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Influence of Season and Sex on Growth and Carcass Performance of Local Rabbits in North-Eastern Algeria

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ABSTRACT

Background: Rabbit farming in Algeria still occupies a modest place, but it presents interesting potential for meat production and income diversification in rural areas. Adapted to small farms, rabbit farming can contribute to improving the supply of animal protein. This study examines the effect of season and sex on the growth, live weight, hot carcass, cold carcass and associated yields of local rabbits raised in the El Tarf province.

Methods: The study was conducted on a total of 83 rabbits raised in a traditional system in Ain Elkarma, El Tarf province (Northeast Algeria), from birth to 14 weeks.

Result: Significant commercial growth occurred during the S7-S10 phase. The season × sex interaction was significant ($p<0.01$), with better performance in females born in winter (1567.3 g S14) in females, which also had the best cold carcasses (≈800 g). Rabbits of both sexes frequently exceed 1000 g by the 9th week in winter. A strong correlation between live weight and cold carcass weight ($r = 0.867$; $p<0.001$) was observed, confirming the link between body development and marketable muscle mass. Conversely, cold yields remain remarkably stable, with no significant influence of season, sex or live weight ($p>0.05$; $R^2<0.10$), indicating a low sensitivity of these parameters to biological or climatic variations. This stability enhances the predictability of final yield and is a major asset for the technical and economic optimization of the rabbit farming sector. The results reveal an adaptive plasticity of this local population and indicate the interest of differentiated management strategies according to season and sex to optimize zootechnical value in a semi-humid environment.

Key words: Carcass performance, Cold carcass yield, Commercial growth, Local algerian population, Rabbit farming.

INTRODUCTION

Rabbit farming is an important source of meat in Algeria and contributes to the supply of animal protein in rural and peri-urban areas (Boukhalfa *et al*., 2020; Bharathy *et al*., 2022). In this context, the local rabbit, in addition to the breeds and/or strains listed such as the so-called “Kabyle” breed or the synthetic white strain ITELV 2006 (Sid *et al*., 2018), mobilizes many researchers to characterize it as fixed and efficient breeds (Boukabane *et al*., 2018 and Bouhali *et al*., 2023).

In Algeria, studies on the local rabbit have mainly focused on nutrition, reproduction and general performance, while the combined effect of season and sex on weekly growth remains poorly documented (Mouhous *et al*., 2020; Maziz-Bettahar *et al*., 2019). However, these two factors can influence growth dynamics, particularly in Mediterranean environments subject to marked thermal and photoperiodic variations (Lebas *et al*., 2019; El-Aksher *et al*., 2020; El-Sabrout *et al*., 2023). Studying this interaction is therefore necessary to better understand the expression of the growth potential of the local Algerian rabbit population. Carcass quality and hot and cold yields, for their part, represent essential indicators for the techno-economic evaluation of the meat sector (Abdel-Rahman *et al*., 2023).

This study therefore aims to evaluate the combined effect of season and sex on growth with the objective evaluation of carcass performance of these local rabbits. Its objectives are to quantify live weight variations according to season × sex groups. By simultaneously studying growth, hot and cold carcass masses and corresponding yields, this study proposes a multidimensional approach to identify optimal slaughter periods, improve livestock management strategies and refine techno-economic prediction tools. Ultimately, this approach should help to define more relevant slaughter windows and to propose breeding practices better adapted to local conditions, with a view to the sustainable valorization of local Algerian rabbits.

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MATERIALS AND METHODS

This study was conducted on a rabbit farm in Aïn El Karma, wilaya of El Tarf, northeastern Algeria, characterized by a semi-humid Mediterranean climate. The rabbit kits came from the same litters and local, non-genetically selected herds (Zerrouki *et al*., 2005) and were fattened according to traditional practices (Saidi *et al*., 2013; Mourad *et al*., 2015). The rearing was carried out with natural ventilation and lighting, with ad libitum feeding based on green fodder and local agricultural by-products and free access to water.

