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Biochemical Assessment of the Impact of Temperature Stress on the Homeostasis System in Quails

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Abstract. *Usually, in birds, as in all warm-blooded animals, homeostasis is understood as a combination of internal processes involving hormones, the endocrine system and metabolism. In order forquails raised in warm temperature conditions (summer months) to not fall into thermostress, biomarkers should be used to make timely diagnoses. In order to clarify the stress caused by temperature stress in breeding (mother) quails during the study period, we aimed to use the hormone cortisol as a biomarker. During the study, in order to examine the homeostasis indicators (physiological and biochemical) of temperature stress in all groups, the internal body temperature of the quails, the amount of cortisol, glucose, and hematological markers were first determined.*
The results showed that good results for quails were obtained during the period of maintaining air exchange at 4.5 m^3/h. Our research showed that the cortisol hormone can be used as a biomarker for timely and accurate determination of stress in quails during hot summer days.

Keywords: *quail, homeostasis, temperature stress, blood, biochemical markers, cortisol, erythrocytes*

Introduction

In the modern globalized world, numerous extreme factors exist that exert adverse effects on most physiological functions of living organisms. Under extreme conditions, alterations in homeostatic processes may occur, leading to the development of serious functional disorders within the organism. In birds, as in all warm-blooded animals, homeostasis is generally understood as the integration of internal processes involving hormones, the endocrine system, and metabolism. A considerable number of studies have been conducted in this field, particularly in regions characterized by high ambient temperatures, where the negative effects of heat stress on birds have been extensively investigated. Heat stress is known to disrupt endocrine balance and metabolic pathways in poultry (Lara & Rostagno, 2013; Scanes, 2016). These studies have focused on the changes occurring in the organism, especially in homeostatic regulation, under conditions of elevated temperature. Prominent researchers working in this area have elucidated the effects of various stress factors on the physiological state and productivity of animals and birds and have developed preventive measures to mitigate such adverse conditions (Mammadova, 2017, pp. 210–212; Taghiyev & Mammadova, 2018, pp. 109–112).

Studies conducted by researchers investigating avian immunity have demonstrated that when the ambient temperature in poultry housing reaches 40 °C for a period of two hours, a fivefold increase in the level of the hormone corticosterone produced by the adrenal glands is observed.

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During this period, alongside elevated corticosterone levels, significant changes in blood glucose concentration occur, resulting in an increase in glucose levels. Exposure to temperatures above the physiological norm not only leads to increased concentrations of corticosterone and glucose but also causes a reduction in hemoglobin content within erythrocytes by up to 28%. These alterations may adversely affect the overall health status and productivity of birds (Gross & Siegel, 1985, pp. 2230–2233; Vertiprakhov, 2021).

As is well known, the hormone cortisol is synthesized in the adrenal glands, which are paired endocrine organs, and plays a continuous role in regulating various stress responses in animals and birds. Adrenocorticotropic hormone (ACTH) is secreted into the bloodstream from the anterior lobe of the pituitary gland and, under its influence, stimulates the production of glucocorticoids in the cells of the adrenal cortex. Among these glucocorticoids, cortisol is considered one of the most essential in humans, animals, and birds. During stress, cortisol production increases in humans, animals, and birds, resulting in elevated cortisol concentrations in the blood. The synthesis of excessive amounts of cortisol requires a substantial expenditure of energy, which may limit the availability of energy necessary for the production of other hormones within the organism (Rustamova, 2019, pp. 63–68; Rzayev & Farzaliyev, 2014; Volodina et al., 2014, pp. 31–36).

To ensure timely diagnosis and prevent the development of heat stress in quails reared under high-temperature conditions during the summer months, the use of appropriate biomarkers is essential (Abushakhmanova, 2001, pp. 28–29; Amirov et al., 2020). During the course of the study, we aimed to identify the stress induced by temperature exposure in breeding (mother) quails by considering the hormone cortisol as a biomarker.

Materials and Methods

The study was conducted on a total of 100 breeding quails of the Texas Albino and Pharaoh breeds, which were divided into four groups using multiple experimental models. During the experiment, to investigate the effects of temperature stress on homeostatic (physiological and biochemical) parameters in all groups, the internal body temperature of the quails was first measured, followed by the determination of blood pH, cortisol levels, alkaline phosphatase activity, total protein content, glucose concentration, and hematological markers. All analyses were performed using modern automated analyzers (URIT-2900Vet Plus and URIT-880Vet).

Results and Discussion

Considering the points mentioned above, to investigate the changes in homeostasis of breeding quails during enhanced air exchange aimed at preventing temperature stress, the level of cortisol was measured. The obtained results are presented in Table 1.

Table 1.
Cortisol Levels in the Blood of Breeding Quails (n = 50, M ± m)
During Different Air Exchange Periods in Housing Facilities

Parameters	Groups				
	Control 3,5 m^3/hour	I experiment 3,0 m^3/hour	II experiment 4,0 m^3/hour	III experiment 4,5 m^3/hour	IV experiment 5,0 m^3/hour
Cortisol mg/dL: Morning	49,87±1,44	50,43±1,73	48,10±1,87	40,20±2,01	40,40±1,69
Cortisol mg/dL: Noon	53,74±2,14	54,70±1,76	49,70±1,64	40,31±2,19	42,14±1,43
Cortisol nmol/l: Evening	47,70±2,19	49,80±1,68	44,50±2,04	39,1 ± 2,11	38,70±1,51

As shown in Table 1, cortisol levels were higher in the morning and at noon, while by the evening (around 19:00), their concentrations decreased across all groups. This decline is attributed not only to the reduction in ambient temperature but also to changes in the microclimate within the housing facility, specifically the decrease in temperature. In the group where air exchange was maintained at a constant rate of 3.0 m³/hour per kilogram of body weight (Experiment 1), cortisol levels in breeding quails were highest in the morning and at noon, reaching 50.43 mg/dL and 54.7 mg/dL, respectively. These elevated cortisol levels indicate a state of significant temperature-induced stress in the breeding quails. In the control group, where breeding quails were kept under standard farm conditions, cortisol levels were considerably lower compared to those in Experiment 1, measuring 0.56 nmol/L and 0.96 nmol/L, respectively. Although the air exchange rates in Experiments II and III differed by only 0.5 m³/hour, cortisol levels in breeding quails maintained in Experiment III did not reach the upper limit observed in quails, remaining within acceptable physiological norms. These results indicate that maintaining an air exchange rate of 4.5 m³/hour produces favorable conditions for quail husbandry. Specifically, in Experiment III, cortisol concentrations were 40.20 ± 2.01 mg/dL in the morning, 40.31 ± 2.19 mg/dL at noon, and 39.1 ± 2.11 nmol/L in the evening. During the period of biomarker assessment, i.e., after confirming that the breeding quails were experiencing stress, their clinical and physiological parameters were determined. The obtained results are presented in Table 2.

Table 2.
Clinical and Physiological Parameters of Breeding Quails During Heat Stress (M ± m, n = 50)

Parameters	Groups				
	Control	I experiment	II experiment	III experiment	IV experiment
Internal (Core) body temperature, ^{0}C	41,70±0,81	41,90±1,04	41,50±0,53	41,25±0,29	41,14±0,73
Heart Rate, 1 min.	193,1±1,14	198,8±1,19	182,5±0,93	180,6±0,72	180,1±0,87
Respiratory Rate, 1 min.	39,9 ± 0,83	43,6 ± 0,75	34,8 ± 0,08	31,1 ± 0,09	29,6 ± 0,03
Erythrocytes, 10^{12}/L	2,81 ± 0,26	2,78 ± 0,14	2,84 ± 0,19	3,02 ± 0,21	3,04 ± 0,11
Leukocytes, 10^9/L	26,56±0,41	26,93±0,28	26,44±0,17	26,39±0,49	26,35±1,04
Hemoglobin, g/L	86,9 ± 2,11	83,9 ± 2,04	93,7 ± 3,06	114 ± 2,78	116 ± 3,19
Erythrocyte Sedimentation Rate (ESR), mm/hour	6,7 ± 0,27	7,2 ± 0,08	4,8 ± 0,08	4,6 ± 0,06	4,5 ± 0,02

As shown in Table 2, after the occurrence of temperature stress in quails, the internal body temperature of breeding quails in the control and Experiment 1 groupswhere air exchange was maintained at 3.0 m³/hour and 3.5 m³/hour, was observed to increase to 41.90 °C in Experiment 1 and 41.70 °C in the control group. In Experiments III and IV, these values were lower by 0.45 °C and 0.56 °C compared to the control group, and by 0.65 °C and 0.76 °C compared to Experiment I, respectively. Measurement of heart rate revealed that breeding quails in Experiment I, where air exchange was the lowest, exhibited the highest heart rate at 198.8 ± 1.19 beats per minute. In contrast, quails in Experiment III and IV had heart rates of 180.6 ± 0.72 and 180.1 ± 0.87 beats per minute, respectively. Analysis of respiratory rate revealed that during periods of temperature stress, the number of respirations exceeded the physiological norm by 13.9 times. In the control group, breeding quails performed 39.9 ± 0.83 breaths per minute. This parameter was even higher in Experiment 1, where air exchange was maintained at 3.0 m³/hour. Specifically, breeding quails experiencing temperature stress in this group exhibited 43.6 ± 0.75 respirations per minute, representing an increase of 17.6 times above the physiological norm.

Conclusion

1. The results indicate that only minimal differences exist in the effect of air exchange on the clinical and physiological condition of quails in Experiments III and IV.
2. Based on the findings from Experiment III, it was possible to maintain breeding quails at zoohygienic normative levels in housing facilities with an air exchange rate of 4.5 m³/hour per kilogram of body weight, thereby preventing temperature-induced stress while also conserving electrical energy.
3. During the summer months, the impact of temperature stress on homeostasis in breeding quails can be effectively regulated by monitoring blood cortisol levels, allowing for the early detection and mitigation of abnormal physiological conditions.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Assessment of Quality Loss Due to Hail Impact in Citrus Plants

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Abstract. *In recent years, the frequency and intensity of natural disasters affecting the agricultural sector have increased considerably as a consequence of climate change. Citrus orchards located in the southern regions of Azerbaijan are particularly vulnerable to these changes. Hail events cause substantial damage to both the productivity and quality parameters of citrus fruits. This article examines the quality losses occuring in citrus fruits during hailstorms and evaluates the the socio-economic implications of these losses for local farming households. Natural phenomena such as hailstorms negatively influence agriculture by reducing both product quantity and quality. Mechanical injuries inflicted on fruits diminish their marketability, shorten shelf life and result in lower sales prices. Consequently, the accurate estimation of quality loss is a prerequisite for the correct monetary valuation of damage. Based on field observations and farm level from the Lankaran and Astara regions, the proportions of hail damage, crop loss, and market price changes were analyzed. Furthermore, the effectiveness of existing insurance mechanisms and the extent of implementation of technical anti-hail protection measures were assessed, and the principal challenges faced by farmers were identified.*

Keywords: *citrus orchards, hail damage, quality loss, socio-economic impact, agriculture, climate risk*

Introduction

Citrus cultivation is one of the promising branches of agriculture in the subtropical zones of Azerbaijan. The “State Program for the Development of Citrus Fruit Growing in the Republic of Azerbaijan for 2018–2025”, prepared in accordance with Presidental Decree No. 3227 dated September 12, 2017 “On additional measures for the development of citrus fruit, tea and rice production in the Republic of Azerbaijan”, aims to strengthen state support for citrus production, ensure the effective utilization of sectoral potential and stimulate citrus fruit output (President of the Republic of Azerbaijan, n.d.).

Citrus (Latin: *Citrus*) is a genus belonging to the family Rutaceae within the order Sapindales. The internationally recognized scientific name of the genus is Citrus L., 1753 (Linnaeus, 1754). Citrus fruits (lemon, orange, tangerine, grapefruit, etc.) are widely cultivated in the subtropical zones of Azerbaijan and possess considerable economic significance.

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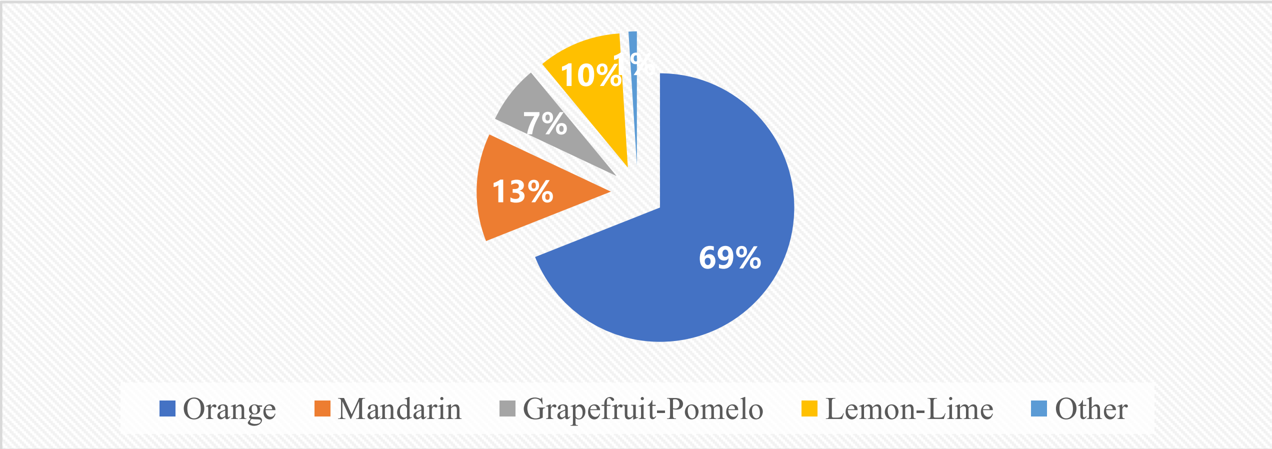

Figure 1. Distribution of global citrus fruit production by species

As illustrated in Figure 1, oranges rank first in global production volume. Mandarins occupy second place with approximately 13%, while lemons and limes collectively account for about 10% (Hasanov & Aliyev 2011; FAO, 2021). According to data from the State Statistical Committee of the Republic of Azerbaijan, in 2024, mandarin orchards constituted 71.8% (3278.5 ha) of the total cultivation area (4564.1 ha). Lemons (15.4%) and oranges (12.8%) follow, respectively (State Statistical Committee of the Republic of Azerbaijan).

The productivity and quality of citrus crops are strongly influenced by agro-climatic factors (frost, hail, snow, wind, storms, floods, excessive rainfall etc.). Among this hazards, hailstorms are particularly destructive, causing severe losses in both yield and quality. Mechanical impacts, surface deformation and spotting of fruits during hail events significantly increase the proportion of non-marketable produce.

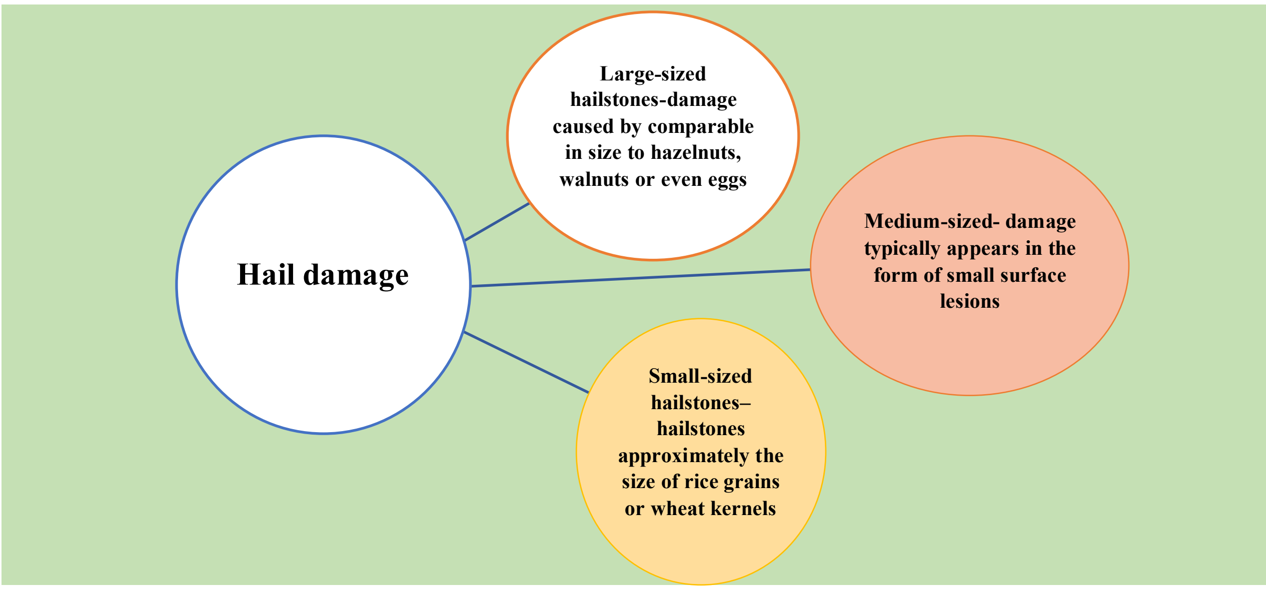

Figure 2. Categories of damage based on hailstone size

Methods

Sampling and registration procedure:
Exclusion of fallen fruits: Fruits that fall to the ground as a result of hail are recorded as a quantitative loss but are excluded from quality loss calculations. Quality loss is determined solely for fruits remaining on the tree canopy.
Sampling: A defined number of fruits (e.g. 50) are collected from the damaged area using a random sampling approach to represent the overall damage level.
Classification: Sampled fruits are categorized according to established regulatory tables.
Large hailstones striking fruits or peduncles cause fruitdrop, cracking of the peel, perforation and abscission of leaves, and cracking of bark on branches and shoots. Additionally, such injuries create favorable conditions for bacterial and fungal infections, which may result in dieback of branches and shoots (Adigozelova & Huseynov, 2025; Babayeva & Mammadov, 2025), Medium-sized hailstones generally do not cause fruit abscission; however, they produce superficial wounds on fruits, leaves, and branches leading to tissue darkening. These wounds often enlarge as fruit development continues (Ozdemir & Aksoy, 2018). Small-sized hailstones rupture oil glands in the fruit peel, primarily affecting fruits and leaves (Training material, 2021) (Agrarian Insurance Fund, 2021; TARSIM, 2019).

Factors

- Size of hailstones
- Precipitation rate
- Precipitation intensity
- Duration of precipitation
- The stage of development where plants and fruits are present

Figure 3. Factors affecting hail damage severity

Although hailstone size, velocity, intensity and duration are critical determinants of damage, the phenological stage of plants is equally important. In other words, hail events occuring outside sensitive developmental stages may not result in yield losses (Aliyev, 2020).

Results and Discussion

Hail, like other plants, affects citrus crops in two ways, causing quality and quantity losses. The first is the loss of commercial value of the product, which manifests itself in the change in appearance as a result of damage to the fruit peel. The second is the loss of yield due to the fall of flowers and fruits to the ground due to the effects of hail. Depending on the size and depth of the wounds on the fruit, the market value is classified as harmless, slight, moderate, severe, and very severe damage, as shown in Table 1 below (Agrarian Insurance Fund, 2021).

