Because rain-fed agriculture is highly dependent on the climate, which has a significant impact on agricultural production (Nasreldin and Elsheikh, 2022; Bağdatlı et al., 2015). Additionally, just 5% of the 30 million hectares of fertile land in the nation are actually harvested. In fact, more than a third of South Sudanese experienced moderate to severe food insecurity in 2010, with severe child acute malnutrition accounting for around 13% of those cases (World Bank, 2013). The distribution of rainfall within a season as well as its overall seasonal amount can both have an effect on agricultural productivity (Bağdatlı and Bellitürk, 2016b). Crop output is most adversely affected by droughts with extremely low total seasonal quantities (Elsheikh et al., 2022a). However, more minor intra-seasonal fluctuations in rainfall distribution during the growing seasons of crops, without a change in the overall seasonal amount, can still result in significant yield losses (Elsheikh et al., 2022b; Bagdatlı et al., 2023). This means that the overall number of wet days throughout the year is not as significant as the number of rainy days during the growth season. The aim of this review is to examine the challenges and risks facing the agriculture sector and the future prospects in South Sudan.

AGRICULTURE in SOUTH SUDAN: CHALLENGES and PROSPECTS

South Sudan is a landlocked nation with authority over 96% of the Nile River Basin in East-Central Africa. The Democratic Republic of the Congo (DRC), Uganda, and Sudan are its northern neighbors. Ethiopia, Kenya, and the Central African Republic are its eastern and western neighbors.

Latitudes 3.5° and 12° North and longitudes 24° to 36° East define the tropical region in which South Sudan is situated. 658842 km2 is the total area. The whole country is covered with expansive grasslands, wetlands, and tropical forests. Among its natural resources are significant ones for forestry, agriculture, mining, water, wildlife, and energy (Jubek et al., 2019). In sub-Saharan Africa, the country has one of the lowest population densities, with fewer than 13 people per square kilometer. In the northern desert zones, seasonal agriculture, pastoralism, fishing, and hunting are the main sources of income. Numerous options for a living are available in the nation's low, forested savannahs. The three areas (formerly historic provinces) that make up the country are Bahr el Ghazal in the northwest, Equatoria in the south, and Greater Upper Nile in the northeast. There are currently thirty-two states in the nation instead of the initial ten (MOE, 2015).

Due to its enormous acreage and favorable agro-ecological conditions, South Sudan has tremendous potential for sustainable agricultural growth. Prime agricultural land makes up more than half of the entire land area, while the remaining 50% is made up of marginal agricultural land, forests, mountains, rivers, and wetlands. South Sudan has a total land area of around 658,842 km^2, of which 27,712 km^2 are cultivated. The yearly rainfall in a large portion of the nation is sufficient for growing a variety of crops. Rainfall varies by location, ranging from 500 mm annually in the north, where a growth season of 100–150 days is provided, to roughly 2000 mm in the southwest, where a growing season of 150–250 days is provided. Thanks to several permanent large and small rivers, seasonal rivers, and underground water reservoirs, irrigated agriculture has tremendous potential. There are also vast swamplands that could be used for elaborate plans to produce sugarcane and rice (Ministry of Agriculture, 2012).

Prior to 2011, the Food and Agriculture Organization of the United Nations estimated that Sudan's total water withdrawal was roughly 27,590 million m^3 in 2005. With 26,150 million m^3, agriculture accounted for the vast majority of water use. 1,140 million m^3 of withdrawals came from municipalities, whereas 300 million m^3 came from industry. In order to estimate the water use in South Sudan after that year, the Food and Agriculture Organization used data for Sudan from before 2011 and assumed the following assumptions: the same amount for both South Sudan and Sudan combined; no substantial changes had occurred. Prior to 2011, the population of South Sudan was 17% that of Sudan, and the vast majority (75%) of industries (especially those in the petroleum sector) are located in Sudan. After 2011, it is expected that surface and groundwater extraction (primary and secondary) will be about 658 million m^3/year, or about 1.3% of the total renewable water supply, with agriculture using the most water and an average annual withdrawal of 60 m^3/year (Musa and Kongas, 2023). The less precipitation has an impact on ecosystem life. The most variable climate factor, in terms of time and place, among the climate parameters is the amount of precipitation (Bağdatlı and Arslan, 2020; Elsheikh, 2021).

Although the South Sudanese government is gradually enforcing water management policies and regulations, it is incredibly challenging to provide water facilities, services, and infrastructure in a way that is both effective and affordable because of the ongoing conflict, low population densities, and widely dispersed villages and towns (Jubek et al., 2019). Due to factors including scarcity of water, population increase, environmental degradation, and unintentional irrigation in agriculture, water resource management is becoming more and more crucial (Bağdatlı and Arıkan, 2020a; Bağdatlı and Ballı, 2019). This reflects the importance of the development and mechanization of agriculture in South Sudan.

Up to 95% of South Sudanese people are dependent on farming, herding, or fishing, according to the Food and Agriculture Organization of the United Nations. Any disturbance to this industry has repercussions that could hurt South Sudan's broader economy. Food insecurity has gotten worse as a result of sharp price increases brought on by soaring inflation, stifled markets and commerce, and low food production as a result of armed conflict or natural catastrophes (FAO, 2016). Traditional subsistence agriculture predominates in the Republic of South Sudan, where crop production and animal husbandry are the main sources of income for around 78% of households. Farmers rely on conventional farming methods and rain-fed agriculture. This combination makes them particularly vulnerable to climate change, especially unpredictable rainfall. Unfavorable meteorological circumstances, such as yearly flooding and recurrent droughts, reduce the output of crops and livestock. Flash floods in South Sudan's low-lying areas, especially those near the Sudd and Marcher wetlands and the White Nile, have destroyed trees, but droughts are also hastening the spread of the desert (Jubek et al., 2019). For this reason, it is anticipated that the Republic of South Sudan will experience similar developments.

Despite the variety of crops grown, South Sudan's agricultural industry is still mostly traditional and has low yields. For instance, it is well known that, in the cereal subsector, the vast majority of farmers do not employ high-yielding crops, synthetic fertilizers, or herbicides. The average yield of South Sudan, which ranged from 2005 to 2009, was just 0.97 tons per hectare, which is significantly less than the average yield of Egypt, where the majority of the cereals are grown under irrigation, which was 7.64 tons per hectare. These poor cereal yields in South Sudan are the result of numerous issues smallholder farmers face. The three main issues were pests and agricultural diseases, a lack of seeds, and irregular rains (South Sudan, 2013).

The main factors affecting the average distribution of precipitation are the effects of surface topography, atmospheric circulation patterns, and moisture availability (Bağdatlı and Arslan, 2019; Bağdatlı and Arıkan, 2020b). The first two of these characteristics are affected by temperature (Bağdatli and Can, 2020). Since the 1980s, the amount, intensity, frequency, and kind of precipitation have all altered, demonstrating that changes in temperature brought on by people are changing precipitation patterns (Elsheikh, 2021; Bağdatli and Can, 2019; Afreen et al., 2022). The earth's soil layer is essential for sustaining plant life, providing mechanical support, and supplying water and nutrients (Bağdatlı and Ballı, 2020). During the day, energy is captured by the soil and released as heat at night (Bellitürk and Bağdatlı, 2016). A crucial but insufficient need for the sector's effective development is the presence of arable land and a suitable climate. South Sudan must be able to ease the development of crucial off-farm infrastructure.

Production of crops in the current state, depending on the agro-ecological zone, South Sudan grows a wide variety of food and commercial crops. The area with the greatest potential for sustainable crop production is the Green Belt zone with the highest average yearly rainfall. Casava, sorghum, groundnuts, sesame, maize, finger millet, beans, pigeon peas, and vegetables (onions, okra, tomatoes, cabbage, eggplant, cucumber, and pumpkins) are among the crops. Citrus, pineapple, mango, banana, plantains, and other fruits are also grown. Other crops include papayas, yams, and sweet potatoes, which are raised for both domestic consumption and market sale (South Sudan, 2013). South Sudan has the capacity to become a significant exporter of cereals while also being self-sufficient domestically. However, the main obstacles to realizing this potential are mostly internal and, as a result, are under the control of policymakers: minimal use of the available arable land, low and declining productivity caused by inefficient farming practices, high marketing margins brought on by inadequate infrastructure, and proliferation of taxes (South Sudan, 2013).

