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# Thesis

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## Title:

**Effect of dietary supplementation on body weight and its evolution in adult ewes raised in steppe conditions**

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*The project is carried out through a collaborative research-action approach, with the support of both national and international partners, committed to promoting sustainable pastoral livestock farming.*

*We would like to express our deep appreciation to all project members for their continuous support, commitment, and for the valuable opportunity to contribute to this pioneering initiative.*



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## **DEDICATION**

### ***To my beloved parents,***

*In appreciation and gratitude for your boundless generosity and unwavering support, which have been the cornerstone of my academic and personal journey.*

### ***To my dear brothers,***

*For your sincere companionship and constant encouragement, which have been a source of strength and inspiration to me.*

### ***To my esteemed family members and relatives,***

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*For the fruitful collaboration and the kind spirit we shared, which played a significant role in overcoming challenges.*

*I dedicate this humble work to everyone who had a hand in this journey.*

**RAHMA**

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*I dedicate this work, above all, to a truly exceptional person who holds a special place in my heart: my Aunt Farida, for her unconditional love, invaluable support, and constant encouragement throughout my journey.*

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## **DEDICATION**

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## **LIST OF ABBREVIATIONS AND ACRONYMS**

BCS: Body Condition Score

BW: Body Weight

C° : Degree Celsius

DSA : Directorate of Agricultural Services

G : Gram

GDP : Gross Domestic Product

GLM: General Linear Model

HNLP: High Nutritional Level Plan

HP: Heat Production

HR: Heart Rate

Kcal : Kilocalorie

LNLP: Low Nutritional Level Plan

MADR : Ministry of Agriculture and Rural Development

MAX: Maximum

MIN: Minimum

m: meter.

mm : Millimeter

NDF: Neutral Detergent Fiber

P : Threshold Signification

PH: Hydrogen Potential

Qx : Quintal

SE: Start of the Experiment

Sig : Signification

SPSS: Statistical Package for Social Sciences

% : Percentage

**INTRODUCTION AND  
PROBLEMATIC OF THE  
RESEARCH**

## I. INTRODUCTION

### 1 General Context of Sheep Farming in Algeria

Sheep farming plays a vital and multidimensional role in Algeria, with far-reaching impacts across multiple dimensions: economic, ecological, cultural, and religious, underscoring its deeply rooted place in rural Algerian society for centuries. It is a pillar in the establishment of Algeria's rural and agricultural economy, especially in agro-pastoral zones, where it plays a crucial role, such as maintaining food security, generating income, and rural employment contributing significantly to the sustainability and resilience of local agro-ecosystems. Furthermore, it is a mere source of meat contributing over 50% to the national production of red meat and 10–15% to the agricultural gross domestic product (GDP) (Moula, 2018)

From an environmental ecological perspective, sheep farming is one of the few systems that can sustainably utilize locally available resources in all local agroecosystems. The genetic diversity, the rusticity and physiological resilience of the sheep populations in Algeria allows them to adapt to a wide range of agro-ecosystems, from arid and semi-arid regions to mountainous terrains and coastal pastures (Belkasmi, 2021). They are well adapted to harsh climatic conditions and fragile environments and able to value spontaneous annual vegetation of natural pastures and rangelands and cereal crops and co-products. Sheep farming can convert low-quality forage into valuable animal products, thus contributing to ecosystem balance while maintaining productive use of vast, otherwise marginal lands.

Beyond its economic and ecological roles, sheep farming holds significant sociocultural value, by being deeply rooted in cultural identity, religious traditions, and historical practices. Ancestral livestock management practices and local knowledge are passed down through generations, reinforcing social cohesion and preserving indigenous pastoral heritage. Sheep play a central role in major cultural and religious events, notably during Eid al-Adha, Ramadan and other holidays reinforcing the symbolic and religious role of sheep, associating them with good fortune and strong societal values (Kanoun *et al.*, 2013)

Sheep farming in Algeria is far more than a simple agricultural activity; it is a multifaceted system that anchors rural life, sustains local economies, and upholds cultural and environmental traditions. Its ability to integrate economic productivity with ecological balance, while preserving genetic biodiversity and cultural heritage, makes it an essential component of Algeria's rural development strategy.

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However, despite its critical role, sheep farming in Algeria remains marginalized compared to the bovine and poultry sectors. It receives limited institutional support and investment, often being overlooked in favor of more intensive and industrialized forms of animal production. Most sheep production systems are still managed extensively or semi-extensively, relying heavily on natural pastures and traditional practices. This lack of modernization and structural organization significantly affects productivity, limits market integration, and exposes the sector to climatic and economic shocks.

Without a coherent national strategy to support value chain development, health monitoring, genetic improvement, and producer training, the full potential of Algerian sheep farming remains untapped. This presents the most paradoxical aspects of the current situation: despite the vast natural rangelands and the genetic adaptability of local breeds, the meat productivity remains low, and the price per kilogram of lamb is the highest.

The sheep farming sector needs to receive attention in development strategies through targeted investments, research, and supportive policies to unlock its full potential for food security, and environmental resilience.

## 1.1 Sheep breeding systems

Sheep breeding systems in Algeria are deeply influenced by ecological, socio-economic, and cultural factors. These systems can be categorized into extensive, semi-extensive, and more rarely intensive models, each with distinct characteristics, challenges, and levels of productivity

### a. Extensive Systems

The extensive system is the most traditional and common in Algeria, particularly in steppe and semi-arid and arid regions. This system plays a vital socio-economic role for isolated areas where it represents the main source of income and sustains pastoral traditions. However, it is highly vulnerable to climate variability, land degradation, and seasonal forage shortages.

It is characterized by:

- Low-input, low-output operations
- Dependence on natural grazing with minimal supplementation
- Use of traditional management practices such as nomadism (Azaba) and transhumance, where herds migrate seasonally to exploit pasture availability
- Large flock sizes managed by families or community units

## INTRODUCTION AND PROBLEMATIC OF THE RESEARCH

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### **b. Semi-Extensive Systems**

In response to growing environmental pressures and changing socio-economic conditions, many farmers have shifted toward semi-extensive systems. These systems combine:

- Controlled grazing with strategic supplementation (barley, wheat bran, crop residues)
- Partial sedentarization of herds, reducing mobility while maintaining pasture use
- Often practiced in semi-arid cereal-producing zones, where integration with crop farming helps manage feed supply

Semi-extensive systems are characterized by the strategic use of supplemental inputs to improve animal performance and health, while preserving the core elements of traditional herding practices.

### **c. Intensive Systems**

Less common, intensive sheep farming is emerging in peri-urban areas and among commercial farms. This system is defined by

- Full confinement or very limited grazing
- Complete reliance on concentrate-based diets
- Improved genetics

This system is not practiced exclusively by farmers, but also by traders aiming to produce market-ready sheep for specific religious celebrations focused on rapid fattening and meeting peak market demand during key cultural events. These systems enable higher productivity, particularly for meat production, but require significant investment and infrastructure. Their development remains limited by access to capital, technical expertise, and market stability.

## INTRODUCTION AND PROBLEMATIC OF THE RESEARCH

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**Photos 01, 02 and 03:** Different kind of sheep systems in Algeria; (A): intensive system, (B): semi extensive system, (C): extensive system.

As final point, sheep farming in Algeria has historically been predominantly extensive, heavily dependent on natural resources. Traditional systems including seasonal nomadism (Azaba) and transhumance, where flocks migrate seasonally to access diverse pastures have long characterized the sector (**Bencherif, 2011**) However, due to increasing sedentary populations and environmental degradation, there has been a noticeable shift toward more semi-extensive systems (**Meziane et al., 2024**), combining traditional grazing practices with partial settling of herds and increased use of supplemental feeding. This change aims to better manage limited forage resources and ensure the economic sustainability of farms in a more challenging environmental context.

This transition has also brought diversification in production systems, ranging from nomadic-extensive to semi-sedentary, semi-extensive and fully sedentary models-intensive.

## INTRODUCTION AND PROBLEMATIC OF THE RESEARCH

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These systems vary in terms of herd size and degree of intensification, depending on local environmental conditions and the availability of resources to farmers (**Laoun *et al.*, 2015**).

### 1.2 Nutritional Resources and Feeding Strategies: Reliance on Natural Grazing

Most of the national sheep flock, concentrated between the high cereal-producing plateaus and the vast steppe regions (**Ouali *et al.*, 2023**). This geographic distribution is closely linked to the availability of natural forage and has shaped the dominant production systems across the country. Extensive and semi-extensive systems prevail in these areas, relying heavily on seasonal grazing across natural rangelands.

Under the different sheep breeding systems in Algeria, the animals' diet depends largely on natural grazing, which fluctuates significantly by season and region. While spring and early summer offer relatively abundant and diverse pastures; the Autumn and Winter periods are characterized by forage scarcity, particularly in arid and semi-arid zones where vegetation is scarce, and precipitation is limited. The use of concentrated feed and the integration of sheep farming with cereal crop production have become common strategies, particularly in semi-arid regions, to compensate for the shortage of natural pastures farmers often rely on feedstuffs such as barley, wheat bran, and crop residues, ...etc. as observed (**Slimani *et al.*, 2022**) the Algerian steppe.

For both natural pastures and supplementary feed, the nutritional quality, consistency, availability, and balance of are frequently inadequate and can be insufficient to meet the nutritional requirements of the flocks, particularly during physiologically demanding periods such as late gestation, early lactation, and fattening...etc.

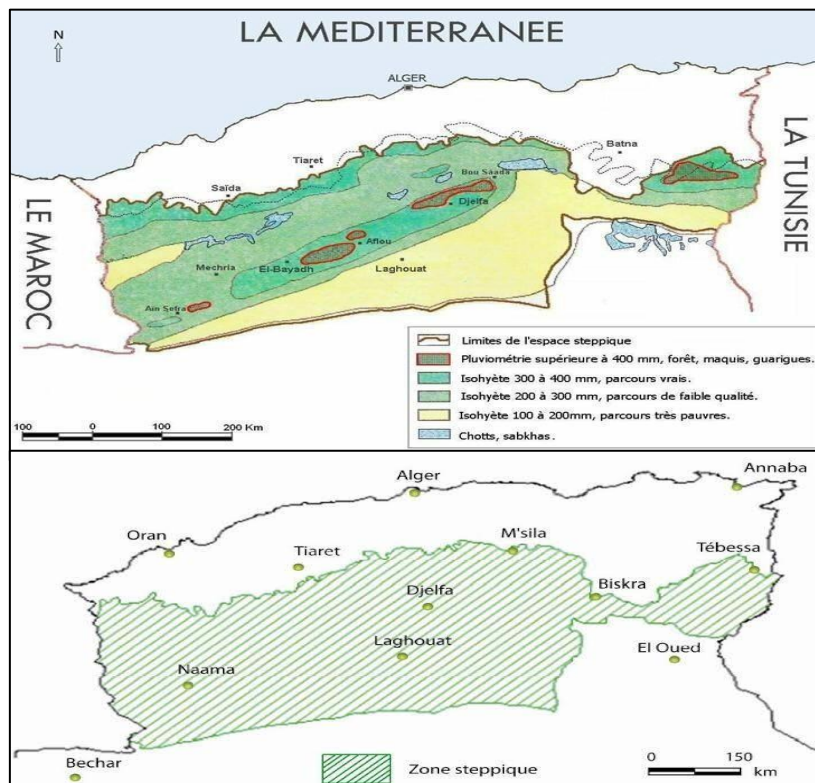
In sheep farming in the Algerian steppes, supplemental feeding has become essential due to the gradual decline of natural pastoral resources. The Algerian steppe, a region primarily dedicated to pastoral activities and extending over approximately 20 million hectares, is regularly threatened by climate variability as well as the increasing frequency and intensity of extreme events (**Bensmira *et al.*, 2020b**). Indeed, this climatic instability is reflected in increased interannual variability of precipitation, a decrease in rainfall, rising temperatures, and more frequent droughts. These unfavorable climatic changes have had severe consequences on grazing areas, leading to a progressive desertification process characterized by a significant regression and depletion of vegetation cover, along with changes in floristic composition, caused by drought, overgrazing, and accelerated land clearing (**Bensmira *et al.*, 2020b**).

## INTRODUCTION AND PROBLEMATIC OF THE RESEARCH

Natural pastures, which are the main source of food for the herds, vary greatly depending on the season and region. They are relatively abundant in spring and early summer but become scarce in autumn and winter. This variability forces farmers to use additional feed, such as barley and bran, to cover the nutritional gaps during critical periods (**Harkat *et al.*, 2024**).

These supplements are often distributed in varying quantities, around 300 g per head per day, with a notable increase before breeding periods or sacrificial festivals(500-800g) (**Meziane *et al.*, 2024**).