The study involved 83 rabbit kits (males and females) distributed across three seasons (autumn, winter, spring) to evaluate the season × sex interaction on growth dynamics. The fattening period extended from 2022 to 2023, with monitoring from W0 (birth) to W14 (14 weeks) according to maturity stages. Weekly weighings were carried out at a fixed time using a precision electronic scale (±1 g). Average weekly weights were then calculated for each sex and each season. The slaughter took place at the animal science laboratory, Department of Agronomy, Chadli Ben Djedid University of El Tarf. It is important to emphasize that this is not a slaughterhouse in the strict sense of the term, but rather a slaughtering area. The rabbits were weighed just before slaughter and their live weight at slaughter was recorded. The following criteria were measured according to the standards of the World Rabbit Science Association (Blasco and Ouhayoun, 1996). Immediately after evisceration, the carcasses were weighed (hot carcass weight), then placed in a cold room for 24 hours, after which the cold carcass weight was measured. The formulas applied to calculate slaughter performance were as follows:

$$\text{Hot carcass yield [YH (\%)]} = \frac{\text{Hot carcass weight}}{\text{Live weight}} \times 100$$

$$\text{Cold carcass yield [YC (\%)]} = \frac{\text{Cold carcass weight}}{\text{Live weight}} \times 100$$

Statistical analysis

Statistical analysis were performed using R (v4.5.1) with the tidyverse, ggplot2, car and emmeans packages (R Core Team, 2023). Live weight, hot/cold carcass weight and yields were subjected to a two-way ANOVA (sex × season) with post-hoc comparisons using emmeans (Tukey's method). Relationships between weight variables were investigated using Pearson's correlation coefficient (r). The assumptions of normality and homogeneity of variances were verified using the Shapiro-Wilk and Levene tests, respectively. The significance level was set at $p<0.05$, with a graded notation ($p<0.05$, $p<0.01$, $p<0.001$). The results were illustrated by boxplots, fitted curves and correlation graphs produced with ggplot2 (Wickham *et al*., 2023).

RESULTS AND DISCUSSION

Weekly adjusted weight (LWW, by season and sex S0-S14)

Table 1 shows a typical sigmoidal growth pattern in weekly adjusted body weight from birth to 14 weeks of age across all season-sex combinations, with no significant difference at birth (33.2-48.0 g; $p>0.05$), suggesting that local Algerian rabbits are well adapted to Mediterranean climatic conditions, as previously reported for comparable North African populations (Zerrouki *et al*., 2001). Nevertheless, a sex-related effect was detected at birth in spring, where males were heavier than those born in autumn (44.6 g vs. 33.2 g; $p = 0.0096$), possibly reflecting the influence of increasing photoperiod and favorable thermal conditions on fetal development (Ouhayoun, 1997), whereas the absence of a significant seasonal effect in females ($p = 0.13$) is consistent with their greater reproductive stability (Piles *et al*., 2000). Although these neonatal differences were modest, they appeared to be amplified during postnatal growth, leading to a season-dependent sexual dimorphism, as also suggested by Martínez-Paredes *et al*. (2022). From weeks 6 to 8, growth acceleration became more pronounced in females ($p = 0.0244$), particularly in those born in winter, which may be explained by moderate temperatures and suitable photoperiod conditions that favor feed intake and metabolic efficiency (Theau-Clément, 2021; Dalle and Paci, 2014). Accordingly, winter females recorded the highest weight at S8 (893.6 g), outperforming males (630.6-707.1 g; $p = 0.011$). Where the ranking was winter females (1567.3 g) > spring females (1381.8 g) > mid-winter males (1131.0 g; $p = 0.0019$). Overall, these findings highlight a strong interaction between season and sex throughout the growth trajectory and support the interest of adapting breeding management to the reproductive season, particularly by favoring autumn-winter kindling (Gidenne *et al*., 2010).

