UNIVERSITE KASDI MERBAH OUARGLA
Faculté des Sciences de la Nature et de la Vie

Département des Sciences Agronomiques

Mémoire de Master Académique

Domaine : Sciences de la Nature et de la Vie
Filière : Sciences agronomiques
Spécialité : Parcours et élevage en zones arides

THEME

Qualitative Assessment of Dromedary (*Camelus dromedarius*) Dung According to Husbandry Systems in the Ouargla Region

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Soutenu publiquement :
Le 23 /06 / 2025

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ANNÉE UNIVERSITAIRE 2024/ 2025

Acknowledgements

Dedications

To my dear parents, for all their sacrifices, support, and prayers throughout my studies

*To my brothers **Salah** & **Ziad**, and sisters **Batoul**, **Ikram** & **Assil** for their belief in me*

*To my dear friend & brother **ABBASSI Mouad** who's been here from the start of my studies*

*To my colleagues **Wided** & **Marwa** for being here throughout this modest work*

*To a close friend **Khaoula** for her support and honest help*

To all the friends & family I made throughout my academic career without exceptions

IMAD

List of acronyms

Sys	System
ANOVA	Analysis of Variance
OM	Organic matter
MM	Mineral matter
C/N	Carbon to nitrogen ratio

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Abstract

Introduction

The dromedary camel, often referred to as "the ship of the desert," has accompanied nomadic populations for millennia, offering a reliable means of transportation across arid landscapes due to its exceptional adaptability to harsh climatic conditions (**Dekmouche, 2023**). Beyond its role in mobility, it sustains the livelihoods of pastoralist communities, such as those in the Ouargla region of the Algerian Sahara, by providing essential products including meat, milk, wool (*oubar*), and even manure, which serves as a potentially valuable organic input for agriculture.

Although camel Husbandry remains marginal on a national scale in Algeria, it constitutes a key animal resource for desert regions. The camel population increased from 234,220 in 2000 to 324,199 in 2013 and reached 416,519 in 2018. Compared to the 120,000 recorded in 1987, this growth reflects the increasing recognition of the camel's importance in the national economy through employment creation and supply of animal products (**Meghelli, 2020**). According to the latest FAOSTAT data, the Algerian camel population had reached approximately 439,134 head by 2023 (**FAOSTAT, 2025**).

In a country where the Sahara covers over three-quarters of the territory, camel Husbandry is spread across three agroecological zones: the Sahara, the Saharan Atlas, and the Steppe. It is present in 17 Saharan wilayas (provinces) and 9 steppe regions (**Chehma, 2005**; **Saadoud, 2019**).

The Saharan ecosystem is marked by extreme edaphic and climatic constraints, supporting only hardy vegetation such as woody species, halophytes, and thorny plants. In this resource-scarce environment, the dromedary exhibits remarkable adaptability, surviving, reproducing, and producing meat and milk under extensive systems that rely almost entirely on natural rangelands (**Chehma, 2009**). The camel contributes significantly to the valorization of Saharan spaces. Its selective yet non-destructive grazing behavior helps preserve fragile ecosystems (**Longo et *al.,* 2007**), while its capacity for endozoochoric seed dispersal enhances vegetation regeneration (**Trabelsi et *al.,* 2016**). The animal's diet is intimately tied to the various types of desert vegetation, which form the foundation of extensive camel farming systems (**Trabelsi et *al.,* 2017**).

Often overlooked, the dromedary camel represents a valuable yet underexploited resource with substantial economic potential. In Algeria, camels are primarily raised for meat and milk, with meat being the main product (**Brahimi, 2021**). The country accounts for 2.6% of global camel

meat production, with 15,913.96 tons produced in 2023 (**FAOSTAT, 2025**). This orientation toward meat is likely influenced by the genetic characteristics of local camel populations, which favor meat production (**Senoussi, 2012**).

Regarding milk, although interest in camel dairy products has been increasing, national production remains modest. With an average yield of only 6 liters per day, Algeria contributes 0.4% to global camel milk production, reaching 15,013.6 tons in 2023 (**Kadri, 2021**; **FAOSTAT, 2025**).

In addition to meat and milk, the camel skin has shown promise as an alternative source of halal gelatin, offering a safer substitute for bovine gelatin, which carries the risk of zoonoses such as bovine spongiform encephalopathy (**Redjeb, 2022**).

Dung is another significant byproduct. It serves as both organic manure and fuel for pastoralists in resource-poor areas (**Champak & Sahan, 2006**). However, due to the camel's efficient nitrogen recycling—recovering up to 97% of nitrogen at renal and intestinal levels—its dung is low in nitrogen content and slow to decompose due to a moisture content below 15%, limiting its immediate fertilizing value (**Faye et *al.,* 2022**).

However, studies have shown that its potential can be enhanced through treatment processes such as co-digestion with municipal organic waste, which not only increases biogas production (up to 57.3% methane) but also improves the quality of the digestate as a biofertilizer (**Benaissa et *al.,* 2017**).

The bio methanation of animal waste, including that of camels, represents a sustainable energy solution for remote areas of the Sahara. Experiments in Algeria have shown that these organic materials enable low-cost biomethane production while also contributing to the fertilization of agricultural soils (**Tou & Touzi, 2001**).

Nonetheless, understanding the nutrient composition of camel manure represents an opportunity for agricultural application, especially in the fragile and nutrient-poor soils of the Sahara (**Dekmouche, 2023**).

According to the same author, these soils are often skeletal in nature and require organic inputs. Traditional livestock (camels, sheep, and goats) and the more recent introduction of dairy cattle and broilers could help enhance soil fertility and support agricultural expansion. Environmental

challenges also make sustainable livestock waste management a pressing concern. Among available manures, camel dung emerges as particularly relevant due to the predominance of camel farming in arid regions like Ouargla.

However, the absence of standardized data on camel dung quality hinders the development of agronomic guidelines. This study therefore focuses on evaluating the fertilizing potential of camel dung by analyzing parameters such as nitrogen, organic carbon, pH, electrical conductivity, and other relevant elements.

The analysis is conducted across the major husbandry systems in the Ouargla region—extensive, semi-intensive, and intensive. By correlating manure characteristics with feeding practices, the study aims to assess the impact of diet on the physicochemical and biochemical composition of camel dung, and its potential applications in:

- Agricultural use after proper processing
- Biogas and green energy production;

Part One: Work Methodology

1   Investigative Approach

The objective of this study is to go further into understanding the effect of dietary changes on the composition of dromedary manure, through physicochemical and biochemical analyses that determine the fertilizing value of it as well as the possibility of using it in the processing industry from the three existing camel husbandry systems in the Ouargla region.

To achieve this work, we followed a methodological approach that involves dividing our work into four main stages:

1.1   bibliographic research

Before proceeding with the investigations, we initiated the study by conducting a literature review to better grasp the subject. The establishment of a documentary fund proved relevant by collecting data from technical-administrative structures (reports and statistics), supported by academic research works (thesis, articles, proceedings, and books).

This literature review, undertaken at various technical-administrative and camel husbandry guidance structures in the Ouargla region, particularly involved "**La Direction Des Services Agricoles**" **(DSA)** and several meteorology websites such as **(Tutiempo, Infoclimat)**, in order to gather as much information as possible regarding camel husbandry. Information related to registered breeders and the locations of farms across the study region was also collected.

1.2   Development of survey framework

The survey was designed to gather the maximum amount of information relevant to our study. In light of the set objectives, we established an interview framework composed of various categories, primarily focusing on the following elements:

- Identification of breeders and targeted animals;
- Nutritional management;
- Health management.

1.3   Selection of study areas

The choice of the Ouargla region for this study is not random but stems from the resurgence of camel husbandry in this Saharan region over the past two decades. This resurgence is a result of socio-economic changes within the breeder community, particularly in their lifestyle (education and increased settlement), which have led to the emergence of new

economic valorisation pathways and significant changes in herd management, notably in nutritional practices.

Furthermore, the selection of this region is justified by:

- The presence of a large dromedary herd, which has made this region one of the main cradles of camel husbandry in the Northern Algerian Sahara.
- The significant role that the dromedary plays in the socio-economic development of this region.

To conduct the field investigations, three representative zones were selected and retained, namely: Oued N'sa, Bamendil, et Hassi Beghla.

1.4 Choice of holdings

Our study focused on three camel husbandry systems (extensive, semi-intensive, and intensive). The targeted farms are located in the aforementioned areas.

The criteria for selecting the chosen holdings were as follows:

- The presence of the targeted husbandry systems: extensive, semi-intensive, and intensive.
- Accessibility.
- Availability and cooperation of breeders.
- Reliability of information.