This map illustrates the ecological diversity and strategic location of Algeria's steppe zone, which serves as a transitional ecological barrier between the fertile Mediterranean north and the arid Sahara in the south. Represented by a green hatched area, the steppe zone includes cities such as 'Djelfa', 'Laghouat', 'Naama', 'Tiaret', 'Biskra', 'El Oued', 'Tébessa', 'M'sila', and 'Béchar'. It is characterized by a semi-arid climate and vegetation adapted to drought, reflecting a gradual degradation of natural resources especially vegetation cover and water toward the south. This ecological decline directly affects agriculture and livestock farming in the region.



**Figure 01 : Algerian steppes (Nedjraoui *et al.*, 2008).**

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## 1.2.1 Zootechnical Consequences of Nutritional Constraints

Sheep zootechnical performance can be significantly influenced by nutritional constraints. Insufficient feeds, particularly in important stages like gestation and lactation, can have adverse effects on ewe fertility, conception and lambing frequency as well as metabolic disorders in the ewes and slaughter of lambs. Moreover, an unbalanced diet and immunodeficiency increases the incidence of illnesses and mortality, especially in young lambs (Meziane *et al.*, 2024).

The result of these nutritional deficiencies and imbalances observed in certain farms lead to significant variability in zootechnical performance among groups of sheep. This heterogeneity represents a major obstacle to the implementation of genetic improvement programs and complicates the technical and economic management of flocks (Houssou *et al.*, 2021).

The implementation of optimized management practices becomes necessary, and the embracement of innovative technologies aimed at boosting productivity and long-term sustainability.

In this context, understanding the feeding behavior of sheep under different production systems becomes essential for designing more effective and sustainable nutritional interventions. Feeding behavior defined by parameters such as grazing time, intake rate, selectivity, and adaptation to feed types is influenced by various factors including breed, physiological state, environmental conditions, and feed availability. Characterizing and analyzing these behaviors under Algerian farming conditions is therefore crucial to identify current limitations and propose context-specific solutions aimed at improving feed efficiency, animal welfare, and overall flock productivity.

## 2 Feeding behavior of sheep

### 2.1 Definition

Feeding behavior serves as a valuable indicator for developing effective management strategies in sheep, enabling appropriate nutritional and health care to ensure the animals' well-being and ultimately enhance flock productivity (Amorim *et al.*, 2025).

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(Boval & Sauvant, 2019) highlight that feeding behavior influences both feed efficiency and the robustness of ruminants by reflecting their ability to adapt to a variety of available resources. In this context, measuring feeding behavior parameters is associated with identifying and classifying the patterns of feeding, rumination, and idleness exhibited by the animals (Campos *et al.*, 2018).

According to (Jean-Blain, 2002), feeding behavior in ethology is defined as the set of actions through which an animal seeks, selects, and consumes food in adequate quantities to meet its energy and nutrient requirements.

Similarly, (Toates, 1980) noted that ruminants, like other livestock species, strive to align their food intake with their nutritional needs. While many species depend on forage, few are as remarkably adapted as ruminants, which exhibit a unique feeding behavior that combines ingestion and rumination. This combination is essential for breaking down food particles and maintaining optimal rumen pH levels. Together, these activities play a pivotal role in the lives of ruminants.

### 2.2 Factors influencing feeding behavior

- Sheep grazing behavior is shaped by several pasture and forage factors. When there's more forage available and the grass is taller, sheep can take bigger bites, which can speed up grazing, but it might also mean they spend more time chewing. The types of plants in the pasture and their stage of growth also matter. Sheep are pickier eaters when plants are young and tender but become less selective as the plants mature. The quality of the forage plays a role too; when the plants are high in fiber, like with more Neutral Detergent Fiber (NDF), sheep need to chew and ruminate more to digest it properly. All of these factors come together to influence how, what, and how much sheep eat in a pasture (Silva & Filho, 2020).
- Animal-related factors, such as genetics and breeds, greatly influence how sheep feed and utilize forage. Genetic background and breed can affect their feeding behavior, how much they eat, and how efficiently they convert feed into energy (Kaitholil *et al.*, 2023).
- Additionally, age and sex, along with physiological conditions like pregnancy or lactation, shape their nutritional needs and grazing patterns. For example, lactating ewes require more nutrients and often graze differently compared to dry ewes or young lambs,

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highlighting how individual differences impact overall feeding behavior (Silva & Filho, 2020b).

- Environmental and management factors significantly influence how sheep graze and digest their food. Weather conditions, especially temperature and humidity, can affect grazing habits. Sheep tend to graze less during hot periods and ruminate more during cooler times, such as at night. The way pastures are managed, including grazing schedules, intensity, and the number of animals per area, also shapes grazing behavior. When forage is scarce, sheep may change their feeding strategies to meet their nutritional demands. Moreover, providing supplementary feed, like concentrates, can impact grazing patterns by affecting digestion and nutrient absorption in the rumen (Silva & Filho, 2020b).

### 3 Importance and objective of our study: research of nutritional behavioral under limiting conditions

Sheep farming in Algeria faces major challenges, particularly related to feeding and management, which threaten the sustainability of this essential sector. To overcome these issues, the use of easy technologies has become increasingly necessary. Among the most promising innovations are sensor-based tools used to study the grazing behavior of animals to understand how animals interact with pastures, the amount of food they eat in a specific time, the number of meals, how long they eat, grazing time...etc

By using these technologies, we can understand the grazing behavior and energy balance of goats browsing the Algerian steppe (Chebli *et al.*, 2022) this information is crucial for understanding how sheep interact with their environment, their nutritional intake, energy balance, and adaptation to the harsh conditions of the Algerian steppe.

**Our study aims to:** characterize grazing behavior under steppe conditions using sensor technology, as a step toward smarter and more resilient sheep production systems.

More importantly, our approach will enable us to design more effective supplementation strategies that reduce both nutritional losses and the environmental impact caused by uneven grazing patterns. Ultimately, to develop precision livestock farming practices which can improve animal productivity, health, and welfare while also lowering costs and promoting the long-term sustainability of pastoral systems in Algeria.

# **MATERIAL AND METHODS**

## II. MATERIAL AND METHODS

### 1 Study Subjects

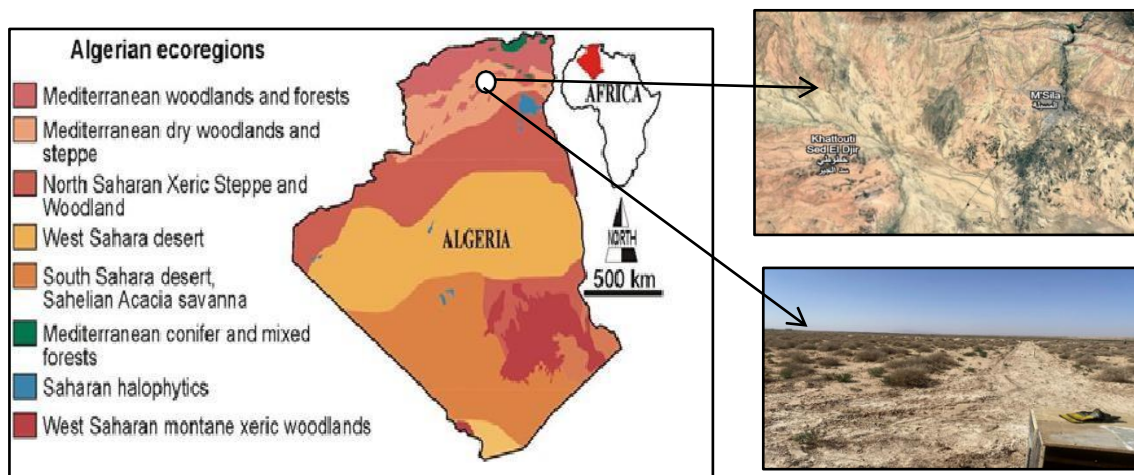
The primary objective of this study is to deepen the understanding of grazing behavior in sheep farming in Algeria, particularly within steppe ecosystems. This is achieved by improving the prediction of animals' maintenance energy requirements and promoting the adoption of user-friendly, low-cost technologies.

This work directly addresses a major challenge in Algerian livestock systems: the limited knowledge of actual feed intake by animals, even during grazing. This lack of precise information often leads to supplementation practices that are based on empirical or traditional methods rather than scientific evidence. As a result, nutritional management tends to be inefficient, potentially compromising animal performance and resource use. By generating accurate data on grazing intake, this study aims to support more rational and science-based supplementation strategies, adapted to extensive and semi-extensive production systems.

### 2 Study area

Our study was conducted on the commercial farm located in the province of M'sila, in the southern part of the country (35° 37' 49" N, 4° 10' 36" E), this farm is situated in a steppe region with a semi-arid climate which serve as a transition zone between the Tellian Atlas to the north and the Sahara to the south. It is considered a representative site of steppe ecosystems, which cover a significant portion of Algeria's pastoral lands (figure 02).

Small ruminant farming, particularly sheep, is the predominant agricultural activity in the region, reflecting both the ecological suitability and the socio-economic reliance of local populations on pastoralism (Zemour & Sadoud, 2021).



**Figure 2:** The geographical location of the study site: satellite photo of the region (Google Earth) and a photo of the experimental pasture 10

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### 2.1 Soil and Climatic Characteristics of the Study Area

#### 2.1.1 Climatic Conditions

The region exhibits a semi-arid climate, characterized by low and irregular annual precipitation, which averages less than 250 mm. Seasonal climatic extremes are typical:

- Winters are cold and dry, with average temperatures around 4°C and minimal rainfall.
- Summers are long, dry, and very hot, with maximum temperatures frequently exceeding 39°C.

These harsh conditions strongly influence forage availability, vegetation dynamics, and animal nutritional behavior, making the area a pertinent site for studying grazing patterns, feed intake, and adaptive management strategies in extensive sheep production systems.

##### a. Temperature

Temperature represents a limiting factor of utmost importance, as it controls all metabolic processes and thus determines the distribution of all plant species and communities of living beings in the biosphere (**Ramade, 2009**).

This fundamental role of temperature becomes even more evident when considering its direct influence on vital physiological phenomena, such as photosynthesis, respiration, and digestion follow Van't Hoff's law, which states that the rate of a reaction is a function of temperature.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Average temperature (°C)	7,7	8,8	13,1	17,1	21,8	27,5	31,2	30,2	24,8	19,6	12,4	8,4
Min Temperature (°C)	3,4	3,8	7,2	10,7	14,8	19,8	23,3	23	19,9	14,4	8,2	4,4
Max temperature (°C)	12,7	14,2	19,1	23,4	28,3	34,4	38,2	37	30,8	25,2	17,3	13,2

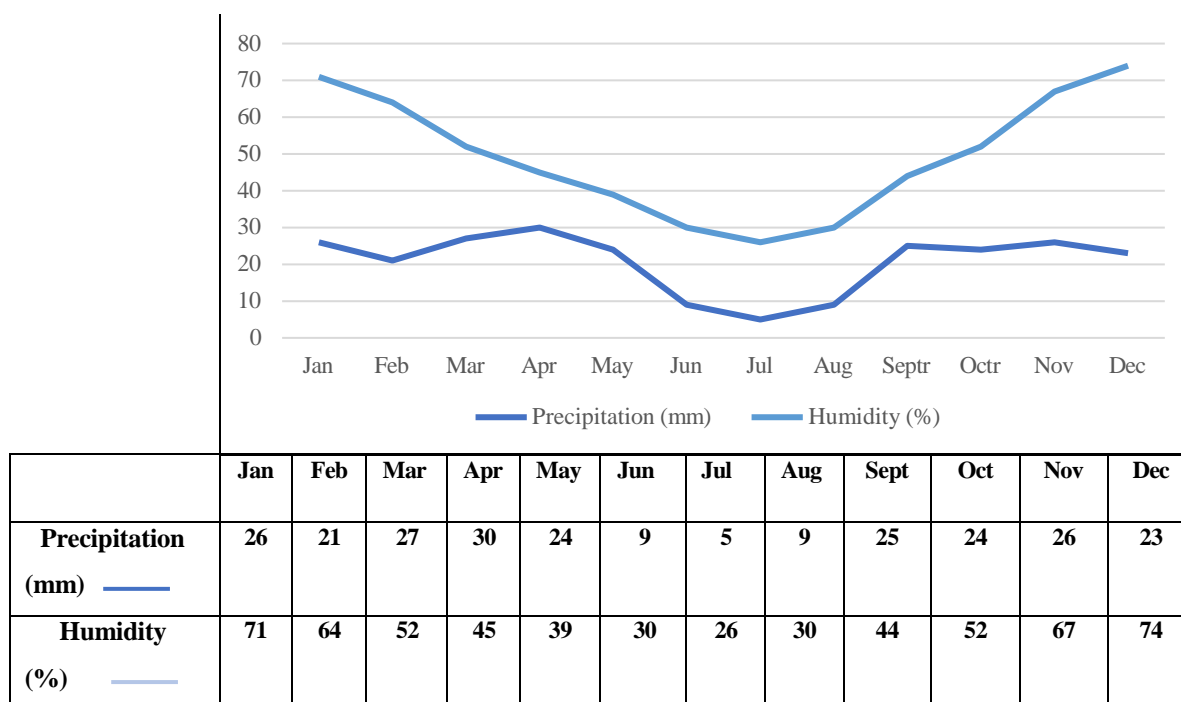
**Table 1:** Monthly Average, minimum (min) and maximum(max) temperatures at Khettouti Sed El Djir Area (1991 - 2021) Resource: tutiempo.net

##### b. Precipitation and Humidity

Precipitation and humidity are two essential climatic factors that directly influence plant growth and ecosystem dynamics and the well-being of livestock animals by affecting forage availability, water resources, and thermal comfort.