In general, the South Sudanese food deficit can be reduced by addressing the structural issues that lead to low agricultural productivity, such as infrastructure improvements, the provision of agricultural services, institutional strengthening, and the adoption of well-thought-out policies and regulations. Other interventions will include bettering the land use and tenure system, using natural resources wisely, having suitably skilled human resources, and organizing rural communities (Ministry of Agriculture, 2012). Approximately 695 thousand tons of cereal were produced net (i.e., less a 20% post-harvest loss), while 885 thousand tons were consumed, resulting in a 200 thousand-ton import. The deficit not only poses a significant threat to food security, but it also increases the likelihood that external and fiscal balances will deteriorate, leading to a rise in the need for food aid and obstructing sector development (Figure 1) (South Sudan, 2013). By expanding the area under cultivation and improving productivity, it is possible to increase the output of cereals and other crops in South Sudan.

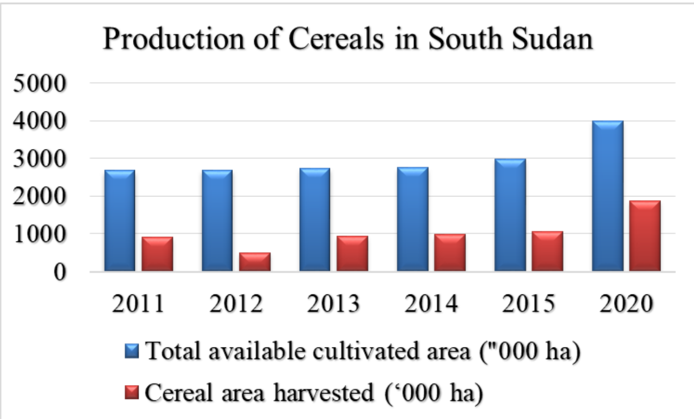

Figure 1. Production of Cereals in South Sudan

Despite the country's natural resources in terms of land and water, its agricultural industry is operating at a significant fraction of its potential and generating at levels that are much lower than those of its less endowed neighbors. Attracting high-impact foreign direct investment and connecting it to the nation's smallholder farmers and farmer cooperatives are necessary for the country to accomplish an export-led agricultural transformation and growth. Additionally, given the significance of cereals in the population's diet, the cereals industry needs to be at the forefront of initiatives to improve the traditional sector and lay the groundwork for a competitive performance in export markets (South Sudan, 2013).

According to the South Sudan Development Plan's Economic Development Pillar, small-scale private, primarily family-based agriculture and livestock industries have the greatest potential for initial new growth (Ministry of Agriculture, 2012). Therefore, there is a need to attract foreign direct investment in South Sudan while taking advantage of the experiences of other countries in order to promote the agricultural sector.

RECOMMENDATION and CONCLUSION

As a significant supplier of raw resources, food, and foreign currency, agriculture continues to be an important component of the economy in South Sudan. The majority of the labor force is employed there, and it might be used to diversify the economy. However, no thorough research has been done to explain how this sector's output relates to food security. Because agriculture in particular has been ignored, the issue has gotten worse.

The expansion of South Sudan's agriculture has also been uneven. According to research, the vast majority of South Sudanese are said to experience food insecurity. The South Sudanese agricultural sector is characterized by a subsistence-based approach, low productivity, a lack of infrastructure and market institutions, low levels of technology and inputs, and a high degree of rainfall sensitivity. The South Sudanese agricultural sector is mostly focused on low-yielding, rain-fed agriculture, where the outcome of a harvest is greatly influenced by the amount of precipitation, whether negative or positive.

South Sudan's low availability of improved or hybrid seed, capacity for seed multiplication, and low profitability and efficiency of fertilizer use due to a lack of complementary improved practices and seed are the main factors limiting agricultural productivity. Adopting better techniques is less profitable when there is a lack of market access and transportation infrastructure. In order to advance the agricultural industry, it is necessary to draw in international investment while also benefiting from other nations' experiences. Additionally, by enlarging the farmed area and raising output, the construction of essential non-agricultural infrastructure must be made possible in South Sudan.

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Role of Encapsulation Nutrients for Improvement of Ruminant Performance and Ruminant Derived – Products

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Abstract

Encapsulation nutrient technology has emerged as a transformative approach to enhance ruminant nutrition and improve the quality of products derived from ruminants. This method involves the protection of sensitive compounds through encapsulation, enabling controlled release and targeted delivery. In the realm of ruminant nutrition, encapsulation has led to improved nutrient utilization, reduced wastage, and enhanced animal performance. It safeguards essential nutrients, including vitamins, minerals, probiotics, and additives, from rumen degradation, ensuring optimal health and growth. Moreover, in ruminant-derived products, encapsulation practices have contributed to superior product quality by enhancing taste, texture, and shelf life. It can mask unpalatable compounds, release flavor enhancers, and reduce oxidation in meat and dairy products. However, the broader implementation of encapsulation technology faces challenges related to cost, formulation complexities, and regulatory approval. Addressing these obstacles and fostering sustainable practices will be crucial in realizing the full potential of encapsulation technology in the ruminant and ruminant-derived product industries. Future research should focus on sustainable materials, cost-effective methods, and tailored solutions for different ruminant species, bioavailability studies, methane mitigation technologies, and long-term health assessments. Furthermore, education, interdisciplinary collaboration, and the development of regulatory standards are essential to ensure the safe and effective use of encapsulation technology in ruminant and ruminant-derived products.

Keywords: Encapsulation Technology, Ruminant Nutrition, Ruminant-Derived Products, Nutrient Protection, Feed Additives

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INTRODUCTION

Ruminants, including cattle, sheep, and goats, play a vital role in global agriculture, contributing to the production of meat, milk, and other essential products (Kumar et al., 2017). However, optimizing their nutrition and enhancing the quality of ruminant-derived products pose ongoing challenges. Encapsulation nutrient technology, a versatile and innovative approach, has gained prominence in addressing these challenges by improving ruminant nutrition and the quality of products obtained from them (Khezri et al., 2016).

The encapsulation process involves the entrapping of bioactive compounds within a protective matrix, enabling controlled release, targeted delivery, and preservation of the compounds until they reach their desired destinations (Mehta et al., 2017).

Previous studies have shown significant potential in the use of encapsulation technology for the improvement of livestock products. Researchers have explored different encapsulation methods and materials to effectively deliver essential nutrients, improve feed efficiency, and enhance animal well-being (Grilli et al., 2013; Hu et al., 2015; Kim et al., 2020; Konkol and Wojnarowski, 2018; Natsir et al., 2019; Stamilla et al., 2020; Tao et al., 2020). Encapsulated probiotics, for example, have been shown to promote gut health and boost the immune system of livestock, leading to improved growth rates and reduced disease incidence (Rajam & Subramanian, 2022). Additionally, encapsulation of volatile compounds in animal feed has the potential to minimize feed wastage and reduce the environmental impact of livestock farming (Adineh et al., 2020)

In addition to its role in ruminant nutrition, encapsulation technology has found application in ruminant-derived products, such as meat and dairy. It has the capacity to enhance the sensory attributes and shelf life of these products, leading to increased consumer satisfaction and marketability (Yu et al., 2020). By masking unpalatable compounds, releasing flavor enhancers, and reducing oxidation in meat and dairy, encapsulation technology has paved the way for improved product quality.

While the application of encapsulation technology in ruminant nutrition and products holds significant promise, it is essential to consider the existing gaps and challenges in this field. These include cost considerations, formulation complexities, and regulatory approval, which may hinder the broader implementation of this technology. Addressing these obstacles is crucial for realizing the full potential of encapsulation technology in ruminant and ruminant-derived products.

The purpose of this review is to explore the current state of encapsulation nutrient technology in ruminant nutrition and products, highlighting its potential benefits and addressing the challenges that need to be overcome for its successful implementation. By examining the existing knowledge, identifying scientific gaps, and proposing future directions, we aim to contribute to understanding how encapsulation technology can positively impact ruminant farming and the quality of ruminant-derived products.

DEFINITION OF ENCAPSULATION

Encapsulation is a process that involves enclosing one substance within another, typically using a protective shell or carrier material. In the context of ruminant nutrition, encapsulation is used to protect and deliver specific nutrients, such as vitamins, minerals, and probiotics, to ruminant animals. The encapsulating material can vary, including polymers, lipids, proteins, or a combination of these (Akhavan, 2018).

PRINCIPLES OF ENCAPSULATION IN RUMINANT NUTRITION

Nutrient Protection: Encapsulation offers a protective barrier that shields sensitive nutrients from degradation in the harsh conditions of the rumen. This ensures that valuable nutrients, such as heat-sensitive vitamins, can reach the lower digestive tract intact (Nocek, 2017).

