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Effect of Adding Different Levels of Maca (*Lepidium Meyenii*) Roots on Feed Additine Rumen Fermentations Local Black Goats

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ABSTRACT

The study aimed to evaluate the effect of using mace root powder as a feed additive on rumen fermentation rate in Iraqi black goat males by measuring volatile fatty acids, ammonia nitrogen, pH and total bacterial count in rumen fluid of local Iraqi black goat males. Sixteen male black local goats were selected and divided into four groups equal (T1T2T3T4) 4 animals per each treatment. They were weight 14.81±2.32 kg and 3.5-4 months of age . Maca powder was added at a rate of 0, 2, 4and 6 g / head / day. The results showed a significant increase ($P \leq 0.05$) in the concentration of acetic, Propionic and Butyric acid at zero time before feeding for T2T3T4 as coefficients with the control treatment T1 and high significance ($P \leq 0.01$) for the concentration of acetic for T2T3T4 on the control treatment T1 and after 6 hours significant ($P \leq 0.05$) for the concentration of actatic acid Propionic For T2T3T4 coefficients on control treatment T1, and significant ($P \leq 0.05$) at zero o'clock to measure the bacterial count of T2T3T4 parameters on the control treatment T1 .The results indicate that supplementing with 2, 4, and 6 g/head/day of Maca powder significantly enhances rumen function, The addition of maca plant has improved growth through feed intake, which has further aided digestion.

Key words bacterial Count, medicinal plants, volatile fatty acids, bacterial Count.

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INTRODUCTION

Goat production contributes to the economy of many developing countries. It provides food security and livelihoods to the majority of the population worldwide. Nowadays, there are more than one billion goats in the world, and their number is constantly increasing (Singh et al., 2025). There are several reasons for increased interest in goat production due to the small size of their bodies, high fertility, early physiological maturity, and multiple seasonal cycles (Muthanna & Shihab, 2023). The importance of goats in Iraq indicates that these animals are adapted to harsh environmental conditions and malnutrition, so the improvement of these animals is important because they have a wide scope for genetic improvement, which contributes to filling part of the deficit resulting from the lack of meat and milk and their high prices (Mohammed et al., 2023).In recent years, several studies have analyzed the bioactive compounds of several plants that are beneficial to humans and animals (Calabrò et al., 2022; Korkmaz, 2018). Of these plants, Maca (*Lepidium meyenii*) is a plant belonging to the Brassicaceae family; it is a medicinal plant (Ismawi et al., 2024) with high nutritional value and is native to the Andes of Peru (Korkmaz, 2018; Tafuri et al., 2019).Maca root shows high nutritional value, including important fatty acids such as linolenic acid (omega-3 fatty acid) and linoleic acid (omega-6 fatty acid) (Cui et al., 2003; Ulloa del Carpio et al., 2024), and is considered a medicinal plant due to the presence of many bioactive antioxidant compounds, such as polyphenols, macamides, macades, macaridine, alkaloids, and glucosinolates (Paternina-Ricardo et al., 2022; Turgud & Narinç, 2022), which are considered agents for lowering cholesterol and anti-inflammatory (Korkmaz, 2018). These chemical compounds found in plants show effects in strengthening the immune system.

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Many plants and their extracts have been used as feed additives in animal nutrition for many years to raise the rate of weight gain, improve product quality, and increase immunity (Çetin et al., 2021). In addition, medicinal plants and their secondary metabolites have veterinary medicinal properties such as immunological regulators, growth stimulants, antioxidants, and antimicrobials metabolism (Gaddafi et al., 2025).Therefore, this study aims to use different levels of maca plant powder as food additives to identify the extent of its effect on rumen fermentations, which include volatile fatty acids (propionic, acetic, and butyric acids), ammonia nitrogen concentration, pH, and microorganisms in rumen fluid.

MATERIALS AND METHODS

This study was conducted at the Ruminant Research Station of the Ministry of Agriculture / Iraq / Akrkov from 1/5/2024 to 30/7/2024. Sixteen male black local goats were used at the age of 3.5-4 months and with an average weight of 14.81±2.32\ kg different levels of maca roots were used (0,2,3and 4) g/head/day, to study their and effect on rumen fermentation. The experiment was conducted for all animals under the same environmental, nutritional and health conditions. All animals were fed concentrated diet at 3% of body weight per day, coarse fodder (alfalfa hay) was provided freely, and the breeding system inside the barn was individually for calculating the intake and residual of concentrated and coarse feed for each animal per day.