## MATERIAL AND METHODS

Precipitation provides the necessary water for soil and vegetation, while humidity controls evaporation and transpiration. Together, they regulate the water cycle and contribute to the water balance of many natural environments. Low humidity coupled with reduced precipitation can lead to significant water stress. These two parameters are therefore fundamental to the functioning of terrestrial and aquatic ecosystems (Brutsaert, 2005)



**Figure 3:** Monthly average of humidity and precipitation in M'sila (1991 – 2021)

Source: climate-data.org

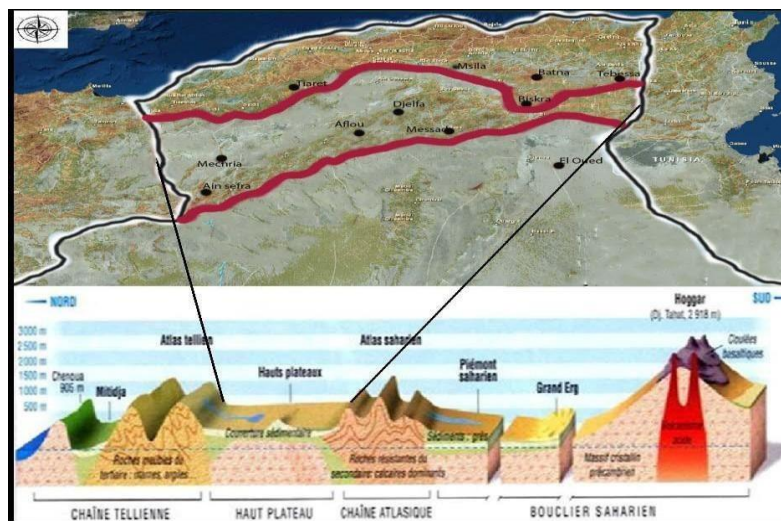
The study area is characterized by a marked deficiency in both precipitation and humidity. This scarcity of moisture significantly limits plant growth, reducing the availability and diversity of natural forage resources. Consequently, livestock in this region are frequently exposed to nutritional stress, which can affect their health, behavior, and productivity.

### 2.1.2 Topographical and Physical Characteristics

Steppe soils are characterized by low organic matter content which limits their fertility and reduces their capacity to retain moisture and nutrients, high vulnerability to erosion and deterioration, and the presence of calcareous deposits that reduce the depth of usable soil (Khaldi, 2014).

## MATERIAL AND METHODS

Most of the steppe zone is located between the Tellian Atlas and the Saharan (or pre-Saharan) Atlas as shown in figure.



**Figure 4:** The topographic characteristics of Algerian steppe (Gaci, 2022)

This area forms high plateaus ranging from 900 to 1200 m in elevation, constituting the Maghrebian steppe domain, which is broadly referred to as the High Plains (Khenioui *et al.*, 2023).

- **Soil characteristics**

Soil is an essential component of the environment, serving as the direct support for numerous human activities and most continental ecosystems (Larabi, 2018). In the study region, soil types vary with geomorphology. Mountainous areas have shallow lithosols and rendzines on hard rocks, while softer substrates host regosols and calcareous brown soils. On glacis with calcareous-gypsum crusts, poorly developed xeric calcimagnesian soils dominate, typical of arid steppe and Saharan zones. Flood-prone areas like "Faidhs" and "Dayas" feature deep sierozems and recent alluvial soils rich in silt, clay, and organic matter. Slopes with sand accumulations contain raw mineral soils of alluvial or aeolian origin, low in organic content (Bendib *et al.*, 2019). Finally, Halomorphic soils, including saline (Solonchaks) and sodic types, are characterized by high sodium content and low organic matter. They are typically found in deep depressions like "Chotts" and "Sebkhas. (Ben Hamouda *et al.*, 2017).

### 2.1.3 Ecological characteristics

The landscape is primarily open rangeland, dominated by native grass and shrub species, and is traditionally used for extensive livestock grazing.

## MATERIAL AND METHODS

The steppe ecosystem is home to a variety of forage species that are essential for sustaining livestock under arid and semi-arid conditions. These plants have adapted to harsh environmental constraints such as low rainfall, high temperatures, and poor soil fertility. The following table presents some of the principal forage species commonly found in steppe regions, highlighting their botanical characteristics, palatability, and seasonal availability for grazing.

		
<b><i>Anabasis articulata</i></b> (Adjram )	<b><i>Artemisia campestris</i></b> (Wormwood)	<b><i>Stipa tenacissima</i></b> (Alfa grass)
		
<b><i>Atriplex halimus</i></b> (Gtef)	<b><i>Retama raetam</i></b> (ar-rotm)	<b><i>Ziziphus litus</i></b> (Sedra)
		
<b><i>Astragalus spinosus</i></b> (Astragale épineuse)	<b><i>Salvia rosmarinus</i></b> (Romarin)	<b><i>Thymelaea hirsuta</i></b> (Mithnan)

**Table 2:** Visual reference table on the main forage plants in the Steppe.

## MATERIAL AND METHODS

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### 2.2 Crop and Livestock Production Activities in the study area

#### 2.2.1 Crop Production

All livestock farmers practice cereal cultivation. The choice of crop species varies depending on the year and the objectives of the agropastoral. Most large-scale agropastoralists prioritize barley cultivation to meet the needs of their herds, regardless of the year. Others prefer to grow durum wheat in good years and usually purchase barley, which is generally less expensive. Small-scale agropastoralists cultivate both cereals to meet the household's food needs and provide fodder for their small herds (Bencherif, 2011).

Crop production	Cereals	Fodder Crops	Fruits	Olives	Market Gardening
Cultivated Area (Qx)	324,200	1,278,400	852,930	111,270	2,829

**Table 3:** Main Crop Yields (in Quintals) in the M'Sila Region (Source: DSA 2016)

#### 2.2.2 Animal Production

Traditionally, the steppe has been dedicated to the extensive farming of sheep, goats, and dromedaries, with occasional cereal cultivation as a supplementary activity (Aïdoud *et al.*, 2006). Current livestock systems in the steppe are mainly centered around sheep, often raised alongside goats.

While national statistics provide an overview of herd size and species distribution across the country, data at the steppe level offer a more precise understanding of the dynamics specific to arid and semi-arid zones. The following table (or section) compares livestock numbers nationally and within steppe zones, highlighting the importance of this sector in fragile ecosystems. The table below, summarizes the livestock population at the national level and within the steppe region.

## MATERIAL AND METHODS

Livestock Numbers (Head)	Sheep	Goats	Cattle	Camels	Horses
National total (Head)	29,428,929	4,986,116	1,780,591	416,519	151,516
Steppe total (Head)	18,360,916	2,369,048	188,743	33,871	32,525
Percentage in steppe (%)	62	47.5	10.6	8.1	21.5

**Table 4:** Comparative Trends in Livestock Populations: Steppe vs. National Contexts (Source: MADR, 2019).

### 3 Animals, experimental design, and management

#### 3.1 Animal Material

26 ewes were used for the experiment, including three age groups: lambs of 1 year old, adult ewes aged 1 to 8 years, and older than 5 years including primiparous and multiparous.

The animals identified were allocated into two groups according to their weight (BW) and body condition score (BCS), heavy and light ewes two weeks before the experimentation to attend two homogenic nutritional status between groups. This sampling aimed to establish two nutritionally homogeneous groups. Each group was then subjected to a specific dietary supplementation treatment.

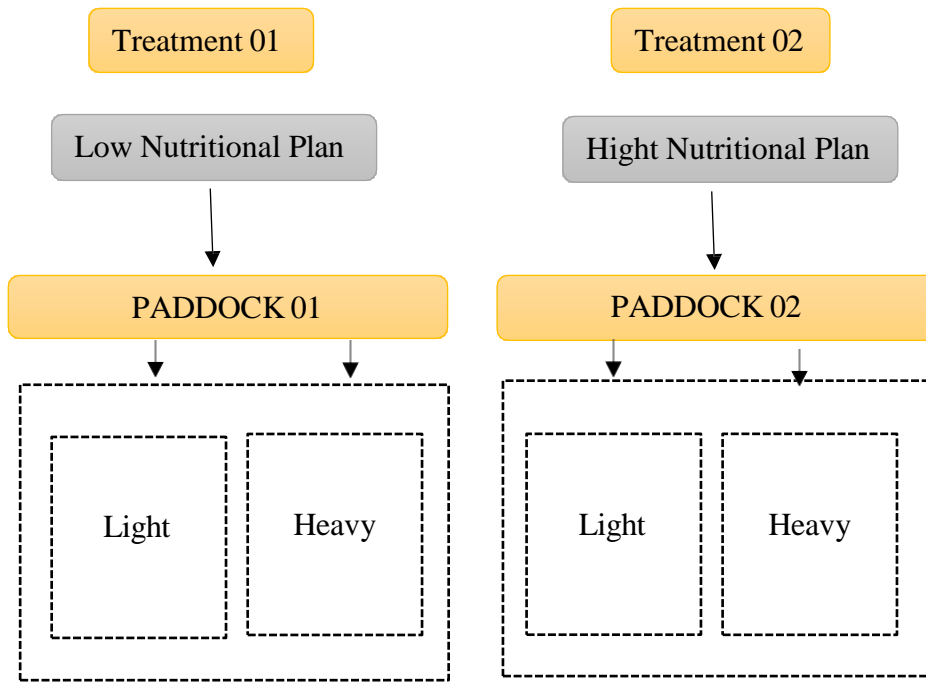
The animals were managed on spontaneous steppe and were supplemented with straw and barley grains. The ewes graze for about 6 hours per day.

#### 3.2 Experimental Design

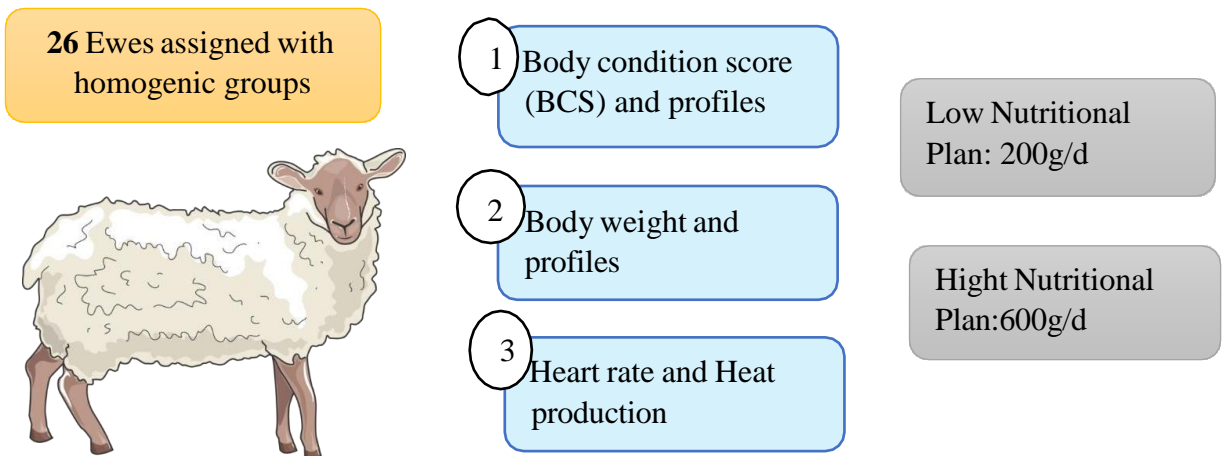
The study was designed using a factorial approach, incorporating two main factors. Two paddocks were set up with electric fencing to accommodate the two groups of animals.