Seasonal effects on rabbit growth performance

Repeated measures ANOVA showed highly significant seasonal effects on rabbit weight trajectories ($p<0.001$), with a season × sex interaction also significant ($p = 0.023$), confirming that the expression of growth potential depends on the combination of these two factors. Winter conditions appear generally favorable, due to reduced heat stress which improves intake and directs more energy towards growth (Noblet and Renaudeau, 2021). In this context, females from winter births showed the best performance over the whole period, with a live weight of 1567.3 g at S14, compared to 1381.8 g in spring and 1052.1 g in autumn, corresponding to an asymptotic advantage of 49%; they also reached 893.6 g at S8, or about 51% of their asymptotic adult weight ($W\infty = 1748$ g), with an ADG of 15.2 g/d. Conversely, autumn females show a more moderate weight at S8 (853.2 g) and a lower ADG (13.0 g/d) (Fig 1), which suggests an early compensatory type growth allowing them to limit the effect of less favorable conditions at the end of

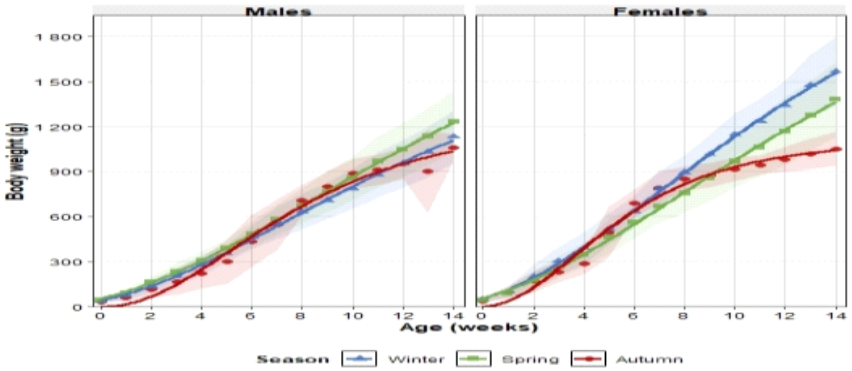
growth, as described in semi-humid systems (Gidenne *et al.,* 2019). In males, those born in spring show a more marked initial growth, with a weight 43% higher from the first week (88.8 g versus 62.0 g in autumn), an advantage which is maintained until adulthood (1,234.7 g at S14), but their terminal performance seems more sensitive to the progressive increase of thermal stresses, which can delay the growth optimum towards S10 (Gacem *et al.,* 2009; Lebas *et al.,* 2019). These sex-specific seasonal differences appeared as early as the seventh week, as indicated by Dunn's multiple comparison tests ($p<0.05$) and they are consistent with observations reported in other climatic contexts, notably in India, where the season of birth significantly influences post-weaning growth (Gupta *et al.,* 2022).

Evolution of commercial growth: interactions between sex and season (7 to 10)

Fig 2 highlights a marked season × sex interaction during the S7-S10 commercial window, reflecting significant variability in growth performance among the groups studied. Winter-born females exhibited the best performance, with the highest average daily gain (ADG) (15.2 g/d) and maximum live weight at S8 (893.6 g), confirming their position as the most favorable combination for commercial production of local rabbits in Algeria (Lebas *et al*., 2019; Gidenne *et al*., 2019). Winter males followed with similarly high values (14.4 g/d), while five of the six groups exceeded the commercial threshold of 12.5 g/d, with the exception of autumn males (12.2 g/d), confirming

Table 1: Least squares means (±SE) for the body weight of local rabbits by season and sex (week 0-week 14), (M: Males, F: Females).