Preparation of the diet

Diet formulation and chemical composition of feed Stubbs were presented in Table (1) Maca plant was purchased from the local markets in the form of dried roots and after purchasing it was ground in the form of powder and chemical analysis of maca was carried out according to Table (1) and maca plant powder was given to each animal daily at a rate of 0, 2, 4, 6 g / head / day by adding it to the daily concentrated feed.

Table 1. Chemical composition of concentrated feed As DM basis

Chemical composition	Concentrated Diet	alfalfa hay	Maca
Dry matter	96.56	89.23	95.5
Organic matter	90.33	92.49	92.1
Crude protein	15.52	14.88	19.6
Ether extract	3.45	1.53	3.8
Crude fiber	5.43	21.57	19.4
Nitrogen-free extract	65.93	54.51	49.3
cinders	9.67	7.51	7.9
Metabolic energy	12.43	10.96	11.40

The percentage of dry matter, fat, fiber and ash was calculated according to method (2) and protein according to method (38):

NFE = 100 – (Ash + Protein +Fiber +Fat)

Organic matter = 100 – ash

Metabolic Energy (MJ/kg dry matter) = 0.012 × protein + 0.031 × fat + 0.005 × fiber + 0.014 × NFE (Ministry of Agriculture, Fisheries and Food [MAFF], 1975)

Rumen Fluid Collection

The process of collecting rumen fluid from the animals was carried out at the end of the experiment at 0, 3, and 6 hours post-feeding. A stomach tube (6 mm in diameter) was inserted into the rumen of the animals, and a vacuum pump was connected to withdraw the fluid. The collected rumen fluid was immediately filtered through four layers of medical gauze and divided into three equal parts in 50 mL plastic containers. The first part was treated with a few drops of 0.2 N hydrochloric acid (HCl) to arrest microbial activity and preserve the sample for ammonia nitrogen analysis; this portion was kept frozen until analysis (Filípek & Dvořák, 2009). The second part was directly stored in the freezer for volatile fatty acids (VFAs) analysis. The third part was used immediately for the determination and counting of microbial populations. This collection and preservation process was repeated at all three designated time points.

Measurement of Volatile Fatty Acids (VFAs): The concentration of volatile fatty acids in the rumen fluid was determined according to the method described by Cottyn and Boucque (1968), utilizing gas

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chromatography (Shimadzu GC-2010, Kyoto, Japan) as outlined by Jagoš et al. (1977).

Microbial Count Determination: The total count of anaerobic bacteria was determined using the scientific procedures and cultivation methods described by Andrews (1992).

Ammonia Nitrogen Measurement: After thawing the frozen rumen fluid samples, the concentration of ammonia nitrogen (NH3-N) was determined using the Kjeldahl distillation method as detailed by the AOAC International (2012) and further adapted from the application protocols of Anonymous (1984).

pH Measurement: The pH of the rumen fluid was measured immediately after collection at 0, 3, and 6 hours post-feeding using a portable digital pH meter equipped with automatic temperature compensation (Digital pH Meter ATC).

Statistical Analysis: All experimental data were statistically analyzed as a Completely Randomized Design (CRD). A one-way analysis of variance (ANOVA) was performed using the SAS Institute (2012) statistical software package. Significant differences among treatment means were determined using Duncan's (1955) multiple range test at significance levels of $P < 0.05$ and $P < 0.01$. The data were analyzed according to the following statistical model:

$Y_{ij} = \mu + T_i + e_{ij}$

Where:

Y_{ij} = The experimental observation

μ = The overall mean

T_i = The fixed effect of the treatment (maca powder level).

e_{ij} = The random experimental error.