Table 1.
Variation in quality loss in citrus crops during hail events

Quality loss (in points)	Damage level	Total area of injury (cm^2)	Depth of damage (mm)	Quality loss (%)
1	Harmless	0	0	0
2	Slight	2	2	25
3	Moderate	3	3	50
4	Severe	5	5	75
5	Very severe	Fragmented	Fragmented	100

When calculating quality loss, fruits that fall to the ground as a result of hail are not taken into account. The fruits remaining on the plant's canopy (50 pieces) are collected without selection and classified in the above order. As can be seen from the table, the area of damaged peel on the fruit is 2 cm^2 and a depth of 2 mm, this causes a 25% loss in quality. When the area and depth of hailstones increase to 3 cm^2 and 3 mm, the damage loss increases to 50%, respectively (Figure 3).

Figure 4. Visual classification of hail damage on mandarin fruits

As can be seen from the picture, the first fruit from the left is completely healthy since it was not hit by hailstones. Damages of minor diameter and depth are observed on the second fruit. In the third fruit, the damage caused by hailstones has increased in both volume and depth, which has caused a loss of quality that reduces its appearance and commercial value. The fruits shown in the fourth and fifth pictures will certainly have no commercial value since they have been severely damaged by hailstones. In such cases, it is advisable to collect the damaged product and deliver it to juicing plants for the purpose of extracting fruit juice. Of course, in the above cases, the remaining damage is paid to the insured by the Agricultural Insurance Fund. The calculation of quality loss in citrus plants is given in Table 2.

Table 2.
Calculation of quality loss during hail risk event

Trees examined N	Tree yield before damage (kg)	Fruits falling to the ground due to risk		Classification of damage in fruits (%)					Quality loss (%)	Quality loss damage ratio (%)	Total loss ratio (%)
		kg	%								
A	B	C	D	0	25	50	75	100	E	F	D+F
1	20	3	15,00	13	10	14	7	6	33,5	28,5	43,5
2	30	8	26,7	15	8	12	10	5	34,4	25,3	52,0
3	39	13	33,3	7	15	10	11	7	31,4	20,9	54,2
Avg.	29,7		25,0							24,9	49,9

It should be noted that fruits that fell to the ground or remained on the tree but experienced a 100% quality loss due to hail impact were considered as fallen fruits. As shown in the table, in this case the loss amounted to 25.0%. The damage resulting from loss was 24.9%. Thus, it was determined that the total damage to a citrus orchard caused by hail accounted for 49.9% of the total. It is important to note that the yield of fruit trees can usually be determined using two methods:

1. By calculating: Number of main branches per tree × number of lateral branches per main branch × number of twigs per lateral branch × average number of fruits per twig × average weight of a fruit ÷ 1000.
2. By canopy assesment: All fruits in ¼ of the tree canopy are examined and counted. The resulting number is multiplied by four to estimate the average number of fruits per tree, which is then multiplied by the average fruit weight to determine the tree's average yield.

For a citrus orchard, planted with a spacing of 5x3 meters, there are on average 666 trees per hectare. During the calculation, the average yield per tree was 29.7 kg, which is equivalent to 197.8 centners per hectare. Therefore, the loss of yield due to both quantitative and qualitative factors in the citrus orchard amounted to be 98.0 centners per hectare (197.8 x 49.9%). Naturally, in the such cases, the remaining loss is compensated to the insured by the Agrarian Insurance Fund. Both the insurance sum, the insurance premium and insurance payout are calculated as follows:

- The insurance amount is calculated using the following formula: Insurance sum= Area x expected yield per hectare x market price per center. In our example, for a 5 hectare orange orchard in Lankaran, with an expected yield of 197.8 centners per hectare and a market price of 150 AZN per center, the insurance sum amounts to 148,500 AZN (5×197,8×150).
- Insurance premium = insurance sum x insurance rate/100 According to the decision of the Board of the Agrarian Insurance Fund dated December 30, 2021, No. 26/21 (Ministry of Justice of the Republic of Azerbaijan, n.d.), the "Conditions for Agrarian Insurance of Orange Plants" provide coverage for damage to the fruit part of orange plants caused by the following risks: hail, fire, earthquake, landslide, hurricane, storm, flood, frost, excessive snowfall, wild animal attacks, plant diseases and pests. In this case, the insurance rate for the Lankaran-Astara region was accepted as 2.56%. The insurance rate for the coverage of quality loss due to hail is 1.05%. If the farmer wishes to insure the crop against quality loss as well, then the total insurance rate is 3.61% and the calculated as follows: Insurance premium = 148500 x 3.61% /100 = 5360.86 AZN. The insured pays 50% of the premium, which in our example is 2680.43 AZN.
- Insurance payout = 148500 x 49.9% – 148500 x 10% = 59251.5 AZN.

Here, 49.9% represents the damage caused by hail in terms of both quantity and quality loss. The 10% is the unconditional deductible (the portion of the loss not covered by insurance and borne by insured).
Management strategy for damaged crops – The most appropriate strategy for crops with minimal or no commercial value is industrial processing.
Delivery to juice factories Delivery: It is advisable to collect damaged produce (not indiscriminately, i.e. regardless of the degree of damage) and deliver it to juicing plants for juice extraction. This prevents total loss and provides the farmer with an additional, albeit minimal, source of income.
Cost Considerations: This process involves taking into account collection costs, transportation costs, and the price offered by the plant. Sometimes, handing over for processing can be more cost-effective than leaving the product in the field.
The Role of the Agrarian Insurance Fund – The Agrarian Insurance Fund (AIF) plays a decisive role in reducing the financial risks of agricultural producers.
Compensation for loss: In the above cases (i.e., when an insured event occurs), the cost of the remaining damage, including loss of quality, is paid to the insured by the Agrarian Insurance Fund.
Calculation basis: The amount to be paid by the AIF is calculated based on the percentage of quality loss determined by assessing the fruits remaining the tree canopy. The financial equivalent of these loss percentages is precisely defined in the Fund's regulations.
Objective: This mechanism protects farmers from significant economic losses caused by natural disasters, enabling them to continue production activities and restore investments.

Conclusion

Accurate assessment of quality loss in fruits due to hail damage is fundamental for agricultural management and insurance mechanisms. Targeted evaluation of crop damage (area and severity) allows farmers to make informed decisions regarding the timing of market sale or industrial processing. Together with the Agrarian Insurance Fund, this process ensures the resilience and financial security of the agricultural sector.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Agrochemical Characteristics of the Soils of the North-East Part of the Greater Caucasus (Gobustan District)

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Abstract. *The study investigated the agrochemical properties of the soils of the Gobustan region, located in the northeastern part of the Greater Caucasus. Effective use of fertilizers requires studying the specific characteristics of individual soil types and the amount of nutrients that can be absorbed in these soils. Therefore, before we started the experiment, we took soil samples from the gray-brown (chestnut) soils of the Gobustan region in order to study their agrochemical properties and determined the amount of nutrients absorbed in the laboratory. The results of the research on the mountain gray-brown (chestnut) soils studied under wheat show that the soils are weakly and moderately humified and have a neutral to slightly alkaline soil reaction. Ammonium nitrogen (NH_4-N), exchangeable potassium, and mobile phosphorus were studied, and scientifically substantiated agrochemical and agrotechnical measures were proposed in accordance with the existing indicators.*

Keywords: *Greater Caucasus, agrochemical properties, humus, soil reaction, nitrogen*

Introduction

The north-eastern part of the Greater Caucasus Mountain system of the Republic of Azerbaijan has complex geomorphological characteristics. The Gobustan district located in this area is characterized by a semi-desert landscape, low precipitation and high evaporation. Such conditions directly affect soil-forming processes and determine the formation of agrochemical properties of soils. The study of the soil cover in the Gobustan region was carried out by H. A. Aliyev, V. H. Hasanov, A. A.Ibrahimov and others, and it was determined that the following soil types are distributed in the area: mountain-meadow steppe, brown mountain-forest, gray-brown (chestnut), dark brown, gray-dark brown, gray soils.

The Gobustan district is located in the north-eastern part of the Greater Caucasus and is characterized by a semi-desert–dry steppe landscape, which directly affects soil-forming processes (Ismayilov, 1998). The low annual precipitation and high evaporation in the area weaken humus accumulation and cause agrochemical poverty of soils (Mammadov, 2007). Mainly gray, light-gray and gray-brown soils are distributed in the Gobustan area, which are considered characteristic for the arid climate zone (Volobuyev, 1953). Gobustan soils mainly have a neutral and weakly alkaline reaction (pH 7.3–8.3), which is explained by the predominance of carbonate parent rocks (Kovda, 1973). The conducted studies show that the humus content in gray soils usually does not exceed 1–2 %, which indicates low soil fertility (Salayev, 1979).

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The high content of calcium carbonate in soils is one of the main factors limiting the uptake of phosphorus by plants (Aliyev, 2015). The amount of mobile phosphorus is often at a low or medium supply level, which makes the application of mineral phosphorus fertilizers necessary (FAO, 2006). The low level of total nitrogen is related to the low content of organic matter and weak biological activity in soils (Hasanov & Abdullayev, 2016).

According to the FAO WRB system, Gobustan soils are mainly classified into the Calcisols and Cambisols soil groups (FAO, 2015). The analysis of agrochemical indicators shows that in Gobustan soils the development of agriculture is possible only with scientifically substantiated fertilization and soil protection measures (Mammadov & Khalilov, 2010). The study of agrochemical indicators of soils has important significance from the point of view of correct placement of agricultural crops, construction of the fertilization system on scientific bases and protection of soil fertility. From this point of view, the study of the current state of agrochemical characteristics of mountain gray-brown soils of the Gobustan District is a relevant scientific and practical issue.

Object and methodology of the research

The research was carried out on mountain gray-brown (chestnut) soils of the Gobustan district located in the north-eastern part of the Greater Caucasus. In order to determine the agrochemical characteristics of the area where we conducted the research, soil samples were taken from the experimental field by the envelope method without carrying out any agrotechnical and agrochemical measures, respectively from the 0–20, 20–40, 40–60, 60–80, 80–100 cm layers, and in these samples the amount of total and plant-available forms of nutrients was determined. Care of crops and agrotechnical measures were carried out at the agronomic norm accepted for wheat crops, taking into account the agrochemical indicators of the soils of the experimental field (Figure 1).

Figure 1. Gobustan district research area

In the taken soil samples humus (by the I. B. Tyurin method), total nitrogen (by the Kjeldahl method), easily hydrolyzable nitrogen (by the I. B. Tyurin and M. M. Kononova method), water-soluble nitrogen (by the colorimetric method with Nessler reagent), ammonium nitrogen (NH_4-N) (by the D. P. Konev method), nitrate nitrogen (by the Grandval–Lyaju method), total phosphorus (by the A. M. Meshcheryakov method), water-soluble phosphorus (by the Denige method in the modification of A. Malyugin and E. Khrenova), mobile phosphorus (by the B. M. Machigin method), total potassium (according to Smith), water-soluble potassium (by the V. G. Aleksandrov method), exchangeable potassium (by the P. B. Protasov method, by viewing in a flame photometer in a 1% ammonium carbonate extract), soil pH in suspension was determined using a potentiometer.

Results

Efficient use of fertilizers requires the study of the specific characteristics of individual soil types and the amount of plant-available nutrients in these soils. Therefore, before the experiment was established, in order to study the agrochemical properties of gray-brown (chestnut) rainfed soils of the Gobustan district, mixed soil samples were taken and the amount of assimilable nutrients was determined in the laboratory.

For analysis, soil samples were taken by the envelope method from 5 layers; 0–20, 20–40, 40–60, 60–80, 80–100 cm. As a result of the studies, it was found that in the 0–20 cm layer humus is 2.98%, decreasing to 0.84% in the 80–100 cm layer. Total nitrogen in the 0–20 cm layer is 0.18%, and in the 80–100 cm layer it is 0.08%. Total phosphorus ranges between 0.22–0.10 %, and total potassium varies between 2.65–1.45%. In the above-mentioned layers easily hydrolyzable nitrogen varies between 87–29 mg/kg, water-soluble ammonium 8.40–2.28 mg/kg, ammonium nitrogen (NH_4-N) 24.41–9.45 mg/kg, nitrate nitrogen 7.40–1.35 mg/kg, water-soluble phosphorus 6.45–2.32 mg/kg, mobile phosphorus 19.6–8.6 mg/kg, water-soluble potassium 42.12–15.08 mg/kg, exchangeable potassium between 277.00–162.90 mg/kg (Table 1). It should be noted that the high amount of total basic nutrient elements cannot indicate the degree of supply of these soils with nutrients that can be assimilated by plants. R. Mammadov proposed a scale evaluating the amount of humus in the Republic of Azerbaijan, according to this scale the soils of the experimental area are sufficiently humus and low-humus. For this, in all farms soil-protective agrotechnical measures should be correctly used and attention should be increased to improvement works.
Agrochemical properties of soils under the wheat plant

Table 1.
Gobustan district, gray-brown (chestnut) soils year 2025

Depth, cm	pH	Humus %	Nitrogen					Phosphorus			Potassium		
			General %	Hydrolyzed, mg/kg	N/NH_3		N/NO_3 mg/kg	General %	Water-soluble mg/kg	Mobile phosphorus, mg/kg	General %	Water-soluble mg/kg	Exchangeable mg/kg
					Water-soluble mg/kg	Absorbed mg/kg							
0-20	7,4	2,98	0,18	87	8,40	24,41	7,40	0,22	6,45	19,6	2,65	42,12	277,00
20-40	7,5	2,42	0,16	76	6,60	23,98	6,70	0,18	5,41	18,4	2,43	36,10	268,02
40-60	7,7	1,27	0,14	65	5,35	17,98	4,85	0,17	4,32	16,3	2,24	31,15	241,08
60-80	8,2	0,99	0,10	47	3,45	14,84	2,90	0,13	2,45	11,7	1,67	20,85	185,14
80-100	8,2	0,84	0,08	29	2,28	9,45	1,35	0,10	2,32	8,6	1,45	15,08	162,90

Discussion

In Azerbaijan gray-brown soils are the most widely distributed soil type. Its area is 1,883 thousand hectares and covers 21.4% of the territory of the Republic. These soils are encountered in the form of a wide belt in the foothill regions of the Greater and Lesser Caucasus, in the Ganja-Gazakh massif, in Gobustan and in the Nakhchivan Republic. They are located at a height of 200–400 m above sea level. Gray-brown (chestnut) soils have 3 subtypes: a) dark, gray, light gray-brown (chestnut) (Salayev, 1979).

Without taking into account the potential and effective fertility of the soil, the efficient application of fertilizers in agriculture is not considered possible. By determining the total reserve of nutrients in the soil, it is possible to correctly apply fertilizers, increase the effective fertility of the soil and obtain a high yield. Determination of the total amount of soil nutrients forms an idea about the reserve nutrients there, which are considered a reserve for plant development. By agrochemical properties of the soil, mainly the reaction of the soil environment, the reserves and forms of nutrients present in the soil are meant.

For soils poorly supplied with nutrients necessary for agricultural crops, it is advisable to apply all of the recommended annual fertilizer rates, for moderately supplied soils half of this rate, and for highly supplied soils one-third or half of it (Bagirova & Bakhishov, 2021, pp. 54–57).

Conclusion

It has been determined that the reaction of the soil solution is weakly alkaline (pH-7.40-8.20). The soils of the area are relatively weakly supplied with nutrients easily assimilated by plants, including ammonium nitrogen (NH_4-N), mobile phosphorus (P_2O_5) and exchangeable potassium. In general, the amount of nutrients decreased as it went to lower layers. These soils, according to the gradation of nutrient supply, are weakly supplied. In order to obtain a high grain yield, it is necessary to apply fertilizers to the soils in certain norms and ratios. It should be noted that the high total amount of basic nutrients cannot indicate the degree of supply of these soils with nutrients assimilable by plants (Bagirova & Bakhishov, 2021, pp. 54–57).

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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A Review of Research on *Prangos acaulis (D.C.)* Bornm.

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Abstract. *Medicinal plants occupy an important place in both traditional and modern medicine as rich sources of biologically active compounds. Among these plants, Prangos acaulis (D.C.) Bornm. has attracted the attention of researchers due to its diverse pharmacological effects. The plant has long been used in folk medicine for the treatment of various diseases, which has increased scientific interest in investigating its chemical composition and biological activity. The aim of this review article is to systematically summarize and analyze the existing scientific literature on the traditional uses, phytochemical composition, and pharmacological properties of Prangos acaulis (D.C.) Bornm. The article examines the findings of recent phytochemical, laboratory-based, animal model, and limited clinical studies. Overall, the available data indicate that Prangos acaulis (D.C.) Bornm. possesses significant therapeutic potential and may serve as a promising natural source for the future development of new pharmaceutical agents.*

Keywords: *Prangos acaulis (D.C.) Bornm., biologically active compounds, pharmacological activity, therapeutic potential, scientific review*

Introduction

Medicinal plants represent one of the oldest forms of medicine and have been used in traditional healthcare systems for thousands of years in many countries around the world. Empirical knowledge of their beneficial effects has been transmitted across generations within human communities (Marrelli, 2021). For many years, plant-based medicines have served—and continue to serve—as a primary source of medical treatment in developing countries. Owing to their natural antiseptic properties, plants have long been utilized for therapeutic purposes in medicine. Accordingly, research has expanded toward investigating the potential properties and applications of aerial plant extracts for the development of nanomaterial-based drugs, including those targeting diseases such as cancer (Greenwell, 2015). Medicinal plants are rich sources of numerous bioactive compounds, including alkaloids, flavonoids, terpenoids, phenolic compounds, and essential oils.

Plant-derived alkaloids constitute one of the largest and most diverse groups of natural compounds. This class comprises approximately 12,000 naturally occurring substances. The principal distinguishing feature of alkaloids is the presence of a basic nitrogen atom in some part of the molecule; however, nitrogen atoms involved in amide or peptide bonds are not included in this definition. Owing to this broad definition, alkaloids are characterized by considerable structural diversity and are often biologically unrelated in terms of their origin. A significant proportion of these compounds exhibit strong biological and pharmacological activities (Bribi, 2018).

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Flavonoids constitute a large subgroup of secondary metabolites and are classified as phenolic compounds. These substances are widely distributed in plants and prokaryotic organisms. To date, more than 6,500 flavonoids have been identified. Flavonoids protect plants against various biotic and abiotic stress factors, exhibit a wide range of biological functions, and play a crucial role in interactions between plants and their environment. They absorb harmful ultraviolet (UV) radiation, thereby preventing cellular damage. Although flavonoids are not considered essential for plant survival, they are biologically active and influence the transport of the plant hormone auxin. In addition, flavonoids play a key role in flower color formation and in protecting plants against microorganisms and insects (Samanta et al., 2011).