The animals were evenly divided into two groups of 13 ewes each, balanced for age, BCS, and BW. The groups received two different supplementation levels: a high level (approximately 600 g of barley grains) and a low level (200 g of barley grains).

# MATERIAL AND METHODS



**Diagram 01:** Experimental Design



**Diagram 2:** Parameters Monitored During the Experiment

## MATERIAL AND METHODS

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### 4 Measures

#### 4.1 Diet Analysis

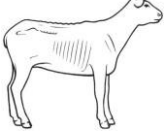
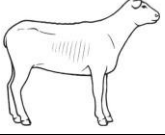
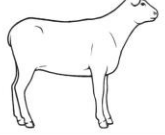
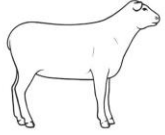
During the experiment, ewes had access to the allocated pastures; a steppe pasture, then they receive a concentrate ration consisting of barley and mineral and a vitamin mixture. Two types of supplementations were utilized, a low nutritional plan (LNP) with low complementation of 200 g per day per head and a high nutritional plan (HNP) with 600 g per day per head.; ewes also had access twice a day to fresh drinking water.

##### ◇ Body weight and body condition score

During the experiment, BW was measured once a month using a portable digital weighing scale.

The BCS was assessed following the method described by **(Russel, 1984)**

performed by palpation of the dorsal spines and the transverse processes of the lumbar vertebrae. The scoring is done on a scale from 0 to 5. (Table 07) and was evaluated by one technician, every month.

Description of Animal Condition	Assigned BCS	Figure
Cachectic state: animal in danger, unfit for work. Unable to prolonged effort, requires frequent and long rest.	0-1	
Animal with low endurance	2-3	
Animal fit for work	3-4	
Plethoric animal (overly fat). Lacks endurance for work.	5	

**Table 5:** Body condition scoring

## MATERIAL AND METHODS

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### 5 Behavioral Observations

Behavior was characterized by:

#### 5.1 Heat Production

for measurements of Heart rate rating of Heat energy to HR to measure the energy expenditure.

Energy expenditure in sheep can be estimated by monitoring their heart rate (HR) combined with movement activity. In this method, each sheep is fitted with a specialized belt device that continuously records both heart rate and physical activity data throughout the observation period.

The heart rate sensor detects the beats per minute, which correlates with the animal's metabolic rate, to provide a more accurate estimation of the animal's total energy expenditure.

This approach allows us to monitor the metabolic energy and animal behaviors under grazing conditions.



**Photo 04:** Instrumented animals wearing heart rate measurement devices. Data Analysis

The data collected during the experiment included nutritional, behavioral, and metabolic parameters. For each parameter, three to four repeated measurements were recorded to assess their dynamics over time. Statistical analysis was performed using the General Linear Model (GLM) with the repeated measures procedure, after verifying the assumptions of application, particularly sphericity (tested using Mauchly's test). In the event of a violation of the sphericity assumption, correction was applied using the Greenhouse-Geisser method.

In addition to the effect of the trial period, the models included fixed effects related to the nutritional plan level, the subjects' initial body condition, and their starting weight, in order

## **MATERIAL AND METHODS**

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to assess their influence on the parameters studied. Post-hoc analyses were conducted to compare means between the different experimental groups in cases of significant differences.

To clearly visualize the trends, graphs showing the temporal evolution of the parameters based on the variation factors were generated. All analyses were performed using Statistical Package for the Social Sciences (SPSS) version 26, with a significance threshold set at  $p < 0.05$ .

# **RESULTS AND DISCUSSION**

## RESULTS AND DISCUSSION

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### III. RESULTS AND DISCUSSION

#### 1 Effect of dietary supplementation on body condition and body weight dynamic

The effect of the different treatments on Body Condition Score (assessed every two weeks) and Body Weight (measured monthly) throughout the experimental period was examined. The results are as follows:

##### 1.1 Effect on body condition dynamic

The evolution of BCS throughout the experimental period revealed moderate variations across the different time points ( $p \approx 0.07$ ), with no significant effect of individual factors when considered separately ( $p > 0.05$ ). However, a common trend was observed across all experimental groups. (Table 6)

Source of Variation		Dynamic (Sig)	Level (Sig)
<b>Factors</b>	<b>Period</b>	0,073	
	<b>NLP</b>	0,411	0.710
	<b>SBCS</b>	0,245	0.002 <0.001
	<b>Parity</b>	0,868	0.398
<b>Interactions</b>	<b>Parity * NLP</b>	0,421	0.519
	<b>SBCS * NLP</b>	0,495	0.413

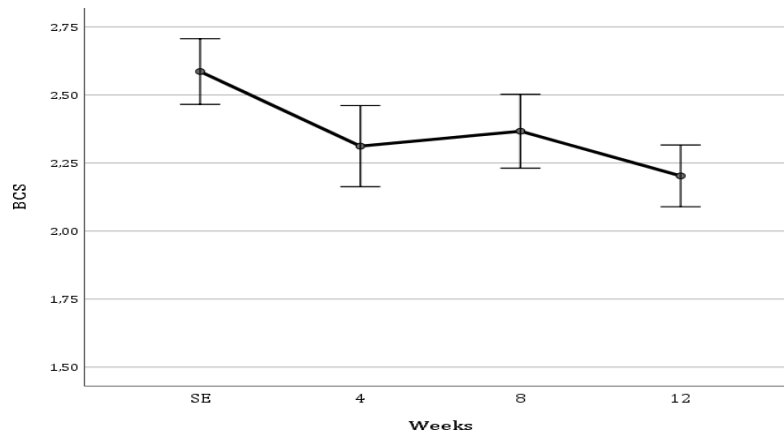
**Table 6:** Effect of dietary supplementation on body condition (*NLP: Nutritional Level Plan, BCS: Body Condition Score, Sig: significance at  $p < 0.05$* )

- *The BCS dynamic profile*

The overall trend in BCS across the experimental period, measured every month during the experiment, was presented in the figure below. Initially, animals show a relatively high average BCS of around 2.6, but a noticeable decline is observed in week 4, dropping to approximately 2.3, a slight recovery occurs in week 8, yet the BCS continues to fall by week 12, reaching around 2.2.

## RESULTS AND DISCUSSION

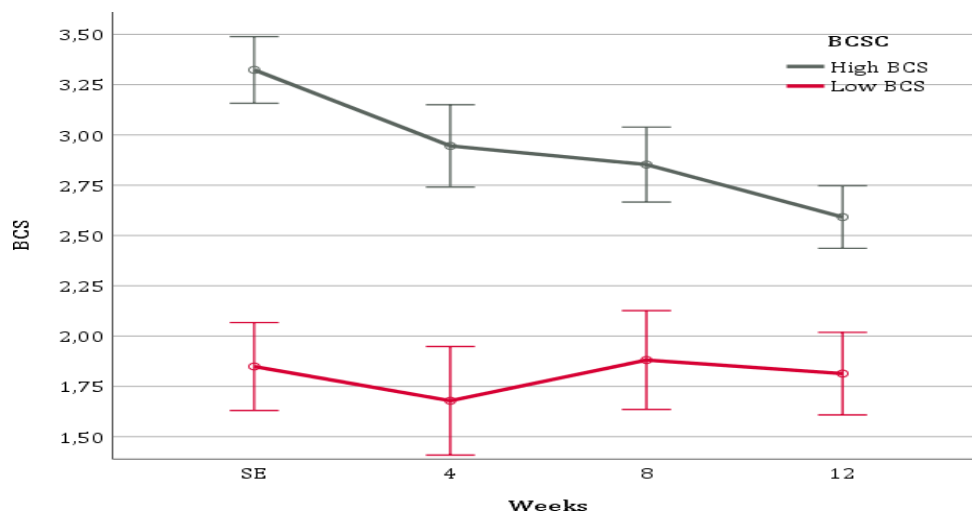
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**Figure 05:** Body condition score evolution profiles (SE: start of the experiment)

- ***Effect of the initial BCS***

Animals with different initial BCS levels (High BCS vs. Low BCS) trend differently over time at  $p < 0.05$ . Animals classified under the High BCS group start, as shown in the figure below, with a much higher average BCS (around 3.3), but show a steady decline across the 12 weeks, ending at approximately 2.7. In contrast, the Low BCS group begins with a lower BCS (around 1.8) and shows minimal change over time, with slight fluctuations but no significant upward trend. This suggests that while animals with higher reserves lose more condition over time, possibly due to greater mobilization of fat stores those starting at a lower BCS fail to recover or improve their condition significantly. The differences between the two groups remain consistent throughout, highlighting the importance of initial BCS in managing animal health and productivity.

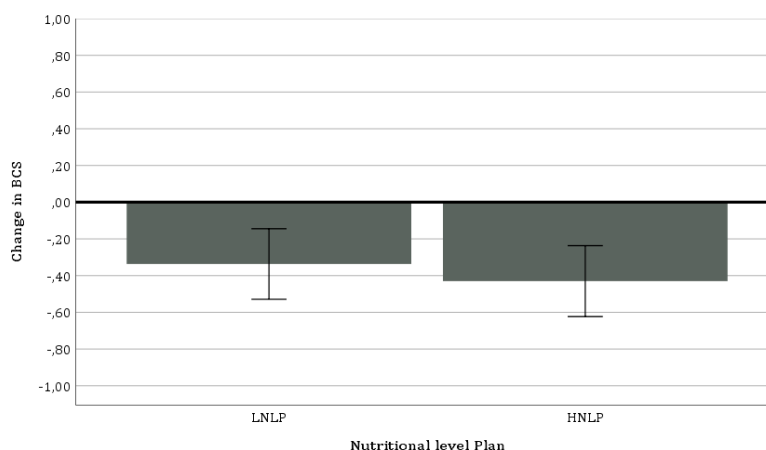


**Figure 06:** Body condition score profiles according to the initial ewes' BCS

## RESULTS AND DISCUSSION

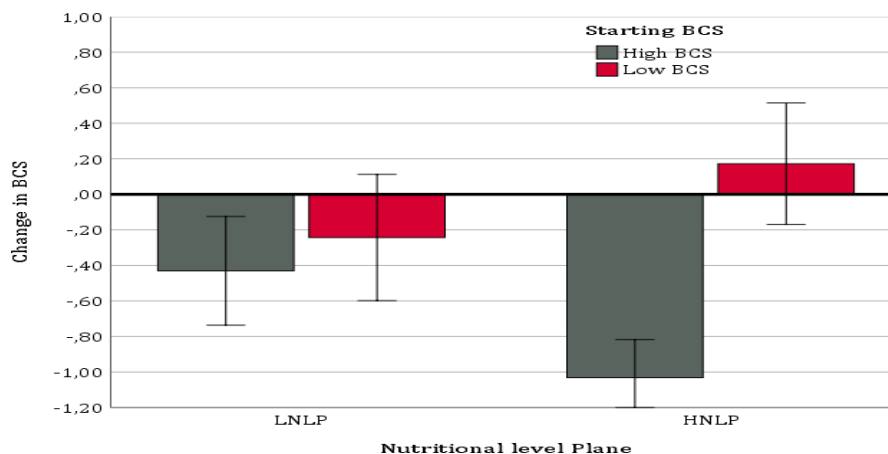
### 1.1.1 Change in body condition between the start and end of the experiment

The boxplot below compares the change in BCS between the L-NLP and the H-NLP. In both groups, the median BCS change is negative, indicating an overall loss of body condition over time. However, H-NLP exhibits a slightly greater decrease in BCS than L-NLP, and both have moderate interquartile ranges. This result suggests that increased nutritional intake did not necessarily prevent condition loss and may reflect higher metabolic demand in animals fed more intensively.



**Figure 7:** Change in BCS between the start and the end of the experiment

Therefore, when animals were separated by initial BCS: high BCS and low BCS. The most striking result was seen in high-BCS animals under H-NLP, which show a large median drop in BCS with relatively small variability, suggesting consistent fat mobilization in this group. In contrast, low-BCS animals on H-NLP tend to gain condition or maintain it, as indicated by a slightly positive or neutral median. L-NLP groups show similar trends but with more variation. This indicates that initial condition strongly influences how animals respond to diet.