The selected husbandry farms, chosen based on these criteria, are indicated on (Map N°1)
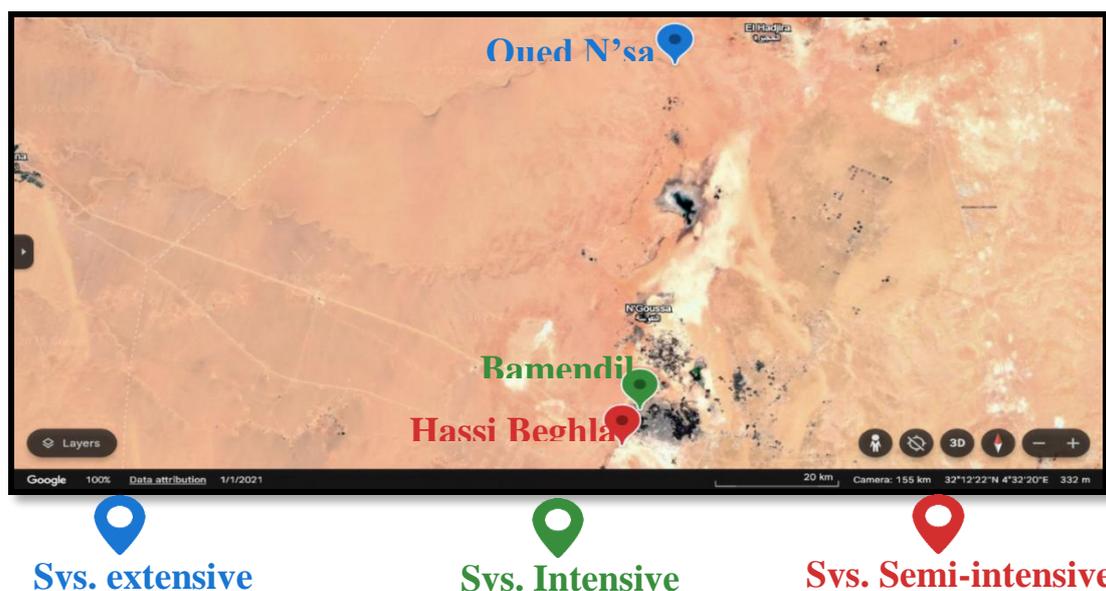
Map 1. Location of selected livestock holdings (Google Earth, 2025)

Our methodological approach is summarized in the following exploratory outline:
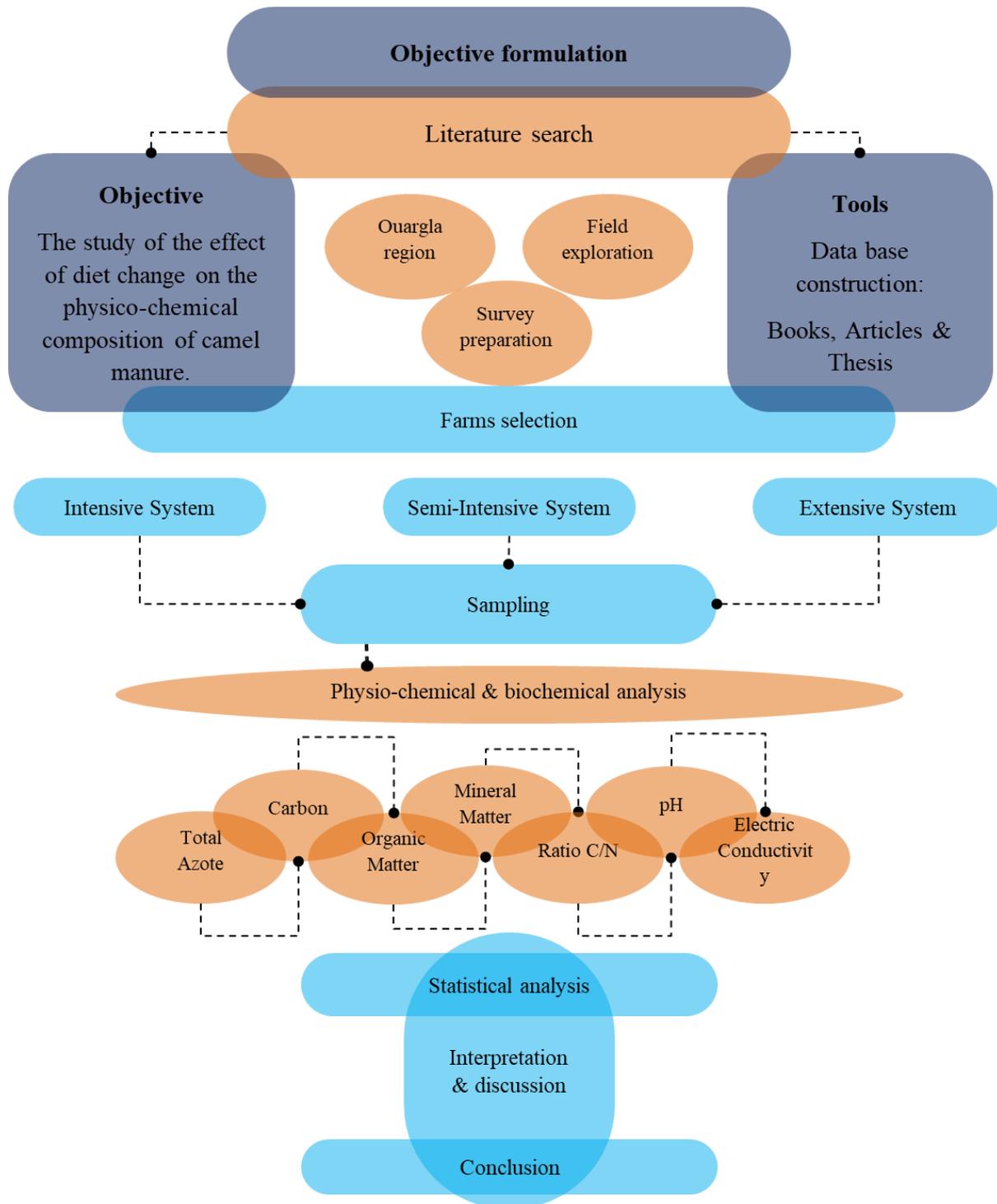
Figure 1. Exploratory outline of the work

2 Monographic synthesis of the study region

2.1 Geographical setting

Ouargla is located in the Northeast of Algeria, more specifically in the northern part of the Algerian Sahara. It is bounded to the Northeast by the provinces of El Oued and Touggourt, to the Northwest by the provinces of Djelfa and M'Ghair, to the West by the provinces of Ghardaïa and Meniaa, to the Southwest by the province of Ain Salah, to the Southeast by the province of Illizi, and to the East by the Tunisian border. Its geographical coordinates are: 5° 19' 30 E longitude and 31° 56' 57 N latitude **(Google, 2025)**.

The study region is situated in a large, enclosed basin, the lower valley of Oued Mya, whose extremities are represented to the West by Bamendil and Mekhadma, to the North by Bour-El-Haicha, to the East by Sidi Khouiled and Hassi Ben Abdallah, and to the South by Beni Thour, Ain-Beida, and Rouissat.
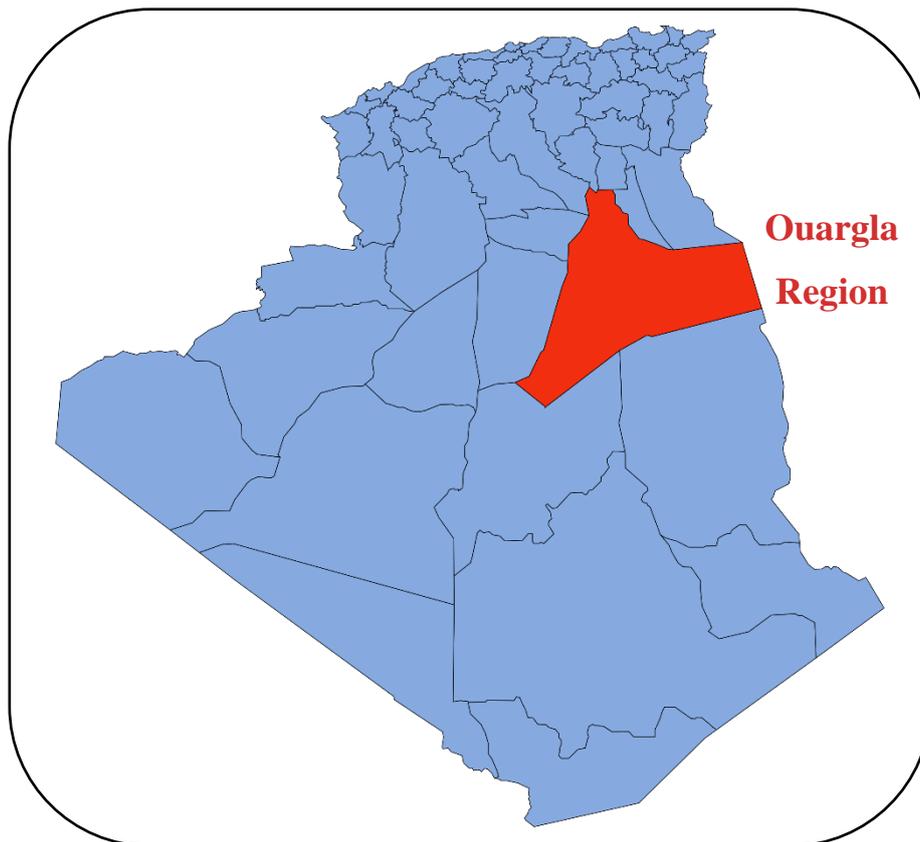
Map 2. Geographic location of study area (Wikipedia, 2025)

2.2 Climate of the study area

Climate, due to its attributes such as temperature, precipitation, wind, and relative humidity, controls many biological and physiological phenomena **(Dubief, 1950)**. The Ouargla region benefits from a hot desert climate typical of the Sahara, characterized by very long and extremely hot summers and short, very mild winters. The climate is hyper-arid and extremely dry throughout the year. **Table N°1** presents the climatic data for the region.