Terpenoids are considered one of the most important classes of natural compounds synthesized by various genera of plants, fungi, algae, and sponges. Due to their wide range of therapeutic applications, these substances have held great pharmaceutical significance since ancient times. For example, the aromatic leaves of eucalyptus trees are recognized as a rich source of terpenoids. Among the numerous pharmacologically valuable terpenoids, this article reviews both well-studied and relatively recently discovered examples and discusses their medical applications (Jaeger & Cuny, 2016).

Phenolic compounds are secondary metabolites present in plants and play an important role in plant stress tolerance. Their structure consists of an aromatic ring and hydroxyl groups, and they are mainly synthesized from phenylalanine. Phenolic substances regulate plant growth and development, seed germination, and also participate in defense mechanisms against infections, intense solar radiation, and other stress factors. A key characteristic of these compounds is their strong antioxidant activity, which is closely related to their chemical structure (Kulbat, 2016).

Essential oils are volatile, complex natural compounds with strong aromas that are synthesized by aromatic plants as secondary metabolites. These oils are typically obtained through steam or hydrodistillation, a method that was first developed by Arab scholars during the Middle Ages. Essential oils are well known for their antiseptic properties (against bacteria, viruses, and fungi) as well as their therapeutic effects. Historically, they have been used in embalming, food preservation, and as antimicrobial, analgesic, sedative, anti-inflammatory, antispasmodic, and local anesthetic agents. Although these properties have remained largely unchanged to the present day, their mechanisms of action—particularly antimicrobial effects—are now better understood. In nature, essential oils play a crucial role in plant defense systems by providing protection against bacteria, viruses, fungi, insects, and herbivores. At the same time, they attract certain insects for pollination and seed dispersal, while repelling others (Bakali et al., 2008).

The pharmacological properties of these compounds—including antibacterial, antioxidant, anti-inflammatory, anticancer, and immunomodulatory effects—are being comprehensively investigated in modern scientific research (Ahmad et al., 2023).

Prangos acaulis is a perennial plant species belonging to the Apiaceae family and is mainly distributed in mountainous regions. This species is widely found in Central Asian territories, including Iran, and possesses valuable medicinal properties that are utilized in the preparation of various pharmaceutical products (Latif et al., 2025). In the Azerbaijani language, the plant is known as *Chashir*. In traditional medicine, it has been used for its antifungal, antioxidant, and antibacterial effects, as well as for the inhibition of cytokine release, anti-HIV activity, and for tonic, carminative (anti-flatulent), and anthelmintic purposes (Meshkatalsadat & Hadavand, 2007).

Studies indicate that the chitosan-based nanoformulation of the methanolic extract of *Prangos acaulis* significantly enhances cytotoxic activity against HT-29 and MCF-7 cell lines, with these effects observed at lower concentrations compared to the free extract (Latif et al., 2025). In addition, in other studies, the antibacterial and antibiofilm activities of methanolic extracts of *P. acaulis* have been evaluated, and their potential mutagenic effects have also been investigated. The results obtained demonstrated that the extracts—particularly the root extract—exhibited significant antibacterial activity against the planktonic (single-cell) form of *S. mutans*. Furthermore, it was determined that all extracts inhibited biofilm formation in a dose-dependent manner and exhibited no mutagenic effects. Based on the results of *in silico* analyses, the compounds ar-curcumene, *d*-limonene, and α-pinene were identified as promising candidates for preventing the formation and development of *S. mutans* biofilms. In this regard, *P. acaulis* and its derived products may be considered potential candidates for the development of new pharmaceutical agents (Nosrati et al., 2018). At the same time, GC/MS analyses have revealed that the plant possesses a chemically rich composition in terms of essential oils (Meshkatalsadat et al., 2010). It is worth noting that methanolic extracts obtained from different parts of *Chashir* (*P. acaulis*) have a positive effect on lymphocyte proliferation, and considering the absence of mutagenic (genetic alteration–inducing) effects, this plant may be used as a safe medicinal herb in patients with immunodeficiency (Nosrati & Behbahani, 2015).

Although plants belonging to the genus *Prangos* attract considerable attention due to their rich phytochemical composition and diverse biological activities, systematic review studies summarizing the available scientific data on this genus remain limited. Existing research indicates that the principal secondary metabolites of *Prangos* species are coumarin derivatives, particularly furocoumarins. The potential phototoxic and carcinogenic effects of these compounds highlight the importance of their qualitative and quantitative evaluation. In this context, summarizing the available scientific data on the phytochemical profile, bioactive properties, and traditional uses of the genus may contribute both to a better understanding of the observed biological effects and to the identification of future research directions (Mottaghipisheh et al., 2020).

In this review article, the phytochemical and pharmacological properties of *Prangos acaulis* are summarized within the context of studies conducted on plants belonging to the genus *Prangos*. The main objective of the article is to comprehensively evaluate the therapeutic potential of this species by integrating the available scientific data.

Methods

This review article is based on a comprehensive analysis of the relevant scientific literature. The primary source for the literature search was the Google Scholar database. During the search process, keywords such as *Prangos acaulis* (D.C.) Bornm., biologically active compounds, pharmacological activity, therapeutic potential, and other related terms were used. Primarily peer-reviewed scientific articles published in English were included in the analysis. Data were collected from reliable sources addressing the chemical composition, biological activity, and potential therapeutic effects of the plant.

Botanical and ethnobotanical information

Prangos acaulis is a perennial herbaceous plant covered with dense, short, grayish hairs. The petals are bearded on the outer surface. The stem leaves are small, while the leaves are glabrous or slightly elongated, measuring 8–13 mm in length. The umbels have 5–6 rays. The fruits are elongated and broad, measuring 12–18 mm in length. The flowers of the central umbel sometimes do not produce fruits. The plant reaches a height of 15–40 cm. Flowering occurs in April–May, while fruiting takes place in May–June. It is a xerophytic plant. It is distributed in plains and low mountainous areas, occurring on gypsum- and clay-rich soils as well as in dry ravines (Alikhanova, 2022). The young shoots and leaves have been found to contain 60 mg/% ascorbic acid, 15.03–16.95 mg/% monosaccharides, 2.94–4.01 mg/% sucrose, 14–22.02 mg/% cellulose, various protein compounds, and 0.7–5.02 mg/% lipids. The plant is included in the Red Book (Red Data Book). In Azerbaijan, the species is mainly found in the Nakhchivan Plain and the mountainous regions of Nakhchivan, and is most frequently observed in the Unuschay Valley, the Yeddibulag area, and the foothills of the

Soyutdag and Horkhart ranges (Gasimov et al., 2018). Globally, it is widely distributed from Iran to India and is also found in Turkey. In traditional medicine, it has been used as an emollient, carminative, and anti-flatulent agent (Meshkatalsadat et al., 2010).

Phytochemical composition

Phytochemical investigations have shown that *Prangos acaulis* (D.C.) Bornm. is rich in a variety of biologically active compounds. Studies have demonstrated that the essential oils obtained from the stems, leaves, and flowers of the plant possess a rich and diverse chemical composition. Specifically, in the essential oil obtained from the stem, 3-ethylidene-2-methyl-1-hexen-4-yne was the predominant component, accounting for 56.8% of the total composition. In the essential oil extracted from the leaves, the major constituents were α-pinene (39.54%), 3-ethylidene-2-methyl-1-hexen-4-yne (37.94%), and α-terpinene (10.9%). In the essential oil obtained from the flowers, the principal components were identified as α-pinene (35.4%), 3-ethylidene-2-methyl-1-hexen-4-yne (23.51%), α-terpinene (17.26%), and limonene (13.64%). GC–FID analysis of the essential oil was performed using a gas chromatograph manufactured by Thermoquest-Finnigan. These results indicate that the essential oils obtained from different organs of *Prangos acaulis* differ in their chemical composition and are rich in compounds with high biological activity (Meshkatalsadat et al., 2007).

Although the available information on *Prangos acaulis* is not limited, it remains incomplete. For example, data on the essential oil composition of the plant have been reported, and information on several other characteristics has also been provided. However, similar to other medicinal plants, *P. acaulis* may be rich in certain microelements, the types and quantities of which have not yet been sufficiently clarified. Likewise, the main groups of bioactive compounds—particularly flavonoids—still require further investigation. Therefore, an accurate evaluation of the biological and pharmacological effects of the plant, as well as a more in-depth characterization of its phytochemical profile, remains an important and necessary area of research.

Biological activity and pharmacological properties

Available scientific studies conducted on *Prangos acaulis* indicate that the plant may exhibit various biological activities, which have been primarily evaluated based on *in vitro* analyses carried out under laboratory conditions. The therapeutic effects of many medicinal plants and vegetables widely used in traditional medicine are largely associated with their phenolic composition and antioxidant compounds. Polyphenolic compounds are defined as substances possessing one or more aromatic rings with hydroxyl groups and are reported to neutralize oxygen-derived free radicals by donating hydrogen atoms or electrons. Studies have identified the antioxidant activity of *Prangos ferulacea*, a species within the genus *Prangos* (Goruh et al., 2007). The rich chemical composition of *Prangos acaulis* suggests that this species may also possess potential antioxidant activity. However, due to the limited number of available scientific studies, drawing a definitive conclusion regarding this property is not considered appropriate at the present stage.

Although studies on the antimicrobial activity of the plant are limited, the available scientific evidence demonstrates that it exhibits a certain degree of antimicrobial effect against microorganisms. In one study, an extract obtained from *P. acaulis* was combined with chitosan-based nanoparticles and was found to exhibit antimicrobial activity against several bacterial strains. Although the plant extract was the primary active component in this analysis, the enhancement of the antimicrobial effect was attributed to the contribution of the nanoparticle system. To confirm the properties of the nanoparticles, analytical techniques such as FTIR, FE-SEM, DLS, and zeta potential measurements were employed (Nostari & Ranjbar, 2022). In another study, the effects of methanolic extracts obtained from the roots and leaves of *Prangos acaulis* against *Streptococcus mutans* were investigated. It was reported that the root extract, in particular, exhibited strong antibacterial and antibiofilm activities and showed effective interactions with glucosyltransferase enzymes. These findings suggest that the plant represents a promising natural candidate for the prevention of dental caries (Nosrati et al., 2018).

In cytotoxicity-related studies, the cytotoxic effects of a chitosan-based nanoformulation of the methanolic extract of *P. acaulis* against two cancer cell lines—HT-29 and MCF-7—were evaluated using the MTT assay. The results showed that loading the studied extract onto nanoparticles enhanced its efficacy and led to the manifestation of cytotoxic effects at lower concentrations compared to the free (non-nanoformulated) extract. Based on the obtained results, chitosan–extract nanoparticles (Chitosan-Extract-NPs) may be considered suitable candidates for more extensive *in vitro* and *in vivo* evaluation of their anticancer potential (Latif et al., 2025).

As noted above, the results of phytochemical and biological studies conducted on *Prangos acaulis* indicate that the plant is rich in essential oils. Moreover, its chemical composition is closely associated with the exhibition of certain biological activities. The plant possesses considerable biological potential, which is further supported by the results obtained from laboratory-based antioxidant, antimicrobial, and cytotoxicity studies. Nevertheless, the pharmacological properties of *Prangos acaulis*—namely, the mechanisms of action of these biological activities at the level of living organisms, as well as their efficacy and safety profiles—have not yet been sufficiently investigated. In particular, the need for systematic *in vivo* and pharmacological studies remains unresolved in order to determine dose–response relationships, assess potential toxicological risks, and therapeutically substantiate the obtained findings.

Discussion

As previously noted, earlier phytochemical and biological studies conducted on species belonging to the genus *Prangos* have confirmed that these plants possess significant potential in terms of essential oils and coumarin derivatives. The available scientific data on this genus are, undoubtedly, substantial. However, the species *Prangos acaulis* can be considered to have remained outside the scope of a large portion of these studies. Since its recognition has been largely limited to its essential oil composition, this alone is insufficient for a comprehensive understanding of the plant. Although flavonoids and various coumarin derivatives have been extensively identified in other *Prangos* species (Mottaghipisheh et al., 2020), this highlights even more clearly that these compounds have not yet been systematically investigated in *P. acaulis*. Moreover, the fact that most of the reported biological activities of *Prangos* species remain at the *in vitro* level and that their toxicological profiles have been scarcely studied clearly indicates that the use of plants from this genus in traditional medicine has not yet been scientifically substantiated. In other words, comprehensive phytochemical, pharmacological, and safety-oriented studies to be conducted on *Prangos acaulis* are considered essential both for clarifying the potential of this species and for accurately evaluating the overall biological and therapeutic significance of the genus *Prangos*.

Conclusion

In this review article, we have systematically summarized the available phytochemical, biological, and pharmacological studies on *Prangos acaulis*. It can be concluded that the chemical composition of the plant is predominantly rich in essential oils. It is also well established that essential oils obtained from different plant organs possess distinct chemical profiles. Although studies on biological activity indicate that *P. acaulis* exhibits certain biological effects, such as antioxidant, antimicrobial, and cytotoxic activities, it should be noted that these findings are largely based on a limited number of *in vitro* studies conducted under laboratory conditions.

It should be emphasized once again that the phytochemical profile of *Prangos acaulis*—particularly with respect to flavonoids, coumarins, phenolic compounds, and microelements—as well as its pharmacological mechanisms of action, safety, and toxicological characteristics, has not yet been sufficiently investigated. Future studies should focus on a more detailed characterization of the plant's chemical composition, comprehensive *in vivo* pharmacological and toxicological evaluations, and the establishment of a solid scientific basis for its potential therapeutic applications. In the context of the growing interest in naturally derived bioactive compounds and the search for alternative sources to existing pharmaceuticals, the scientific evaluation of insufficiently studied plants such as *Prangos acaulis* is of considerable relevance. It can be concluded that *Prangos acaulis* represents a promising source of bioactive compounds; however, more in-depth and systematic scientific evidence is required to support its practical application.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Study of High-Yielding, Environmentally Adapted Pome Fruit Varieties Resistant to Diseases and Pests in the Territory of the Nakhchivan Autonomous Republic

Arkinaz Rahimova

Abstract. *The article examines the distribution zones of apple and pear varieties identified in the Ordubad and Sharur districts, as well as varieties resistant to diseases and pests. Phenological observations were carried out on these forms starting from the flowering phase, and the development dynamics of their shoots and fruits were measured every ten days with corresponding records taken. Meeting the growing demand of our population for various fruit products has always been a priority. This requires further expansion of orchards, selection and placement of productive and promising varieties, and their propagation. Therefore, we set out to study local and introduced fruit varieties cultivated in the Nakhchivan Autonomous Republic, their distribution across different districts and zones, and to determine which varieties are more productive under the specific climatic and soil conditions of the autonomous republic.*
Scientifically based selection of local and introduced fruit varieties allows for increasing varietal diversity in agriculture and identifying genotypes with superior economic and quality characteristics. In particular, cultivation of varieties distinguished by high productivity, frost resistance, and resilience to major plant diseases can significantly enhance productivity in pome fruit orchards in the near future. Ultimately, this process contributes to ensuring sustainable agricultural production and partially meeting the increasing demand of the population for fresh fruits and fruit-based products.

Keywords: *pomological descriptions, selection, agrobiological characteristics, phenological observations, diseases and pests*

Introduction

The fulfillment of the growing demand of the population for food products and the creation of agricultural abundance in our country have currently gained broad momentum. The development of the agrarian economy of the republic and the establishment of intensive orchards are issues of state importance, requiring the creation of high-quality fruit varieties and an increase in productivity in agriculture.

In the Nakhchivan Autonomous Republic, apple and pear trees are more widely spread than other fruit crops. The main reason for this is that these fruits ripen at certain times, can be stored for a long period, and are consumed by the population throughout the year.

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Ecological fruit growing has a positive impact on the environment, can significantly improve public health, and strengthen the country's food security. These varieties and forms, which represent the living history of our people's fruit-growing culture, are productive, high-quality, resistant to diseases and pests, tolerant to drought, suitable for long-term storage, and have played an important role in the production of ecologically clean products. The production of ecologically pure fruits significantly affects public health, as they are grown without the use of synthetic pesticides and fertilizers, which reduces the risk of harmful substances entering the human body and contributes to overall health improvement. Apples and pears are widely cultivated in most regions of our republic. They are highly productive crops. In traditional orchards, productivity reaches 130–140 centners per hectare, while in intensive orchards it amounts to 300–450 centners per hectare (Talibov & Bayramov, 2013, pp. 154–156).

In the independent Republic of Azerbaijan, alongside the application of high-intensity technologies to increase overall fruit production in farms and agriculture, the establishment of new intensive-type orchards with high productivity, resistance to diseases, pests, and frost—especially spring frosts—and adaptation to soil and climatic conditions has been set as an important objective (Bayramov, 2013, p. 9).

The creation of new productive, early-yielding, compact-canopy, disease- and pest-resistant intensive orchards is one of the key issues in the development of fruit growing and increasing fruit production (Bayramov, 2019, pp. 24–25).

Unlike other regions of the Republic of Azerbaijan, the territory of the Nakhchivan Autonomous Republic is highly favorable for the cultivation of fruit crops and obtaining high-quality abundant yields. Among fruit crops cultivated in the autonomous republic, the apple occupies the first place among pome fruits and constitutes the majority of them. Wild forms of apple are found in the forests of Bichanak and Nasirvaz. Among cultivated forms, summer, autumn, and winter apple varieties are mostly grown in foothill zones. Summer varieties are cultivated more widely, while winter varieties are less common (Talibov & Bayramov, 2013, p. 154).

To successfully accomplish the tasks set in this field, it is first necessary to select highly productive varieties suitable for the natural-economic conditions of each fruit-growing region, including different zones of our autonomous republic, and widely introduce them into production. From this perspective, identifying and propagating ancient but still insufficiently widespread local apple and pear varieties, as well as developing more productive varieties for farms, is of great practical importance for the successful implementation of the national food program currently being pursued in our republic.

The main purpose of fruit and berry cultivation is to obtain products containing valuable and essential substances necessary for human nutrition, normal growth, and development. In addition to fresh consumption during the fruit season, dried fruits, jams, marmalade, preserves, juices, and other products are used throughout the year. One kilogram of whole milk contains 580–640 calories, while one kilogram of apples produces 440–556 calories, which corresponds to approximately 4/3 of the caloric value of milk (Hasanov, 2000, p. 93).

The results of scientific research indicate that by propagating and expanding the cultivation of these recommended varieties over large areas, the demand of the population of the autonomous republic for high-quality apples can be met in the future. This will also improve the financial income of farming enterprises. The brown, gray-brown, gray-forest, and meadow-steppe soils existing in the Nakhchivan zone ensure the long-term effective cultivation of the recommended apple varieties (Hasanov, 2000, p. 93).

The main objective is to identify apple varieties and forms in the territory of the Nakhchivan Autonomous Republic, to propagate endangered local varieties, study their agrobiological characteristics, and provide pomological descriptions in order to recommend promising varieties to farmers and private households. For this purpose, along with the application of high-intensity technologies in farms to increase overall fruit production, the development of new high-quality, high-yielding, disease- and pest-resistant, frost-resistant—especially to spring frosts—intensive apple varieties adapted to local soil and climatic conditions has been set as an important task (Bayramov, 2017, p. 9).