**Figure 8:** Change in Body Condition Score (BCS) According to Nutritional Plan and Initial BCS Category

## RESULTS AND DISCUSSION

### 1.2 Effect on BW dynamic

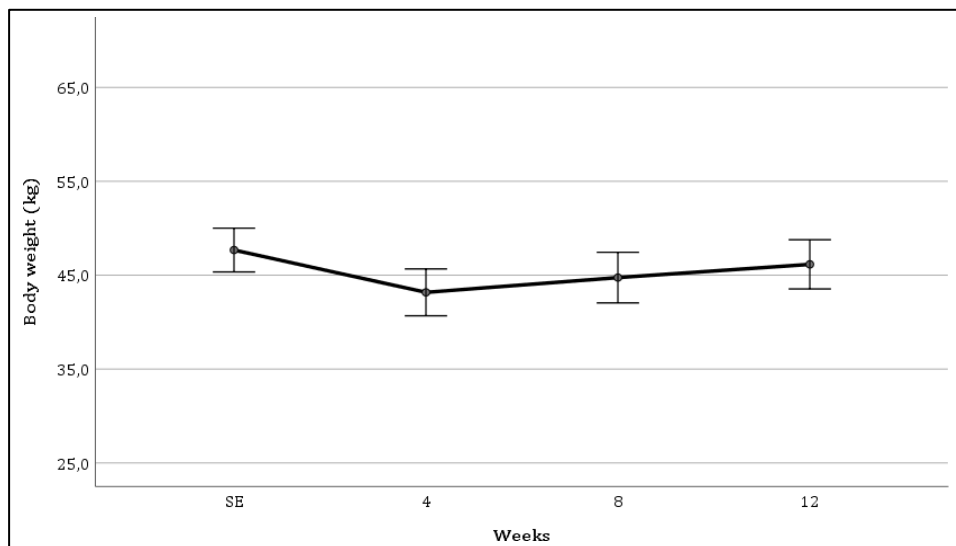
Source		Dynamic (Sig)	Level (Sig)
<b>Factors</b>	<b>Period</b>	0,001	
	<b>NLP</b>	0,002	0.520
	<b>SBW</b>	0,483	0.030
	<b>Parity</b>	0,001	0.020
<b>Interactions</b>	<b>NLP *Parity</b>	0,480	0.561
	<b>NLP * SBW</b>	0,509	0.740

**Table 7:** Effect of dietary supplementation on body weight (*NLP: Nutritional Level Plan, BW: Body weight, Sig: significance at  $p < 0.05$* )

- *Body weight profile*

The overall BW trend across different time points, presented in the graph below, from the start of the experiment then weeks 4, 8, and 12.

At the start, the average BW was just above 45 kg. There is a noticeable decline in week 4, with the average weight dropping slightly below 45 kg. However, from week 4 to week 12, the BW gradually increases, approaching the initial value by the end of the study period.



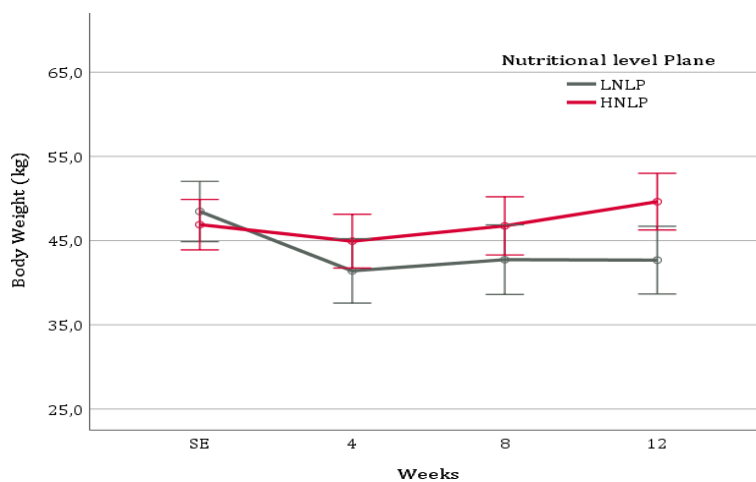
**Figure 9:** Body weight evolution profiles

## RESULTS AND DISCUSSION

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- *Effect of Nutritional plan treatments*

The effect of the two different nutritional level plans (L-NLP and H-NLP) on BW over the experiment timeline was presented in the graph below. Both groups show a decline in BW at week 4. However, the H-NLP group demonstrates a clear and consistent increase in BW from week 4 to week 12, ultimately surpassing its initial weight. In contrast, the L-NLP group remains relatively flat after the initial drop, showing minimal recovery. This suggests that the nutritional intervention provided under H-NLP is more effective in supporting weight maintenance and gain during the study period. These results imply that higher or more balanced nutritional support contributes positively to BW recovery and management.

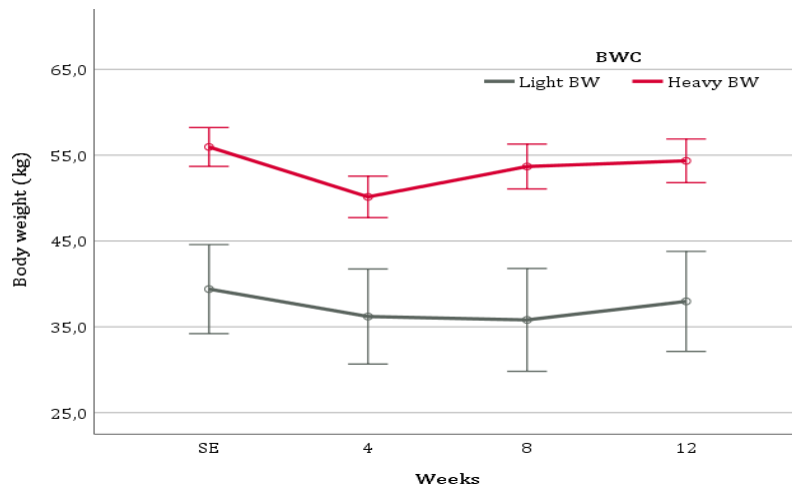


**Figure 10:** Effect of nutritional level plan on body weight profile

- *Effect of initial Boy weight*

The initial body weight had a significant effect on the body weight profile during the experiment period. The graph below compares animals categorized by their initial BW: Light BW and Heavy BW. The Heavy BW group consistently shows higher BW profile compared to the Light BW group. Both groups experience a drop in weight at week 4, but the Heavy BW group demonstrates a more noticeable recovery over time. This indicates that heavier animals are better able to maintain or regain their BW.

## RESULTS AND DISCUSSION

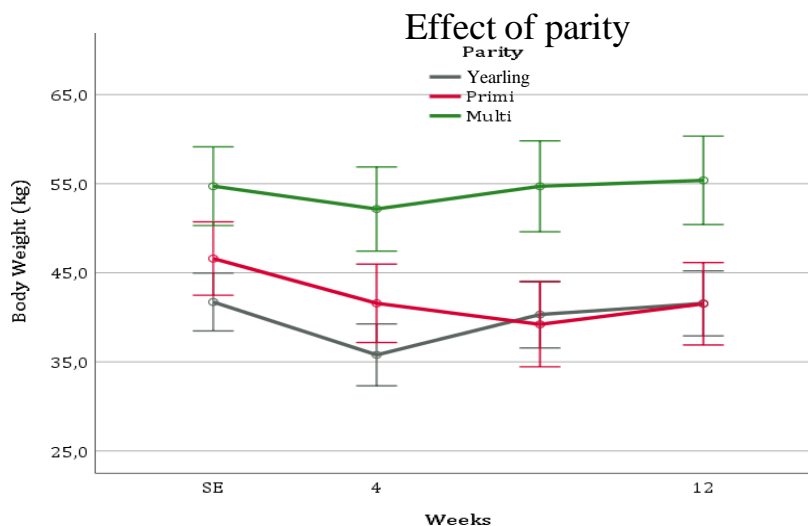


**Figure 11:** Effect of Initial BW on the body weight profiles

- **Effect of parity**

Parity had a significant effect on the evolution of the ewes' BW. The groups represent yearling, primiparous, and multiparous.

The multiparous, as shown in the below figure, maintained the highest BW across all period timelines. All groups show a dip in weight at week 4, but the multiparous group demonstrates a more robust recovery by week 12. The other two groups remain at lower BW throughout the study, with only modest recovery after the initial drop.

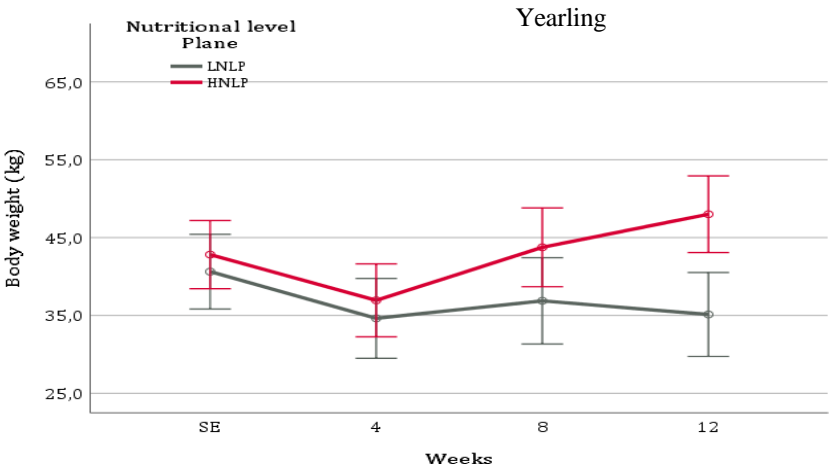


**Figure 12:** Effect of parity

# RESULTS AND DISCUSSION

- *Yearling*

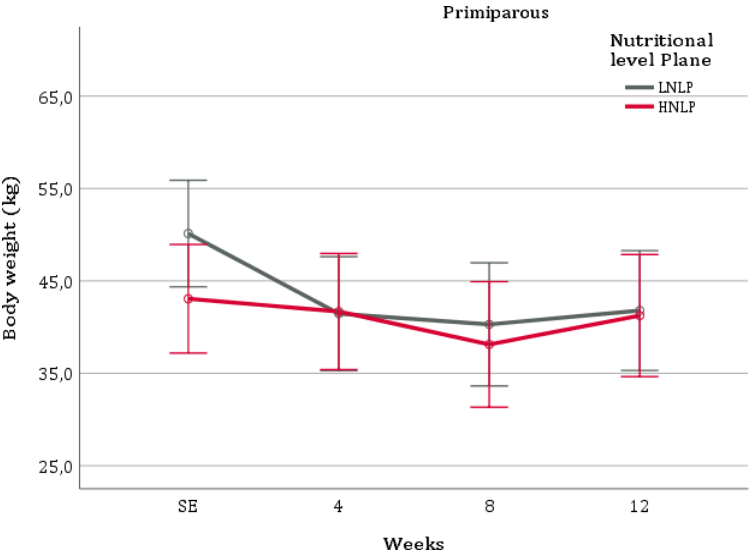
The BW evolution of yearling under two nutritional levels: L-NLP and H-NLP are represented in the figure below. We observed that regardless the nutritional treatment, the yearlings showed a decrease in BW by week 4, with a steeper drop for the LNLP. From week 4 onward, the HNLP group begins to recover significantly, ending the study with higher BW than they started with. In contrast, the L-NLP group remains relatively flat after week 4, with a much smaller increase by week 12.



**Figure 13:** Effect of nutritional Plans on body weight profiles - Yearling -

- *Primiparous*

Among primiparous, both nutritional groups begin with similar BW and show a decline by week 8. However, the H-NLP group displays a more pronounced recovery from week 8 to week 12 compared to the L-NLP group, which remains nearly flat.



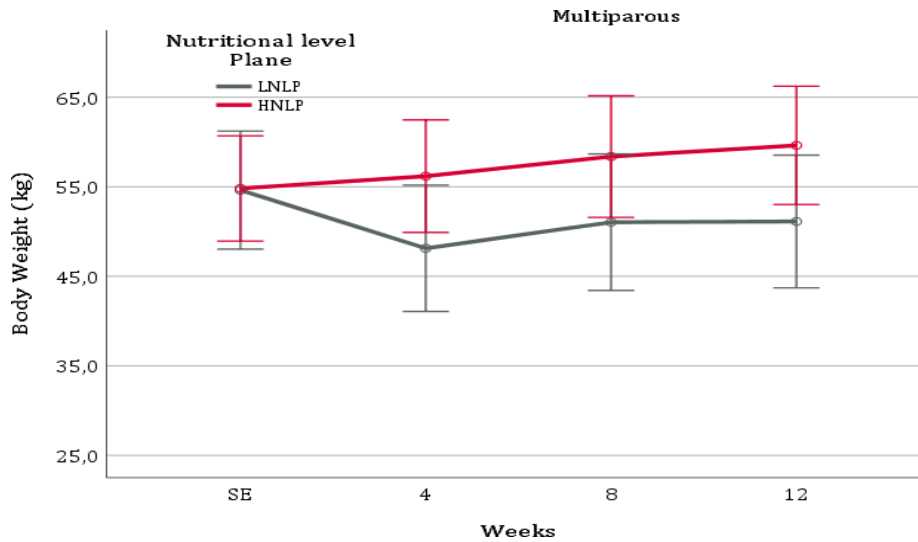
**Figure 14:** Effect of nutritional Plans on body weight profiles - Primiparous 27

## RESULTS AND DISCUSSION

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- **Multiparous**

The multiparous ewes in the H-NLP group not only start with higher BW but also shows a consistent upward trend throughout the study period, peaking at week 12. The L-NLP group of ewes, on the other hand, experiences a dip in week 4 and only a modest recovery afterward. The divergence between the two groups becomes more pronounced over time, indicating that multiparous respond strongly to enhanced nutrition.