Targeted Release: Encapsulation can be designed to release nutrients at specific sites within the ruminant's digestive system. This controlled release enables better absorption and utilization of nutrients, promoting optimal ruminant health (Taghvaei et al., 2021).

Enhanced Bioavailability: Encapsulation technology can enhance the bioavailability of nutrients. By protecting them from ruminal degradation, more of the nutrients can be absorbed in the abomasum and small intestine, where they are most effective (Gupta et al., 2021).

Minimizing Environmental Impact: The use of encapsulated nutrients can reduce the environmental impact of ruminant farming. By preventing the excretion of excess nutrients into the environment, encapsulation can help mitigate issues like nutrient runoff and its associated environmental problems (Hadjipanayiotou, 2000).

Improved Feed Efficiency: Encapsulation can improve feed efficiency by ensuring that the nutrients are delivered to the site where they can be most effectively utilized. This can lead to increased weight gain and milk production in ruminants (Hosseini et al., 2020).

Encapsulation technology has various applications in ruminant nutrition, including the delivery of vitamins, minerals, and other bioactive compounds. It has been used to address specific nutritional challenges in ruminant diets, such as the need for controlled release of nutrients or the protection of sensitive compounds from rumen degradation. These applications have the potential to improve ruminant health, productivity, and overall well-being (Mehdi et al., 2018).

METHODS OF ENCAPSULATION

Encapsulation is a rapidly advancing technology that involves enclosing an active core material, which can be in liquid, gas, or solid form, within a protective barrier made of substances like a matrix or shell. This process results in the creation of capsules at various size scales, including nano, micro, or macrocapsules. There are three main categories of encapsulation: microencapsulation, which ranges in size from 0.2 to 5 µm; nanoencapsulation, with dimensions between 200nm and less than 0.2 µm; and macroencapsulation, which exceeds 5 µm in size. According to a report by Cosco (2006), microencapsulation is the most commonly used method within these capsule-size categories. The following are various encapsulation techniques used in ruminant nutrition.

Coacervation

Coacervation is a method of encapsulation that involves the phase separation of a polymer from a solution. In ruminant nutrition, this technique is used to create microcapsules that can protect sensitive nutrients. Coacervation has been applied to encapsulate vitamins, minerals, and essential fatty acids, allowing them to pass through the rumen unharmed and be absorbed in the abomasum and small intestine (Tamine et al., 2019).

Spray Drying

Spray drying is a widely used encapsulation method in ruminant nutrition. It involves the conversion of a liquid feed additive into a powder by spraying it into a hot drying chamber. This process forms small particles with a protective shell that can safeguard nutrients from ruminal degradation. The encapsulated nutrients are released and absorbed in the lower digestive tract, improving their bioavailability (Mitra et al., 2018).

Extrusion

Extrusion encapsulation is a method that combines heat, shear, and pressure to create a protective matrix around nutrients. This technique is commonly used to produce feed pellets containing encapsulated additives. It allows for the controlled release of nutrients in the digestive system, optimizing their utilization by ruminants (Anwari et al., 2020).

Electrospinning

Electrospinning is a relatively novel encapsulation method with applications in ruminant nutrition. It involves the creation of nanofibers through the application of an electric field. These nanofibers can encapsulate bioactive compounds and release them gradually in the digestive system, offering a promising approach to improve nutrient delivery (Bian et al., 2021).

Emulsification and Solvent Evaporation

Emulsification and solvent evaporation is another method used for encapsulating nutrients in ruminant nutrition. It involves dissolving the nutrient in a suitable solvent, emulsifying it in a polymer solution, and then evaporating the solvent to form microcapsules. This technique offers a versatile approach to protect nutrients from rumen degradation and enhance their bioavailability in the lower digestive tract (Azari et al., 2019).

Alginate Beads

Alginate beads are a type of encapsulation where a nutrient solution is mixed with alginate and then dropped into a solution containing calcium ions. This results in the formation of gel-like beads that encapsulate the nutrient. Alginate beads have been used in ruminant nutrition to protect and deliver nutrients such as enzymes or probiotics, ensuring their controlled release in the digestive system (Mehrotra et al., 2017).

Nanoparticles

Nanoparticles are extremely small structures used for encapsulation in ruminant nutrition. They offer the advantage of being able to encapsulate nutrients at the nanoscale. This enables efficient protection from ruminal degradation and enhanced bioavailability, especially for trace minerals and certain vitamins (Gupta et al., 2021). Encapsulation methods in ruminant nutrition provide a range of options to protect and deliver essential nutrients effectively. Coacervation, spray drying, extrusion, electrospinning, emulsification, and other techniques have been instrumental in improving nutrient delivery, enhancing ruminant health, and optimizing the quality of ruminant products.

MATERIALS COMMONLY USED IN ENCAPSULATION

Encapsulation is a vital technology in ruminant nutrition, and the selection of appropriate materials and an understanding of factors influencing encapsulation efficiency are crucial for optimizing nutrient delivery in these animals. The choice of encapsulating materials significantly impacts the effectiveness of encapsulation in ruminant nutrition. Commonly used materials include:

Polymers: Polymers like alginate, chitosan, and pectin have been used extensively in ruminant nutrition. Alginate beads, for example, have been employed to encapsulate probiotics and enzymes, protecting them from ruminal degradation and ensuring controlled release in the abomasum and small intestine (Oliveira et al., 2019).

Lipids: Lipids are employed to create lipid-based microparticles and nanoparticles. They offer protection for fat-soluble vitamins and essential fatty acids, allowing for their targeted release and improved bioavailability (Lemos et al., 2016).

Proteins: Proteins, such as whey protein concentrate, casein, and soy protein isolate, have been used for encapsulating bioactive compounds like antioxidants and amino acids. Protein-based encapsulation can enhance the stability and release properties of the encapsulated substances (Kumar et al., 2018).

EXAMPLES OF FEED ADDITIVES THAT ARE ENCAPSULATED TO IMPROVE RUMINANT AND RUMINANT-DERIVED PRODUCTS

Encapsulation technology has been employed to enhance ruminant nutrition and improve the quality of ruminant-derived products by protecting and delivering various feed additives. Below are examples of feed additives that are encapsulated for this purpose.

Probiotics and Prebiotics: Probiotic microorganisms and prebiotic compounds are often encapsulated to protect them from the harsh conditions of the rumen. This ensures their targeted release in the lower digestive tract, promoting a balanced gut microbiota in ruminants (Zhu et al., 2018).

Vitamins and Minerals: Encapsulation of vitamins and minerals protects them from rumen degradation, ensuring their availability for absorption in the small intestine. This enhances overall nutrient utilization and supports ruminant health (Górka et al., 2021).

Essential Fatty Acids: Encapsulated essential fatty acids, such as omega-3 and omega-6 fatty acids, are incorporated into ruminant diets to protect them from ruminal degradation. This leads to improved absorption and enhanced health parameters in ruminants (Yáñez-Ruiz & Martín-García, 2018).

Enzymes: Encapsulated enzymes, such as cellulases and hemicellulases, are used to enhance the digestibility of fibrous feed ingredients in ruminant diets. This technology improves feed utilization and animal performance (Santana et al., 2015).

Antioxidants: Encapsulation of antioxidants, such as vitamin E or plant-derived polyphenols, is used to reduce oxidative stress in ruminants and enhance the shelf life and sensory attributes of ruminant-derived products (Soares et al., 2020).

These examples demonstrate how encapsulation technology is applied to protect and deliver a range of feed additives, leading to improved ruminant nutrition, health, and the quality of ruminant-derived products. Encapsulation helps overcome challenges associated with rumen degradation, ensuring that these additives achieve their intended effects in the digestive tract.

FACTORS INFLUENCING ENCAPSULATION EFFICIENCY

Encapsulation efficiency refers to the extent to which the encapsulation process successfully entraps the active compound within the carrier material. Several factors influence encapsulation efficiency in ruminant nutrition:

Polymer Concentration: The concentration of the encapsulating polymer affects encapsulation efficiency. Higher polymer concentrations can provide better protection, but they may also reduce the release rate of nutrients (Das et al., 2019).

pH and Ionic Strength: The pH and ionic strength of the encapsulation solution can affect the interaction between the polymer and the nutrient. Optimizing these parameters is crucial for efficient encapsulation (Gan et al., 2020).

Particle Size and Morphology: The size and morphology of encapsulated particles are important factors. Smaller particles with a more uniform size distribution tend to have higher encapsulation efficiency (Taghvaei et al., 2021).

Stability of the Active Compound: The stability of the nutrient or bioactive compound during the encapsulation process is crucial. Some compounds may be sensitive to heat, moisture, or shear forces, which can affect encapsulation efficiency (Hosseini et al., 2020).