Research Objective
Our objective was to select productive, high-quality varieties adapted to local soil and climatic conditions that are resistant to diseases and pests, and to recommend them to farmers and private households. The Nakhchivan Autonomous Republic has long been renowned for its high-quality and diverse fruit varieties. Through traditional folk selection, numerous pome, stone, nut, and other fruit varieties have been developed, which, in terms of taste, aroma, and other characteristics, are not only comparable to varieties grown in other regions but in many cases even superior to them (Nasir, 1995, pp. 140–141). The purpose of studying these varieties is to identify ancient, highly productive, frost-, disease-, and pest-resistant pome fruit varieties and, by examining their biological and economic characteristics, to recommend the best of them for agricultural production (Hasanov, 2000, p. 93).

Materials and Methods

In carrying out the research work, generally accepted methods in fruit growing were used, including the methodology of the All-Union Scientific Research Institute named after I.V. Michurin (pp. 93–124); I. N. Beideman's "Methodology for Studying the Phenology of Plants and Plant Communities" (pp. 120–136); Z. M. Hasanov's "Fruit Growing" (Laboratory-Practicum) (pp. 12–13); as well as methods for studying the agrobiological characteristics of varieties. Based on these, a study was conducted on the biological characteristics of aboriginal apple varieties cultivated under the conditions of the Nakhchivan Autonomous Republic. For this purpose, research work was initiated in apple orchards in the Sharur and Ordubad districts using the accepted methodology.

The development of the republic's agrarian economy, improvement of food security for the population, and establishment of intensive orchards are issues of state importance, requiring the creation of high-quality fruit varieties and an increase in productivity in agriculture. During the research year, phenological observations were carried out. For this purpose, the calendar timing of the same developmental phases was recorded annually; the periods of flower and leaf formation, flowering stages (beginning, mass flowering, end), fruit ripening time, and the period of leaf fall (from beginning to end) were studied and documented. Highly productive, frost-, disease-, and pest-resistant pome fruit varieties cultivated in the territories of Ordubad and Sharur districts were studied. In addition, several other varieties such as Autumn Apple, Winter Apple, Summer Pear, Juicy Pear, Winter Pear, Sour Pear, and others were identified by us and included in the study.

Depending on climatic conditions, apple varieties were less affected by diseases and pests this year. In cultivated agriculture, agro-technical measures such as deep plowing, cultivation, winter irrigation, crop rotation schemes, row and plant spacing management, sowing or planting timing, fertilization, optimal harvesting period, and selection and application of resistant varieties prevent the spread and development of diseases. Along with all agro-technical measures, timely and effective control against pests, diseases, and weeds is of great importance for obtaining high and quality yields. Thus, to produce plant products free from pesticides, it is necessary to use agro-technical and biological control methods to the maximum extent possible against harmful organisms (pests, diseases, and weeds).

Plants with a long period of relative dormancy are more frost-resistant. Under favorable conditions in autumn, as plant tissues harden, frost resistance develops. During this process, plant tissues transition from one physiological state to another, which increases their frost tolerance. The main reason for frost damage in pome fruit plants is the formation of ice in their tissues. The formed ice exerts pressure on the protoplasm, dehydrates it, damages the cell membrane, and destroys cells. Roots located near the soil surface are less resistant to frost. Depending on the species, the above-ground part of the apple tree can withstand frost down to −32.5 °C during the relative dormancy period, while its roots can tolerate only −7 to −12 °C. Once vegetation begins, roots can freeze at −3 °C.

Results

As a result of the conducted research, the following findings were determined. The apple tree is mainly cultivated in foothill and mountainous areas. It was observed that apple varieties grown in these zones are resistant to frost as well as to diseases and pests. In mountainous regions, the cultivation of high-quality winter apple varieties is favorable. The fruits of apple varieties grown in mountainous zones can be stored for a long time and maintain good quality. The pear tree is mainly cultivated in foothill and lowland areas. It was observed that pear varieties grown in these zones are resistant to frost as well as to diseases and pests. The frost resistance of the studied apple varieties depends on the origin of the variety and the environmental conditions of the region. Local apple varieties cultivated in Nakhchivan are not only of high quality but also frost-resistant. In apple flowers, stamens are frost-resistant, whereas pistils are frost-sensitive and perish at −2 to −3 °C.

The conducted studies revealed that warm and humid weather in spring and early summer creates favorable conditions for the spread of powdery mildew. Infection of leaves and shoots by fungal pathogens was observed repeatedly throughout the vegetation period. Seasonal diseases were monitored several times during the growing season and recorded accordingly. In apples, scab and fruit rot (moniliosis), as well as powdery mildew on fruits, flowers, leaves, and shoots were studied. In apples and pears, observations of scab disease were conducted from its initial appearance until harvest. The infection level of fruits by scab was assessed several times on 10 selected trees per variety. Collected fruits were analyzed according to a scale, and the percentage of infection was calculated (Khalilova et al., 2017, pp. 133, 194).

To prevent diseases, it is necessary to thoroughly study the biological characteristics of their pathogens and implement a comprehensive control system. The control measures should be adapted to local conditions and carried out according to a planned program. Ordubad district has long been famous for its high-quality and diverse fruit species and varieties. Through folk selection, hundreds of rare pome, stone, and nut fruit varieties have been developed here.

A. X. Rollov (1896) noted that fruit growing had been practiced in Nakhchivan since ancient times and highlighted the presence of valuable fruit varieties in the region. He documented the diversity of major fruit crops cultivated in Nakhchivan, among which apples were the most numerous. In the Nakhchivan Autonomous Republic, the highest number of productive, frost-, disease-, and pest-resistant pome and stone fruit varieties is concentrated in Ordubad district. Among them are cherry plum varieties such as Yaz Malasi, Yay Malasi, Rajabi, Qirmizi Alcha, Tabarza, Goycha, cherry, Novras, Gilanar, Ganza, Dirnis, Kulus; apple varieties such as Misri Alma, Qizil Alma, Abrash Alma; pear varieties such as Dagh Armudu, Chil-Chil Armudu, Qirmizi Yanaq Armudu; and quince varieties such as Sari Heyva, Malayi Heyva, Vezri Heyva, Novras Heyva, among others.

In the Nakhchivan Autonomous Republic, apple orchards constitute approximately 50% of all fruit orchards. The main reasons for this are the high quality of apples, their different ripening periods, and their long storage capacity. Winter apple varieties are considered especially valuable. Although autumn and winter apple varieties are less widespread, the demand for them among the population is high. Apple trees are mainly cultivated in foothill and mountainous zones, where they demonstrate resistance to frost, diseases, and pests. Therefore, it is appropriate to expand apple cultivation in the mountainous and foothill villages of the Nakhchivan Autonomous Republic. To increase the production of apple and pear varieties with different ripening periods, it is planned to propagate these varieties through grafting in Sharur and Ordubad districts and distribute them to farms.

Discussion

Our objective was to select local apple and pear varieties adapted to the soil and climatic conditions of Ordubad and Sharur districts, resistant to diseases and pests, to use them in breeding programs, propagate promising varieties and forms, and recommend them for cultivation in farming enterprises. Based on the research conducted in apple orchards in Ordubad and Sharur districts, the following results were obtained:

The Nakhchivan Autonomous Republic, being a fruit-growing region characterized by rich diversity of local and introduced apple and pear varieties and favorable soil and climatic conditions, has significant potential for further development of fruit growing. As a result of the study, 2 apple varieties and 3 pear varieties were identified. The apple varieties Autumn Apple and Winter Apple, as well as pear varieties Summer Pear, Juicy Pear, and Sour Pear, were found to be productive and resistant to diseases and pests. Although summer-ripening local pear varieties are less widespread, their demand is high. Therefore, their cultivation in lowland zones is also necessary.

The recommended apple varieties are resistant to disease and pest pathogens and meet the requirements of the market economy in terms of productivity and fruit quality. It is recommended to expand the area of apple and pear orchards in the Nakhchivan Autonomous Republic by using advanced cultivation technologies and high-yielding varieties.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Investigation of the Anaerobic Fermentation Process of Organic Waste

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Abstract. *Reactors used in the anaerobic fermentation of carbon-containing waste (agricultural, sewage sludge, livestock, etc.) for biogas production have been studied. Various designs of equipment intended for the production of biogas and bio-organic fertilizers through the anaerobic fermentation of waste have been proposed. The advantage of anaerobic fermentation in such reactors lies in the fact that, unlike classical aerobic biological treatment methods, all bacteria function under the same conditions in properly organized anaerobic systems. Bacteria operate under diverse physical and chemical conditions. This allows for the optimization, control, and ultimately improvement of the quality of waste treatment. Equations have been derived to determine biogas productivity based on the proposed biogas systems. From this perspective, the calculation of the biogas plant and the yield of biogas depend empirically on the design and technical parameters of the system. The paper studies the design and technological features of biogas production units for anaerobic fermentation of organic waste. A classification of biogas production technologies and biomass mixing methods is proposed. The types of mixing devices in the chemical industry are considered and the distribution of medium flows during their operation is described. It is established that a promising direction for improving mixing systems in biogas plants is the combination of mechanical and bubbling types of mixing.*

Keywords: *bioreactor, fermentation, biogas, methanotank, organic waste*

Introduction

It is well known that the main element of any technological scheme is the device in which the process takes place – namely, the reactor (Aghayev, 2019). The anaerobic fermentation process of organic waste is carried out in bioreactors, and the output parameters of the process depend primarily on the design that ensures the required technological modes (Huang, 2007). The construction of the bioreactor must prevent the formation of scum, provide complete mixing of the reaction mass, a rational heating system, and continuous operation. Furthermore, the design should not complicate its manufacturing or maintenance. Numerous patents related to bioreactors for anaerobic fermentation processes are available in the literature. Many bioreactors are equipped with mechanical stirrers and heating systems (Gaifullin, 2024; Obono, 2022). It should be noted that these types of reactors have some significant drawbacks. The presence of shaft seals can compromise the hermeticity of the bioreactor, while sludge sticking to the surface of heaters reduces their heat transfer efficiency (Mehraliyev, 2014; Patent AZ I 2007).

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The formation of scum on the surface of the substrate reduces biogas production, and large scum fragments can clog the outlet pipes. Sediment accumulation at the bottom of the bioreactor, where there is no movement, is also among these deficiencies. In general, these bioreactors have complex designs and thus require complex technological and maintenance mechanisms (Bilge, 2012; Obono Mba, 2022). Bioreactors with a dome-shaped lid and a cylindrical body with a conical bottom also exist. These are equipped with inlet/outlet pipes for substrate loading, product and gas discharge, and a circulation line. In such bioreactors, the gas holder and methanotank are integrated into a single body, which contributes to certain functional drawbacks. In the methanotank, fresh organic matter is added to the fermenting mass and mixed (Muradov, 2024).

Thus, the decomposition of organic waste mainly involves the following reactions: hydrolysis process (sugar, amino acids, fatty acids), oxidation phase (C_x – C_6 carbon/fatty acids, C_5 valeric CH_3-CH_2CH_2-CH_2-COOH, C_4 fatty CH_3-CH_2-CH_2-COOH, C_3 propionic CH_3-CH_2-COOH), acid formation (C_2 acetic acid CH_3 – COOH, C_1 formic acid HCOOH) and methane (methane CH_4, carbon dioxide CO_2, H_2O, H_2S, N_2). Based on these, gas is ultimately formed by the following reactions:
1) $C + CO_2 = 2CO$;
2) $C + H_2O$ (g) $= CO + H_2$;
3) $C + 2H_2O$ (g) $= CO_2+2H_2$;
4) $C + 2H_2 = CH_4$;
5) $CO + H_2O$ (g) $= CO_2 + H_2$;
6) $CO + 3H_2 = CH_4 + H_2O$ (g).
In this regard, bioreactors should ensure the implementation of the indicated processes. This weakens the action of hydrolytic microorganisms in the first phase of anaerobic fermentation and worsens the operating conditions for methane-producing bacteria in the second phase. Moreover, the presence of a circular water compartment around the methanotank body – used for the hydraulic seal of the rising bell-type gas holder – complicates the manufacturing and maintenance of the bioreactor. Thus, based on the aforementioned, it can be concluded that the efficiency of anaerobic fermentation processes largely depends on the design of the reactor, i.e., the bioreactor. For this reason, this study focuses on the development of new bioreactor constructions that eliminate the above-mentioned deficiencies and improve performance. In this type of biogas plant, the production of methane occurs under anaerobic conditions. These reactions can be represented as follows:
1. *Methane formation reaction:*
$CH_3COOH \rightarrow CH_4+CO_2$
2. *Hydrogen reduction:*
$CO_2+4H_2 \rightarrow CH_4+2H_2O$
Two new bioreactor constructions for the anaerobic fermentation process have been developed (Gaisina, 2022; Osmonov, 2011). One of the most important areas of development of the national economy of the Azerbaijan Republic is the technological modernization of systems and equipment of chemical and related industries. In this case, further development of theoretical description of processes and devices of various industries plays an important role. Recently, much attention has been paid to the study of biotechnological processes and the development of equipment for their implementation. One of these processes is the process of obtaining biogas as a result of anaerobic fermentation of organic waste (Patent, 2007).

Materials and Methods

Bioreactor with an External Circulation Collector
The bioreactor consists of a cylindrical body with a conical bottom and a lid, pipes for substrate feeding, gas removal, and discharge of the target product (Pristupa, 2007). It also includes a circulation system. According to the research, a circular collector is placed in the upper part of the reactor, connected to the body through pipes mounted at different angles relative to the reference line touching the seating point. Additionally, a Z-shaped collector is installed in the conical bottom

section, directed toward the base of the reactor (Kuznetsova, 2013). The design of these collectors and the placement of inlet systems are engineered such that the flow during circulation breaks up the top layer of the substrate, effectively preventing scum formation. Periodic circulation ensures uniform temperature distribution throughout the bioreactor's volume and accelerates the fermentation process through effective mixing. The downward-directed flows from the lower collector periodically flush out the sediment that accumulates at the bottom of the reactor. The schematic diagram of the bioreactor, as well as diagrams of its individual components, are presented in Figures 1–4. The general view of the bioreactor with relevant connections is shown in Figure 1. It consists of the main body (1), the collector (2), and the circulation system. Pipes (3) and (4) are designated for substrate loading and discharge, respectively.

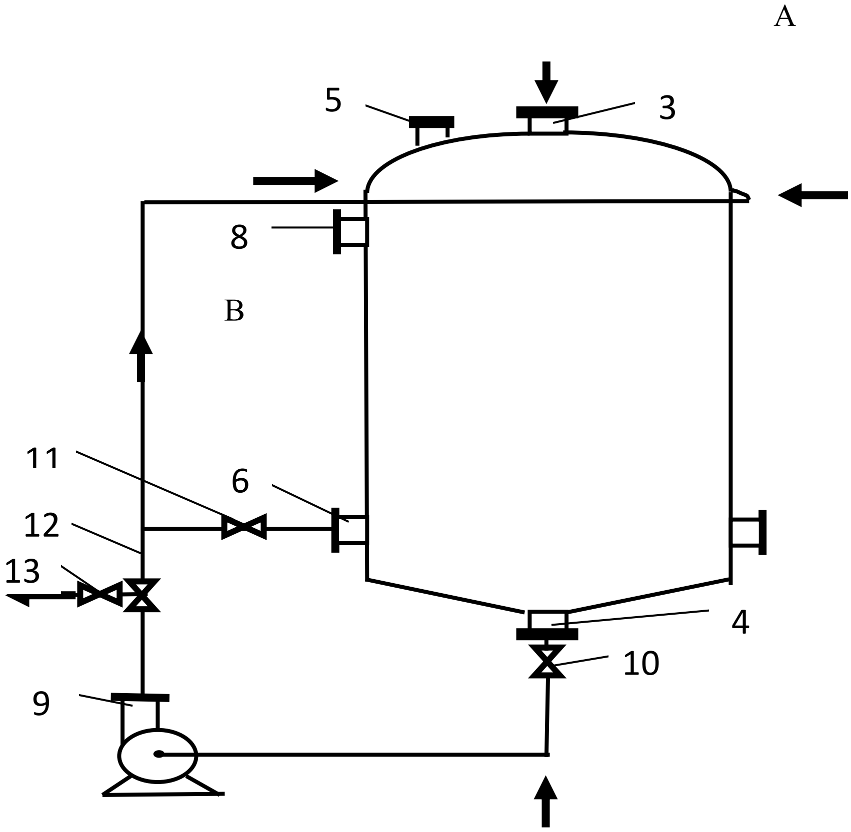

Figure 1. General External View of the Bioreactor

1 – Body; 2 – Collector; 3, 4, 5, and 6 – Branch Pipes; 7, 8 – Tubes; 9 – Circulation Pump; 10, 11, 12, 13 – Valves

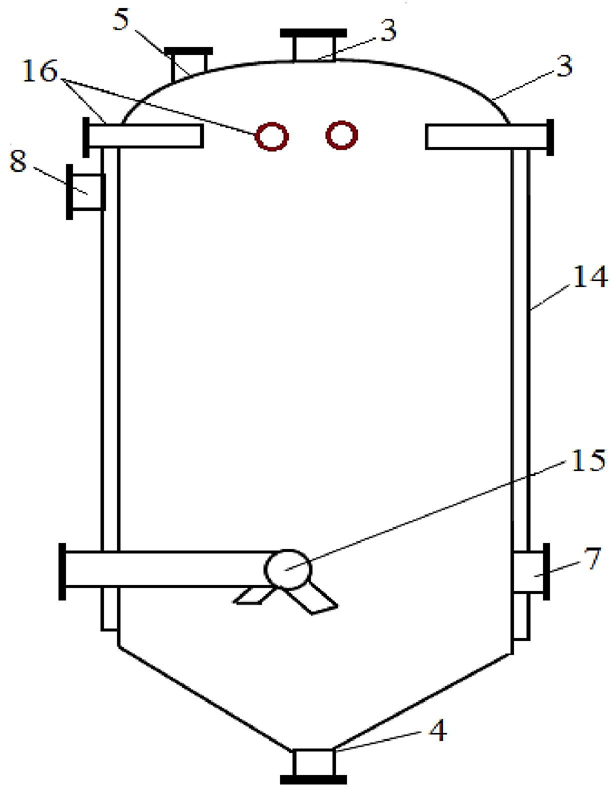

Figure 2. General Sectional View of the Bioreactor

1 – Body; 2 – Collector; 3, 4, 5, and 6 – Branch Pipes; 7, 8 – Tubes; 9 – Circulation Pump; 10, 11, 12, 13 – Valves; 14 – Thermal Jacket; 15 – Z-shaped Collector; 16 – Tubes

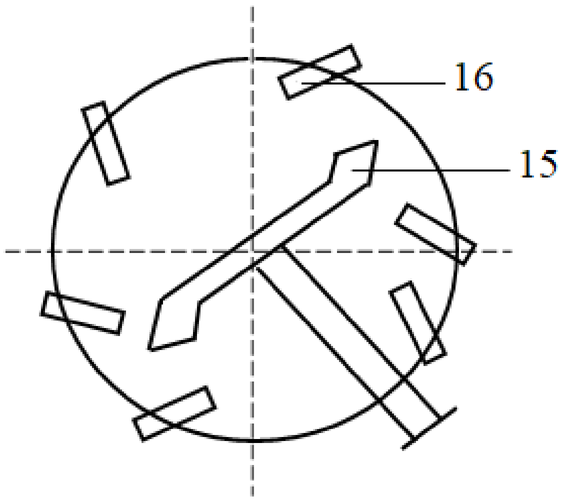

Figure 3. Top Sectional View of the Bioreactor

15 – Z-shaped Collector; 16 – Tubes

The biogas plant works as follows. Organic waste (manure, litter, straw, etc.) is fed through a pipe into a methane tank, where it is fermented to produce biogas and high-quality biofertilizer. A bimetallic temperature sensor signals a change in temperature. Fermentation can occur in psychophilic (5-25°C), mesophilic (27-40 °C) and thermophilic (44-60 °C) temperature modes. The substrate is heated by passing the biogas through vortex tubes. The pressure in the methane tank is controlled by an electric contact pressure gauge. The biogas obtained in the methane tank is sent through a pipeline via a condensate drain to the biogas purification filter, where harmful impurities are removed, and then sent through a pipeline to the compressor. To ensure a uniform temperature in the methane tank and prevent the formation of a crust under the dome, which prevents the release of biogas, the compressor is turned on for two minutes every four hours. To do this, the valve is opened, and the biogas in the compressor is fed into the vortex tube under pressure. This causes a large difference in the temperatures of the gas passing through the vortex tube, since the cold biogas from the cavity enters the gas holder, which has a lower ambient temperature, and is then sent to the consumer.