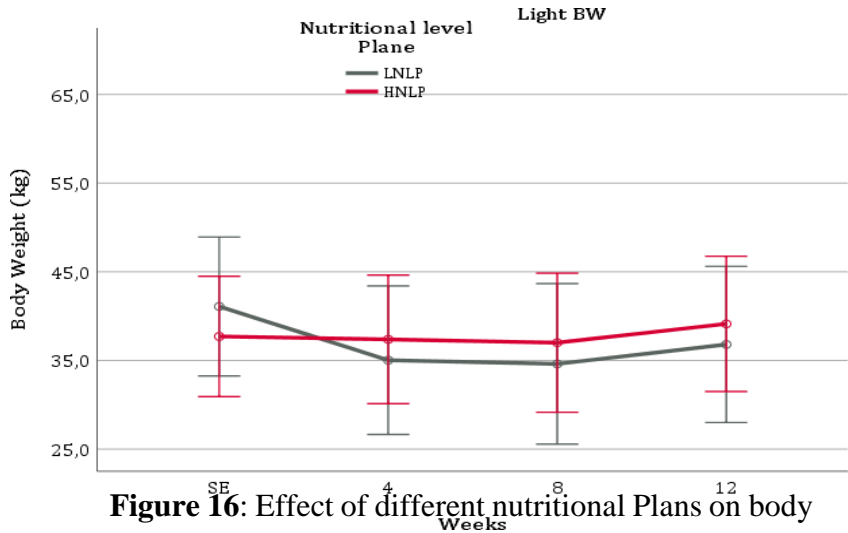


**Figure 15:** Effect of nutritional Plans on body weight profiles - Multiparous –

- **Initial body weight**
- **Light ewes**

The ewes starting the experiment with a light BW, showed (figure below), both the LNLP and HNLP groups, similar body weight profiles. There is a drop in weight by week 4 for both groups, followed by a slight recovery through week 12. However, the difference between nutritional planes is minimal. This suggests that lighter animals may not show a pronounced benefit from higher nutritional supplementation.

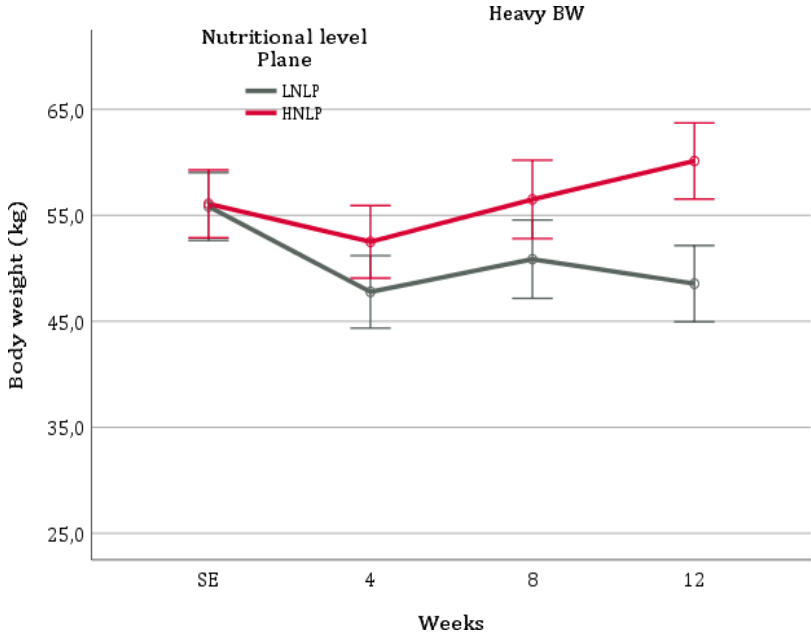
# RESULTS AND DISCUSSION



**Figure 16:** Effect of different nutritional Plans on body weight profile- Light ewes

- **Heavy ewes**

Heavy BW animals show the most distinct response to nutritional intervention. The HNLP group begins with higher BW and maintains a strong upward trajectory after the initial decline at week 4. By week 12, this group shows a marked gain in weight compared to the LNLP group, which remains relatively stable after week 4. The widening gap between the groups over time highlights that heavier animals benefit significantly from enhanced nutrition, allowing for better weight retention and sustained gain.



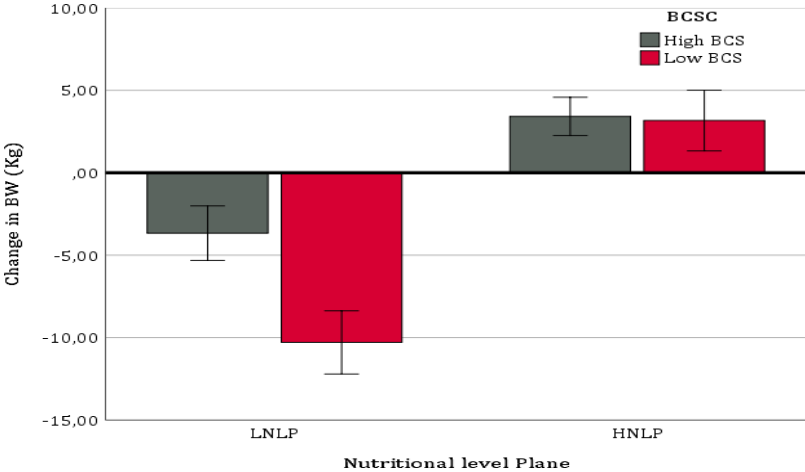
**Figure 17:** Effect of different nutritional Plans on body weight profile- Heavy ewes

# RESULTS AND DISCUSSION

## 1.2.1 Change in body weight between the start and end of the experiment

- Nutritional plan**

The change in BW between animals with high and low (BCS) under L-NLP and H-NLP is shown in the figure below. Under L-NLP, both BW groups lose weight, however, the low BW group experienced a much greater weight loss, nearly -10 kg, while the high BW group loses less than -5 kg. In contrast, under H-NLP, both groups gain weight, with the high BW group gaining slightly more than the low BW group.

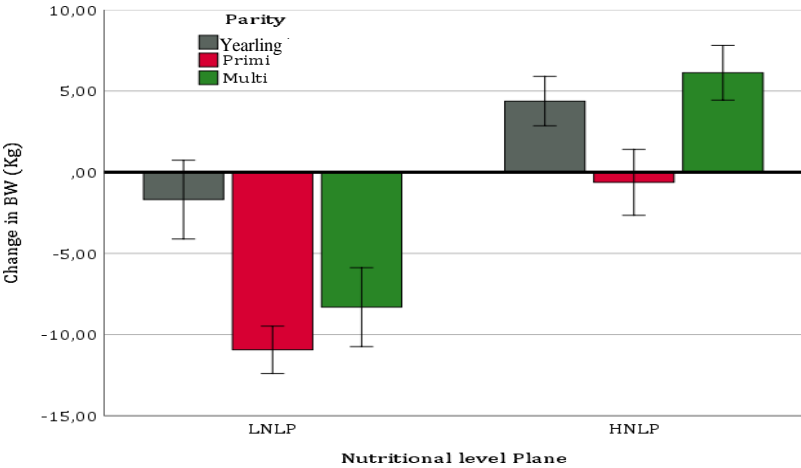


**Figure 18:** Change in BW by nutritional plan

- Parity**

Change in BW for yearling, primiparous, and multiparous under LNLP and HNLP were set up; the results were presented in the following figure.

In L-NLP, all groups lose weight, with primiparous animals experiencing the most severe loss (nearly -12 kg), followed by yearling and multiparous. Under H-NLP, however, all groups either maintain or gain weight. Multiparous benefits the most from improved nutrition, showing the highest weight gain (~7 kg), followed by yearling and primiparous.

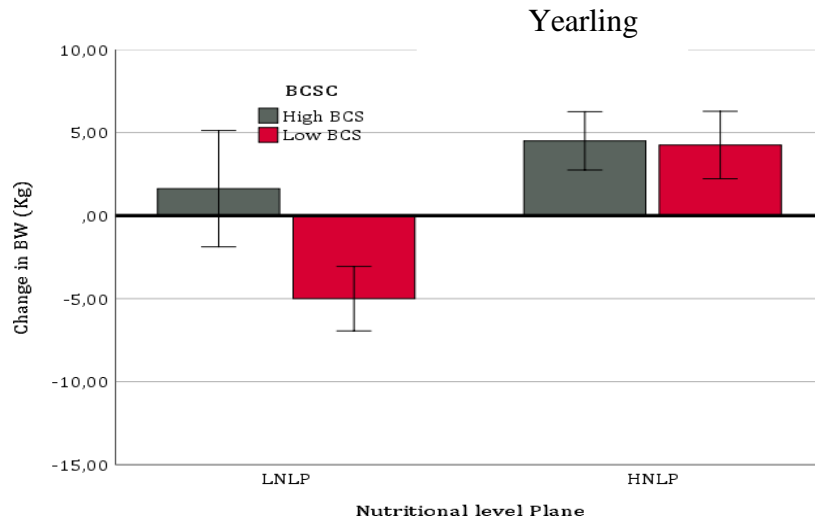


**Figure 19:** Change in BW by parity and nutritional plan

## RESULTS AND DISCUSSION

- **BCS**

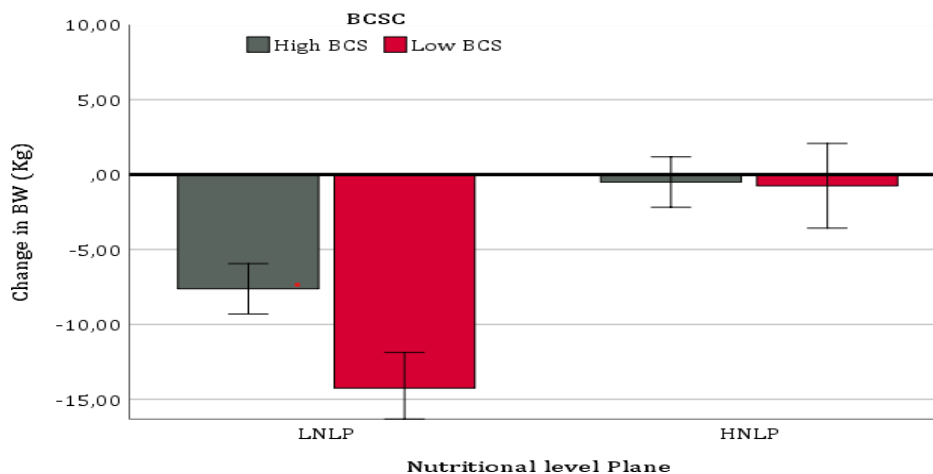
Here, the change in BW is compared between high and low BCS yearling under both nutritional planes. In LNLP, the low BW group shows substantial weight loss (~ -8 kg), while the high BWW group shows less weight loss (~ -4 kg). Under HNLP, both groups gain weight, with the high BCS animals gaining slightly more.



**Figure 20:** Change in BW change according to BCS for the different treatments

In primiparous, low BCS animals on LNLP lose significant weight (approaching -13 kg), while high BCS animals lose less (~ -6 kg). Under HNLP, both groups have minimal changes in weight. This suggests that HNLP helps stabilize weight but doesn't necessarily promote significant gain in primiparous.