Encapsulation Technique: The choice of encapsulation technique (e.g., coacervation, spray drying, or extrusion) can impact encapsulation efficiency. Each technique has its own advantages and limitations, affecting the success of nutrient encapsulation (Noval et al., 2018).

The choice of materials for encapsulation and a comprehensive understanding of factors influencing encapsulation efficiency is crucial for optimizing nutrient delivery in ruminant animals.

RUMINANT NUTRITION ENHANCEMENT USING ENCAPSULATION TECHNOLOGY

Encapsulation for Rumen Bypass: Encapsulation involves the entrapping of nutrients within protective matrices, affording resistance to ruminal degradation. This technology enables the targeted delivery of sensitive nutrients, notably amino acids, vitamins, and minerals, to the lower digestive tract. Consequently, it enhances nutrient utilization, as evidenced by the capacity of microencapsulated amino acids to augment protein synthesis and milk yield in dairy cattle (Gott et al., 2015). Encapsulated nutrients and feed additives are essential for improving animal productivity because they increase the ability to bypass the rumen and reach the intended target. EC promotes the stability and bioavailability of phenolic compounds by serving as a barrier between them and other food components including protein and amino acids as reported by Silva *et al,* (2018). An experiment involving dairy cattle focused on studying how encapsulated amino acids could bypass the rumen and protect them from degradation within it. These encapsulated amino acids were integrated into the diet to ensure they remained intact in the rumen. The outcome of the study indicated a notable enhancement in protein synthesis and a corresponding increase in milk production among dairy cows, underscoring the efficacy of encapsulation technology in facilitating rumen bypass (Bach et al., 2007).

In a sheep nutrition case study, research utilized encapsulation technology to successfully enable essential fatty acids to bypass the rumen. These encapsulated fatty acids were incorporated into the diet to shield them from degradation within the rumen. As a result of this method, there was a noticeable improvement in the absorption of fatty acids, which subsequently led to enhanced health indicators in the sheep (Yáñez-Ruiz et al., 2018). Another study on mineral nutrition in beef cattle explored the use of encapsulation for rumen bypass of essential minerals. Encapsulated minerals were added to the diet to ensure their passage through the rumen intact. The study revealed improved mineral bioavailability and overall health in the cattle (Spears, 2017). Encapsulated vitamins were provided in the diet of goats to protect them from ruminal degradation. The study demonstrated increased vitamin absorption and improved health outcomes in the goats (Abdouli et al., 2020).

Encapsulation for Targeted Nutrient Delivery: Encapsulation, a cutting-edge technology, facilitates the creation of nanoscale carriers for nutrients. These nanocarriers can be precisely directed to specific regions of the digestive tract, optimizing nutrient absorption while minimizing wastage. Recent research underscores the capacity of nanoencapsulated essential oils to ameliorate feed intake, rumen fermentation, and milk production in dairy cattle (Wang et al., 2019).

A study on dairy cows investigated the use of encapsulation for the targeted release of minerals. Encapsulated mineral supplements were included in the diet to enable precise delivery of essential minerals to the lower digestive tract. The results demonstrated improved mineral bioavailability and overall health in the dairy cows (Wang et al., 2016).

In an experiment involving calves, (Ghorbani et al., 2020) explored the use of encapsulated probiotics for targeted nutrient delivery. Encapsulated probiotics were introduced into the diet to ensure that beneficial microorganisms reached the lower digestive tract intact. The study revealed improved gut health and enhanced growth performance in the calves (Ghorbani et al., 2020). Research on beef cattle nutrition examined the regulated discharge of essential oils through the utilization of encapsulation technology. These encapsulated essential oils were incorporated into the cattle's diet to facilitate a gradual and precise release in the lower digestive tract. The findings of the study indicated increased feed consumption, improved rumen fermentation, and enhanced growth performance among the cattle (Li et al., 2017). A study focusing on sheep nutrition examined the use of encapsulation for targeted nutrient delivery in animals consuming high-fiber diets. The results demonstrated improved nutrient utilization and enhanced performance in sheep (Papadopoulos et al., 2019).

Coating for Bitter and Odorous Compounds: Encapsulation techniques are also employed to mitigate the unpalatable taste and odor associated with feed additives, particularly in the context of bitter or pungent compounds such as medications or supplements. Encapsulation of feed additives is shown to enhance voluntary feed intake and the overall welfare of ruminant livestock (Azeem et al., 2017).

González-Bernal et al., (2019) used encapsulation to mask the unpleasant taste of bitter ingredients, in a study focusing on bitter compound masking in feed supplements for cattle. The encapsulation technology effectively improved the palatability of the feed supplement, resulting in increased feed intake and better compliance among the cattle. A case study on the administration of medications to sheep investigated the use of encapsulation technology to mask the pungent odor of certain drugs. Encapsulated medications were administered to sheep, resulting in improved acceptance and reduced stress associated with medication dosing. The encapsulation technology enhanced overall well-being in the treated sheep (Guerin et al., 2020). Another study on goats assessed the palatability of supplements containing bitter compounds. Encapsulation was employed to mask the bitterness of certain dietary components. Goats fed with encapsulated supplements showed increased consumption and improved nutrient intake, enhancing their overall well-being (Di Grigoli et al., 2021). The use of encapsulating technology to prevent the taste and odor of drugs was the subject of a research study in cattle management. Encapsulated medications were included in the cattle's diet, ensuring better compliance and reduced stress during treatment. The masking effect of encapsulation led to improved overall cattle well-being (Daniel et al., 2018).

Encapsulation for Targeted Release in the Gastrointestinal Tract: Advanced encapsulation methodologies can be tailored to achieve precise nutrient release in distinct segments of the gastrointestinal tract. This level of control facilitates the improved utilization of nutrients by making them available at the optimal site and time.

Controlled-release encapsulation of minerals, for instance, has demonstrated heightened mineral bioavailability in ruminant species (Suttle, 2010).

Grilli *et al.* (2013) found that free form sodium selenium is more efficiently absorbed by tissue (plasma and milk) and that microencapsulated sodium selenium is an ideal strategy for preserving nutrients in dairy cattle through ruminal lowering of bioavailability. In ruminant feeding, mechanisms for controlling the rate of ammonia release in the rumen are important for increasing the efficiency of transforming dietary nitrogen into microbial protein. Encapsulation technology provides the possibility to protect sensitive compounds through the feed process and the storage conditions Favaretto et al. (2020). Encapsulated thymol and cinnamaldehyde are active components of essential oils and have antimicrobial and antioxidative characteristics that can improve the gut health of animals Favaretto et al. (2020).

RUMINANT HEALTH AND WELFARE ENHANCEMENT USING ENCAPSULATION TECHNOLOGY

There are several studies on the use of encapsulation technologies in ruminant health enhancement. Researchers employed encapsulated probiotics with antimicrobial properties, in a study on mastitis management in dairy cows. These encapsulated probiotics were administered as a dietary supplement, enabling targeted release in the digestive tract. The results showed a reduction in mastitis incidence and improved udder health in dairy cows (Zanello et al., 2016).

Researchers used encapsulated sodium bicarbonate as a dietary supplement in a trial on preventing rumen acidosis in sheep. Acidosis risk was reduced by the encapsulation method, which enabled the rumen to receive sodium bicarbonate in an efficient way. The findings showed that the sheep's overall digestive health and rumen pH had improved (Hegarty et al., 2017). The urea microencapsulation technique can gradually release this ingredient in the rumen environment, reducing the risk of animal poisoning and improving the synchronism of nutrients in the rumen without compromising productive performance (Melo et al., 2021).

Encapsulated anthelmintics were investigated in a study on the treatment of gastrointestinal parasites in goats. These encapsulated anthelmintics were administered as part of the goats' diet, allowing for controlled drug release in the digestive tract. The study showed enhanced parasite control and overall health in the goats (Githiori et al., 2006). Essential oils (EOs) are an alternative for replacing antibiotics in animal feeds, but their volatile nature demands a high degree of stability. Many studies have reported better antimicrobial activity of EOs by protecting them from degradation using microencapsulation technology (Amin et al., 2021).

In a study conducted on dairy cattle during heat stress conditions, researchers utilized encapsulated forms of feed additives that release slowly in the rumen. This allowed for the controlled release of nutrients, reducing metabolic stress in the animals. It was observed that encapsulated antioxidants and heat stress-reducing compounds led to improved well-being, reduced heat-induced stress, and enhanced milk production (Bernabucci et al., 2015). In another study to reduce heat stress during a long-distance transportation of sheep, researchers used encapsulated plant extracts known for their stress-reducing properties. These encapsulated additives were included in the diet of the sheep before transportation. The results demonstrated a reduction in transport-induced stress, including lower cortisol levels and improved behavior, indicating enhanced well-being during transit (Ali et al., 2019).