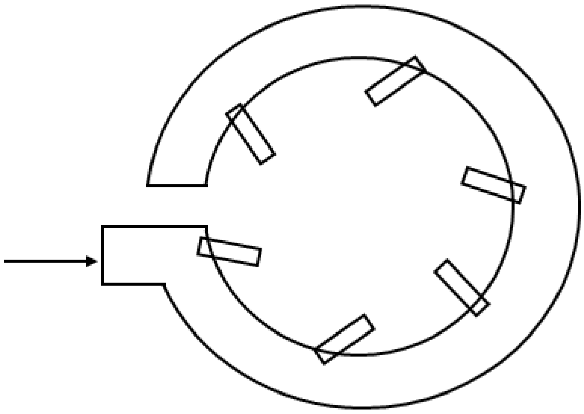

Figure 4. General View of the External Distribution Collector

Pipes 5 and 6 are intended for biogas extraction and for directing the flow into the lower internal collector. The circulation of the reaction mass and the discharge of the fermented mixture are carried out via pump 9. Valves 10, 11, 12, and 13 are designated for flow direction during circulation and discharge operations. The sectional views A-A and B-B of the bioreactor are shown in Figures 2 and 3. Six tubes are positioned at various angles along the perimeter of the bioreactor body and are connected to the external circular collector. The angles at which the tubes are mounted on the body are determined relative to the tangents drawn at those points. The bioreactor is equipped with thermal jacket 14 and a special Z-shaped collector 15. The upper circular collector 2, as shown in the top view (Figure 4), is designed to distribute the flow into tubes 16 during circulation. The view of the lower collector is presented in Figure 5. It has a Z-shaped configuration, with its ends directed downward toward the bottom of the bioreactor. This collector is designed to agitate and remove the sediment accumulated at the bottom section. The operation of the described bioreactor is carried out as follows (Sadigov, 2025). Flow technology was previously used to feed most biogas plants. It involves feeding a certain amount of fresh substrate into the reactor, while simultaneously moving the already fermented residue into a specially designed storage facility. It can be moved into the storage facility by displacement or by selection from the reactor in one of the ways. With this loading technology, the reactor always remains filled and is emptied only for inspection and regular repair work (Hardi, 2025; Yu, 2013).

Results and Discussion

As a result of anaerobic digestion, the main part of biodegradable organic matter is decomposed (oxidized) into CO_2, H_2O and NH_3 (Ziganshin, 2013; Yu, 2023). The remaining organic matter loses its tendency to be processed. Four groups of bacteria participate in anaerobic digestion, mainly *Bacillus, Micrococcus, Pseudomonas* and *Clostridium*, which carry out the stages of enzymatic hydrolysis and acid formation. Microorganisms secrete enzymes, breaking down complex compounds into simple ones (Hasanova, 2021; Nasirova, 2022). Bacteria grow in the presence of a nutrient medium containing carbon and oxygen. The results of many scientists' studies show that a stable fermentation temperature is important for the successful methane production process, and temperature changes affect not only the speed of the process, but also the quantitative composition of the resulting products. The thermophilic mode (50-55 °C) is most applicable in practice. In Azerbaijan, due to difficult climatic conditions, the medium temperature mode (33-35 °C) is mainly used, which is not energy-consuming for biogas plants.

Operation and Structure of the Internal Circulation Collector Bioreactor

After the diluted (substrate) waste is loaded into the bioreactor through pipe 3 to the required volume, a heat carrier (steam or hot water) is supplied to the thermal jacket of the bioreactor. Once the desired temperature regime is established, the circulation pump (9) is activated. At this stage, valves 10 and 12 are opened, while valves 11 and 13 remain closed. In this mode, the flow drawn from the bottom of the reactor enters the upper collector, is distributed into the pipes, and induces a rotational motion in the upper substrate layer, ensuring thorough mixing. If valves 10 and 12 are closed while 11 and 13 are opened, the flow is directed from pipe 6 into the lower collector and removes sediment from the bottom of the reactor. When valves 10 and 11 are open and valves 12 and 13 are closed, the fermented biomass is discharged from the reactor. The biogas generated during fermentation is directed to the gas holder via pipe 5.

Bioreactor with Internal Circulation Collector

The bioreactor consists of a cylindrical body with a dome-shaped cover and a conical bottom. It is equipped with inlet/outlet pipes for substrate loading, product and biogas removal, a gas collector, and a circulation line. At the upper internal part of the reactor, a distributor-mixer collector is installed, containing several pipes positioned at specific angles and distances from each other relative to the substrate surface. At the lower internal part, above the conical bottom, a segment-shaped heat exchanger is mounted, consisting of separate elements connected by pipes.

The structure of the distributor-mixer collector enables the circulation flow to moisten and disintegrate the surface of the substrate, activating both horizontal and vertical motion of the reaction mass and ensuring efficient mixing. This prevents scaling within the bioreactor and ensures uniform temperature distribution throughout the entire reaction volume. The heat exchanger at the bottom not only creates and maintains the temperature regime but also acts as a barrier, preventing large substrate particles and scale from entering the outlet pipelines.

The schematic diagram of the bioreactor and its individual components are shown in Figures 5 to 9. Figure 5 presents the general cross-sectional schematic of the bioreactor, which includes: the main body (1), heat exchanger (2), distributor-mixer collector (3), inlet and outlet pipes for substrate, biomass, and biogas (4, 5, 6), heat carrier inlet pipes (7, 8), circulation pump (9), and control valves (10, 11, 12). The substrate loading level is regulated by the overflow line (13). For maintenance purposes, an inspection hatch (14) is provided inside the bioreactor. To prevent heat loss, thermal insulation (15) is used. The heat exchanger layout is shown in figure 6, where two segmental distributors are connected by pipes 16 and 17. The distributor-mixer collector shown in figures 7 and 8 consists of the body (18) and multiple outlet pipes (19).

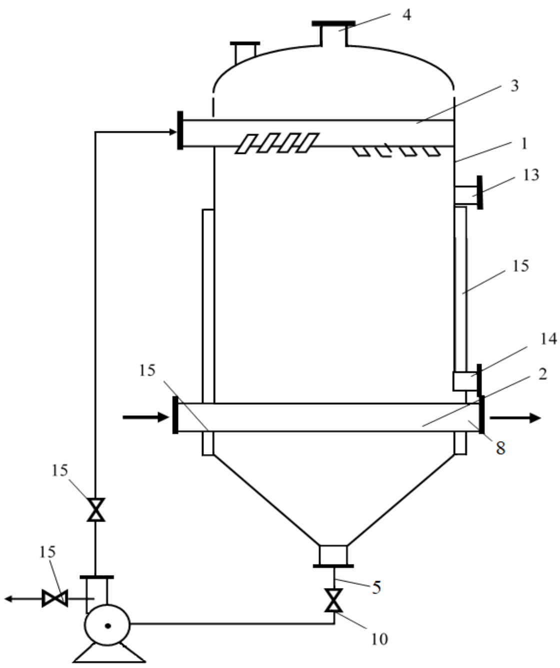

Figure 5. General Sectional View of the Bioreactor

1 – Body; 2 – Heat Exchanger; 3 – Distributor and Mixer Collector; 4, 5, 6, 7, 8, 13, 14 – Branch Pipes; 15 – Thermal Jacket; 10, 11, 12 – Valves; 9 – Circulation Pump

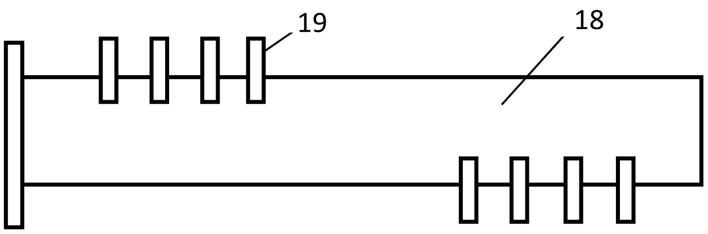

Figure 6. General View of the Distributor and Mixer Collector

18 – Body; 19 – Tubes

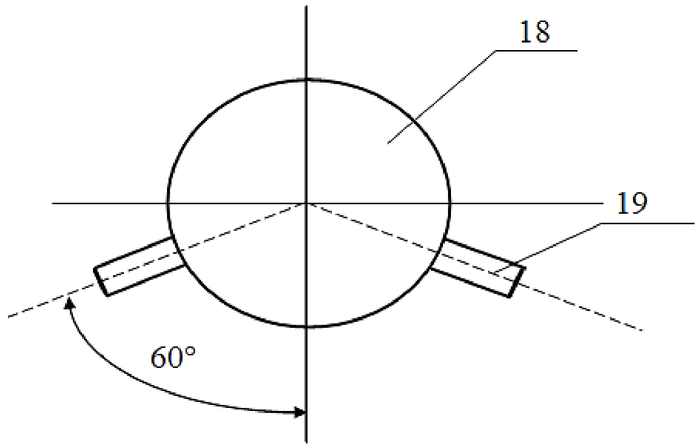

Figure 7. Scheme of the Connection of Tubes to the Body

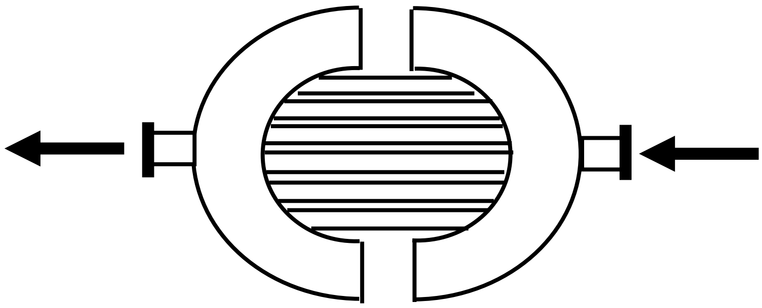

Figure 8. Top View of the Special Heat Exchanger

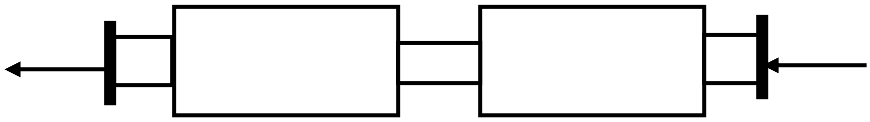

Figure 9. Side View of the Special Heat Exchanger

The tubes are connected to the body at specific angles and are directed in various directions relative to the radius of the bioreactor. The bioreactor operates as follows: The pre-prepared solution is loaded into the bioreactor through branch pipe number 4. After the bioreactor is filled to the required volume, steam or hot water is supplied to heat exchanger number 2, and circulation pump number 9 is activated. Circulation is carried out in a periodic mode. The circulation line is connected to the distributor and mixer collector number 3. During circulation, the solution taken from the lower heated zone of the bioreactor is directed into collector 3, and jets exiting the tubes under pressure strike the surface of the substrate, breaking it up and mixing it in both radial and vertical directions. Thus, complete mixing within the bioreactor volume and uniform temperature distribution are ensured.

The gas flow rate starts after filling, reaches maximum productivity in a few days, and then begins to decrease slowly. Finally, after the specified fermentation time has elapsed, the fermentation chamber is emptied in one go. In this case, part of the fermentation sludge is returned back to seed the next batch of substrate fed to the reactor. Constant flow rate for one reactor is not possible; it is possible to equalize the fluctuations in gas output by fermenting in several reactors with loading shifted in time.

The advantage of anaerobic methods is that, unlike classical aerobic methods of biological treatment, when all bacteria work under the same conditions, in properly organized anaerobic processes, bacteria are separated – they work under different physical and chemical conditions. This allows you to optimize the anaerobic digestion process in terms of productivity, manage it and, ultimately, improve the quality of waste processing.

Conclusion

As a result of a set of theoretical and experimental studies, the nature of the influence of biomass temperature on the efficiency of the anaerobic fermentation process in the mesophilic mode was established. A dependence of the growth rate of microorganisms on temperature was proposed and the values of the coefficients included in it were determined. The obtained dependencies allow one to determine the speed and specific yield of biogas and can be used in the design of industrial biogas complexes.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Study of the Dependence of the Chemical Composition and Nutritional Value of Sheep Feed Grown in the Western Zone of the Republic on Climatic Conditions

Sami Sadigov[1*], Raifa Mustafayeva[2], Aytan Agayeva[3], Rahila Farmanli[4], Gulshan Musayeva[5]

Abstract. *The article studies the dependence of the chemical composition and nutritional value of sheep feeds grown in the western zone of the republic on climatic conditions. The research work was carried out in various farms located in Samukh and Shamkir regions, in the laboratory of the "General and Special Zootechnics" department of the "Zoo Engineering" faculty of the Azerbaijan State Agrarian University. From the research work we conducted, it became clear that the water content of the feeds supplied to the Shamkir region breeding sheep farm is 1.3% higher than the water content of the feeds supplied to the comparable farm. In addition, it is considered more expedient to keep and breed sheep breeds suitable for the area where the farms are located. For this, it is necessary to fully provide these farms with a solid feed base, as well as improve the breed composition of the sheep.*

Keywords: *feeding, water, dry matter, protein, fat, cellulose, ash, alfalfa, grass, corn silage, fodder beet, barley grain*

Introduction

In order to obtain high-quality products and maintain normal physiological activities in sheep, they must receive sufficient, balanced, and nutrient-rich feed throughout the year. Proper feeding affects growth, reproductive efficiency, milk and meat quality, and overall productivity (Abdullayev, 2014). Studies indicate that optimized feeding strategies, including the appropriate balance of energy, protein, vitamins, and minerals, significantly improve growth performance and reduce stress-related metabolic disorders in sheep (Safari et al., 2020; Li et al., 2021; Sousa et al., 2022). Moreover, integrating farm-produced feeds with purchased feed resources ensures cost-efficiency and supports sustainable farm management.

Of all the environmental factors, feeding has the greatest impact on animal productivity, as the animal receives structural material for building tissues, energy and substances that regulate metabolism from feed. A good feed base is the main condition for the successful development of livestock farming. If animals do not receive the necessary amount of feed, even the most specialized mechanization cannot have any effect.

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In livestock farming, not only the quantity of feed, but also its quality is of great importance. Quality is determined by the nutrients in the feed (Abdullayev, 2022; Abdullayev, 2012). In modern times, the most important problem is the production of food products. The livestock sector plays a key role in solving this problem. In many countries, livestock farming is intensively and dynamically developed on the basis of new technologies and its productivity is increased. However, the provision of animal-based foods to the world's growing population remains a challenge. Population growth leads to an increase in demand for livestock products (Abbasov, 2011).

In our republic, along with other livestock sectors, one of the important sources of resources in increasing food products and solving the meat problem is sheep farming. Sheep farming has been developed by the people in Azerbaijan since ancient times and has been used effectively. Sheep farming plays an important role in meeting the demand for wool, leather, meat, and milk. Since the demand for sheep meat is high, sheep meat accounts for 40 or more percent of the meat balance. Valuable fabrics, carpets, and palazzos, etc. are made from sheep wool. Since sheep milk is rich in fat and protein, cheese made from it is very tasty and nutritious (Zeynalova, 2008).

In order to develop scientific, cultural and highly productive livestock farming in the republic, first of all, a solid feed base must be created, for this purpose, abundant and high-quality feed rich in nutrients must be produced intensively, the material and technical base of feed production must be strengthened, the structure of an effective feed base must be created, and fertilizers must be applied to increase the productivity of meadows and pastures, and measures must be taken to improve them superficially and fundamentally. In order to meet the demand for high-quality feed in livestock farming, a multidisciplinary feed base based on the foundations of advanced science must be created. Currently, the pace of development of livestock farming lags far behind the development of life's needs. Although there are many real facts here, the main reason is that livestock farming is provided with a balanced feed rich in nutrients (Zeynalov, 2005).

Animals produce only when the energy content of the nutrients entering the body exceeds the internal needs. The need for nutrients is actually spent on live weight, milk, wool growth and fetal development. In this regard, the need for nutrients depends on the quantity and quality of the product received. On the other hand, since the composition received is not constant, significant errors related to the age and physiological state of the animal must be taken into account. In order to determine these norms, first of all, the digestibility of nutrients during metabolism and the amount in the products received must be known (Durst, 2005).

Science and experience prove that livestock breeding will develop rapidly when feed production is fully adapted to its needs and feeding is strictly followed based on zoo technical rules. For this, the structure of forage crop fields should correspond to the structure of the herd and the direction of livestock production. One of the main ways to increase production efficiency in livestock breeding is not only to produce more feed, but also to feed animals based on correct zoo technical feed rations. Because full consideration of the needs for the amount and quality of feed digestibility in feeding is one of the main factors ensuring the normal course of physiological processes in animals and the production of livestock products (Tahirova, 2018).

Our republic has fertile soil, healthy climate, rich vegetation and diverse fauna. However, despite the presence of so many sheep breeds, the keeping, feeding and breeding of sheep in the places is carried out spontaneously without following zoo-veterinary rules. This, in turn, leads to the loss of the breed composition of sheep, the reduction of meat, milk, wool and other livestock products (Balakishiyev, 2009).

The great potential of sheep to adapt to various conditions of keeping and feeding is their most important feature. That is why it can be said that sheep have spread all over the world. Since sheep have variability and good adaptability, it has become possible to create new breeds and types and to breed them in different ecological zones. Despite the fact that domesticated sheep are exposed to sharp biological and physiological changes under the influence of various extreme ecological conditions, they have preserved and preserved their valuable species characteristics based on their ability to adapt to pasture conditions. They make good use of various pastures (Sadigov, 2022; Sadigov, 2024).