Table 1. Climate data for the Ouargla region for the period (2014-2024)

Month	Temperature (C°)			Humidity (%)	Total rainfall (mm)	Wind (Km/h)
	MIN	**MAX**	**MOY**			
January	4.8	19.1	11.6	44.2	0.21	9.3
February	7.6	21.3	14.4	38.2	2.82	12.8
March	10.8	25.3	18.3	30.2	3.26	14.2
April	15.8	30.4	23.5	26.4	7.71	16.5
May	20.8	35.5	28.6	21.9	3.35	16.6
June	26.0	41.1	34.1	17.4	0.21	16.2
July	28.6	44.0	37.0	15.0	0.05	13.3
August	28.1	42.6	35.7	18.8	0.83	13.0
September	24.5	38.6	31.7	27.3	4.18	13.2
October	17.6	24.6	24.6	34.0	2.75	11.0
November	10.9	24.5	17.5	41.8	5.15	9.2
December	6.6	19.7	12.7	51.6	2.47	9.2
Average	16.8	30.6	24.1	30.6	*33.0	12.9

*: Annual accumulation   **Source: (Tutiempo, 2025)**

2.2.1 Temperature

According to data from Tutiempo website (2014-2024), the average annual temperature in Ouargla is estimated to be 24,1°C. The minimum temperature recorded in the coldest month, January, is 11,6°C, while the maximum temperature observed in the hottest month, July, reaches 37,0°C.

2.2.2 Humidity

For the period 2014-2024, in Ouargla, the average annual humidity was 30,6%, with a maximum recorded during winter in December reaching 51,6%, while during the summer season, it dropped to 15,0% in July.

2.2.3 Rainfall

The climate of the Ouargla region is characterized by the scarcity and irregularity of inter-monthly and inter-annual rainfall. In other words, their rarity, inter-annual and seasonal irregularity, result in an annual accumulation of 30,6 mm. April is the wettest month, recording a maximum of approximately 7,71 mm.

According to the analysis of the ombrothermographic diagram of the Ouargla region (**Figure N°2**), for the period (2014-2024), the dry season extends throughout the year, indicating a significant and nearly permanent rainfall deficit, with a maximum of 7,71 mm in April and a minimum during the months of July and August. In contrast, the average temperatures follow a curve with a maximum recorded in mid-summer (July at 44,0°C and August at 42,6°C) and a minimum in winter, respectively 6,6°C in December and 4,8°C in January (Tutiempo, 2025).
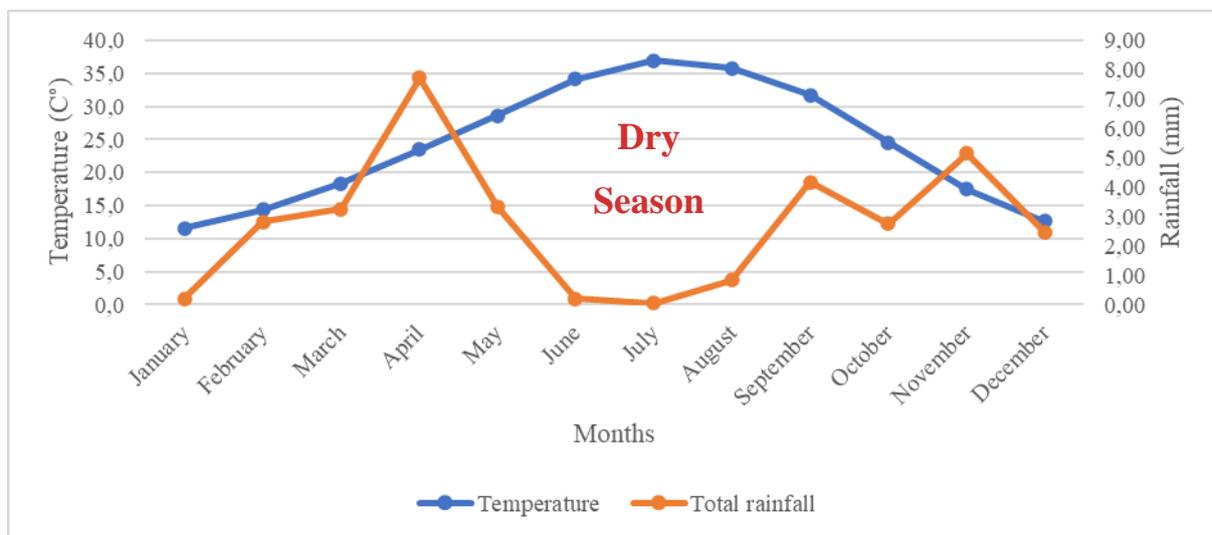
Figure 2. Ombrothermic diagram of Ouargla region (2014-2024)

2.2.4 Wind

Winds in the Ouargla region are frequent, particularly during the period from March to September. According to data from the Tutiempo website (2014-2024), the maximum wind speed is recorded in April at 16,6 Km/h.

2.3 Agriculture sector

The agricultural sector represents a very important factor in terms of economic and social development. The cultivated agricultural area of the province covers a surface of 37171 ha, which is 0.26% of the total area (**Table N°2**), providing rural populations with an income-

generating activity. In contrast, pastures occupy an area of 3759870 ha, which is 26% of the territory.

Table 2. Distribution of areas (ha)

Designation	Surface area (ha)
Pasture	3759870
Agriculture	37171
Bare soil	1513776
Sand	9117519
Total	14428336

Source: (D.S.A, 2024)

2.3.1 Animal production in the Ouargla region

The Ouargla province is also a region with significant pastoral potential, where livestock husbandry is considered one of the most important agricultural activities. Consequently, for the year 2023, there was a total of approximately 87361 heads of livestock across all species, distributed throughout the province. The distribution by species and by province is recorded in **Table N°3**.

Table 3. Distribution of livestock by commune (agricultural company 2021-2022)

Province	Cattle (head)	Sheep (head)	Goat (head)	Camel (head)
Ouargla	141	18702	31686	748
Sidi Khouiled	30	1579	1780	233
N'goussa	13	16593	26208	6909
Hassi Messaoud	123	17451	19465	7729
Rouissat	56	14007	10361	5386
Ain El Beida	23	3608	3004	2672
Hassi Benabdallah	98	1947	2370	998
El Borma	-	7194	10479	7421
Total/ Species	484	81 081	105 353	**32 096**
Total	**219 014**			

Source (D.S.A, 2022)

The husbandry of small ruminants (goats and sheep), which are well adapted to the harsh climatic conditions of the region and provide a substantial monetary income for breeders, accounts for 72,3% of the livestock (**Figure N°3**). Meanwhile, the camel population represents 14,7% of the total livestock, with the proportion of recorded female camels being approximately 90.6%. As for the bovine population, whose introduction is very recent, it remains insignificant at 0.2%.
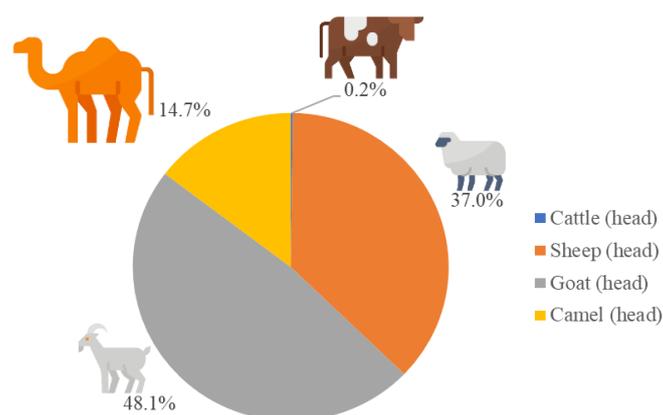
Figure 3. Proportion of livestock in the province of Ouargla

The statistics listed at the D.S.A of Ouargla (2023), reveal animal productions expressed in the following table:

Table 4. Animal production in the Ouargla region (campaign 2023)

Animal production	Quantity
Red meat (Quintals)	**37428**
Sheep	22086
Cattle	3005
Goat	4875
Camel	7462
White meat (Quintals)	**1673**
Broiler chicken	1673
Milk (10^3 L)	**9604**
Cow	470
Goat	2425
Ewe	1296
She-camel	5413
Eggs (10^3 Unity)	**0**
Honey (Kg)	**253.5**
Wool (Kg)	**26830**
Skin & Leather (Kg)	**913**

Source: (D.S.A, 2023)

3   Physio-chemical analysis of muck samples

For the determination of certain physio-chemical and biochemical parameters of dromedary manure from three husbandry systems (extensive, semi-intensive, and intensive), 3 samples were collected from dromedaries belonging to the Sahraoui population. Each sample was analyzed for 17 variables, resulting in a total of 102 data points. Each analysis was performed in duplicate.