A study on weaning stress in calves explored the use of microencapsulation technology to improve nutrient absorption during this critical period. Encapsulated nutrients, including vitamins and probiotics, were administered to calves to support their transition to solid feed.

The encapsulation technology ensured the targeted release of nutrients in the lower digestive tract, mitigating the stress associated with dietary changes and promoting well-being in weaned calves (Vyas et al., 2020). Jones et al., (2018) stress management in beef cattle during transportation explored the use of encapsulated adaptogens. These encapsulated adaptogens were integrated into the diet to mitigate stress during transit. The study observed reduced stress responses, including lower cortisol levels, improved behavior, and enhanced overall health in the transported cattle.

RUMINANT PRODUCT QUALITY AND SENSORY ATTRIBUTES

Encapsulation technology can play a vital role in enhancing ruminant product quality and sensory attributes. Here are case studies that demonstrate the impact of encapsulation technology on these aspects. In a study involving dairy cattle, encapsulated additives were utilized in the diet to enhance milk quality. Encapsulated omega-3 fatty acids and antioxidants were included to protect against oxidation and improve the fatty acid profile of milk. The results showed improved milk quality, including reduced lipid oxidation and enhanced sensory attributes such as taste and aroma (Mach et al., 2017). The impact of encapsulated feed additives on the meat quality of beef cattle was examined. Encapsulated antioxidants and flavor enhancers were integrated into the cattle's diet to reduce meat spoilage and enhance sensory attributes. The study observed improved meat quality, including increased tenderness and flavor, resulting in higher consumer satisfaction (Sensory et al., 2018).

The study on goat milk production investigated the use of encapsulated additives to enhance the flavor of milk. Encapsulated flavor compounds were added to the goat's diet to improve the sensory attributes of the milk. The study demonstrated enhanced milk flavor, leading to increased consumer preference and demand for goat milk products (Bianchi et al., 2021). The use of encapsulation technology to reduce undesirable odors on sheep meat quality was explored. Encapsulated additives were included in the diet to mitigate off-flavors and odors associated with sheep meat. The results indicated a significant reduction in undesirable sensory attributes, leading to improved meat quality and consumer acceptance (Yu et al., 2020).

IMPROVING TASTE, TEXTURE, AND NUTRITIONAL VALUE USING ENCAPSULATION TECHNOLOGY

Encapsulation technology can play a significant role in enhancing the taste, texture, and nutritional value of ruminant-derived products. Sheep milk cheese production investigated the use of encapsulated probiotics and flavor compounds. Encapsulated probiotics were added during cheese production to improve the texture and enhance probiotic survival. Additionally, encapsulated flavor compounds were used to enhance the taste and aroma of the cheese. The results showed improved texture, taste, and nutritional value of the sheep milk cheese, making it more appealing to consumers (Pappa et al., 2019). Encapsulation technology was used on beef patty production; encapsulated hydrocolloids were used to improve texture. The encapsulated hydrocolloids were added to the meat blend to enhance water retention and reduce cooking losses. This resulted in beef patties with improved juiciness and tenderness, enhancing the overall sensory attributes (Xiong et al., 2018).

An experiment on goat milk yogurt production examined the use of encapsulated vitamins and minerals. Encapsulated vitamins and minerals were added to goat milk yogurt to prevent degradation during processing and storage. This resulted in yogurt with improved nutritional value and sensory attributes, making it a more appealing and nutritious product (Aryana et al., 2016). Lamb sausage production explored the use of encapsulated flavor enhancers. Encapsulated flavor compounds were incorporated into lamb sausage formulations to enhance the taste profile. The results demonstrated improved taste and overall consumer acceptance of lamb sausages, contributing to their market attraction (Zhou et al., 2017).

ROLE OF ENCAPSULATION TECHNOLOGY IN EXTENDING SHELF LIFE AND REDUCING SPOILAGE OF RUMINANT-DERIVED PRODUCTS

Encapsulation technology is a valuable tool in extending the shelf life of food products and reducing spoilage. In a study on the shelf life of ruminant-derived meat products, encapsulated natural antioxidants were used in meat. These encapsulated antioxidants were designed to release slowly, providing long-lasting protection against lipid oxidation. The results showed a significant extension of the shelf life of meat products, reduced rancidity, and improved overall quality (Chin et al., 2016). Scientists investigated the use of encapsulated antimicrobial agents in ruminant-derived dairy products. Encapsulated antimicrobials were added to dairy formulations to inhibit the growth of spoilage microorganisms. The study demonstrated a significant reduction in spoilage, leading to an extension of the shelf life of dairy products (Lavilla et al., 2017).

Research focusing on ruminant-derived oils examined the use of encapsulation technology to prevent oxidation. Encapsulated natural antioxidants were added to the oils to protect against lipid oxidation. The results showed an extension of the shelf life of the oils and a reduction in the development of off-flavours (Hosseini et al., 2016). A case study on baked goods made from ruminant-derived ingredients explored the use of encapsulated enzymes. Encapsulated enzymes were added to the baking formulations to control starch retrogradation and improve texture over time. The study demonstrated an extended shelf life and improved textural properties in the baked products (Luo et al., 2018).

ROLE OF ENCAPSULATION TECHNOLOGY ON RUMINANT GROWTH AND PERFORMANCE IMPROVEMENT

Encapsulation technology can significantly contribute to enhancing the growth and performance of ruminants. A study on dairy calf nutrition investigated the use of encapsulated probiotics and prebiotics to enhance growth and health. Encapsulated probiotics and prebiotics were included in the calf diet to promote a balanced gut microbiota and improve nutrient absorption. The results demonstrated accelerated growth, reduced health issues, and enhanced performance in dairy calves (Zhu et al., 2018). Encapsulated feed additives were used to improve growth and feed efficiency on beef cattle. Encapsulated essential oils, enzymes, and amino acids were included in the cattle diet to enhance nutrient utilization and reduce digestive disturbances. The study observed increased weight gain and improved performance in beef cattle (Mavromichalis et al., 2014).

An experiment on sheep nutrition examined the use of encapsulated trace minerals for improved growth and health. Encapsulated trace minerals were integrated into the sheep's diet to enhance nutrient absorption and address mineral deficiencies. The results showed increased growth rates and overall health improvements in sheep (Yazdankhah et al., 2018).

Encapsulated vitamins and minerals were added to the goat's diet to prevent degradation and enhance nutrient absorption. The study demonstrated increased growth, reproduction rates, and milk production in goats (Sabry, 2019). Previous studies have shown that a blend of micro-encapsulated carvacrol, thymol, and cinnamaldehyde can inhibit immune cells and improve growth performance in lambs Alemu et al., (2019).

ROLE OF ENCAPSULATION TECHNOLOGY IN REDUCING METHANE EMISSION

Reducing methane emissions from ruminants is crucial for mitigating the environmental impact of livestock farming. Encapsulation technology can play a role in achieving this goal. A study on dairy cows explored the use of encapsulated lipids in the diet to reduce methane emissions. The encapsulated lipids were designed to inhibit methanogenesis in the rumen. The results showed a significant reduction in methane production without negatively impacting milk production or the overall health of the cows (Beauchemin et al., 2017). In a trial on beef cattle, researchers examined the impact of encapsulated nitrate supplementation in the diet to reduce methane emissions. The encapsulated nitrate provided a slow release of nitrate in the rumen, resulting in decreased methane production while maintaining animal performance (Van Zijderveld et al., 2011). An experiment on sheep investigated the use of encapsulated tannins in the diet to reduce rumen methane emissions. The encapsulated tannins were designed to target methane-producing microbes. The results showed a significant decrease in methane production in sheep without adverse effects on nutrient utilization (Oliveira, et al., 2020). The use of encapsulated 3-NOP, a methane inhibitor, in the diet of goats to reduce methane emissions was employed. Encapsulation allowed for controlled release in the rumen, resulting in a significant reduction in methane production without affecting feed intake or nutrient digestibility (Hristov et al., 2015).

These case studies illustrate how encapsulation technology can effectively reduce methane emissions in ruminants, contributing to more environmentally sustainable livestock production. The cases provided support for the application and impact of encapsulation technology in mitigating methane emissions from ruminant animals.

OBSTACLES IN THE IMPLEMENTATION OF ENCAPSULATION TECHNOLOGY

The implementation of encapsulation technology in ruminant nutrition, while promising, can face several obstacles. These obstacles may include cost considerations, formulation challenges, and regulatory issues.