Farmers should pay attention to the rules of care, cleanliness, lighting and cleanliness of storage areas, heating in winter, and normal temperature in hot weather. All this leads to low and poor quality production. Mountain and foothill regions are of particular importance in the development of meat sheep in our republic. At the same time, farmers engaged in livestock breeding should keep animals adapted to local conditions at the expense of local opportunities (Tagiyev, 2023; Tagiyev, 2025).

Materials and Methods

Nutrition, along with heredity, is the most important condition for the formation of the animal organism. The animal organism is built up on the basis of the absorbed food, and it also performs its life functions with it. Therefore, the development of the animal depends on the quantity and quality of the food it receives throughout its life. It became clear from the research that the feed mixture, which consists of a mixture of raw materials, is more nutritious and increases productivity compared to the barley-wheat groats and bran that farmers usually use. By affecting productivity, more products can be obtained in a short period of time. The meat product produced in 8-9 months can be obtained in 3 months. If we compare the increase in the feeding of dairy and meat animals when using a mixture of enriched feeds, unlike feeding with ordinary feed, milk production increases starting from the 10th day of feeding, and fattening is intensified. From the research we conducted, it became clear that when fed with this feed, the animal becomes more eager (repeated eagerness is reduced to a minimum) and becomes healthier. It is less susceptible to parasitic diseases.

In order to organize the feeding of agricultural animals according to the norm, the chemical composition of the feeds used should be studied first of all. That is why the chemical composition of the feeds should be determined when compiling balanced feed rations. For this purpose, in order to conduct a research study, we studied the chemical composition of the feeds supplied in the private farms of the Samukh district and the private farms of the Samukh district, which are the leading sheep farms of the republic.

Results and Discussion

The chemical composition of the feeds supplied in the private farms of the Samukh district is given in Table 1 below (Table 1). As can be seen from Table 1, the content of alfalfa grass in the feed supplied to the Samukh district breeding sheep farms was 14.80% water, 85.20% dry matter, 78.33% organic matter, 14.35% water, 85.65% dry matter, 78.58% organic matter in meadow grass, 84.68% water, 15.31% dry matter, 14.21% organic matter in fodder beet, 13.25% water, 86.75% dry matter in barley grain.

Table 1.
Chemical composition of feed supplied to the Samukh district breeding sheep farms, %

Feeds	Water	Dry matter	Total	Organic substances				Ash
				protein	oil	cellulose	AEM	
Alfalfa grass	14.80	85.20	78.33	14.45	2.57	25.89	55.42	6.87
Meadow grass	14.35	85.65	78.58	8.36	2.13	26.19	60.26	8.71
Senazh	46.0	54.0	48.59	10.01	1.30	15.78	69.50	5.41
Corn silo	78.58	21.42	19.60	2.10	0.70	6.08	90.01	1.62
Fodder beet	84.68	15.31	14.21	1.49	0.11	1.01	97.00	1.11
Barley grain	13.25	86.75	83.67	10.49	1.88	4.31	82.7	3.06

Table 2 below shows the chemical composition of the feeds supplied to the Shamkir district breeding sheep farm.

Table 2.
Chemical composition of feeds supplied to the Shamkir district breeding sheep farms, %

Feeds	Water	Dry matter	Total	Organic substances				Ash
				protein	oil	cellulose	AEM	
Alfalfa grass	14.30	85.70	78.74	14.45	2.68	25.98	56.84	6.96
Meadow grass	13.85	86.15	77.05	8.5	2.16	26.45	62.89	9.0
Senazh	46.00	55.00	49.58	10.21	1.37	15.92	70.61	5.4
Corn silo	78.08	21.92	19.99	2.16	0.74	6.21	90.89	1.83
Fodder beet	84.08	15.92	14.35	1.56	0.14	1.08	97.28	1.16
Barley grain	13.04	86.96	88.81	10.69	1.92	4.48	82.93	3.15

As can be seen from Table 2, alfalfa grass, among the feeds supplied to the Shamkir district breeding sheep farm, contained 14.30% water, 85.70% dry matter, 78.74% organic matter, meadow grass contained 13.85% water, 86.15% dry matter, 77.05% organic matter, haylage contained 45.00% water, 55.00% dry matter, 49.58% organic matter, corn silage contained 78.08% water, 21.32% dry matter, 19.99% organic matter, fodder beet contained 64.08% water, 15.92% dry matter, 14.35% organic matter, barley grain contained 13.04% water, 86.96% dry matter, and 88.81% organic matter.

From the obtained indicators, it can be concluded that the water content of the feed supplied to the Shamkir district breeding sheep farm is 1.3% higher than the water content of the feed supplied to the comparable farm. Accordingly, the dry matter content of the feed supplied to the Shamkir district breeding sheep farm is 1.0% higher and the organic matter content is 2.4%.

Conclusion

As a result of our many years of scientific research, breeding selection work and experiments, it has been found that the diversity of the chemical composition of feeds is closely related to the natural and climatic conditions of the farms. In this regard, when conducting experiments on the feeding of farm animals in any zone, the chemical composition of the feeds supplied to that farm is first studied. It is necessary to avoid losses during the supply of feeds, as well as when feeding them to animals, and to use feeds efficiently. It is also advisable to use the capacity of existing feed shops and feed kitchens to the maximum extent.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Endemic and Relict Species Found in the Turyanchay State Nature Reserve

Rana Suleymanova

Abstract. *This article discusses the endemic and relict species that inhabit one of Azerbaijan's most important protected natural areas: the Turyanchay State Nature Reserve. The reserve's geographical location, natural conditions and rich biodiversity create favourable conditions for rare plant and animal species to flourish. Endemic species are unique to this territory and are of particular scientific and ecological importance, while relict species have survived from ancient geological periods to the present day. The article emphasises the importance of protecting these species and their role in maintaining ecological balance, as well as highlighting the significance of nature reserves in conservation efforts. Additionally, it briefly highlights the threats posed to these species by human activities. It also considers how nature conservation measures in the reserve contribute to ensuring the sustainability of ecosystems. In this regard, the Turyanchay State Nature Reserve plays a strategic role in preserving biological heritage.*

Keywords: *Turyanchay State Nature Reserve, endemic species, relict species, biodiversity, nature conservation, protected areas*

Introduction

Thanks to its unique geographical location and diverse climatic conditions, Azerbaijan has a rich biological diversity in the South Caucasus. The country's landscape comprises both mountains and lowlands, contributing to the formation of various species of plants and animals. Endemic and relict species are widespread, especially in mountainous areas, and are of great scientific and ecological importance. Endemic species are only found in certain areas, so preserving them is vital for maintaining biodiversity. Relict species, on the other hand, are creatures that have survived from ancient geological times to the present day, reflecting the historical continuity of ecosystems. The protected natural areas of Azerbaijan, particularly the state nature reserves, play a vital role in safeguarding biological diversity. The Turyanchay State Nature Reserve, which has been operating since 1958, is located on the southern slopes of the Greater Caucasus. The relief, climate and hydrography of the reserve have created favourable conditions for the development of rich flora and fauna. The territory contains both forest and mountain steppe landscapes, creating favourable conditions for various endemic and relict species to survive (Aliyev & Hasanov, 2018).

In recent years, anthropogenic influences and climate change have made it increasingly difficult to preserve these species, further emphasising the importance of reserves.

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As well as serving as shelters for rare and threatened species, reserves play an important role in maintaining ecological balance, protecting soil from erosion, and ensuring the sustainability of water resources.

The endemic and relict species living in the Turyanchay State Nature Reserve are brought to the attention of the reader, as are their role in the ecosystem, the protection measures in place, and the problems caused by anthropogenic effects. The Reserve is therefore of strategic importance in preserving biological diversity, contributing to the maintenance of a healthy natural heritage for future generations (Aliyev, 2015).

To ensure the sustainability of the Reserve's ecosystems, modern nature protection technologies are employed. Preserving natural conditions and stabilising the population of rare species generates valuable data for researchers. Protecting endemic plants and relict animals also has a positive effect on ecotourism development. Biological monitoring in the Reserve ensures the sustainable use of natural resources for future generations. Minimising human activity and raising environmental awareness increases the sustainability of the Reserve's ecosystem services (Babayev & Rzayev, 2019).

The Turyanchay State Nature Reserve is located on the southern slopes of the Greater Caucasus in Azerbaijan. The area is mountainous and has a mild mountain climate, which contributes to the formation of various ecosystems and the enrichment of biodiversity. The reserve's combination of forest and mountain steppe landscapes creates favourable conditions for the distribution of various plant and animal species (Huseynov, 2017).

The Reserve is home to numerous endemic and relict plant species. Oak, hornbeam, beech, elm and other forest trees can be found throughout the area. Endemic plants are only found in this geographical area and reflect the main features of the ecosystem. Relict plants, on the other hand, are species that have survived from ancient geological times to the present day, demonstrating historical continuity in biodiversity. These plants play an important role in protecting the soil from erosion and maintaining climate stability.

The area is home to various species of mammals and birds. These include mammals such as bears, roe deer, wolves, foxes and rabbits, as well as various rare birds, all of which are essential to the natural ecosystem. Endemic and relict animal species inhabit natural shelters that ensure the continuity of their offspring. Conserving these species helps to mitigate the risks posed by human impact and climate change. The conservation measures implemented in the reserve ensure the survival of rare and endangered species. Environmental monitoring is carried out and data on plant and animal species is collected. Modern management methods are employed to minimise human impact and protect the ecosystem. The reserve also serves as a primary research laboratory for biodiversity studies and natural sciences.

The Turyanchay State Nature Reserve's ecosystem is sustainable, protecting the soil from erosion, maintaining water resources, and ensuring the balance of nature. The presence of endemic and relict species demonstrates the region's rich biological heritage and plays a strategic role in sustaining nature. In this regard, the reserve is of scientific and environmental importance, ensuring the preservation of natural heritage for future generations.

Methods

The study was carried out in the Turyanchay State Nature Reserve, located in the arid zone of the eastern Caucasus. The area is characterised by pronounced continentality and low moisture availability, which shape the development of xerophytic vegetation. The research focused on arid sparse forests and shrub communities. Field investigations were conducted using a route–plot approach, with sample plots established according to vegetation type. Geobotanical surveys included assessments of species composition, projective cover, vertical structure, and plant life forms. Taxonomic identification followed regional floristic references and contemporary systematic concepts, with particular attention given to rare and protected plant species. The faunal component was assessed in a generalised manner as part of the biocenotic structure of the communities. Animal records were obtained through route surveys based on visual observations and signs of activity, allowing the identification of major trophic groups. Data processing was performed using standard geobotanical and ecological analysis methods.

Results and Discussion

Studies conducted within the Turyanchay State Nature Reserve indicate that its biodiversity is high. Examining the morphological and taxonomic composition of the vegetation revealed that several endemic species are found only in this area. The presence of relict species, on the other hand, sheds light on the area's geological history and ecological stability. The study observed various ecosystems in forest and mountain steppe landscapes, creating favourable opportunities to study the geographical distribution and living conditions of plant and animal species.

Studies on the animal world show that mammals such as bears, roe deer, wolves, foxes, hares and rare bird species are widespread in the Reserve. Populations of endemic and relict animal species are protected in natural shelters, while some species remain endangered due to anthropogenic impacts and climatic changes. Environmental monitoring and biodiversity assessments are continuously carried out in the Reserve, which is important in terms of preserving rare species and determining their role in the ecosystem (Mammadov, 2018).

The results of the study show that the Turyanchay State Nature Reserve is not only a protected area for the survival of rare plant and animal species, but also makes a significant contribution to ensuring the sustainability of ecosystems, protecting land and water resources, and maintaining ecological balance. The conservation of endemic and relict species is of strategic importance for the preservation and transfer of biological heritage to future generations (Guliyev, 2019). Research conducted within the reserve produces scientific and practical results. Based on these results, measures are proposed to ensure the sustainable management and protection of protected areas.

Monitoring the populations of endemic and relict species helps to maintain stable numbers. Observations in the reserve demonstrate the importance of conserving land and water resources for the sustainability of the ecosystem. Minimizing anthropogenic impacts and limiting harmful activities protects the species' habitat. Environmental awareness and educational programmers for local communities support nature conservation in the reserve. Conserving endemic plants and rare animals promotes ecotourism and highlights the region's ecological value. The research results from the reserve form the basis for strategic decisions aimed at maintaining biodiversity. Thus, the Turyanchay State Nature Reserve serves as a model for the protection of biological heritage and sustainable ecosystem management. In addition, steps are being taken to protect biodiversity and reduce anthropogenic impacts through additional monitoring and sustainable use of natural resources. Studies show that the Turyanchay State Nature Reserve acts as a strategically important biological laboratory for Azerbaijan, providing unique opportunities to study endemic and relict species.

The diversity of ecosystems within the Turyanchay State Nature Reserve is of significant scientific interest. The Reserve's vegetation is not limited to species of economic and medical importance; it also creates a favourable environment for rare and threatened endemic-relict plants. Studies of the flora carried out in the reserve show that a number of rare trees, shrubs and herbaceous plants are protected here and also serve as a natural defence against soil erosion and climate change (Guliyev, 2019).

From a faunistic perspective, the Turyanchay Reserve is a refuge for many rare and protected animal species. The mammals and birds that live in the area play a vital role in regulating the ecosystem and maintaining the balance of food chains. Long-term monitoring in the reserve helps to maintain the number of endemic and relict animal populations and ensure the stability of their habitats.

From an ecological point of view, the Turyanchay Reserve plays a vital role in maintaining the region's climate stability and protecting water resources. The rivers flowing through the reserve are vital for ensuring water resources, preventing soil erosion, and maintaining the sustainability of vegetation. Conservation measures and ecological studies carried out in the reserve also increase opportunities for sustainable development and ecotourism, encouraging interaction between local communities and nature.

The Turyanchay State Nature Reserve is of great importance in terms of scientific research and nature protection because of all these factors. Azerbaijan's natural heritage must be preserved for future generations. This is best achieved by protecting endemic and relict species, maintaining the Reserve's biodiversity and ensuring the sustainability of ecosystem services.

Conclusion

The Turyanchay State Nature Reserve is one of the areas of strategic importance for Azerbaijan in terms of the protection of biological diversity. The endemic and relict species found in the reserve play a vital role in maintaining the historical continuity of the ecosystem and its ecological balance. Endemic species, which are unique to this area, demonstrate the area's unique biodiversity and create great potential for scientific research. Relict species, on the other hand, are creatures that have survived from ancient geological times to the present day. They play an important role in maintaining ecosystem stability. These species are considered an invaluable scientific resource in terms of both the ecology of the region and the study of its geological history (National Academy of Sciences of the Republic of Azerbaijan, 2020).

The Reserve has implemented conservation measures and management strategies with the aim of protecting populations of endemic and relict species, ensuring the stability of their habitat and the sustainability of ecosystem services. The number of rare species can be kept from decreasing thanks to environmental monitoring. At the same time, the risks posed by human activity and climate change can be reduced. Measures like these are also important for preventing soil erosion, protecting water resources and making sure vegetation can be sustained.

Consequently, the Turyanchay State Nature Reserve is strategically important for Azerbaijan, as it plays a key role in protecting rare and endangered species, ensuring ecosystem sustainability, safeguarding biological heritage, facilitating scientific research, and promoting ecotourism. Preserving endemic and relict species in the reserve ensures the continuity of nature and guarantees that a healthy and rich biological heritage is passed on to future generations. In this respect, the Turyanchay State Nature Reserve plays a key role in Azerbaijan's environmental policy and biodiversity conservation. It also provides a unique platform for future scientific, environmental and educational activities.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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The Impact of Natural and Anthropogenic Factors on the Microbiological Quality of Groundwater

Fatima Jafarova

Abstract. *Water, considered the «source of life» of humanity, is one of the most important resources. The quality of drinking water is important for human health, environmental protection and economic development. Freshwater is a limited natural resource. With population growth and intensifying anthropogenic impact, the problem of the quality of underground and surface water resources is becoming increasingly acute, since these waters serve as primary sources of drinking and domestic supply.*
The quality of groundwater is controlled by a combination of natural processes and human activities. Natural factors include the interaction between water and rocks, soil leaching, precipitation infiltration and hydrological and biological processes that affect pH, mineralization, and overall hydrochemical composition of water. These processes define the natural background conditions of groundwater quality and vary depending on geological settings and climatic conditions.
At the same time, anthropogenic impacts significantly alter groundwater quality. Agricultural practices involving the application of fertilizer and pesticides supplement, urban expansion, industrial activities and the discharge of untreated or insufficiently treated domestic wastewater contribute to increased concentrations of nutrients, heavy metals and pathogenic microorganisms. Inefficient water management practices further exacerbate these impacts, leading to degradation of groundwater resources and increasing risks to human health and ecosystem stability.

Keywords: *groundwater, natural factors, anthropogenic impact, surface water, sustainable water management*

Introduction

Water is a vital natural resource that supports human health, ecosystem activities and economic development. Although water covers about 71% of the Earth's surface, only a small part of it is present as fresh water for direct human use. Therefore, surface and groundwater play an important role in drinking water supply, agriculture and industry. Population growth, urbanization and climate change increase the pressure on these resources and generate growing concerns about the deterioration of water quality (World Health Organization, 2022).

Microbiological contamination has become a serious water quality problem, especially in regions with poor sewage and wastewater treatment infrastructure. Point and untreated sources of pollution, including rainwater and untreated wastewater, can significantly disrupt the physical, chemical and biological integrity of water systems (Bartram & Ballans, 1996).

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Contamination can lead to water-borne diseases, including diarrhoea, cholera and typhus, posing serious public health risks, especially to vulnerable populations. While natural filtration processes in wetlands, soil and aquatic systems can reduce microbial load, their effectiveness largely depends on local hydrological regimes and seasonal variability (Lenart-Boroń et al., 2017).

Previous studies have evaluated the microbiological quality of water depending on natural or human factors, however, the combined effects of area use, hydrogeology and human activities on microbial groundwater contamination have been systematically studied by few. The distinguishing between natural background conditions and anthropogenic impacts is very important for the development of effective water management and conservation strategies. Therefore, the purpose of this study is to assess the impact of natural and anthropogenic factors on the microbiological quality of groundwater in various types of land use, including in urban, rural and pasture areas. The study, combined with hydrogeochemical and microbiological analysis, aims to identify the main determinants of water quality change and provide evidence-based recommendations for sustainable water basin management.

This study aims to evaluate the influence of natural and anthropogenic factors on the physicochemical and microbiological quality of surface and groundwater. The object of the study is water resources formed under conditions of various land uses, including rural and urban areas, where natural processes and human economic activities have a complex impact on water quality. The main objective of the study is to identify the key determinants of spatial and seasonal variability in water quality indicators, as well as to distinguish between the natural hydrochemical background and pollution caused by anthropogenic loading. Microbiological indicators are emphasized because they are sensitive indicators of contamination and represent a potential threat to public health (Mao et al., 2023)

The study also analyzes the role of hydrological processes such as precipitation, surface runoff and infiltration in the transport and transformation of pollutants. An integrated approach based on a combination of physicochemical and microbiological indicators allows us to deepen our understanding of the processes of water quality formation and to substantiate scientific recommendations for the sustainable management of water resources.