4   In vivo; Food management

The feeds used in the monitored extensive, intensive, and semi-intensive systems are presented in Table **Table N°5**

Table 5. Food diet according to the camel husbandry system

Husbandry system	Feed given to animals	The floral composition of dromedary pastures
Extensive system	/	**Bed of Oued type soil composed of:** *Catananche arenaria* (**Kidan**) *Moltkiopsis ciliata* (**Halma**) *Trichodesma africanum* (**Al kah**) *Zilla macroptera* (**Chebrok**) *Cleome amblyocarpa* (**Netil**) *Anabasis articulata* (**Baguel**) *Ephedra alata* (**Alanda**) *Astragalus gyzensis* (**Foul l'ilbel**) *Genista saharae* (**Merkh**) *Stipagrostis obtusa* (**Seliane**) *Calligonum comosum* (**L'arta**) *Tamarix articulata* (**Ethle**)
Semi-intensive system	3 kg of straw + compound concentrate feed (60% barley + 40% wheat bran) at a rate of 2 kg/day	**Bed of Oued type soil composed of:** *Anabasis articulata* (**Baguel**) *Moltkiopsis ciliata* (**Halma**) *Zilla macroptera* (**Chebrok**) *Ephedra alata* (**Alanda**) *Calligonum comosum* (**L'arta**) *Tamarix articulata* (**Ethle**)
Intensive system	Straw Wheat bran Barley Dry bread Hay	/

5   In-vitro; Manure sampling

The laboratory analysis of manure is a crucial step in planning the management of manure nutrients. Separate samples were collected from various locations of each husbandry system.

The samples were thoroughly mixed and stirred to create final composite samples that are representative of each type of system.

5.1   Sample preparation

In order to determine the physio-chemical characteristics and the content of fertilizing elements, particularly N, K, Mg, and Ca, as well as heavy metals analysis, the dung samples were oven-dried at 105°C for 24 hours, then ground and sieved to 0.5 mm, and subsequently analysed in the laboratory (**Figure N°4).**

The physio-chemical & heavy metals analysis of different types of manure were carried out at the laboratory of "**BIO-RESOURCES SAHARIENNES (BRS)**" and at the "**CENTRE RÉGIONAL DES ANALYSES PHYSICO-CHIMIQUES (CRAPC)**".

Figure 4. Sample preparation using the grinder & the oven

5.2 pH measurement

The pH measurement is carried out according to international standards, after dissolving 6 grams of the sample in 30 ml of distilled water. The method involves preparing a suspension of dried substrate, diluted in five times its volume of water (1:5), then agitating it for 15 minutes and allowing it to settle for at least two hours. The pH is then measured using a pH meter (**Figure N°5**).

Figure 5. pH measurement steps using the scale, magnetic stirrer & the pH meter

5.3 Electrical conductivity measurement

Electrical conductivity (EC) is the measurement of the concentration of soluble ions in order to assess the salinity of the substrate. It is determined using a conductivity meter and is expressed in dS/m. The international standard prescribes a specific method for its measurement. A substrate sample is extracted with water at $20 \pm 1°C$ (using an extraction ratio of 1:5 to dissolve the electrolytes) (**Figure N°6**).

Figure 6. Electrical conductivity measurements

5.4   Determination of organic carbon

For the determination of organic matter content, we used the calcination method (loss on ignition), which is based on the following principle:

A ground sample of the different types of manure is weighed in porcelain crucibles (**Figure N°7)**, which are then placed in a muffle furnace at a temperature of 850°C **(Doggar, 1980)**. The temperature is gradually increased (over six hours) until white ash is obtained. The resulting ash is then weighed.

Figure 7. Calcination process using a muffle furnace

The percentage of organic matter is calculated using the equation of **(Mathieu and Pieltain, 2003).**

$$OM\% = \frac{(P - Q)}{P} \times 100$$

OM%: Organic matter content

P: Sample weight before calcination

Q: Sample weight after calcination

For the assessment of carbon from organic matter, two main factors are considered:

- The factor 1.724 which means that organic matter contains 58% of carbon.
- The factor 2.0 which means that organic matter contains 50% of carbon.

Based on the study by **(Giroux and Audesse, 2004)** of 11 organic fertilisers and soil improvers; factor 2.0 is more appropriate than factor 1.724 to estimate carbon content of organic fertilisers and soil improvers from their OM content.

5.5 Crude Protein Content (Total Nitrogenous Matter) Determination:

The amount of crude protein was determined using the Gornall method (**Gornall et *al.*, 1949**), which is suitable for measuring the amount of protein soluble in solution. The Biuret reagent (copper sulphate in a strong base) reacts with peptide bonds and changes colour upon reaction (**Figure N°8**). A spectrophotometer was used to measure the intensity of the resulting colour. The darker the colour, the higher the protein content.

The process is carried out according to the following steps:

1. The first step consists in preparing the extract 1/25 of (manure/distilled water), then the extract is put on a magnetic stirrer for 15 min.
2. 0.75 ml of monopotassium phosphate solution was added to 1 ml of manure solution (0.01% w/v) and 3 ml of sodium hydroxide solution. The mixture was then homogenized using a vortex mixer. The solution was subsequently cooled at room temperature for 3 minutes.
3. Next, the colour reagent 25% copper sulphate solution is added, with stirring using a vortex mixer every two minutes for a duration of 15 minutes. The mixture is then placed in a centrifuge at 9000 rpm for 10 minutes at 4°C.
4. The absorbance (abs) of the solution was measured using a UV spectrophotometer at 540 nanometres, with 1 ml of the Gornall reagent used as a blank.

The protein content (**Y**) was calculated using the following formula:

$$Y(^g/_L) = 1.8126 \times abs + 0.1705$$

Then the total nitrogen matter was determined using the following formula:

$$N\% = {}^Y/_{NPCF}$$

N%: Nitrogen content

Y: The protein content

NPCF: Nitrogen-to-Protein Conversion Factor (6.25; the classical factor)
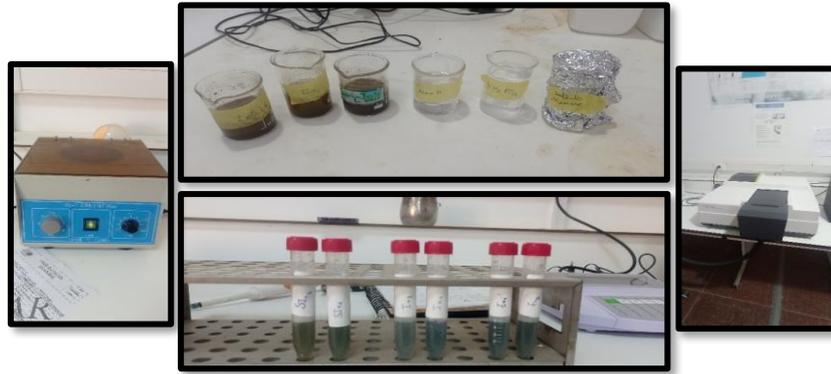
Figure 8. Preparing samples for nitrogen content determination using a centrifuge & a UV spectrophotometer

5.6 Determination of C/N ratio

Once the carbon and nitrogen content are determined, the carbon-to-nitrogen ratio is established by the total carbon on the total nitrogen.

6 Data analysis

In order to determine the effect of diet on the physio-chemical composition and heavy metal content of dromedary manure from the three camel husbandry systems, a statistical evaluation was carried out using one-way analysis of variance (ANOVA) with Excel 2021 software. The significance level was set at $p < 0.05$.

Part Two: Results & Discussion

1 Description of physio-chemical and bio-chemical parameters

The physicochemical and biochemical characteristics of manure are critical determinants of its fertilizing value and environmental impact. This report examines parameters including pH, electrical conductivity (EC), organic matter (OM), carbon (C), mineral matter (MM), nitrogen (N), and carbon-to-nitrogen (C/N) ratio across extensive, semi-intensive, and intensive camel farming systems (Table N°6). These results highlight the interplay between livestock management practices and manure quality, offering insights for sustainable agricultural utilization.

Table 6. Physio/Bio-chemical characteristics of the dung/husbandry system

(Average ± Type Deviation)

	Extensive	Semi-intensive	Intensive	*P-value*
pH	6.65 ± 0.07	7.22 ± 0.04	8.02 ± 0.04	2E-04
EC (dS/m)	5.9 ± 0.42	4.52 ± 0.11	2.26 ± 0.13	0.002
OM%	84.1± 0.001	83.1± 0.008	84.6 ± 0.003	0.1
C%	42.1± 0.001	41.5 ± 0.004	42.3 ± 0.001	0.1
N%	0.4 ± 0.0005	1.6 ± 0.042	0.6 ± 0.0002	0.033
C/N	95.73	26.47	68.16	0.008
MM%	15.9 ± 0.001	17.0 ± 0.008	15.4 ± 0.003	0.1

The significance threshold was determined at p<0.05.