Cost of Encapsulation: The cost of encapsulation can be relatively high, which may deter its widespread use in ruminant nutrition. The production of encapsulated additives or nutrients can involve specialized equipment and materials, resulting in increased expenses for feed manufacturers and farmers (Ahmad, 2014).

Feed Formulation Challenges: Incorporating encapsulated ingredients into animal diets can present formulation challenges. Ensuring the proper distribution and stability of encapsulated nutrients in feed formulations can be complex and may require adjustments to existing manufacturing processes (Sun et al., 2014).

Environmental Impact: The environmental impact of the materials used for encapsulation can be a concern. For instance, the production and disposal of encapsulation materials may have environmental consequences that need to be considered when assessing the sustainability of this technology (Ozkan et al., 2013).

Regulatory Approval: Obtaining regulatory approval for the use of encapsulated ingredients in ruminant diets can be a lengthy and complex process. Compliance with safety and labeling regulations may require extensive testing and documentation (USDA, 2019).

Storage and Handling Considerations: Proper storage and handling of encapsulated additives or nutrients may be challenging, as they can be sensitive to environmental conditions such as temperature and humidity. This adds complexity to on-farm storage and feed management practices (Oliveira et al., 2019).

Technical Expertise: Successful implementation of encapsulation technology may require specialized technical knowledge and expertise in animal nutrition, formulation, and feed manufacturing. Smaller livestock operations or farmers with limited access to technical support may face challenges in adopting this technology (Coelho & Marangoni, 2013).

Addressing these obstacles requires collaborative efforts between researchers, feed manufacturers, regulatory bodies, and the agricultural industry to ensure that encapsulation technology can be effectively and sustainably implemented in ruminant nutrition. The references provided offer insights into encapsulation technology's potential challenges and solutions.

CONCLUSION

Encapsulation nutrient technology has emerged as a versatile and innovative tool in the improvement of ruminant nutrition and ruminant-derived products. Through the controlled delivery of nutrients, enhancement of nutrient stability and targeted release in the digestive tract, encapsulation technology offers a range of benefits for both ruminants and the products derived from them.

The application of encapsulation technology in ruminant nutrition has been shown to enhance nutrient utilization, reduce wastage, and improve animal performance, ultimately contributing to more efficient and sustainable livestock farming practices. Encapsulation technology allows for the protection of sensitive compounds, such as vitamins, minerals, probiotics, and additives, from degradation in the rumen, ensuring that these nutrients are available when and where they are needed for optimal ruminant health and growth.

Furthermore, the use of encapsulation technology in ruminant-derived products has resulted in improved product quality, including enhanced taste, texture, and shelf life. Encapsulation allows for the masking of unpalatable compounds, the controlled release of flavor enhancers, and the reduction of oxidation in meat and dairy products. These advancements contribute to increased consumer satisfaction and marketability of ruminant-derived foods.

While encapsulation technology offers numerous advantages, it is important to acknowledge the challenges, such as cost considerations, formulation complexities, and regulatory hurdles that may impact its widespread adoption. Addressing these obstacles and promoting further research and development in this field is essential to fully unlock the potential of encapsulation technology in ruminant and ruminant-derived product improvement.

Encapsulation technology represents a promising avenue for the enhancement of ruminant nutrition and the quality of products derived from ruminants. With continued innovation and collaboration among researchers, feed manufacturers, and regulatory bodies, encapsulation technology has the potential to make significant contributions to more sustainable and high-quality ruminant production systems.

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Fungal Remediation of Nematocyte with Fluopyram Active Ingredient by *P. frequantans* and its Mortality Effect on *D. magna*

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Abstract

In this study, to understand the bioremediation efficiency of *Penicilium frequantans* soil fungus used as a useful tool for bioremediate a fluopyram nematocide with important environmental parameters such as chemical oxygen demand (COD) and total organic carbon (TOC) studied. Additionally, mortality tests were performed for treated and untreated media with *D. magna* to gain additional knowledge about the toxic effect of this pesticide after bioremediation step. According to the results of the study, *P. frequantans* performed high COD and TOC reduction rates of fluopyron nematocide as 90 % for both parameters in 6 and 7 days respectively. This means *P. frequantans* is a suitable tool for bioremediating this kind of nematocides. According to the *D. magna* mortality test results, TOC and COD values of pesticide dereeased, mortality rates increased by the reason of chemical structure and side products of pesticide.

Keywords: Bioremediator, Chemical oxygen demand, *Daphnia magna, Penicillium frequantans*, Total organic carbon.

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INTRODUCTION

Increasing population, rapid industrialization and advancing technology create a pollution burden, especially in terrestrial and aquatic ecosystems, and this creates negative effects on living life. Disposal of pesticide-containing untreated water from agricultural fields greatly affects the receiving environments near these areas (Luka et al., 2018). In order to eliminate environmental problems caused by organic chemicals, many researchers have preferred physical, chemical or biological treatment methods. Although physical and chemical methods are initially effective, they can also produce toxic secondary metabolites after purification. Bioremediation, one of the biological methods, can effectively prevent these problems (Saravanan et al., 2023).

In agricultural activities, weeds, pests and diseases cause the yield and quality of agricultural products to deteriorate. According to statistics, approximately 30% of agricultural products are damaged every year due to various harmful factors (Kučić Grgić et al., 2019). As a result of this situation, the use of pesticides becomes inevitable. However, as a result of the excessive use of these pesticides, the chemicals in the pesticide not only accumulate in crops but also remain in agricultural soils, affecting soil fertility and indirectly microbial communities (Satapute and Kaliwal, 2016). Pesticides move both vertically and horizontally in the soil. Pesticides leaking into receiving environments and groundwater also pollute water resources, and as a result, aquatic invertebrates and fish are negatively affected (Dwivedi et al., 2011).

Bioremediation refers to the application of microorganisms and other microbial-derived products for the degradation or reduction of various organic pollutants or their toxic effects (Priyadarshanee and Das, 2021). The basic concept of bioremediation is that microorganisms can use pollutants as a source of carbon and/or nitrogen and completely mineralize them into carbon dioxide and water, or at least convert them into non-toxic secondary decomposition products (Shabbir et al., 2018). Therefore, bioremediation is an ideal, environmentally friendly and inexpensive treatment method for the removal of environmental pollutants.

Fluopyram (CAS No.: 658066–35–4) is a nematicide developed by Bayer CropScience (Fought et al., 2009). This pesticide has been used as a promising nonfumigant nematicide in many high value crops including fruits and vegetables. As a result of its widespread use in recent years, its ecotoxicological effects have caused great concern. The low vapor pressure and volatility of fluopyram lead to high adsorption in soil and cause serious damage to microbial communities (Chawla et al., 2018). Zhang et al. (2014) observed that fluopyram had negative impacts on the activity of soil microorganisms and altered the structure and function of the microbial community.

In toxicological experiments, *Daphnia magna* is widely utilized as a model and important organism in the water ecosystem. It possesses several characteristics that make it suitable for research purposes, including ease of reproduction, high sensitivity to environmental stimuli, diverse phenotypes, and ease of treatment and handling (Hiruta and Tochinai, 2014).

In this study, fluopyrom nematocide was prepared at recommended concentrations in agricultural areas and a study was conducted on the bioremediation activities of *P. frequantans* fungus. In addition, a mortality test was performed on *D. magna* in environments where bioremediation activities were carried out, and the difference in mortality between treated and untreated environments was revealed.

MATERIALS and METHODS

Preparing *P. frequantans*

P. frequantans pure fungi cultures used in the study are already available in Munzur University Environmental Engineering laboratories. These cultures were isolated from an agricultural area in Istanbul before.

Pure fungal cultures were first taken from the petri dishes, scraped into the broth medium with a diameter of 1 cm, and added under sterile conditions according to the methods specified in Cruikshank (1972). These cultures were transferred to broth media and placed in a 27°C incubator and multiplied and enriched at 160 rpm.

Preparing Pesticide Solutions

Fluopyram nematocyte was obtained from a commercial company in Tunceli Province, and COD and TOC values were calculated taking into account the amount of active ingredient. Fluopyrom used in the experimental stages was prepared in 250 ml conical flasks at the concentrations recommended for use by farmers: 250, 500, 750 and 1000 ppm.