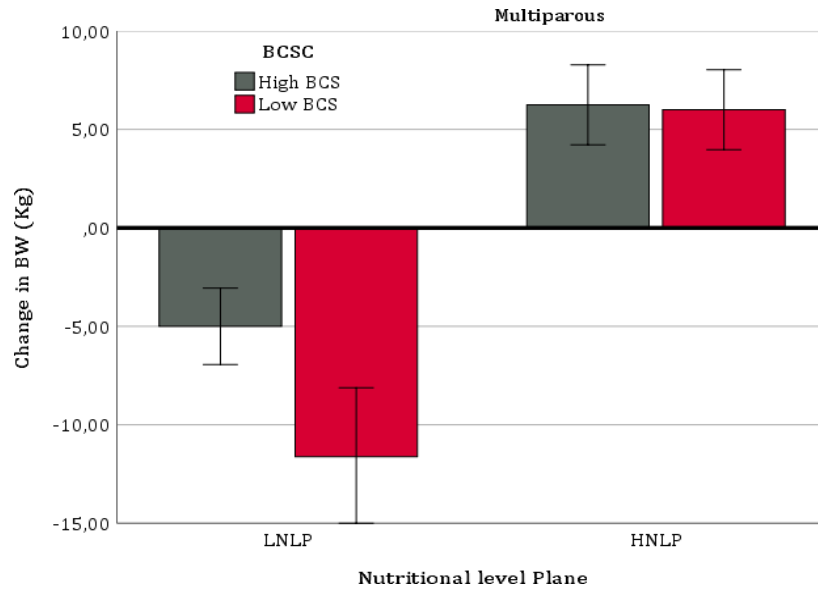
### Change in BW in Primiparous



**Figure 21:** Change in BW in Primiparous

## RESULTS AND DISCUSSION

Finally, in multiparous both high and low BW groups lose weight under L-NLP, but low BW animals lose much more (~ -12 kg). Under H-NLP, both groups gain weight, and the gains are similar (~5–6 kg), indicating strong positive response to improved nutrition regardless of starting BCS. Multiparous clearly shows the most robust gain under high nutrition and less vulnerability compared to other parity groups.



**Figure 22:** Change in BW in Multiparous

## 2 Effect of dietary supplementation on heat production

The effect of the different dietary treatments on heat production was explored and the results of the effect of some fixed factors and their interaction were resumed in the following table.

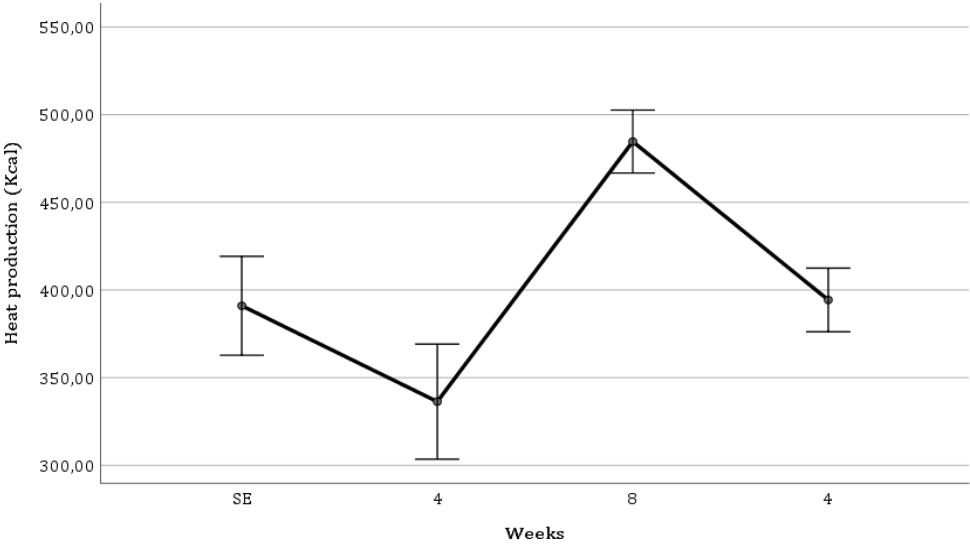
Source of variation		Dynamic (Sig)	Level (Sig)
Factors	Period	0,002	
	Parity	0,985	0.824
	NLP	0,142	0.020
	SBCS	0.742	0.122
	SBW	0.032	0.362

**Table 8:** Effect of dietary supplementation on heat production (NLP: Nutritional Level Plan, BCS: Body Condition Score, BW: body weight, Sig: significance at  $p < 0.05$ )

# RESULTS AND DISCUSSION

- *Heat production trends*

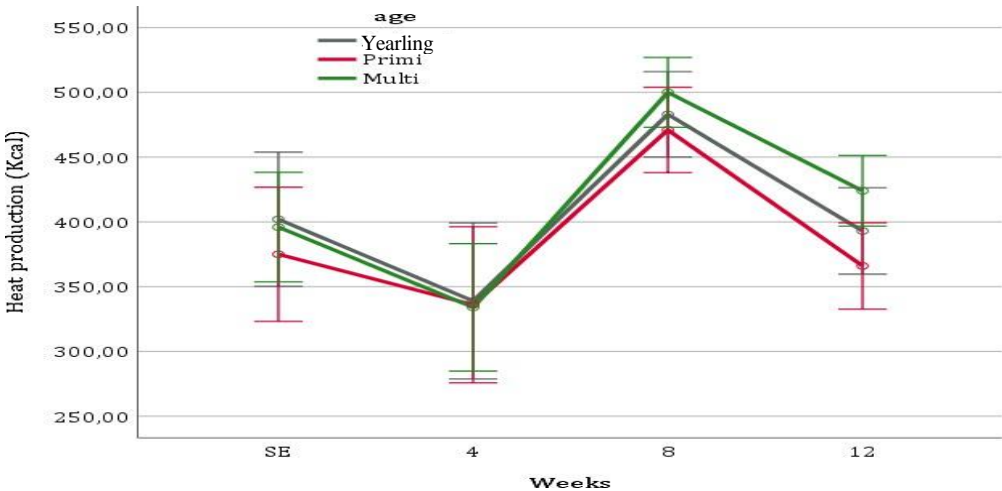
The figure below illustrates the trend of HP (in Kcal) over four time points of the experiment. There is an initial decline in HP from the start of the experiment to week 4, reaching the lowest point at week 4. This is followed by a sharp increase, peaking at week 8, and then a moderate decline by week 12.



**Figure 23:** Heat production evolution of ewes (SE: star of experiment)

- *Effect of parity*

To outline HP across different parity groups, the profiles of HP according to these groups are presented in the figure below. All groups exhibit a similar trend, an initial dip at week 4, a peak at week 8, and a decrease by week 12. Notably, the Multiparous group shows the highest HP at week 8, suggesting a heightened metabolic response. Conversely, the yearling group records the lowest HP at week 12, potentially indicating lower metabolic reserves or energy mobilization capacity. These patterns imply that parity influences energy metabolism.

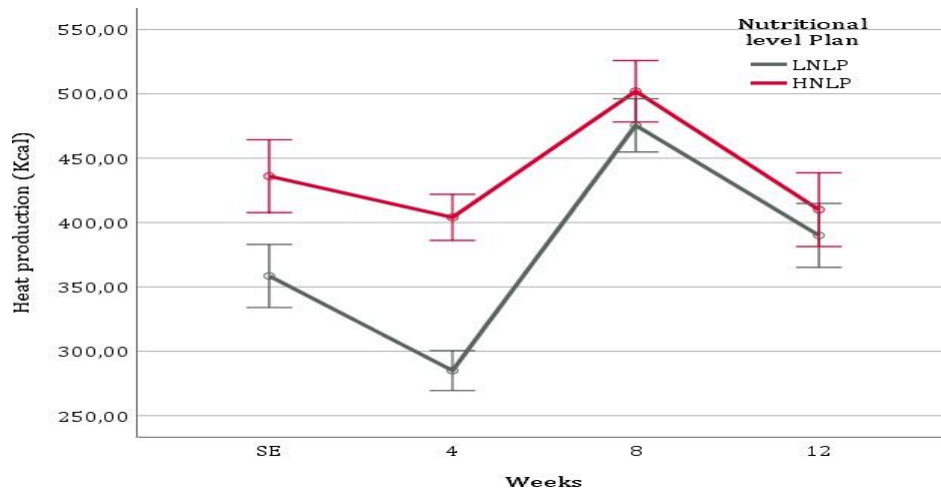


**Figure 24:** Effect of parity on heat production trends

## RESULTS AND DISCUSSION

- **Effect of nutritional plan**

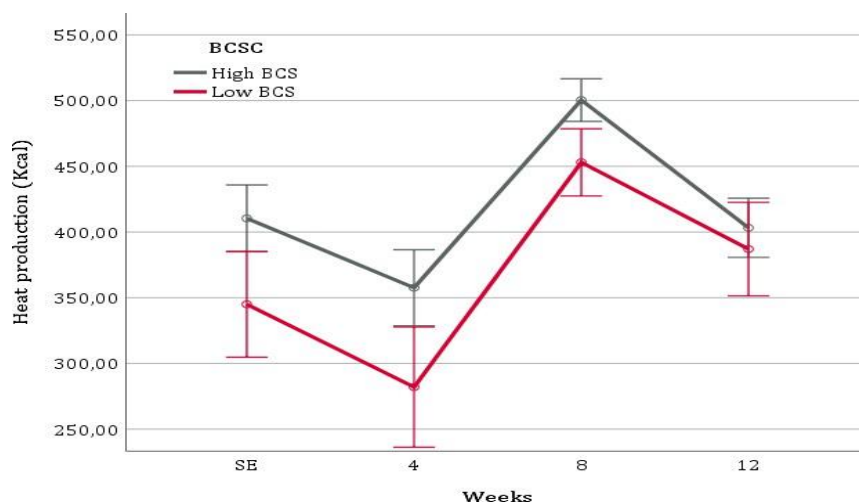
The different trends of HP according to the nutritional treatments are presented below. Across all time points, the H-NLP group consistently shows higher HP. The L-NLP group experiences a pronounced decline in week 4 and a gradual recovery thereafter. The peak at week 8 in the HNLP group is particularly prominent, reinforcing the notion that higher nutritional intake supports sustained metabolic activity.



**Figure 25:** Effect of nutritional level plane on heat production trends

- **Effect of BCS**

This graph displays HP trends among animals according to BCS. High BCS animals show relatively stable and elevated HP, peaking at week 8. In contrast, Low BCS animals display a sharp drop at week 4 and a modest increase at week 8. This indicates that animals with greater body reserves (high BCS) are better able to maintain metabolic activity over time, while those with low BCS may lack the necessary reserves, resulting in decreased HP during energy-deficient periods.

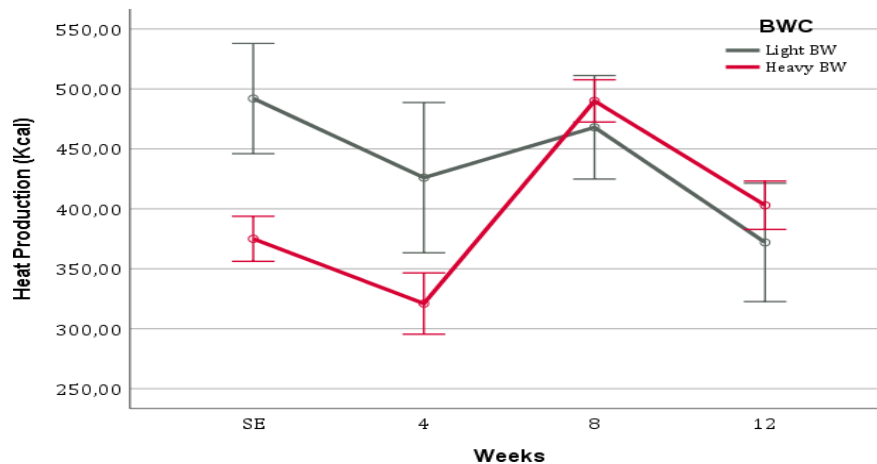


**Figure 26:** Heat production trends according to body condition score

## RESULTS AND DISCUSSION

- **Effect of body weight**

The effect of body weight on the heat production trends are shown in the below figure. Initially, Light BW animals exhibit higher HP, but their output drops sharply by week 4, rebounds in week 8, and drops again in week 12. In the other hand, Heavy BW animals have a more stable metabolic curve, with a modest but clear increase in heat production by week 8. These findings suggest that lighter individuals may experience more pronounced metabolic fluctuations.



**Figure 27:** Heat production trends according to the initial ewes' body weight

### 3 Discussion:

#### 3.1 Effect of dietary supplementation on body condition score BCS

Ewes receiving different levels of dietary supplementation exhibited distinct patterns of BCS evolution throughout the experimental period, reflecting underlying differences in metabolic status, as also described by *Caldeira et al., 2007*. These variations indicate that energy requirements are closely linked to body condition, with BCS serving as a key indicator of the animal's ability to mobilize or store energy under varying nutritional conditions.

Our results regarding the evolution of BCS under nutritional stress are consistent with those reported by (*Macé et al., 2019*) in their analysis of intra-flock variability in meat sheep. In their work, they observed a general decline in BCS during the early weeks of dietary restriction, followed by stabilization, which aligns closely with the pattern observed in our trial.

Similar to our results, they found that initial body reserves play a critical role in shaping individual responses to feed restriction; ewes with higher initial BCS exhibited a greater decline, suggesting higher metabolic demands and a greater ability to mobilize fat reserves.