1.1 pH Dynamics in Camel Dung

1.1.1 Variation Across Husbandry Systems

The pH of camel manure exhibited statistically significant differences ($p = 2 \times 10^{-4}$) among the three systems (Figure N°9), with values of 6.65 (extensive), 7.22 (semi-intensive), and 8.02 (intensive).
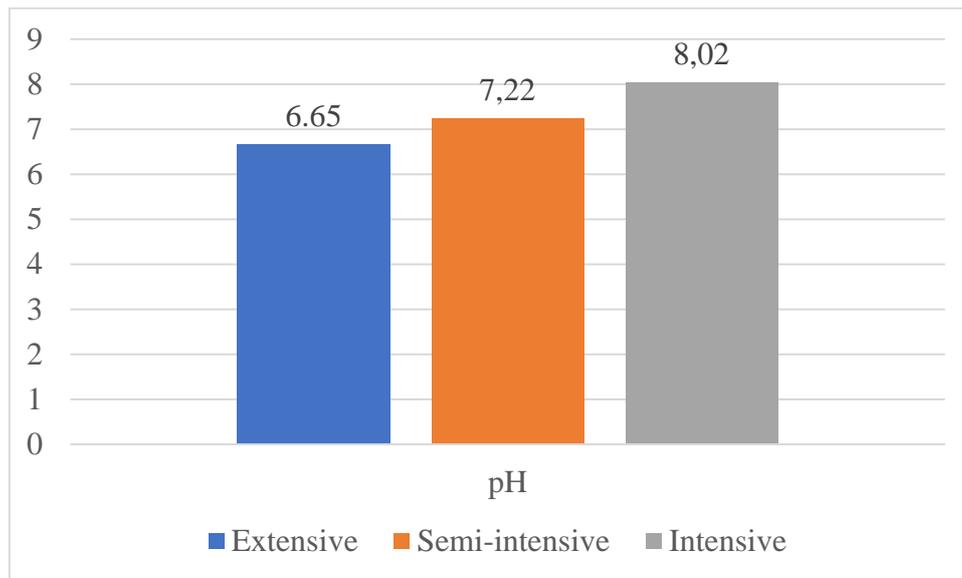
Figure 9. Variation of pH depending on the husbandry systems.

This trend toward alkalinity in intensive systems is consistent with the general trends observed regarding manure pH. The average pH value recorded in this study (7.30) is slightly close to that reported by **Siboukeur (2013)** (8.33) in camel.

Dekmouche (2023) reported generally higher pH values, with the semi-intensive system exhibiting the highest level (9.48), followed by the extensive (8.15) and intensive systems (7.56). While both studies confirm that husbandry systems impact manure pH, their observed trends differ: our findings indicate a linear increase in pH corresponding to intensification, whereas **Dekmouche (2023)** observed a peak in alkalinity specifically at the semi-intensive level. These discrepancies could be attributed to variations in diet composition and management practices.

The progression from neutral to alkaline conditions likely stems from dietary differences, such as increased concentrate feeds in intensive systems, which elevate ammonia production during manure decomposition.

1.1.2 Implications for Soil and Emissions

Manure pH influences microbial activity and nutrient availability. Alkaline conditions (pH > 7) in intensive systems may suppress acid-producing bacteria, reducing emissions of volatile fatty acids but potentially increasing ammonia volatilization (**Meiirkhanuly et *al.*, 2020**). Conversely, near-neutral pH in semi-intensive systems balances nutrient retention and microbial diversity, making it advantageous for soil amendment (**Xu et *al.*, 2023**). Notably,

while manure pH itself does not directly alter soil pH, its alkaline nature can buffer acidic soils over time, particularly when applied repeatedly (**Lipiec et *al.*, 2021**).

1.2 Electrical Conductivity (EC) and Salinity

1.2.1 Trends in Salt Content

Electrical conductivity (EC), a proxy for soluble salt content in manure, varied significantly across camel production systems. The EC values decreased notably from extensive (5.9 dS/m) to semi-intensive (4.53 dS/m), and were lowest in intensive systems (2.26 dS/m), with the trend reaching statistical significance (p = 0.002) (Figure N°10). These values are markedly higher than those reported by **Dekmouche (2023)**, who found lower EC levels across all systems in ascending order: extensive (2.33 dS/m) < semi-intensive (3.05 dS/m) < intensive (3.39 dS/m).

The reduced EC in intensive systems likely reflects more controlled feed formulations with lower salt and mineral content, aimed at optimizing digestibility and reducing the accumulation of non-assimilable minerals in manure. In contrast, the elevated EC in extensive systems may arise from less regulated diets that include higher levels of naturally occurring salts.
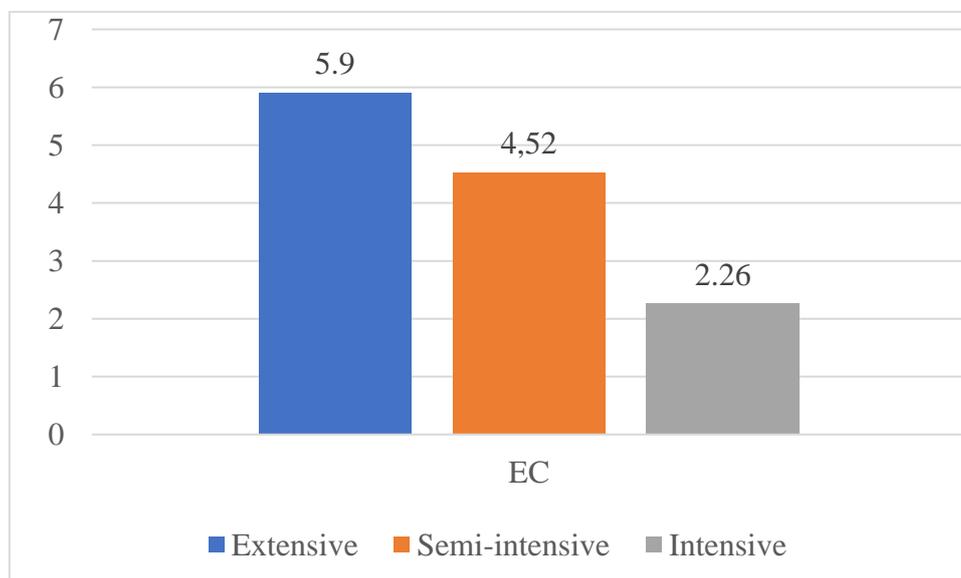
Figure 10. Variation in electrical conductivity (dS/m) depending on the husbandry system.

1.2.2 Salinity Risk Assessment

Using soil salinity classifications, fresh camel manure EC values (2.26–5.9 dS/m) fall within the "slightly saline" to "moderately saline" ranges for sandy soils. While moderate

salinity enhances nutrient availability in arid soils, excessive application could exacerbate salinity in soils, necessitating tailored management strategies **(Ismayilov et *al.,* 2021)**.

1.3 Organic Matter and Carbon Composition

1.3.1 Stability Across Systems

OM% (84.1 ± 0.001 extensive, 83.1 ± 0.008 semi-intensive, 84.6 ± 0.003 intensive) and C% (42.1 ± 0.001, 41.5 ± 0.004, 42.3 ± 0.001) (Figure N°11) showed no significant differences ($p = 0.1$), these results are higher than the results reported by **(Dekmouche, 2023)** which states that the organic matter increased from 70.64% in intensive system to 83.67% in semi-intensive system and carbon content from 35% to 41% throughout the systems. This consistency indicates that camel diets across systems provide comparable lignocellulosic content, which resists rapid decomposition **(Lipiec et *al.*, 2021)**.

High OM% (≥83%) underscores manure's value in improving soil structure and water retention, particularly in sandy soils where organic amendments increase porosity by 29.8–72.9% **(Xu et *al.*, 2023)**.
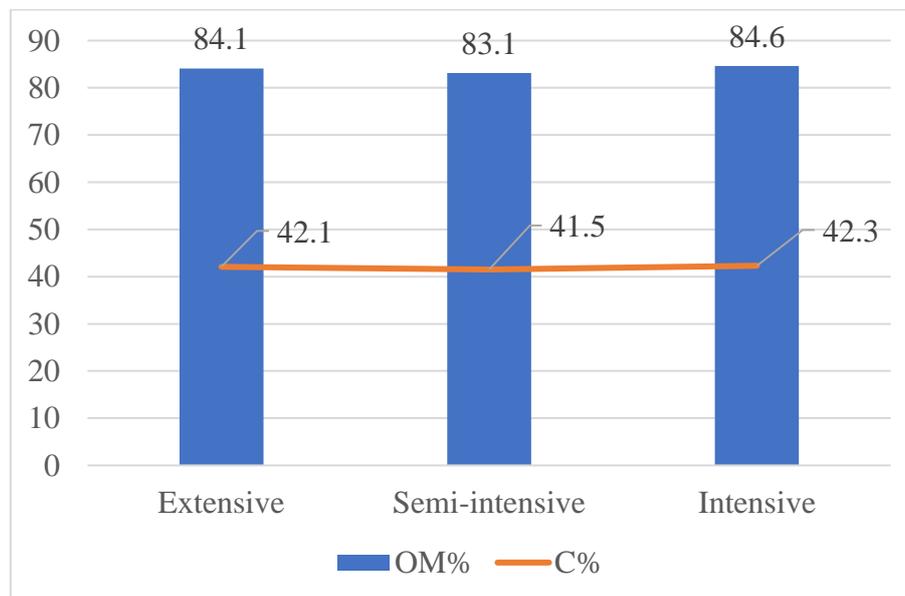
Figure 11. Variation in organic matter and carbon content (%) according to husbandry systems

1.4 Nitrogen Content in Manure Across Husbandry Systems

Semi-intensive livestock systems recorded the highest nitrogen content in dung ($1.6 \pm 0.042\%$), significantly exceeding that of extensive ($0.4 \pm 0.0005\%$) and intensive systems ($0.6 \pm 0.0002\%$) ($p = 0.033$). As illustrated in Figure N°12, these values are substantially smaller

than those reported by **Dekmouche (2023)**, likely due to differences in feeding strategies. Specifically, semi-intensive systems often incorporate protein-rich rations, where an optimal balance between forage and concentrate intake enhances nitrogen retention efficiency. This leads to higher nitrogen excretion via manure, thereby increasing its fertilization potential.