Bioremediation of Fluopyram

To investigate the bioremediation activities of *P. frequantans* on fluopyram on the basis of COD and TOC, firstly the Chemical Oxygen Demand (COD) and Total Organic Carbon (TOC) values in the enriched environment in which *P. frequantans* was found were measured. All of the experimental studies were performed triplicate and average value of these replicants were used. While the open relux method specified in standard method 5220B was used for COD analysis in the study; in TOC analyses, the standard method high temperature combustion method 5310A was preferred with Shimadzu TOC-V device.

For COD assays DR860 HACH spectrophotometer, the closed-reflux colorimetric method was used to calculate the COD concentration. The test values are the average of three readings, and the measurement discrepancies were found to be less than 0.02. The effectiveness of COD and TOC elimination discovered using Eq (1) and Eq (2)

$$COD\ removal\ (\%) = \frac{(COD_{initial} - COD_{final})}{COD_{initial}} \times 100 \quad (1)$$

$$TOC\ removal\ (\%) = \frac{(TOC_{initial} - TOC_{final})}{TOC_{initial}} \times 100 \quad (2)$$

$COD_{initial}$ and COD_{final} (mg/L) are the values of initial COD and COD after bioremediation process at time *t*, respectively.
$TOC_{initial}$ and TOC_{final} (mg/L) are the values of initial TOC and TOC after bioremediation process at time *t*, respectively.

As a result of COD and TOC measurements made every 24 hours, when a value close to the application concentration of fluopyram in the agricultural field was reached, 1 ml of *P. frequantans* (Each ml of mushroom contains approximately 10^6 colony-forming individuals) was started to be added to the fluopyram media for bioremediation activities. The samples taken every 24 hours were filtered through 0.45µm filter paper, and bioremediation studies were followed by COD and TOC analyzes on these filtrates. In order to inhibit the activity of fungal colonies during this process, one drop of freshly prepared 1N H_2SO_4 was added to the filtrates.

Mortality on *Daphnia magna*

D. magna organisms were obtained from Fırat University Fisheries Engineering Laboratories and species determinations were made in advance. *D. magna* individuals were kept in a 120-litre aquarium for a period of one month to adapt to laboratory conditions acclimated to a 16:8-hour light: dark cycle at a temperature of 16–18°C (±1) at laboratory. During the adaptation period of *D. magna*, the daily mortality rate was determined to be less than 10%. *D. magna* was fed periodically once a day with a mixture of dry spirulina powder and baker's yeast (*Saccharomyces cerevisiae*), and the aquarium water was regularly aerated with an air pump. Additionally, 25% of the water has been renewed at a rate of 1/7.

To evaluate mortality rates, nine different experimental groups were created. In this context, 350 mL of filtered water was taken from all application groups (control, 250, 500, 750 and 1000 ppm treated and untreated media at the same concentrations) and placed in polycarbonate containers filled with natural living water (NLW) on the 11th day. The water temperature in each container was adjusted to 20°C (±1) by air conditioning, and changes in water temperature were checked regularly. There are 10 first stage juvenile *D. magna* individuals in each container. Test organisms were not fed throughout the experiment and a 16:8-hour light: dark photoperiod was maintained. Three repetitions were made for each experimental group. The number of dead daphnia in each container was counted after 24, 48, and 72 hours. At the end of the test period, that is, after 72 hours, mortality rates were calculated as percentages in each experimental group (Babu et al., 2015).

RESULTS and DISCUSSION

Bioremediation Studies Results on the basis of COD and TOC

In the study, the bioremediation activity results based on Chemical Oxygen Demand (COD) and Total Organic Carbon (TOC) shown by *P. frequantans* on Fluopyram nematocytes at different concentrations are shown in Figures 1 and 3 on a concentration basis; on the basis of removal efficiency, it is shown in Figures 2 and 4.

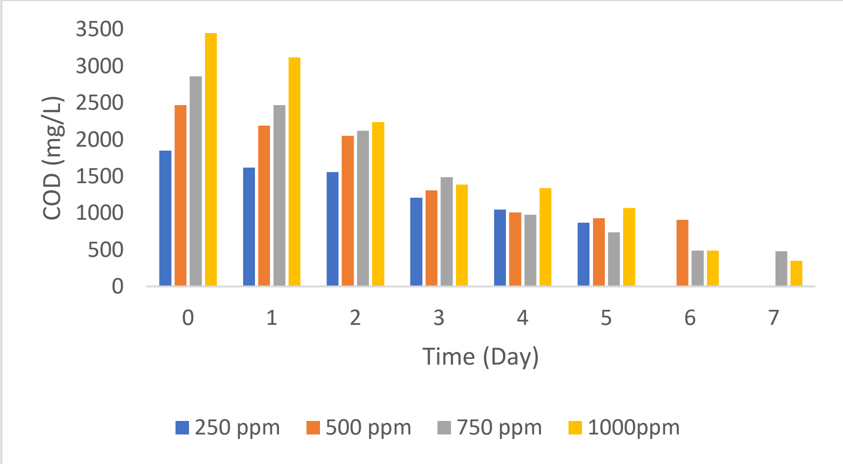

Figure 1. COD decrease based on concentration *by P. Frequantans*

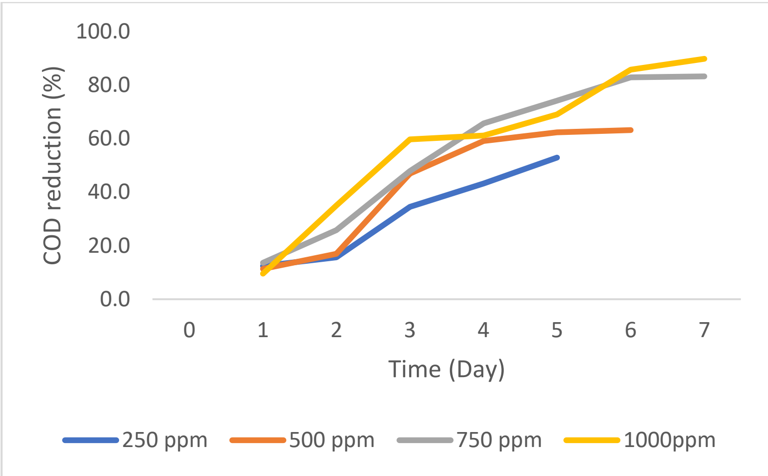

Figure 2. COD reduction efficiency by *P. Frequantans*

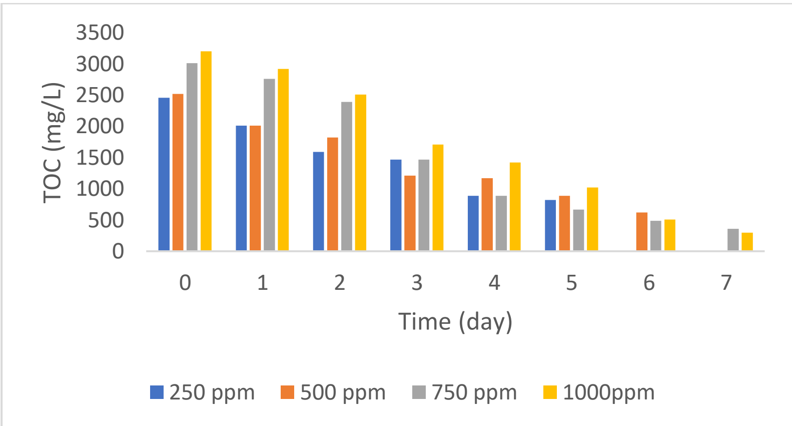

Figure 3. TOC decrease based on concentration by *P. frequantans*

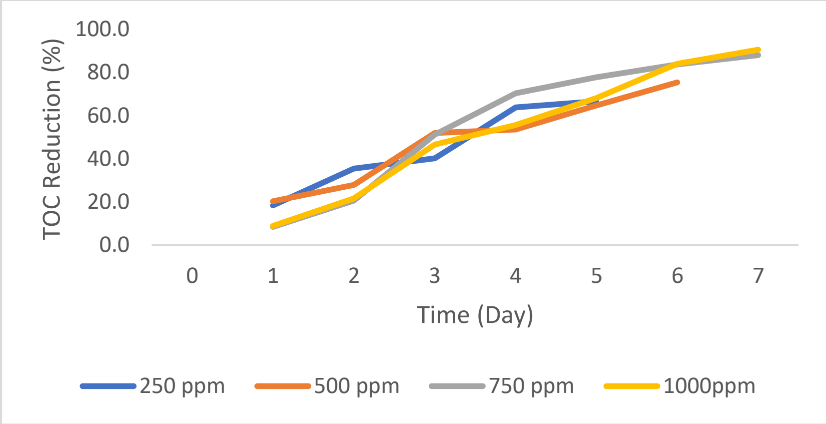

Figure 4. TOC reduction efficiency by *P. frequentans*

According to the results of the removal performance of *P. frequantans* on nematocyte with fluopyrom active ingredient on COD basis, the COD value, which had an initial value of 1850 ppm, was reduced to 870 ppm with 53% at the end of 5 days in a 250 ppm environment It is seen that the COD value, which has 2470 ppm value in the 500 ppm environment, decreased to 910 ppm, which means a decrease of 63.2% at the end of 6. days.
The initial COD value, which was 2860 ppm in the 750 ppm environment, decreased to 480 ppm by 83.2% at the end of 7 days, while the highest removal efficiency was achieved with a decrease of 89.9% in the 1000 ppm environment. With this decrease, it is seen that the initial value of 3450 ppm has been reduced to 350 ppm.