## RESULTS AND DISCUSSION

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Furthermore, both studies (our and **Macé *et al.*, 2019**) highlighted that multiparous ewes are more sensitive to dietary restriction than primiparous ones, likely due to cumulative physiological burdens from previous reproductive cycles. The observed stabilization phase in both studies also reflects the capacity of sheep to physiologically adapt to prolonged nutritional challenges.

These parallels reinforce the significance of individual variability in body reserve dynamics and support the need for precision feeding strategies that consider parity and initial BCS to optimize flock resilience and productivity.

### 3.2 Effect of dietary supplementation on body weights

Meat production from sheep represents a key economic component of overall productivity. In situations of nutritional stress, particularly when animals rely on poor-quality pastures, dietary supplementation plays a critical role in maintaining body weight and supporting growth, making it an essential management tool for sustainable meat production.

Our results showed that nutritional treatments have a significant effect on the body weight trends. The body weight profiles also were affected by parity, initial body weight with better trends for multiparous and heavy ewes.

Nutritional stress has been shown to negatively impact the oxidative status of sheep and trigger physiological responses such as weight loss according to **Chauhan *et al.*, 2014**; who suggest that it can be mitigated through appropriate dietary supplementation which can explain the superiority of the HNP ewes. Additionally, multiparous ewes tend to manage their body reserves more efficiently over time, possibly due to physiological memory from previous reproductive cycles, leading to improved long-term weight gain (**Menni *et al.*, 2017**).

Our findings agree with **Nageye & Koyuncu, 2024b** in Kırircık sheep. Their research highlighted that ewe with higher live weights and optimal BCS exhibited significantly improved performances. This supports our observation that multiparous ewes, which maintained the highest average BW (~55 kg) and responded best to HNLP, are physiologically better positioned to support reproductive functions. Conversely, yearlings, which started with lower BW and showed greater weight loss under LNLP, likely face greater metabolic stress, potentially reducing their reproductive success.

Furthermore, our results confirm that nutritional strategies play a critical role in modulating body weight responses, particularly in heavier ewes, aligning with the notion that

## RESULTS AND DISCUSSION

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fertility outcomes are closely linked to the animal's nutritional status and metabolic reserves. These parallels suggest that the interaction between live weight, parity, and nutrition must be carefully considered in reproductive management programs to optimize fertility performance in sheep.

### 3.3 Effect of dietary supplementation on heat production

Our study identified a biphasic pattern in HP in sheep, marked by an initial decrease from the starter phase to week 4, followed by a peak at week 8, and a subsequent decline by week 12. These variations reflect shifting metabolic demands, influenced by physiological processes such as tissue accretion, maintenance, and dietary adaptation. Notably, sheep with higher BCS, greater body weights, and those on HNLP exhibited increased HP, particularly at week 8, suggesting heightened metabolic activity.

These results are aligned with those reported by **Goetsch (2023)**, who observed that grain-supplemented grazing ewes showed increased heat energy expenditure due to enhanced basal metabolism and tissue synthesis. Similarly, our study found that well-nourished sheep and those with higher BCS had elevated HP, especially during growth-intensive phases, reinforcing the impact of energy intake on metabolic output.

Moreover, Goetsch's findings show that HP rises with improved nutrition and declines under forage restriction align with our results, where HNLP groups consistently exhibited higher HP in early stages. However, the diminishing differences between groups by week 8 may indicate metabolic adaptation or a plateau effect, suggesting that while increased nutrition initially boosts metabolic activity, its influence may stabilize over time.

The association between (BCS/BW) and HP further supports Goetsch's conclusions, as sheep with greater body mass showed higher energy expenditure, likely due to the increased cost of maintaining larger tissue mass. This highlights the vital connection between body composition and metabolic function in grazing systems.

# **CONCLUSION**

## CONCLUSION

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### IV. CONCLUSION

Based on our study conducted in Steppe, we draw the following conclusions regarding the impact of dietary restriction on BCS, BW, and HP in ewes:

First, we found out that BCS loss is more pronounced in animals with substantial initial reserves. Ewes with a high BCS exhibit a greater ability to mobilize fat reserves, leading to a more significant decline in BCS under nutritional restriction. This effect is particularly evident in primiparous ewes, as their elevated energy demands make them more vulnerable to dietary limitations compared to other groups.

Second, the results highlight the importance of tailoring feeding plans not only based on initial weight but also according to BCS and parity. This ensures optimal physical condition and productivity for ewes. Additionally, ewes with low BCS are particularly susceptible to nutritional restrictions, which can negatively impact their reproductive performance and overall well-being. Consequently, well-structured nutritional interventions are essential to maintaining their physiological balance.

Regarding HP, our findings highlight the importance of body weight as a key factor influencing metabolic dynamics and suggest that energy management strategies in growing sheep should be tailored according to weight class: our results reveal distinct metabolic patterns between lightweight and heavyweight sheep over the course of the study. Lightweight sheep exhibited higher HP during the starter phase reflecting greater relative energy demands for physiological adaptation followed by a decline, suggesting a transitional phase in metabolic regulation or improved feed efficiency. In contrast, heavyweight sheep started with lower HP values during the early stages but showed a sharp increase later.

We concluded that our results highlight how initial physiological status including body weight, body condition, and parity interacts with nutritional strategies to influence both energy reserves and metabolic responses in ewes. Heavier animals with better initial condition maintained more favorable profiles, although they also exhibited greater absolute losses in BCS, suggesting higher mobilization potential. In contrast, lighter animals were more sensitive to nutritional constraints. The observed effects of nutritional treatment on BW and the influence of parity and BW on heat production further emphasize the need for precise and adaptive feeding strategies to optimize flock resilience and overall productivity.

Finally, in pasture-based systems, where individual feed intake is often unknown and difficult to monitor, such adaptive management becomes even more critical. The integration of

## **CONCLUSION**

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sensors to monitor heat production and estimate energy expenditure can offer a powerful tool to bridge this gap. By providing real-time insights into the animals' metabolic status, sensors can inform better decisions on supplementation levels, tailored to both individual needs and environmental conditions. This technology-driven approach has the potential to significantly improve nutritional efficiency, animal welfare, and overall system sustainability in extensive sheep production.

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## **Abstract:**

The study was designed to investigate the effect of dietary supplementation on body reserve mobilization, assessed through body condition score (BCS) and body weight (BW), with the aim of improving animal performance under low-input, pasture-based sheep production systems in the Algerian steppe. For this purpose, 26 ewes aged between 1 to 8 years were used and allocated into four groups according to two factors: dietary treatment (high nutritional plan vs. low nutritional plan) and the initial body condition score (BCS). Body condition score and body weight were recorded monthly throughout the study. Additionally, heat production was calculated to assess the metabolic response of the animals under the different nutritional regimens. Our results showed that BCS and BW dynamics were significantly influenced by dietary supplementation, parity, and initial physiological status. Ewes with high initial BCS experienced greater losses in body condition, suggesting enhanced fat mobilization. In contrast, those with low BCS struggled to improve their condition. Similarly, ewes on the high nutritional plan demonstrated better BW recovery, especially among multiparous and heavy animals. Heat production patterns revealed that animals with higher BW and better nutrition showed elevated metabolic activity. These findings underscore the importance of individualized feeding strategies tailored to body reserves and parity to enhance productivity and resilience in extensive systems. In conclusion, targeted nutritional management, considering initial BCS, BW, and parity, is essential for optimizing energy balance, maintaining body condition, and improving metabolic responses in ewes grazing under harsh steppe conditions. Implementing precision feeding approaches and integrating sensor-based monitoring can further support sustainable sheep production in low-input environments.

**Keys words:** Ewes, Steppe, Nutritional plan, Dietary supplementation, Body condition score, Body weight, heat production

## **Résumé**

Cette étude a été élaborée pour évaluer l'effet de la supplémentation alimentaire sur la mobilisation des réserves corporelles, à travers le suivi de l'état corporel (BCS) et du poids vif (BW), dans le but d'améliorer les performances animales dans les systèmes d'élevage ovin extensifs à faibles intrants de la steppe algérienne. Pour ce faire, 26 brebis âgées de 1 à 8 ans ont été réparties en quatre groupes selon deux facteurs : le traitement nutritionnel (plan nutritionnel élevé vs plan nutritionnel faible) et le score corporel initial. Le BCS et le BW ont été enregistrés mensuellement tout au long de l'étude. De plus, la production de chaleur a été calculée pour évaluer la réponse métabolique des animaux selon les différents régimes alimentaires. Nos résultats ont montré que la dynamique du BCS et du BW était significativement influencée par la supplémentation alimentaire, la parité et l'état physiologique initial. Les brebis avec un BCS initial élevé ont connu des pertes corporelles plus importantes, suggérant une mobilisation accrue des graisses. En revanche, celles ayant un BCS faible ont eu du mal à améliorer leur état. De même, les brebis soumises à un plan nutritionnel élevé ont mieux récupéré leur poids, notamment les multipares et les animaux lourds. Les tendances de production de chaleur ont révélé une activité métabolique plus élevée chez les animaux mieux nourris et avec un poids plus élevé. Ces résultats soulignent l'importance d'une gestion nutritionnelle individualisée adaptée aux réserves corporelles et à la parité pour renforcer la résilience et la productivité dans les systèmes extensifs. Une gestion nutritionnelle ciblée, tenant compte du BCS initial, du poids vif et de la parité, est essentielle pour optimiser l'équilibre énergétique, maintenir la condition corporelle et améliorer la réponse métabolique des brebis dans les conditions difficiles de la steppe. L'intégration d'approches de nutrition de précision et de capteurs de surveillance peut encore améliorer la durabilité des systèmes d'élevage ovin à faibles intrants.

**Mots-clés :** Brebis, Steppe, Plan nutritionnel, Supplémentation alimentaire, Score corporel, Poids vif, Production de chaleur.

## **المخلص**

صُممت الدراسة لبحث تأثير المكملات الغذائية على تعبئة الاحتياطي الجسمي، من خلال تقييم حالة الجسم (حالة الجسم) والوزن الجسمي (الوزن الجسمي)، بهدف تحسين أداء الحيوانات في نظم إنتاج الأغنام المعتمدة على المراعي ذات المدخلات المنخفضة في السهوب الجزائرية. لهذا الغرض، تم استخدام 26 نعجة تتراوح أعمارها بين 1 و8 سنوات وتوزعها إلى أربع مجموعات وفقاً لعاملين: المعاملة الغذائية (نظام غذائي عالي مقابل نظام غذائي منخفض) وحالة الجسم الأولية (حالة الجسم). تم تسجيل حالة الجسم والوزن الجسمي شهرياً طوال مدة الدراسة. بالإضافة إلى ذلك، تم حساب إنتاج الحرارة لتقييم الاستجابة الأيضية للحيوانات تحت الأنظمة الغذائية المختلفة.

أظهرت نتائجنا أن ديناميكية حالة الجسم والوزن الجسمي تأثرت بشكل كبير بالمكملات الغذائية وعدد الولادات والحالة الفسيولوجية الأولية. النعاج ذات حالة الجسم الأولية المرتفعة عانت من فقدان أكبر في حالة الجسم، مما يشير إلى تعبئة أكبر للدهون. في المقابل، النعاج ذات حالة الجسم المنخفضة واجهت صعوبة في تحسين حالتها. وبالمثل، أظهرت النعاج في النظام الغذائي العالي تعافياً أفضل في الوزن الجسمي، خاصة بين النعاج متعددة الولادات والحيوانات الثقيلة الوزن. كشفت أنماط إنتاج الحرارة أن الحيوانات ذات الوزن الجسمي الأعلى والتغذية الأفضل أظهرت نشاطاً أيضاً أعلى. تؤكد هذه النتائج على أهمية استراتيجيات التغذية الفردية المصممة حسب الاحتياطي الجسمي وعدد الولادات لتعزيز الإنتاجية والقدرة على التحمل في النظم الواسعة. يُعد الإدارة الغذائية المستهدفة، التي تأخذ في الاعتبار حالة الجسم الأولية والوزن الجسمي وعدد الولادات، أمراً ضرورياً لتحسين التوازن الطاقي والحفاظ على حالة الجسم وتعزيز الاستجابات الأيضية في النعاج التي ترعى في ظل ظروف السهوب القاسية. يمكن لتنفيذ أساليب التغذية الدقيقة ودمج المراقبة المستندة إلى أجهزة الاستشعار أن يدعم بشكل أكبر إنتاج الأغنام المستدام في البيئات ذات المدخلات المنخفضة.

**الكلمات المفتاحية:** تربية الأغنام، السهوب، سلوك الرعي، درجة الحالة الجسمية، الوزن الحي، الجزائر، التغذية التكميلية.