Materials and Methods

1. *Research area and sampling place*
The study was carried out to evaluate the effects of natural and anthropogenic factors on the microbiological quality of groundwater in various types of land use, including in cities, villages and grasslands. Sampling points include wells and boreholes that open aquifers in fractured or porous rock formations with conventional groundwater sources. To evaluate the state of the natural background, sampling points were selected in areas with minimal anthropogenic impact. Soil samples were collected near water sources to characterize possible sources of contamination (Baird et al., 2013).
2. *Sampling procedure*
Groundwater samples were periodically collected to reflect temporal variations, including dry and wet periods. Sterile containers were used and samples were transported to the laboratory under refrigerated conditions (4 °C). Soil samples from the top 0-25 cm layer were collected in triplicate at each site. Samples were dried, homogenized and sieved (<2 mm) prior to chemical analysis (Rao et al., 2022).
3. *Hydrogeochemical analysis*
Physicochemical parameters such as temperature, electrical conductivity (EC), pH, dissolved oxygen (DO), oxidation-reduction potential (ORP), total amount of dissolved solids (TDS) and salinity were measured in situ with portable multiparametric devices. Water samples for laboratory analysis are

filtered (0.45 microns), acidified with nitric acid for cationic analysis and stored in polypropylene bottles. The major ions were analyzed using ion chromatography. The composition of the isotopes (approx. $\delta^{18}O$ approx. $\delta^{2}H$) and isotopes of sulfates (approx. $\delta^{34}S\text{-}SO_4$, approx. $\delta^{18}O\text{-}SO_4$) by means of mass spectrometry of isotopic ratios to evaluate the origin of the water and the possible sources of contamination. Radon activity in groundwater (^{222} Rn) was measured in the field with an in-field radon monitor (RAD7) (Liu et al., 2023a).

4. *Microbiological analysis*

The microbiological quality of groundwater was evaluated using selective and differential means for selective and differential media for various bacteria, including sulfite-reducing clostridia, including common coliform bacteria, fecal coliform bacteria, enterococci, Pseudomonas spp. andsulfite-reducing clostridia.

The following selective and differential media were used:
Chromocult Coliform Agar – Total number of coliform bacteria and E. coli
McConkey Agar – Gram-negative bacteria that ferment lactose
Lactose Tergitol 7 Agar – fecal coliform
Plate Count Agar (TTC) – the total number of heterotrophic bacteria
Bile Aesculin Azide Agar – Enterococci
Slanetz and Bartley Agar – Enterococci enumeration
Cetrimide agar – Pseudomonas spp.
TSC Agar – sulfite-reducing clostridia

All products were incubated according to recommended conditions and bacterial colonies were calculated in CFU/100 ml according to standard water quality standards (Lyons et al., 2023).

5. *Soil analysis and Statistical Treatment*

Soil samples were analyzed for pH, organic matter and metallic traces such as iron and manganese. Acid acid digestion (aqua regia) was used to analyze the metals, then atomic absorption spectroscopy (AAS). Soil properties were analyzed to evaluate their potential contribution to groundwater contamination though leaching and water-rock interaction (Subramaniyan & Elango, 2024).

Data from hydrogeochemical, microbiological and soil analyses were collected and processed using statistical and multidimensional approaches to determine the relationship between natural and anthropogenic factors and groundwater quality. Hierarchical clustering analysis (HCA) and correlation analysis can be applied to identify relationships between water quality parameters and to distinguish between natural and anthropogenic influences on groundwater quality.

Results and Discussion

The assessment of groundwater quality for different types of land-use conditions indicates that microbiological pollution occurs under the combined influence of natural environmental factors and anthropogenic activities. The main role in the distribution and abundance of microbiological indicators in underground water systems is played by differences in land use patterns, hydrogeological conditions and seasonal patterns.

Microbiological indicators such as total coliforms, fecal coliforms, enterococci, Pseudomonas spp., and clostridia, which reduce sulfite, are widely used to assess groundwater sanitation and safety. Their presence in groundwater reflects both recent episodes of pollution and the long-term impact of land use factors. Increased concentrations of coliform bacteria and enterons are most commonly associated with agricultural activities, animal husbandry, and infiltration of untreated or insufficiently treated domestic wastewater. This confirms the high sensitivity to microbiological contamination of shallow water layers and groundwater filling areas (Lyons et al., 2023).

Seasonal variability represents an additional factor affecting groundwater quality. Increased precipitation and surface runoff during periods of high humidity contribute to the transfer of pollutants from soils and surface sources to groundwater through infiltration processes. In dry periods, on the contrary, a decrease in dilution and an increase in the duration of water stay in the water layer can lead to the continuation of microbiological contamination. This seasonal trend highlights the need to consider climatic conditions when interpreting groundwater quality data (Wang et al., 2024).

Natural hydrogeological factors also make an important contribution to the formation of the microbiological state of groundwater. Granulometric composition of soils, composition of organic substances and mineral composition of rocks determine filtration properties of environment and survival at migration of microorganisms into underground horizons. In areas with favorable geological conditions, natural self-cleaning processes can reduce microbiological stress, but with high anthropogenic stress, their effectiveness is often insufficient (Zhang et al., 2024).

A thorough analysis of microbiological and physicochemical indicators makes it possible to more fully understand the processes of formation of groundwater quality. The application of multitasking statistical methods such as hierarchical cluster analysis and correlation analysis helps to identify examples and associations between water quality indicators and potential sources of pollution. Such an integrated approach is necessary to distinguish between the natural hydrochemical background and pollution of anthropogenic groundwater.

In general, the discussion shows that groundwater quality cannot be explained by the influence of one factor. It is formed as a result of a complex interaction of land use, hydrogeological conditions, seasonal variability and anthropogenic activity. The findings highlight the need to implement comprehensive groundwater monitoring and management programs, taking into account both natural processes and anthropogenic pressure, to ensure long-term safety and sustainable use of groundwater resources.

Conclusion

The study assessed the influence of natural and anthropological factors on the microbiological quality of groundwater under different land use conditions, including urban, rural and grazing areas. The analysis shows that groundwater quality is determined by the combined effects of hydrogeological environments, soil characteristics, seasonal variability and human activities. Land use practices and proximity to potential sources of contamination play a key role in determining the presence and distribution of microbiological indicators, such as coliform bacteria, enterococci, Pseudomonas spp. and sulphite-reducing clostridia (Wang et al., 2024).

The results underline the need to consider both natural background conditions and anthropogenic pressures in assessing the safety and vulnerability of groundwater. An integrated approach combining microbiological and physicochemical indicators is essential for a comprehensive groundwater quality assessment. This approach can support informed decision-making in water resource management (Ravindiran et al., 2023).

Overall, this study highlights the importance of sustainable groundwater protection strategies, including regular monitoring, protection of charging areas and reduction of sources of anthropogenic pollution. Future research should focus on long-term and seasonally resolved assessments to improve understanding of groundwater pollution processes and increase the effectiveness of groundwater management and protection practices.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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The Role of Microorganisms in Ecosystems and the Maintenance of Ecosystem Stability

Hijran Samadli

Abstract. *Microorganisms are fundamental to ecosystem functioning and stability across terrestrial, aquatic, atmospheric, and host-associated systems. They act as ecosystem engineers by stabilizing sediments through biofilm formation and extracellular polymeric substances, enhancing structural integrity and regulating nutrient cycling. Airborne microbial communities further illustrate ecological adaptability, influencing atmospheric processes and contributing to environmental connectivity. Technological advancements have harnessed microbial communities for environmental management, including bioremediation, bioaugmentation, and wastewater treatment, supporting ecosystem resilience and sustainable resource management. In host-associated ecosystems, such as the human gastrointestinal tract, microbial diversity maintains homeostasis, supports immune function, and provides resilience against environmental or physiological disturbances. Early-life colonization, dietary changes, and hormonal influences shape microbial community dynamics, emphasizing the role of microbiomes in health and ecosystem-like stability within hosts. Anthropogenic pressures, particularly excessive antibiotic use, threaten microbial diversity, disrupt community balance, and reduce ecosystem resilience. Maintaining microbial diversity and understanding microbial ecosystem dynamics are essential for ecological sustainability, human health, and environmental management. Integrating ecological knowledge with molecular and biotechnological approaches provides a pathway to monitor, predict, and enhance ecosystem stability. Microorganisms, through their metabolic diversity and adaptive capacity, play a vital role in sustaining ecosystem integrity, regulating biogeochemical cycles, and maintaining functional resilience in the face of environmental change. Protecting microbial ecosystems is therefore crucial for long-term ecological balance and environmental sustainability.*

Keywords: *microorganisms, ecosystem stability, microbiome, environmental management, biofilms*

Introduction

Microbial ecology is a dynamic and interdisciplinary field that examines the relationships between microorganisms and their environments, as well as the interactions among microbial populations themselves. Microorganisms—including bacteria, archaea, fungi, protozoa, and viruses—represent the most abundant and diverse forms of life on Earth. They inhabit virtually every ecosystem, from terrestrial soils and freshwater systems to marine environments and extreme habitats such as thermal springs and hypersaline lakes. Their metabolic diversity enables them to drive fundamental biogeochemical cycles and sustain life on the planet (Barton & Northup, 2011; Madigan, 2012).

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The foundations of microbial ecology lie in understanding how microorganisms influence and are influenced by physical, chemical, and biological factors in their habitats. Environmental parameters such as temperature, pH, nutrient availability, oxygen concentration, and moisture play critical roles in shaping microbial community composition and activity (Maier et al., 2009; Kirchman, 2012). Microorganisms participate actively in nutrient cycling processes, including the carbon, nitrogen, sulfur, and phosphorus cycles. Through processes such as decomposition, nitrogen fixation, nitrification, denitrification, and methanogenesis, microbes regulate ecosystem productivity and global climate systems (Barton & Northup, 2011; Kirchman, 2012). Marine ecosystems, in particular, demonstrate the immense ecological importance of microorganisms. Marine microbes are responsible for approximately half of global primary production and significantly contribute to carbon sequestration in the oceans. Advances in microbial oceanography have revealed complex microbial networks that respond rapidly to environmental changes, highlighting the importance of microbial diversity in maintaining ocean health (Bowler et al., 2009). Microbial community ecology focuses on the structure, function, and dynamics of microbial assemblages in natural environments. Rather than studying single species in isolation, this approach emphasizes interactions among multiple populations and their collective behavior. Konopka (2009a; 2009b) describes microbial community ecology as an effort to determine how microbial diversity influences ecosystem functioning and how environmental disturbances alter community structure. Modern molecular tools such as metagenomics, metatranscriptomics, and high-throughput sequencing have revolutionized this field, allowing scientists to analyze microbial communities without the need for cultivation. Microbial interactions are central to ecosystem stability and resilience. Microorganisms engage in cooperative, competitive, symbiotic, commensal, and antagonistic relationships. These interactions often form complex ecological networks that determine nutrient exchange, energy flow, and overall community stability. Network-based approaches have provided new insights into microbial interactions, helping researchers move from descriptive studies toward predictive ecological models (Faust & Raes, 2012). Understanding these interactions is crucial for applications in biotechnology, agriculture, environmental remediation, and human health. Environmental microbiology extends the principles of microbial ecology to applied contexts, examining how microbes influence environmental quality and public health. Microorganisms play a dual role: they contribute to environmental sustainability through waste degradation and bioremediation, yet they can also pose risks as pathogens or agents of disease (Krasner, 2010). Laboratory-based approaches remain essential for isolating, identifying, and characterizing environmental microorganisms and for studying their physiological and metabolic capabilities (Charles & Brendecke, 2011; Maier et al., 2009).

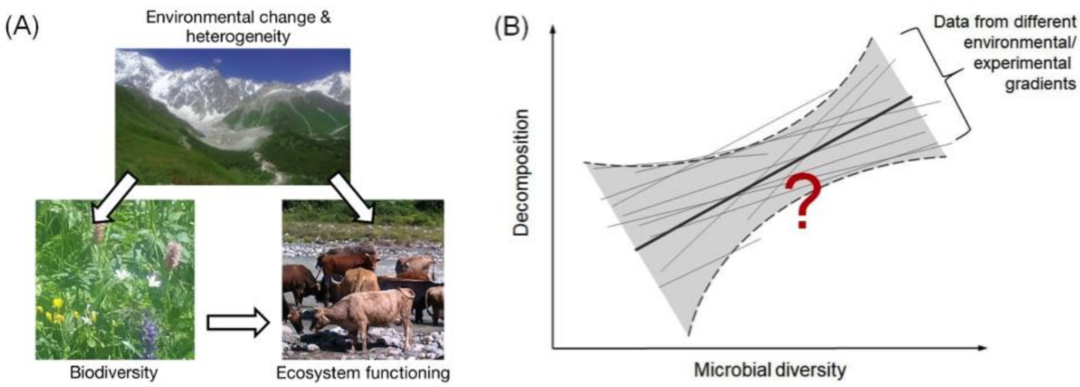
Recent developments in environmental microbiology emphasize the integration of ecological theory with experimental and computational methods. By combining laboratory experiments, field observations, and modeling techniques, researchers aim to better predict microbial responses to environmental change (Charles et al., 2015). This integrative perspective strengthens our capacity to address global challenges such as climate change, emerging infectious diseases, water quality management, and sustainable agriculture. Microbial ecology provides critical insights into the invisible yet powerful microbial world that underpins all ecosystems. From regulating global biogeochemical cycles to shaping environmental health and stability, microorganisms are fundamental drivers of planetary processes. Continued research integrating ecological theory, molecular biology, and environmental sciences will deepen our understanding of microbial communities and enhance our ability to manage natural and engineered ecosystems sustainably (Barton & Northup, 2011; Kirchman, 2012; Faust & Raes, 2012).

Microbial Diversity and Ecosystem Function Across Environmental Gradients

Microbial diversity plays a fundamental role in maintaining ecosystem stability, productivity, and resilience, particularly under changing environmental conditions. Across terrestrial and aquatic ecosystems, microbial communities regulate key biogeochemical processes such as carbon turnover, nutrient mineralization, decomposition, and soil formation. Increasing evidence shows that biodiversity—both aboveground and belowground—enhances ecosystem resistance and recovery following environmental stressors, including climate extremes and anthropogenic disturbances (Isbell et al., 2015; Soliveres et al., 2016). Environmental gradients such as temperature, moisture, pH, nutrient availability, and atmospheric CO_2 concentration strongly influence microbial community structure and functionality. Long-term exposure to elevated CO_2 levels, for example, has been shown to alter soil carbon turnover processes and reshape microbiome composition, thereby affecting ecosystem carbon cycling dynamics (Beulig et al., 2016). Similarly, geographic and temporal variability in soil biodiversity demonstrates that microbial distribution patterns are shaped by both abiotic and biotic drivers across ecosystems (European Commission, 2016).

Microbial community dynamics are particularly evident during organic matter decomposition. During litter degradation, bacterial and fungal communities undergo succession patterns that reflect shifts in substrate availability and environmental conditions. Studies have revealed complex interactions among decomposers that determine nutrient release rates and ecosystem productivity (Purahong et al., 2016). In paddy soils and peatlands, microbial populations responsible for plant polymer degradation and biopolymer breakdown have been identified using metatranscriptomic and community-level analyses, demonstrating functional specialization within microbial consortia (Wegner & Liesack, 2016; Ivanova et al., 2016). Recent advances in integrated omics approaches have significantly improved our understanding of microbial community-wide metabolic networks. Comparative multi-omics analyses enable researchers to identify key functional pathways driving ecosystem processes and to link taxonomic diversity with metabolic capabilities (Roume et al., 2015).

These approaches reveal that microbial ecosystem functioning is not solely dependent on species richness but also on functional redundancy and network interactions within microbial communities. Biodiversity effects are not limited to single trophic levels. Multifunctionality within ecosystems depends on interactions across plants, microbes, and soil fauna. Research has shown that biodiversity at multiple trophic levels is essential to sustain ecosystem multifunctionality, particularly under environmental stress (Soliveres et al., 2016). Moreover, long-term experimental studies indicate that ecosystem functioning can diverge over time depending on diversity levels, highlighting the temporal dimension of biodiversity–function relationships (Guerrero-Ramirez et al., 2017). Climate extremes further emphasize the stabilizing role of biodiversity. Experimental evidence demonstrates that higher biodiversity increases the resistance of ecosystem productivity to extreme climatic events, suggesting that diverse microbial and plant communities provide buffering capacity against environmental fluctuations (Isbell et al., 2015). Therefore, understanding microbial diversity–ecosystem function relationships across environmental gradients is critical for predicting ecosystem responses to global change.



A Environmental change and heterogeneity determine the biodiversity and the functioning ofecosystems (modified after Eisenhauer et al., 2016). In addition, changes in biodiversity canhave significant effects on ecosystem functioning, which can be masked by strong environmental gradients. Only by accounting for environmental heterogeneity can the role of biodiversity for ecosystem functioning be wholly realized. B Hypothesizedpositive relationship between microbial diversity and decomposition (overall positive relationship with confidence intervals; no real data was used to create this figure). Thediversity gradient in soil microbes is supposed to be caused by different environmental conditions. The different grey lines indicate BEF relationships across different experimental and environmental gradients

Microbial Communities in Contaminated and Subterranean Environments

Microbial communities demonstrate remarkable adaptability across diverse and extreme environments, including contaminated industrial sites, engineered wastewater systems, agricultural soils, and subterranean cave ecosystems. Environmental stressors such as heavy metals, polycyclic aromatic hydrocarbons (PAHs), nutrient limitations, and hydrological changes significantly influence microbial diversity, structure, and metabolic potential. Understanding these responses is essential for predicting ecosystem functioning and developing sustainable environmental management strategies. In contaminated industrial soils, microbial communities respond differently to various pollutants depending on contaminant type and concentration. Heavy metals and PAHs exert selective pressures that shape community composition and functional gene distribution. Soil microbiomes exposed to these contaminants exhibit divergent adaptive mechanisms, including metal resistance systems and hydrocarbon degradation pathways (Yang et al., 2022). Such functional shifts demonstrate how environmental gradients drive microbial selection and ecosystem process modification. Wastewater treatment systems provide another model for studying microbial functional dynamics. In low carbon-to-nitrogen domestic wastewater, the efficiency of nitrogen removal is strongly influenced by hydraulic retention time (HRT) and the type of biodegradable polymers used as solid carbon sources. Variations in operational parameters alter microbial community structure and enhance simultaneous nitrification–denitrification (SND) processes (Wu et al., 2021). These findings highlight the link between engineered environmental conditions and microbial-mediated nutrient cycling.