The nutrient density of manure from semi-intensive systems implies significant agronomic benefits. According to **Xu et *al.* (2023),** such manure could reduce the reliance on synthetic nitrogen fertilizers in cropping systems by 35.6% to 142.6%, depending on crop type and soil conditions. Thus, these systems not only enhance nutrient recycling but also contribute to more sustainable agricultural practices.
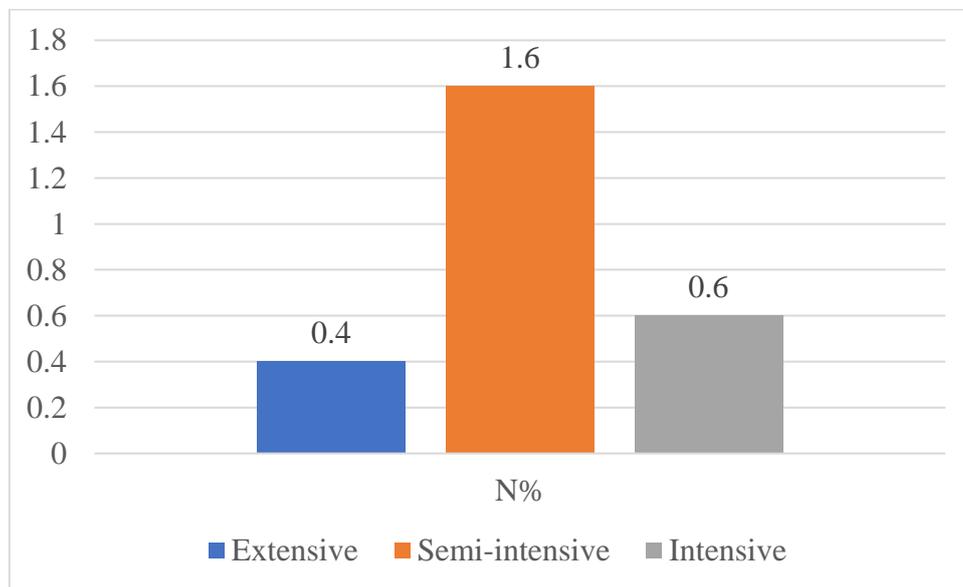
Figure 12. Variation in nitrogen content (%) depending on the husbandry system.

1.5 Decomposition Efficiency of Manure by System Type

The carbon-to-nitrogen (C/N) ratio differed significantly across livestock systems ($p = 0.008$), with semi-intensive systems showing the lowest ratio (26.47), followed by intensive (68.16) and extensive systems (95.73) (Figure N°13). A lower C/N ratio enhances microbial activity by supplying sufficient nitrogen for microbial protein synthesis, thereby accelerating organic matter decomposition. As a result, manure from semi-intensive systems can release plant-available nutrients within 4–6 weeks post-application **(Xu et *al.,* 2023).**

In contrast, the higher C/N ratio observed in extensive systems suggests a slower decomposition process. Such conditions can lead to temporary nitrogen immobilization, where microbes consume available nitrogen to decompose the carbon-rich material, reducing its

immediate availability to plants. To mitigate this, pre-application composting is often recommended to lower the C/N ratio and improve nutrient release dynamics (**Atallah et** *al.,* **1995).**
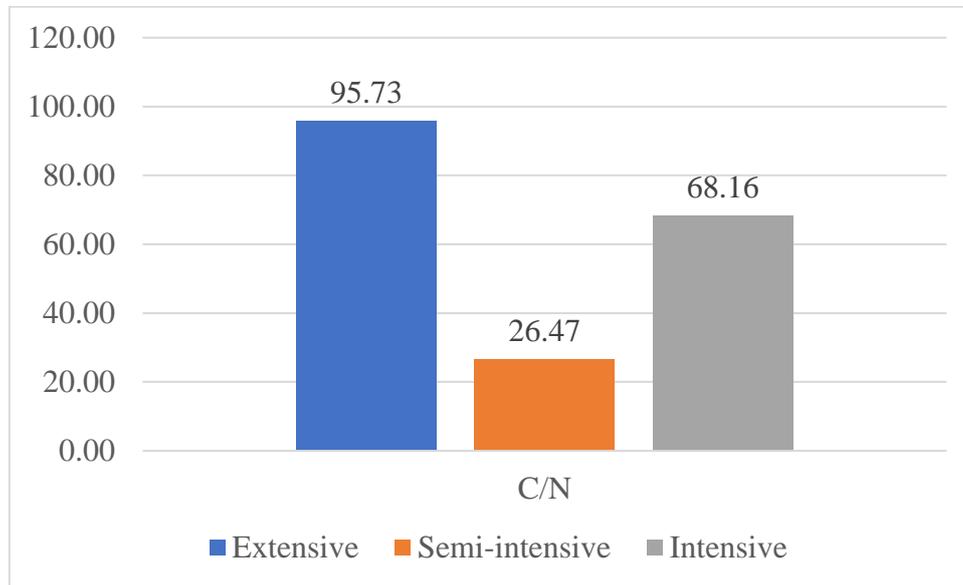
Figure 13. Variation in the C/N ratio according to the husbandry systems.

1.6   Mineral Matter: Compositional Analysis Across Husbandry Systems

The mineral matter (MM) content of Camel manure varied across production systems, with values recorded at 15.9% ($\pm$0.001) in extensive systems, 17.0% ($\pm$0.008) in semi-intensive systems, and 15.4% ($\pm$0.003) in intensive systems (Figure N°15). Although these differences were not statistically significant ($p = 0.103$), the numerical increase of 10.4% in semi-intensive systems compared to intensive systems may hold practical relevance. These findings report lower MM% than those documented by **Dekmouche (2023)**, who observed 29.35% and 23.44% in extensive and intensive systems, respectively, but are closely aligned with his semi-intensive system value of 16.31%, potentially due to similarities in feed composition.

Mineral matter in manure primarily reflects ash content derived from undigested inorganic residues, including macro-elements such as calcium, magnesium, and potassium, as well as trace elements like zinc and copper. The relatively elevated MM% in semi-intensive systems likely reflects targeted mineral supplementation practices in formulated feeds—an intervention aimed at enhancing animal health and productivity.

1.6.1 Agronomic Significance of Mineral Content

The MM% inversely correlates with OM% ($R^2 = -0.98$), as mineral content occupies physical space otherwise filled by organic components. Semi-intensive systems' higher MM% (17.0%) (Figure N°14) suggests greater potential for micronutrient delivery to soils. Calcium and magnesium critical for soil structure and cation exchange capacity are typically enriched in mineral-rich manures, with calcium concentrations in livestock manures ranging from 0.5% to 4.5% depending on feed sources **(Lorimor et *al.*, 2004)**.
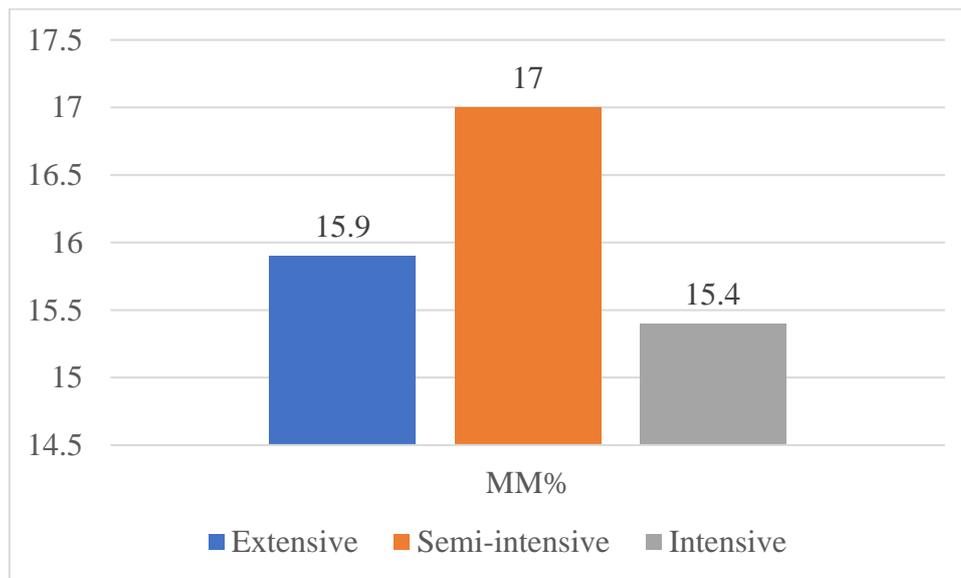
Figure 14. Variation in mineral content (%) depending on husbandry systems

2 The use of camel dung based on the livestock husbandry system

The valorisation of dung according to the husbandry system (extensive, semi-intensive, or intensive) must take into account their specific physio-chemical characteristics as well as the constraints and opportunities specific to each production method. The results show notable differences in key parameters such as pH, electrical conductivity (EC), the C/N ratio, and nitrogen (N) content, which justifies a differentiated management approach.