RESULTS AND DISCUSSION

Effect of Maca Root Supplementation on Volatile Fatty Acids (Acetic, Propionic, and Butyric Acids). The results presented in Table 2 reveal significant differences ($P \leq 0.05$) in the concentrations of acetic, propionic, and butyric acids at 0 h (pre-feeding). For acetic acid, the maca-supplemented treatments (T3 and T4) significantly outperformed the control group (T1). Additionally, the T4 treatment exhibited a significantly higher concentration of both propionic and butyric acids compared to the control (T1) at this initial time point.Three hours post-feeding, a substantial increase in the overall concentration of volatile fatty acids (VFAs) was observed, with highly significant differences ($P \leq 0.01$) among the treatments. Specifically, the maca-supplemented groups (T4, T3, and T2, respectively) showed a highly significant superiority in acetic acid concentration over the control (T1). Furthermore, T3 and T4 maintained a significant superiority ($P \leq 0.05$) in butyric acid concentration compared to the control group (T1).At 6 h post-feeding, significant differences ($P \leq 0.05$) persisted. The T3 and T4 treatments outperformed the control (T1) in acetic acid concentration, while all maca-supplemented treatments (T4, T3, and T2) exhibited significantly higher propionic acid concentrations compared to the control group (T1). The concentration of VFAs in the rumen fluid directly reflects the metabolic activity and fermentation efficiency of rumen microorganisms. Microbial activity typically surges following the consumption of rapidly fermentable feeds, which subsequently elevates VFA production. In this study, the higher VFA concentrations observed at 0 h in the maca-supplemented treatments compared to the control suggest a carryover effect of active fermentation from the previous feeding cycle.Following feeding, VFA concentrations rose at 3 h compared to the 0 h baseline, particularly in the maca-treated groups. The higher concentrations of acetic and butyric acids in these groups point to enhanced microbial fermentation. The rise in butyric acid, in particular, is often associated with the fermentation of protein-rich substrates.Our findings show that the T4 treatment (the highest level of maca supplementation) yielded the highest rates of butyric acid at both 0 h and 3 h. This outcome is closely linked to the nutritional profile of maca roots, which contain high levels of crude protein (approximately 19.6%) and carbohydrates (approximately 44.8%), as detailed in Table 1.The presence of highly fermentable carbohydrates supplies ruminal microorganisms with a rapid and readily available energy source, which directly accelerates the synthesis of short-chain fatty acids. Furthermore, incorporating these dietary additives is known to optimize overall feed

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utilization efficiency and improve feed intake in animals (Alobeidi & Al-Samaraee, 2018).These findings align with previous research indicating that basal diets without maca supplementation exhibit lower fermentation capacities. Conversely, diets enriched with maca are fermented at a faster rate, demonstrating a highly positive impact on ruminal fatty acid production (Vastolo et al., 2023).

Table 2. Effect of Adding Different Levels of Maca Root in Concentrated Diet on Volatile Fatty Acid Concentration in Rumen Fluid for Male Local Black Goats (Mmol/100ml) (mean ± SE)

VFA (Mmol/100ml)	T1	T2	T3	T4	Sign
VFA (Mmol/100ml) zero time					
acetic	2.55 ± 0.04 c	2.64 ± 0.01 bc	2.69 ± 0.04 ba	2.76 ± 0.02 a	*
Propionic	3.20 ± 0.03 b	3.19 ± 0.03 b	3.27 ± 0.03 ba	3.31 ± 0.01 a	*
Butyric	1.27± 0.10 b	1.45 ± 0.03 ba	1.44 ± 0.04 ba	1.50 ± 0.02 a	*
VFA (Mmol/100ml) After 3h					
acetic	5.72 ± 0.04 b	5.88 ± 0.03 a	5.91 ± 0.0 a	5.94 ± 0.0 a	**
Propionic	6.93 ± 0.07	6.93 ± 0.01	6.95 ± 0.03	6.99 ± 0.01	N. S
Butyric	4.06 ± 0.06 b	4.14 ± 0.04 ba	4.23 ± 0.01 a	4.25 ± 0.03 a	*
VFA (Mmol/100ml) After 6h					
acetic	10.24 ± 0.13 b	10.47 ± 0.07 ba	10.61± 0.01 a	10.62± 0.02 a	*
Propionic	8.80 ± 0.05 b	9.13 ± 0.01 a	9.08 ± 0.03 a	9.07± 0.08 a	*
Butyric	7.38 ± 0.05	7.65± 0.03	7.71 ± 0.04	7.58 ± 0.19	N. S

Characters between rows indicate the comparison between coefficients within the set, * (P≤0.05), ** (P≤0.01), and N. S, First transaction control 0 Maca, second transaction 2g/head per day Maca, third transaction 4g/head per day Maca, fourth transaction 6g/head per day Maca