Agricultural water management also affects active root-associated microbial communities. In rice paddies, irrigation strategies influence microbial populations involved in arsenic, iron, and sulfur biogeochemical cycles. Changes in redox conditions alter microbial functional groups, thereby impacting nutrient availability and contaminant mobility (Zecchin et al., 2017). This demonstrates how anthropogenic management practices regulate belowground microbial processes and ecosystem health. Subterranean cave ecosystems, characterized by low nutrient input and limited anthropogenic activity, represent unique habitats for microbial life. Studies of caves in different geographical regions reveal distinct microbial assemblages shaped by mineralogical composition, geochemical properties, and organic substrate availability. Microbial communities in caves exhibit specialized metabolic pathways adapted to oligotrophic conditions (Zada et al., 2021). Similarly, karst cave systems show complex diversity patterns and microbial co-occurrence networks that reflect environmental heterogeneity and spatial structuring (Zhu et al., 2019). In caves with low anthropogenic disturbance, microbial diversity and substrate preferences provide insights into natural ecosystem functioning. Investigations in Romanian cave systems have revealed distinct microbial distributions associated with organic matter availability and microclimatic conditions, emphasizing the ecological importance of subterranean microbiomes (Bogdan et al., 2023). These findings contribute to our broader understanding of microbial biogeography and ecological specialization. Microbial diversity across environmental gradients—from contaminated soils and wastewater systems to agricultural lands and pristine caves—demonstrates both resilience and functional plasticity. Microbial communities not only respond to environmental stress but also actively regulate ecosystem processes through nutrient cycling, contaminant transformation, and energy flow. Integrating ecological, geochemical, and molecular approaches is essential for advancing our understanding of microbial ecosystem functioning under natural and anthropogenic influences.

Microorganisms as Drivers of Ecosystem Function and Stability

Microorganisms are fundamental components of all ecosystems and serve as primary drivers of ecological processes that sustain environmental stability. From terrestrial soils and aquatic sediments to atmospheric systems and host-associated microbiomes, microbial communities regulate nutrient cycling, organic matter decomposition, energy flow, and structural integrity. Their remarkable metabolic diversity enables them to adapt to fluctuating environmental conditions while maintaining ecosystem resilience. Understanding the ecological roles of microorganisms is essential for predicting ecosystem responses to anthropogenic disturbances and global environmental change. In natural environments, microorganisms function as ecosystem engineers. In sedimentary systems, microbial assemblages contribute directly to sediment stability through biofilm formation and the secretion of extracellular polymeric substances (EPS). These polymers bind sediment particles together, reducing erosion and enhancing structural cohesion. By modifying physical properties of sediments, microbial communities regulate hydrological processes and nutrient exchange at the sediment–water interface, thereby maintaining aquatic ecosystem stability (Gerbersdorf et al., 2009). This engineering capacity illustrates how microorganisms actively shape their habitats rather than merely inhabiting them. Microbial influence extends beyond terrestrial and aquatic systems into the atmosphere. Urban aerosol studies have revealed diverse and dynamic airborne bacterial populations that respond rapidly to environmental fluctuations such as temperature, humidity, and pollution levels (Brodie et al., 2007). These findings demonstrate that microorganisms participate in atmospheric processes, potentially influencing nutrient deposition and biogeochemical cycling on a broader scale. The presence of active microbial communities in air systems reinforces the concept that ecosystems are interconnected through microbial dispersal and ecological exchange. Technological advancements have further emphasized the environmental significance of microorganisms. Microbial-based approaches in environmental management—including bioremediation, bioaugmentation, and wastewater treatment—have proven effective in restoring polluted ecosystems and enhancing nutrient cycling efficiency (Chinthala, 2013; Chinthala, 2014). By exploiting microbial metabolic pathways, scientists can mitigate environmental contamination, improve soil fertility, and promote sustainable ecosystem functioning. These applications underscore the importance of preserving microbial diversity as a resource for ecological innovation.

Beyond environmental systems, microorganisms form complex host-associated ecosystems that are crucial for health and physiological stability. The human microbiome represents a dynamic and resilient microbial community that contributes to digestion, immune regulation, and pathogen resistance. The stability of this ecosystem is directly linked to human health, as disruptions in microbial composition may reduce resilience and increase disease susceptibility (Relman, 2012). Microbial diversity within the gastrointestinal tract ensures functional redundancy, enabling the system to recover from environmental or dietary perturbations.

Early-life microbial colonization plays a critical role in shaping long-term ecosystem stability within the host. The neonatal gastrointestinal tract undergoes rapid microbial succession, establishing foundational microbial communities that influence immune development and metabolic programming (Mackie et al., 1999). Similarly, transitional phases such as weaning significantly alter microbial diversity in animal gastrointestinal systems, reflecting the dynamic nature of host-associated microbial ecosystems (Konstantinov et al., 2004). These developmental processes highlight the importance of ecological succession and adaptation in maintaining microbiome stability. Other host-associated ecosystems also demonstrate microbial regulation influenced by physiological factors. The vaginal microbiome, for instance, is strongly shaped by hormonal fluctuations, which affect microbial composition and ecological balance (Farage et al., 2010). In the oral cavity, the early establishment of bacterial flora determines long-term microbial community structure and oral health outcomes (Könönen, 2000). These examples illustrate how microorganisms maintain homeostasis within host environments and contribute to systemic stability. However, microbial ecosystem stability is increasingly challenged by anthropogenic pressures. One of the most significant disturbances is the overuse of high-stability antibiotics. Excessive antibiotic application alters microbial diversity, disrupts ecological balance, and promotes the emergence of resistant strains in both clinical and environmental settings (Zdziarski et al., 2003). Such disturbances reduce microbial resilience and compromise essential ecosystem services, including nutrient cycling and pathogen suppression. Alterations in gut microbiota composition have been linked to metabolic disorders and immune dysfunction, emphasizing the importance of maintaining microbial equilibrium (Baker et al., 2009). Studies on captive animal systems demonstrate that digestive microbiota exhibit varying degrees of temporal stability depending on environmental conditions and dietary inputs (Becker et al., 2011). These findings further support the concept that microbial ecosystem stability is shaped by both internal and external environmental factors.

Microorganisms function as key regulators of ecosystem stability across multiple ecological scales. They stabilize physical environments, sustain nutrient cycles, influence atmospheric processes, and maintain host health. Their adaptive capacity allows ecosystems to resist and recover from environmental stressors, thereby promoting resilience. At the same time, anthropogenic disturbances such as antibiotic overuse and environmental pollution threaten microbial diversity and ecological balance. Protecting microbial diversity and understanding microbial ecosystem dynamics are therefore essential for sustainable environmental management and public health strategies. Integrating ecological theory with molecular and biotechnological approaches will enhance our ability to monitor, predict, and manage ecosystem responses to global change. As invisible yet indispensable components of life on Earth, microorganisms remain central to the maintenance of ecosystem stability and resilience.

Conclusion

Microorganisms are indispensable drivers of ecosystem stability, functioning across diverse habitats including soils, sediments, aquatic systems, the atmosphere, and host-associated environments. By stabilizing physical structures, regulating nutrient cycling, and maintaining community resilience, microbial assemblages act as ecosystem engineers that sustain ecological balance. In host-associated systems, such as the human microbiome, microbial diversity ensures physiological stability and health, highlighting the parallels between environmental and host ecosystems. Anthropogenic pressures, including pollution, habitat alteration, and excessive antibiotic use, threaten microbial diversity and compromise ecosystem resilience. Preserving microbial communities and understanding their dynamics is therefore essential for maintaining ecosystem functioning, environmental sustainability, and human well-being. Advances in microbial biotechnology and ecological monitoring provide tools to harness microbial potential, restore disrupted ecosystems, and enhance system stability. Ultimately, microorganisms are both the foundation and regulators of ecosystem integrity. Protecting microbial diversity, promoting sustainable management practices, and integrating ecological and biotechnological approaches are critical for ensuring long-term stability, resilience, and sustainability of ecosystems in the face of environmental change.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Biological Knowledge in Our Lives

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Abstract. *Life on Earth cannot be imagined without living organisms. Biology is the science that studies organisms possessing all the characteristics of life. Living organisms are mainly classified into four major kingdoms: plants, bacteria, fungi, and animals. Viruses, however, are acellular forms of life and can reproduce only by entering the cells of other organisms. Various methods are used to study living organisms, including observation, experimentation, measurement, and microscopy. In addition, to facilitate their study, biologists classify organisms into groups based on common characteristics. In modern systematics, the origin of organisms, their structural features, and their evolutionary relationships are taken into account. Living organisms can be found on land, in water, in the air, and inside the bodies of other organisms. Within the biosphere, which is a complex system, the circulation of matter and energy occurs continuously. As a result of human activities, nature is sometimes exposed to strong negative impacts, and waste is generated daily in industrial and household activities. This waste is one of the main sources of environmental pollution and contributes to the disruption of ecological balance. To prevent this, recycling, more efficient use of natural resources, and environmental protection measures are essential factors.*

Keywords: *cell, microscope, experiment, evolution, biogeocenosis*

Introduction

Biology is a branch of science that studies living organisms. The word “biology” originates from the Greek terms bios (life) and logos (study or science). The development of biological science has a long and ancient history. The earliest scientific works related to living organisms date back to the period before the Common Era. During the 4th–3rd centuries BC, the Greek philosopher Aristotle composed works such as “History of Animals,” while Theophrastus, in the 4th century BC, wrote “History of Plants”. As biological knowledge expanded over time, the question of how life originated became a topic of continuous scientific debate. Some scholars argued that life emerged from non-living matter, whereas others claimed that it originated from pre-existing living organisms. Additionally, certain thinkers supported the idea that nature is unchangeable (metaphysics), while others emphasized its constant transformation and development (dialectics).

By the 20th century, biology had become one of the leading natural sciences (Eybatov & Mammadkhanli, 2010). Through continuous development and integration with information technologies, it has gained significant importance in addressing major issues related to medicine, agriculture, ecology, and environmental conservation.

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Today, biology is closely interconnected with numerous scientific disciplines, including biochemistry, biophysics, cybernetics, biotechnology, biogeography, and others. Furthermore, biology includes many specialized branches that focus on different groups or aspects of living organisms, such as botany, zoology, mycology, microbiology, cytology, histology, morphology, anatomy, physiology, molecular biology, systematics, embryology, genetics, breeding, phenology, and ecology.

Although living and non-living components of nature are closely related, living organisms possess several distinctive characteristics (Mammadov, 2013):

1. Chemical composition – Living and non-living matter share similar chemical elements, primarily oxygen, carbon, hydrogen, and nitrogen.
2. Metabolism and energy exchange – Living organisms carry out metabolic processes within cells, including assimilation (synthesis) and dissimilation (breakdown).
3. Reproduction – Since the lifespan of an organism is limited, reproduction ensures the continuity of life, which is made possible through heredity.
4. Growth and development – Living organisms are capable of increasing in size and mass; in plants this process continues throughout life, while in animals it occurs up to a certain stage.
5. Responsiveness to stimuli – Organisms can react to changes and influences from their external environment.
6. Adaptation to environmental conditions – Living systems adjust their structure and functions to survive and operate effectively in specific environments.
7. Discrete organization – Biological systems are composed of distinct functional and structural units, such as individuals, species, and biocenoses, which interact with one another.
8. Historical development – Living organisms undergo long-term evolutionary changes, progressing from simpler to more complex forms.

For the study of living organisms, several levels of biological organization are conventionally distinguished (Mikayilov, 2011):

1. Molecular level – All living organisms are composed of biological molecules such as proteins, nucleic acids, and polysaccharides. At this level, metabolic processes, energy transformations, and the transmission of genetic information begin.
2. Cellular level – The cell represents the smallest structural and functional unit of life and plays a key role in metabolism and information transfer.
3. Organismal level – At this level, individual organisms function as integrated systems, with organs and organ systems performing specific tasks throughout the life cycle from birth to death.
4. Population–species level – A population consists of individuals of the same species living in a defined area and represents the basic structural unit of a species, where elementary evolutionary changes occur.
5. Biogeocenotic level – This level involves the coexistence and interaction of different species within a shared environment, resulting in a stable and dynamic ecological system.
6. Biospheric level – The biosphere encompasses all biogeocenoses on Earth and includes global processes such as the circulation of matter and the transformation of energy.

Methods

All living organisms are composed of small cells that cannot be seen with the naked eye. Cells were discovered only after optical lenses were invented. The development of the microscope created broad opportunities for the study of various objects. As a result of these studies, scientists succeeded in obtaining unusual observations (Khan, 2014; Madigan et al., 2012; Faust & Raes, 2012). In addition to all this, certain technical tools are used to study biological objects, such as microscopes, centrifuges, computers, and so on. In biology, observation is employed to visually monitor events and biological entities; experiments are conducted to reveal their characteristics; comparison is used to identify natural patterns; historical development is studied to understand growth processes; and descriptive methods are also applied.

Organisms have acquired various adaptations in the struggle for survival. These adaptations are very diverse. The external and internal structure of animals, their instincts, behaviors, as well as their adaptation to living conditions are all interconnected. Plants living in different natural environments have also developed a number of adaptations to environmental factors. In adaptation to drought, leaves may transform into thorns or scales, while in adaptation to cold, plants are generally shorter with very small leaves, roots are located close to the soil surface, sugar accumulates in cells, and water content is low.

In general, the facts demonstrating organisms' adaptation to the environment are as follows:

- Morphological adaptation — coloration suitable for the environment, warning colors, camouflage, etc.
- Physiological adaptation — hibernation, subcutaneous fat layer, dense fur coverage, etc.
- Biochemical adaptation — hemoglobin molecules' function of binding and transporting gases, etc.
- Ethological (behavioral) adaptation — mating behavior, parental care, protection from predators, migration, etc., in animals with highly developed nervous systems.

In the biosphere, organisms are not distributed evenly. Their greatest density is observed at the boundaries of the lithosphere and hydrosphere favorable for life, as well as at the contact zones in the atmosphere. The total of living organisms in the Earth's crust and the energy accumulated there forms the planet's biomass. Ancient people, by observing wild animals, birds, and fish, became fascinated by their astonishing perfection and tried to apply these features in life. Thus, by creating objects that resembled the internal or external structure of various living beings existing in the surrounding world, they made the first inventions. Today, although people possess numerous technical tools, they still benefit from nature and have achieved great success in the field of nanotechnology in the modern era. In the creation of modern technologies, similarities of such natural phenomena are reproduced:

1. Rocket jet propulsion – squid
2. Air conditioner – termite
3. Airplane – bird
4. Tweezers – bird's beak
5. Excavator bucket – strong claws of a bird
6. Radar – bat

Living organisms have acquired various adaptations in the struggle for survival. Adaptations are very diverse. The external and internal structure of animals, their instincts and behavior are also related to their adaptation to living conditions. Plants living in different natural habitats have also acquired a number of adaptations to environmental factors. In adaptation to drought, leaves are transformed into spines or scales; in adaptation to cold, the size and leaves are very small, roots are located close to the soil surface, a large amount of sugar accumulates in the cell sap, and the amount of water is low.

In general, the facts proving the adaptation of organisms to the environment are as follows: Morphological adaptation — coloration suitable to the environment, warning coloration, camouflage, etc. Physiological adaptation — hibernation, subcutaneous fat layer, dense fur covering, etc. Biochemical adaptation — the function of hemoglobin molecules in binding and transporting gases, etc. Ethological (behavioral) adaptation — mating behavior, care of offspring, protection from predators, migration, etc., in animals with a highly developed nervous system.

In the biosphere, living organisms are not distributed with the same density. Their greatest density is observed at the boundary of the lithosphere and hydrosphere, which are favorable for life, as well as at their contact boundaries with the atmosphere. The total amount of living organisms in the Earth's crust and the energy accumulated there form the planet's biomass.

Results

Changes occurring in the Earth's crust affect the life of organisms and, consequently, the proportion of biomass. These changes mainly result from human interference with nature. The establishment of large cities, cultivation of technical crops over wide areas, and construction of large industrial facilities lead to the compression and destruction of natural communities. Draining wetlands, converting natural grasslands into agricultural fields, and deforestation cause drastic climate changes. In areas where the development of fauna and flora becomes impossible, the capacity for self-regulation is lost, and the nutrient cycle does not function properly (Foley et al., 2005; Chapin et al., 2011; Steffen et al., 2015).

This makes it clear that biological knowledge is extensive. Such knowledge is particularly essential in agriculture and medicine, where it is used to solve numerous theoretical and practical problems. Without acquiring this knowledge and following its principles, it is impossible to meet the population's demand for food products. By studying the laws of heredity and variability, it becomes possible to develop highly productive plant varieties, animal breeds, and microbial strains. Recently, the use of genetic engineering to create new gene combinations has led to organisms with new hereditary traits, the production of biologically active substances on an industrial scale, the development of new biological pest control methods in agriculture, and more. This demonstrates both the continuous advancement of biology and its significance. Moreover, biological knowledge is crucial for humans in preventing many diseases, maintaining personal health, and developing methods to combat illnesses. It also highlights the importance of understanding the impact of human activities on the environment, finding ways to prevent pollution, and protecting nature, which underscores the necessity of acquiring general biological knowledge.

Discussion

Plants also constitute an important part of the living world on Earth. Over time and with changes in location, they have given rise to many plant forms with different structures. Plants differ from one another both in structure and size and are very diverse. The existence and reproduction of blue-green algae and iron bacteria in hot springs where water emerges at temperatures of 60–65 degrees, as well as the survival and reproduction of these algae in permanent glaciers colored "red" and "green," are among the most interesting and unusual phenomena in nature (Tutayuq, 1967).

Over millions of years of evolution, nature has perfected every cell and every organ of our body. Our body is the most complex creation of nature. In addition to sustaining vital activity, the organism enables humans to create, to study nature, and to uncover its secrets, the greatest of which is humanity itself. The most fundamental need of a human being is to preserve life and health (Tutayuq, 1967). The absence of diseases and bodily defects is the main condition for human happiness, the comprehensive development of personality, and full enjoyment of life (Eybatov & Mammadkhanli, 2021). Understanding the surrounding world becomes possible through the interaction of individual analyzers (Tozmer & Petrishina, 1987). In order to adapt to the changing conditions of the external environment, the human organism possesses broad biological capabilities (Farajov, 2011). As we know, among living beings, humans occupy the highest stage, having passed a long path of development like their ancestors and acquired a modern appearance (Aliyeva, 2007). Human conscious activity, the changes made in nature, social interactions, and achievements in science are the result of complex processes occurring in the brain.Biological evolution is irreversible and deals with the historical development of living organisms, changes in the genetic composition of populations, the formation of adaptations, the emergence and extinction of new species, and changes in the biosphere and biogeocenoses as a whole.

Conclusion

From all this, it becomes clear that biology, although an ancient science, is still a developing field. By using biological sciences, humans can effectively benefit from nature in every area—from following hygienic rules and maintaining proper nutrition to obtaining high-quality products in agriculture, as well as knowing the correct principles for the protection and conservation of water, soil, the atmosphere, the environment, and nature as a whole. The more educational work is carried out among people and the more biological awareness is promoted about the efficient use of natural resources, the greater the contribution will be to building a healthier and more prosperous life for future generations.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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