2.1 The use of dung in the extensive system

In the extensive system, the dung has a moderately acidic to neutral pH (6.65), a relatively high electrical conductivity (5.9 dS/m), a balanced C/N ratio (95.73), and a low nitrogen content (0.4%). These characteristics reflect minimally decomposed organic matter with a good carbon-to-nitrogen balance, making it well-suited for slow composting or direct use as an organic amendment on natural grasslands or extensive crops **(Bernal et *al.,* 2009; Sánchez et**

al., **2017**). However, since the available nitrogen level remains low, it may be necessary to enrich the compost with other nitrogen sources depending on crop needs (**Dadi et *al.,* 2022**).

2.2 The use of dung in the semi-intensive system

In the semi-intensive system, the dung shows nitrogen level of (1.6%) and an optimal C/N ratio (26.47), indicating a relative excess of rapidly mineralizable nitrogen. The moderately high EC (4.52 dS/m) and neutral pH (7.22) suggest an unstable material that could lead to nitrogen losses through ammonia volatilization or leaching (**Larney and Angers, 2012**). Therefore, prior composting is strongly recommended to stabilize the material, reduce environmental risks, and improve agronomic efficiency. Adding carbon-rich materials (plant residues, sawdust, straw) would help rebalance the C/N ratio, promoting better fermentation and proper compost maturation (**Jiménez and García, 1992; Sánchez-Rodríguez et *al.,* 2018**).

2.3 The use of dung in the intensive system

Finally, in the intensive system, the dung has a high alkaline pH (8.02), low EC (2.26 dS/m), low nitrogen content (0.6%), and a C/N ratio of 68.16. These characteristics are typical of partially degraded manure with good potential for composting or direct use after a short stabilization period. The risk of nitrogen losses is moderate, but the low EC could indicate a depletion of soluble elements, which may require supplementation depending on soil needs (**Cofie et *al.,* 2005; Aira et *al.,* 2006**).

Thus, a differentiated valorisation approach allows for optimized dung management based on its nature: mandatory composting for nitrogen-rich manure with a low C/N ratio (semi-intensive), direct use possible in extensive systems, and rapid valorisation after stabilization in intensive systems. This approach not only helps reduce environmental impacts but also better aligns organic amendments with local agronomic needs (**Petersen et *al.,* 2007; Adhikari et *al.,* 2009**).

To better summarize the practical implications of the physio-chemical characteristics of manure according to livestock systems, the table below outlines specific valorisation recommendations. It highlights, for each system (extensive, semi-intensive, intensive), whether prior composting is necessary, the possibility of direct use, recommended adjustments (particularly in terms of C/N ratio or pH), as well as the most appropriate valorisation strategies. This table is directly based on the detailed observations presented earlier (sections 2.1 to 2.3) and provides an operational overview to support decision-making for tailored manure

management. It thus serves as a bridge between result analysis and their concrete application in sustainable agriculture.

Table 7. Recommended dung valorisation strategies according to the livestock system

Husbandry system	Composting needed	Direct usage	Recommended adjustments	Specific recommended valorisation
Extensive	Partially, to reduce electrical conductivity (EC) and homogenize the material	Possible, particularly on meadows or soils tolerant to salts	Monitoring of pH and slight maturation if necessary	Slow organic fertilization, soil amendment poor in organic matter
Semi-intensive	Indispensable, due to excess nitrogen (low C/N) and instability	Impossible, risk of phytotoxicity and ammonia losses	Incorporation of carbon-rich co-substrates (straw, plant residues)	Accelerated composting; production of stabilized compost for deficient soils
Intensive	Optional, dung being relatively balanced (C/N≈10)	Possible, after a brief stabilization, especially if the soil is not alkaline	Control of alkaline pH; possible association with a more acidic manure	Targeted use in market gardening or high value-added crops (horticulture)

Valorisation of camel dung according to the husbandry systems

The sustainable management of camel dung represents a strategic opportunity for the production of renewable energy and the improvement of soil fertility. The comparative analysis of the physio-chemical characteristics of dung from three livestock systems (extensive, semi-intensive, and intensive) helps guide valorisation strategies along three main axes: methanation, thermal valorisation, and conversion into green fuels.

2.4 Methanation (biogas production)

Methanation is based on the anaerobic degradation of organic matter to produce biogas. A Carbon/Nitrogen (C/N) ratio between 20 and 30 is considered optimal to support methanogenic microbial growth and prevent inhibition caused by excess nitrogen (**Yadvika et al., 2004**).

- **Extensive:** The dung has a C/N ratio of 95.73 and a high organic matter (OM) content (\~84%), making it suitable for methanation in co-digestion with a carbon-rich substrate, such as crop residues (**Weiland, 2010**).

- **Semi-intensive:** With an optimal C/N ratio (26.47) and nitrogen content of (1.6%), direct methanation is not recommended. A substantial carbon input is required to avoid ammonia accumulation, which inhibits methanogenesis (**Chen et *al.,* 2008**).

- **Intensive:** A C/N ratio of 68.16 allows for moderate methanation, provided that lignocellulosic materials (straw, leaves) are added to reach the optimal ratio (**Raposo et *al.,* 2011**).

2.5   Thermal valorisation (combustion, green coal)

Combustion or carbonization relies on the organic carbon and organic matter content, which determine the calorific value. A low mineral content (<20%) is also favourable as it reduces residual ash (**Demirbas, 2004**).

- All three types of dung have high organic matter content (>83%), a carbon content of around 42%, and moderate mineral content (15–17%), making them suitable for thermal valorisation.

- Intensive dung, in particular, with low electrical conductivity (EC) and a basic pH, is well-suited for direct combustion after drying or for the production of fuel briquettes (**Méndez et *al.,* 2013; Guendehou et *al.,* 2016**).

2.6   Production of green fuels (biochar via pyrolysis)

Pyrolysis allows for the thermal transformation of manure into biochar, a stable carbon-rich material used as a soil amendment, environmental filter, or slow-burning fuel (**Lehmann and Joseph, 2015**).

- **Intensive dung**, with its high pH, low EC, and high carbon content, is particularly well-suited for slow pyrolysis. The resulting biochar improves water retention, cation exchange capacity, and provides long-term carbon sequestration in soils (**Downie et *al.,* 2009; Kammann et *al.,* 2015**).

- **Extensive and semi-intensive dung** can also be valorised through pyrolysis, although pre-drying and homogenization are recommended.

The following valorisation diagram provides a synthetic overview of the main energy transformation pathways for camel dung based on the specific characteristics of the three livestock systems (extensive, semi-intensive, and intensive). It visually represents the results of the physio-chemical analysis detailed in the text, highlighting the most appropriate directions for each system.

This graphical representation thus serves to summarize the technical recommendations derived from the experimental data, facilitating decision-making for differentiated and sustainable management of organic waste in camel farming systems.
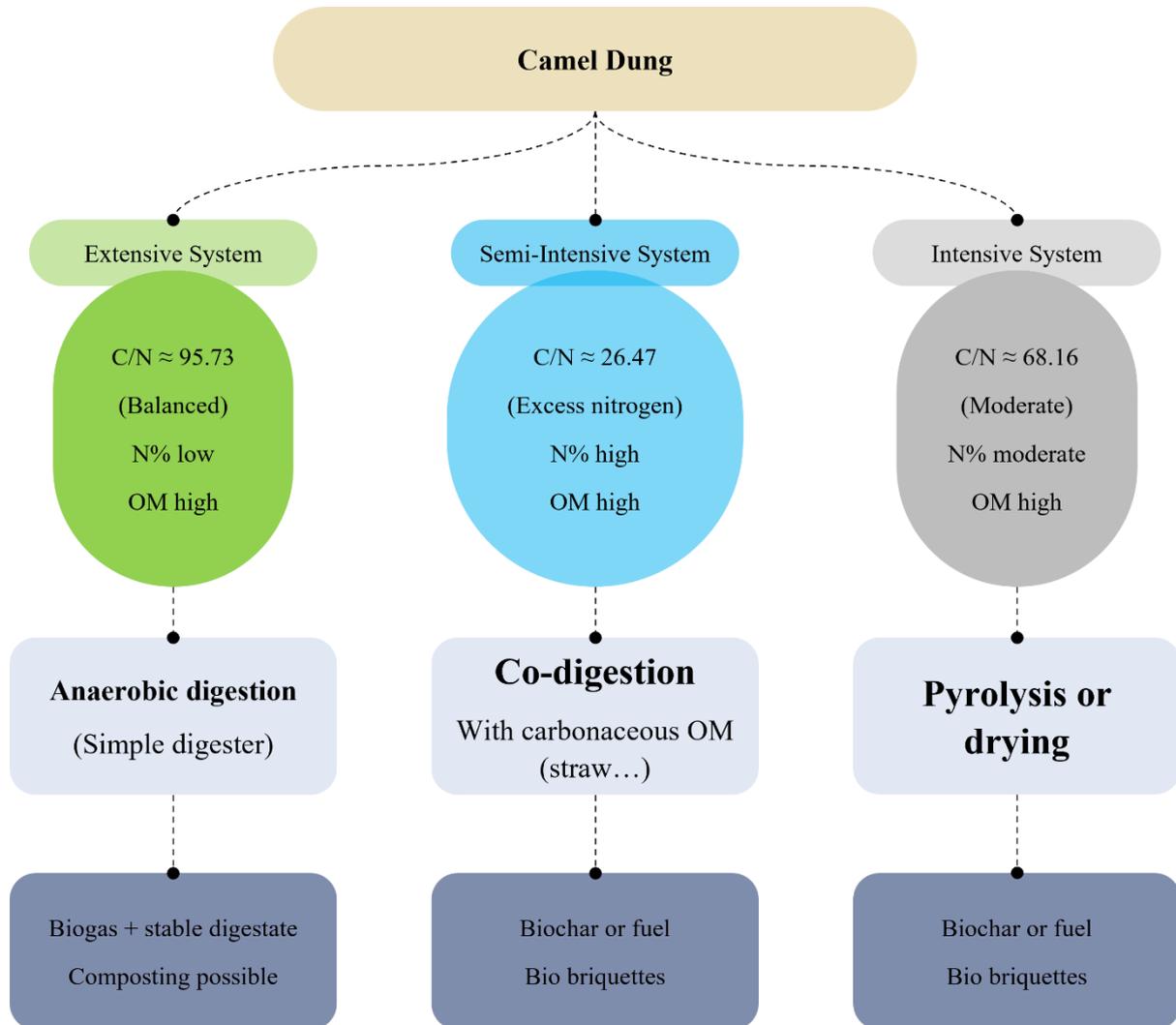
Figure 15. Camel dung valorisation scheme based on the husbandry system