TOC measurements were also made in the filtrate samples taken for COD measurements. When the decreases in this parameter are examined; at the end of 5 days in a 250 ppm environment, the initial TOC value of 2460 ppm decreased by 66.7% to 820 ppm; the TOC value, which had an initial value of 2520 ppm in a 500 ppm environment, decreased to 620 ppm with a decrease of 75.4% at the end of 6 days; and it was determined that the TOC value, which initial value was 3010 ppm in a 750 ppm environment, decreased to 360 ppm with a decrease of 88% at the end of 7 days. The highest removal efficiency on a TOC basis, 90.6%, was observed in the 1000 ppm environment at the end of 7 days. While the initial TOC value in this environment was 3200 ppm, it decreased to 300 ppm.

Various soil fungi are used for the bioremediation of different xenobiotics such as pesticides, polyaromatic hydrocarbons and heavy metals. Immobilized cells may show high performance in bioremediation and may also have an increased tolerance to toxic substances. Moreover, these microorganisms can show effective degradation and good stability (Aneez et al., 2011). Chikhi et al. (2016)' Streptomyces spp. It was determined in a study using immobilized microbial cells that they could remove xylene in the range of 90-99%. Additionally, a higher microbial population was determined to show a higher xylene degradation rate in immobilized cells than in free cells. Saez et al. (2012) also reported that the removal of lindane using immobilized Streptomyces cells was more effective than free cells in all support matrices tested. Similarly, the removal of diazinon, an insecticide, from liquid media resulted in the elimination of Streptomyces spp. species, which were found to increase by up to 20% when immobilized (Briceño et al., 2015).

Pesticide applications applied to plant roots can negatively affect plants by affecting the bacteria and fungi in the phyllosphere layer of the soil. Xu et al. (2020) also determined that S-metolachlor application (10 mg/kg soil, 14 days) reduced the diversity in the wheat phyllosphere and changed the composition of the microbial community. Azospirillum and Herbaspirillum have been found to reduce pesticide residues by 73.9% and approximately 99.7%, respectively. This indicates that S-metolachlor may cause changes in the phyllosphere microbial composition and reduce the presence of beneficial nitrogen-fixing bacteria in plants, thereby impairing plant nutrient absorption.

Zhao et al. (2020) applied the herbicides R-imazethapyr and S-imazethapyr at a concentration of 40 µg/L (soil) to *Arabidopsis thaliana*. An analysis of leaf layer microbial alpha and beta diversities revealed an increase in these indices, indicating an effect of this enantiomeric herbicide on the structure of the bacterial community. At the family level, the effects of pesticide treatments on bacterial abundance differed. The abundance of the dominant Pseudomonadaceae was decreased by 22% and 41% after R-imazethapyr and S-imazethapyr treatments, respectively, compared to that in the control group.

Endophytic microorganisms also directly affect pesticide bioremediation. Nasrollahi et al. (2020) suggested that the endophytic bacteria *B. altitudinis* DB26-R and *B. subtilis* subsp. inaquosorum B6-L could biodegrade 58.52% and 51.32% of the initial concentrations of diazinon (20 ppm), respectively.

Mortality results

The mortality rates at the end of the 96-hour period seems that treated and untreated environments at 250 ppm are 70% and 55%, respectively. In treated and untreated environments at 500 ppm, these rates increase to 80% and 50%, respectively. Mortality rates in treated and untreated environments at 750 ppm are 90% and 35%, respectively. Finally, in 1000 ppm treated and untreated environments, these rates were determined to be 85% and 45%, respectively. According to these results, the highest mortality rate was seen in the 750 ppm application group, purified by 90%; the lowest mortality rate as 35%, was detected in the 750 ppm untreated application group. Due to increasing concentrations, mortality rates were observed to be higher in treated environments (Figure 5). This may be thought to be due to the toxic effects of by-products that emerge after the pesticides are broken down. The fact that no mortality rate was observed in the control group indicates that the living conditions and population health of the test organisms used in the experiment are intact.

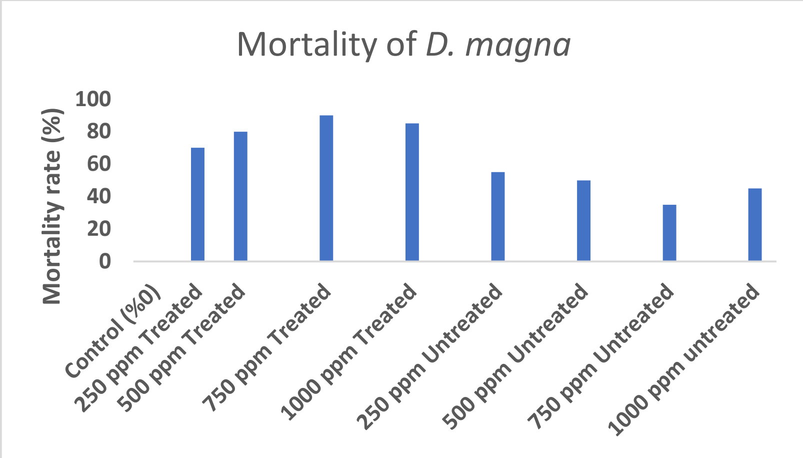

Figure 5. Mortality rates (%) of treated and untreated environments on *D. magna*

Daphnia's response to toxic substances varies depending on the level of contamination and duration of exposure (Ren et al., 2009). Juveniles of Daphnia have been reported to be more sensitive to toxic pollutants than adults (Hanazato, 1991). Daphnia cannot directly purify incoming wastewater, however, theoretically, it has been stated that Daphnia may experience growth inhibition as a result of oxygen depletion (Pous et al., 2020). Therefore, 10-15 days old *D. magna* was used in this study.

Williams et al. (2000) also stated that the large-scale use of herbicides makes it necessary to evaluate their toxic potential on non-target species. It is known that Daphnia species are more sensitive to toxic chemicals than other creatures. This sensitivity is associated with increased sensitivity of the relevant sodium channel, small body size, and changes in metabolic rate (Korkmaz et al., 2021).

The results of mortality tests showed that especially the *S. pseudosanguinis* bacterial isolate was highly effective in the detoxification of herbicides. The non-biodegradability of pyroxasulfone may lead to increased mortality in environments with high removal efficiency. Aghoghovwia and Izah (2018) reported that environmental toxicants can affect various organs or systems of *D. magna*. Colomer et al. (2019) stated that *D magna* can survive longer when exposed to foreign substances than in calm conditions when food concentrations do not limit their biodegradation capacity.

CONCLUSIONS

This is the first study on the use of the *P. frequantans* fungus obtained from agricultural soils in the bioremediation of the Fluopyram nematocyte and the subsequent reflections of its toxic effects on *D. magna* in the untreated and treated pesticide environments. When recent literature was examined, it was seen that the microorganisms used for bioremediation activities were mostly microorganisms isolated from the activated sludge of pesticide producing industries. What distinguishes this study from others is that the *P. frequantans* fungus was isolated directly from an agricultural field and used in the bioremediation study.

The nematocyte with the active ingredient fluopyram used in the study is a highly preferred product, especially in recent years. It offers a biological treatment method recommendation for agricultural lands to farmers who are considering using this product to rehabilitate their agricultural lands. In addition, the opinion has emerged that bioremediation activities can be examined with COD and TOC parameters instead of high-cost chromatographic methods to monitor this bioremediation process. The results reveal that the *P. frequantans* has the capacity to successfully eliminate fluopyrome nematocyst. Therefore, the use of this fungus is recommended. According to the results obtained from mortality studies on *D. magna*, it is thought that the by-products, namely metabolites, of the pesticide may have a toxic effect on *D. magna.* This means that, considering the fact that agricultural lands are exposed to pesticides, the sensitivity, adaptation and bioremediation capacity of such microorganisms to pesticides may be naturally high.

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