Effect of Maca Root Supplementation on the Bacterial Count of Rumen Fluid: The results presented in Table 3 show significant differences ($P \leq 0.05$) in the ruminal bacterial count at 0 h (pre-feeding). Specifically, the T4 treatment recorded a significantly higher bacterial count (10.33 x 10^x CFU/mL) compared to the control treatment T1 (9.59 x 10^x CFU/mL). However, no significant differences were observed in the number of bacterial colonies among the treatments at 3 and 6 h post-feeding.The elevated bacterial count observed at 0 h in the maca-supplemented diets can be attributed to the plant's rich content of dietary fiber, which ranges from approximately 4% to 10% of its dry weight (Wang & Zhu, 2019). These structural carbohydrates serve as an ideal substrate for cellulolytic and beneficial rumen bacteria, supporting their maintenance and proliferation even before the digestion of the newly offered feed begins.Moreover, maca roots contain bioactive compounds such as phenols, glucosinolates, and macamides, which have been shown to stimulate the activity of rumen microorganisms. These compounds function effectively as prebiotics that nourish and selectively promote the growth of beneficial gut and rumen bacteria prior to the onset of primary feed digestion.These observations are supported by previous in vivo studies on male rams, where maca supplementation led to a significant improvement ($P < 0.05$) in the digestibility coefficients of nutrients, indicating the creation of a highly favorable ruminal environment for microbial growth (Garba et al., 2023a; Mahdy et al., 2024).These findings further demonstrate that improving the nutrient density of the diet enhances the overall rumen environment, which directly supports the growth and proliferation of the microbial community. This expansion in the microbial population subsequently accelerates the fermentation process, leading to a substantial increase in the production of total volatile fatty acids .

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Table 3. Effect of Adding Different Levels of Maca Plant Roots in Concentrated Diet on Total Bacterial Count (Cfu/ml) (mean ± SE) in Rumen Fluid of Male Local Black Goats

Tret	T1	T2	T3	T4	Sign
Bact. Count, zero time × 10^9 Cfu/ml	9.59 ± 0.33 b	9.67 ± 0.67 b	9.89 ± 0.67 ba	10.33 ± 0.33 a	*
Bact. Count, After 3h ×10^9 Cfu/ml	10.28 ± 0.25	10.31 ± 0.11	10.54 ± 0.38	10.89 ± 0.29	N.S
Bact. Count, After 6h × 10^9 Cfu/ml	10.58 ± 0.03	10.95 ± 0.28	10.66 ± 0.41	10.62 ± 0.10	N.S

Characters between rows indicate the comparison between coefficients within the set, * (P≤0.05), ** (P≤0.01), and N. S, First transaction control 0 Maca, second transaction 2g/head per day Maca, third transaction 4g/head per day Maca, fourth transaction 6g/head per day Maca.

Effect of Maca Root Supplementation on Ammonia Nitrogen Concentration and pH in Rumen Fluid: The results presented in Table 4 show significant variations in the concentrations of ammonia nitrogen (NH3-N) and pH values in the rumen fluid. Ruminal ammonia concentration serves as a key indicator of how efficiently animals utilize dietary nitrogen; an optimal balance ensures that nitrogen is incorporated into microbial biomass rather than being wasted, which would otherwise be excreted and contribute to environmental pollution.According to established literature, the peak of ruminal ammonia formation occurs approximately 1 h post-feeding when animals are fed non-protein nitrogen (NPN) sources, whereas it peaks between 3 and 5 h post-feeding when the dietary nitrogen originates from true protein sources (Calomeni et al., 2015; Geron et al., 2016).In alignment with these patterns, the values in Table 4 show elevated rates of ammonia nitrogen production 3 h post-feeding, particularly for the maca-supplemented treatments (T2, T3, and T4), reflecting highly active ruminal fermentation. Because maca roots possess a high crude protein content comprised of true protein, they significantly support the synthesis of microbial protein. Approximately 80% of ruminal microorganisms utilize this produced ammonia nitrogen directly for their growth and structural reproduction (Bach et al., 2005; Garba et al., 2023b). Furthermore, the ruminal pH values remained well within the physiological normal range of 5.5 to 7.0, thereby providing an optimal environment for microbial proliferation and stable fermentation. These findings are consistent with those of Cobellis et al. (2016), who evaluated various medicinal plants and observed that their dietary inclusion did not adversely alter baseline ruminal pH values .As reported by Dijkstra et al. (2012) as well as Khafipour et al. (2009), ruminal pH is inversely related to the concentration of volatile fatty acids (VFAs); as VFA production peaks, pH values concurrently decline. This explains the noticeable decrease in pH values observed at 3 h post-feeding in this study, coinciding with peak VFA concentrations and establishing a highly favorable environment for microbial activity Additionally, indicated that maca supplementation exerts broader positive physiological effects beyond its direct impact on ruminal fermentation. Their study revealed that supplying maca roots to dams from late gestation through lactation significantly improved the birth and weaning weights of their offspring, with maca-supplemented groups consistently recording the highest body weight gains.