Conclusion

This study provided a thorough characterization of the physicochemical and biochemical properties of dromedary camel dung under three husbandry systems (extensive, semi-intensive, and intensive). The results revealed significant differences in pH, electrical conductivity, nitrogen, carbon, organic and mineral matter contents, as well as in the C/N ratio. These variations reflect the impact of feeding and animal management practices on the quality of excreta.

Manure from the extensive system, rich in organic matter but low in nitrogen, is suitable for slow fertilization, particularly on sandy or nutrient-poor soils. Semi-intensive manure, with high nitrogen content and a very low C/N ratio, requires prior composting for stabilization. Finally, intensive system manure shows a good balance between nutrient content and stability, making it suitable for rapid valorization, especially for demanding crops.

Moreover, the results demonstrate that the different types of manure also hold strong potential for energy recovery, notably through anaerobic digestion (biogas production), pyrolysis for biochar production, and thermal recovery (briquettes, solid fuels).

In light of these results, we recommend:

1. Implementation of differentiated manure management strategies according to the husbandry system:

- Compulsory composting for semi-intensive manure, with the addition of carbonaceous materials.
- Possible direct use of extensive and intensive manure after short maturation.

2. Farmer awareness campaigns on the importance of manure treatment to reduce environmental risks (ammonia volatilization, soil salinization).
3. Monitoring of soil responses to manure application over the medium and long term, particularly changes in pH, salinity, and organic matter content.
4. Development of practical training programs for farmers and technicians on composting, co-digestion, and thermal valorization techniques.

From a future research perspective, it would be of interest to:

- Deepen the microbiological analysis of the manure to better understand degradation dynamics and potential health risks.

- Test agronomic effects under real cultivation conditions (field trials) to quantify impacts on yield, soil fertility, and water retention.
- Assess the economic feasibility of different valorization pathways (compost, biogas, biochar) for farmers in arid regions, including cost–benefit analysis.
- Explore the potential of integrating manure management with other agricultural biomass sources (crop residues, date palm waste).

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Abstract

Abstract: This study aims to characterize the physicochemical and biochemical properties of dromedary dung derived from three camel husbandry systems (extensive, semi-intensive, and intensive) in the Ouargla region, in order to assess its potential for agricultural and energy valorization. A structured methodological approach was adopted, including the selection of representative sites and laboratory analyses of manure samples. The parameters measured included pH, electrical conductivity (EC), organic matter (OM), carbon (C), nitrogen (N), the carbon-to-nitrogen (C/N) ratio, and mineral matter. The results revealed that the semi-intensive system had the highest nitrogen content (10.2%) and the lowest C/N ratio (4.23), indicating an unstable material requiring prior composting. The extensive system, with a C/N ratio of 15.32 and high EC, is suitable for slow-release fertilization. The intensive system showed intermediate characteristics with good stability. Three valorization pathways are proposed: (i) anaerobic digestion, recommended for extensive and intensive systems when combined with carbon-rich co-substrates; (ii) thermal valorization, made possible by the high organic matter content (>83%); and (iii) pyrolysis for biochar production, particularly suitable for intensive dung. These findings highlight the relevance of differentiated camel manure management based on the husbandry system to optimize its agronomic and energy use in a sustainable manner.

Keywords: *Dromedary, Dung, Husbandry system, Fertilizing elements, Energy valorization, Ouargla, Algeria.*

التقييم النوعي لروث الإبل وفقًا لأنظمة التربية في منطقة ورقلة

ملخص: تهدف هذه الدراسة إلى توصيف الخصائص الفيزيائية والكيميائية والبيوكيميائية لروث الجمل الناتج عن ثلاثة أنظمة لتربية الإبل في منطقة ورقلة، وهي النظام الواسع، شبه المكثف، والمكثف، وذلك بهدف تقييم إمكانيات استغلاله في الزراعة وإنتاج الطاقة. تم اعتماد منهجية علمية تضمنت اختيار مواقع تمثيلية وجمع عينات من الروث وتحليلها مخبرياً من خلال قياس درجة الحموضة، التوصيلية الكهربائية، نسبة المادة العضوية، الكربون، النيتروجين، النسبة بين الكربون والنيتروجين، والمادة المعدنية. أظهرت النتائج أن النظام شبه المكثف يحتوي على أعلى نسبة نيتروجين وأدنى نسبة بين الكربون والنيتروجين، مما يعكس عدم استقرار المادة العضوية وضرورة خضوعها لعملية تحلل هوائي مسبقة. أما النظام الواسع، فهو يتميز بتوازن في التركيب وارتفاع التوصيلية، مما يجعله مناسباً للتسميد البطيء، في حين يُظهر النظام المكثف خصائص وسطية واستقراراً مقبولاً يسمح باستخدام الروث بعد فترة قصيرة من التثبيت. وقد تم تحديد ثلاث طرق رئيسية للاستغلال: التخمير اللاهوائي لإنتاج الغاز الحيوي، خاصة في النظامين الواسع والمكثف مع إضافة مواد غنية بالكربون، والاستغلال الحراري بفضل ارتفاع المادة العضوية، والتحلل الحراري لإنتاج الفحم النباتي، لا سيما من روث النظام المكثف. تؤكد هذه النتائج على أهمية اتباع نهج إداري متمايز لروث الإبل حسب نظام التربية لتحقيق استغلال زراعي وطاقوي فعال ومستدام.

الكلمات المفتاحية: الإبل، الروث، نظام التربية، العناصر المخصبة، الاستغلال الطاقوي، ورقلة، الجزائر

Évaluation qualitative du crottin de dromadaire (*Camelus dromedarius*) en fonction des systèmes d'élevage dans la région de Ouargla

Résumé : Cette étude vise à caractériser les propriétés physico-chimiques et biochimiques du crottin de dromadaire issu de trois systèmes d'élevage (extensif, semi-intensif, intensif) dans la région de Ouargla afin d'en évaluer le potentiel de valorisation agricole et énergétique. Une approche méthodologique structurée a été adoptée, incluant le choix de sites représentatifs, et des analyses de laboratoire portant sur des échantillons de fumier. Les paramètres mesurés comprennent le pH, la conductivité électrique (EC), la matière organique (OM), le carbone (C), l'azote (N), le rapport C/N, et la matière minérale. Les résultats révèlent que le système semi-intensif présente la plus forte teneur en azote (10,2 %) et le plus faible rapport C/N (4,23), reflétant une matière instable nécessitant un compostage préalable. Le système extensif, avec un rapport C/N de 15,32 et une EC élevée, est adapté à une fertilisation lente. Le système intensif présente des caractéristiques intermédiaires avec une bonne stabilité. Trois axes de valorisation sont proposés : (i) la méthanisation, à privilégier pour les systèmes extensifs et intensifs avec co-substrats carbonés ; (ii) la valorisation thermique, rendue possible par une haute teneur en matière organique (>83 %) ; (iii) la pyrolyse pour la production de biochar, notamment adaptée au fumier intensif. Ces résultats soulignent l'intérêt d'une gestion différenciée du fumier camelin selon le système d'élevage, afin d'optimiser son usage agronomique et énergétique de manière durable.

Mots-clés : *Dromadaire, Crottin, Système d'élevage, Éléments fertilisants, Valorisation énergétique, Ouargla, Algérie.*