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Table 4. Effect of Adding Different Levels of Maca Root in Concentrated Diet on Ammonia Nitrogen C Local Black Goats oncentration(mg/100 ml) and pH(mean ± SE) in Rumen Liquid for Male Black Domestic Goats

Tret	T1	T2	T3	T4	Sign
Ammonia nitrogen concentration NH3-N (mg/100ml)					
zero time	11.67 ± 3.08	10.51 ± 0	14.0 ± 2.02	11.67 ± 1.16	N.S
After 3h	10.50 ± 2.02	12.84 ± 3.08	14.0 ± 1.02	15.17 ± 1.16	N.S
After 6h	9.33 ± 1.16	12.84 ± 2.33	11.67 ± 1.16	16.34 ± 7.64	N.S
PH					
0	6.30 ± 0.09	6.15 ± 0.19	6.47 ± 0.28	6.44 ± 0.15	N.S
After 3 h	6.26 ± 0.21	6.18 ± 0.15	6.52 ± 0.24	6.38 ± 0.01	N.S
After 6 hours	6.32 ± 0.13	6.11 ± 0.23	6.31 ± 0.30	0.09 ±6.39	N.S

Characters between rows indicate the comparison between coefficients within the set, * (P≤0.05), ** (P≤0.01), and N. S, First transaction control 0 Maca, second transaction 2g/head per day Maca, third transaction 4g/head per day Maca, fourth transaction 6g/head per day Maca

CONCLUSION

In conclusion, supplementing the diets of local Iraqi black goat males with Maca root powder at 2, 4, and 6 g/head/day significantly improves rumen fermentation and microflora. The additive stimulated a significant increase in volatile fatty acids (acetic, propionic, and butyric) and total bacterial counts. These improvements enhanced digestion and feed intake, ultimately leading to better growth performance. Consequently, Maca powder can be used as an effective natural feed additive to boost goat productivity.

CONFLICT OF INTEREST

There is no conflict of interest, according to the authors, when it comes to publicizing the current inquiry.

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تأثير إضافة مستويات مختلفة من جذور نبات الماكا كمكمل غذائي في تخمرات كرش الماعز المحلي الاسود

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المستخلص

أجريت هذه الدراسة لتقيم اضافة نبات طبي كمكمل غذائي من مسحوق جذور نبات الماكا كمكمل غذائي في تخمرات الكرش والتي تضمنت الاحماض الدهنية الطيارة وتركيز نتروجين الامونيا والاس الهيدروجيني (PH) والاحياء المجهرية في سائل الكرش لذكور الماعز المحلي الاسود العراقي. تم استخدام 16 ذكر ماعز محلي اسود قسمت عشوائيا الى أربع مجاميع(T4T3T2T1) بواقع 4 حيوانات لكل معاملة بمعدل متوسط وزن 14.81± 2.32 كغم وبعمر 3.5-4 شهر. تم اضافة مسحوق نبات الماكا بمعدل 0، 2، 4 و 6 غم /راس / يوم. اظهرت النتائج زيادة معنوية ($P\leq0.05$) في تركيز حامض acetic، Propionicو Butyric عند الساعة صفر قبل تغذية للمعاملات T2T3T4على معاملة السيطرة T1 ومعنوية عالية ($P\leq0.01$) لتركيز acetic للمعاملات T2T3T4على معاملة السيطرة T1 وبعد 6 ساعات لوحظ زيادة معنوية ($P\leq0.05$) لتركيز حامض aceticو Propionic للمعاملات T2T3T4التي تفوقت على معاملة السيطرة T1 ، ومعنوية ($P\leq0.05$) عند الساعة صفر لقياس العد البكتيري للمعاملات T2T3T4على معاملة السيطرة T1 ، وبالتالي حققت المجموعات التي اعطيت 2 ، 4 ، 6 غم/ راس /يوم مسحوق نبات الماكا افضل النتائج . ان إضافة نبات الماكا أدى الى تحسين النمو من خلال تناول العلف مما ساعد على الهضم اكثر.

كلمات مفتاحية: العد البكتيري، النباتات الطبية، الاحماض الدهنية الطيارة