Season	Automn		Winter		Spring	
Sex	M	F	M	F	M	F
Week 0	33.2±7.8a	38.1±8.4a	37.8±10.0a	48.0±11.3a	44.6±9.1b	43.5±9.4a
Week 1	62.0±24.4a	96.6±40.8a	74.3±26.8a	99.6±33.5a	88.8±25.4b	90.4±33.3a
Week 2	114.3±56.1a	169.3±71.5a	135.1±44.9a	199.7±83.7a	163.4±41.0a	171.6±62.3a
Week 3	166.5±89.2a	231.6±68.6a	202.2±55.5a	302.5±94.7a	235.0±59.2b	265.9±71.3a
Week 4	221.3±102.7a	287.7±71.2a	275.3±68.8a	389.9±109.8a	308.5±61.7a	349.1±75.0a
Week 5	299.9±147.3a	496.1±169.4a	356.3±57.8a	515.6±105.3a	391.2±68.0b	466.7±116.9a
Week 6	437.1±172.7a	690.1±91.2a	463.7±78.7a	634.3±106.4a	483.0±85.5a	562.8±110.1a
Week 7	547.7±167.6a	791.5±107.7a	560.1±104.6a	784.0±119.2a	582.1±102.0a	669.5±115.3b
Week 8	708.1±103.7a	853.2±80.2a	630.6±120.1a	893.6±113.6a	671.0±117.4a	757.6±133.1b
Week 9	802.0±98.0a	876.2±81.3a	708.4±119.2a	1014.8±131.8a	765.9±134.7a	856.9±154.8b
Week 10	886.1±98.0a	914.9±77.7a	787.4±134.9a	1145.8±144.5b	857.6±147.3a	966.9±175.4a
Week 11	911.9±102.7a	944.1±66.2a	877.0±152.0a	1231.9±157.9b	967.2±170.8a	1061.1±190.6a
Week 12	955.3±103.7a	979.2±83.2a	950.3±159.1a	1339.3±164.8b	1046.1±182.0a	1168.5±223.5a
Week 13	900.1±276.9a	1019.5±101.6a	1029.7±168.8a	1472.7±207.0b	1134.6±188.7a	1273.5±230.3a
Week 14	1059.3±86.5a	1052.1±114.1a	1131.0±173.9a	1567.3±230.8b	1234.7±203.6b	1381.8±248.8a



Blue (-) = Winter; green (++) = Spring; red (••) = Autumn. Data points indicate LSMEANS (weeks 0 to 14).

Fig 1: Seasonal growth curves in rabbits, by sex; with significance tests.

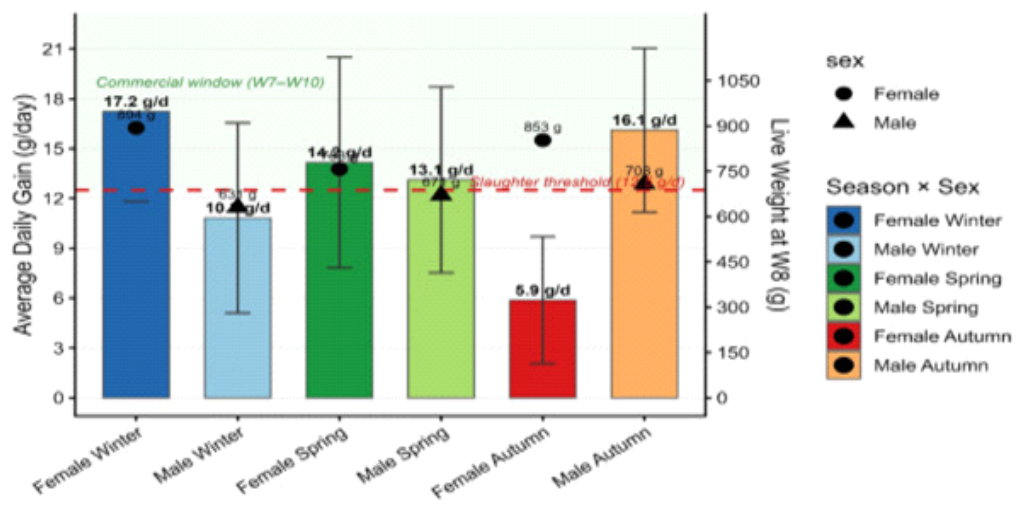
the combined effect of season and sex on growth efficiency (Gupta *et al*., 2022; Bashiru and Oseni, 2025). At S8, spring males exhibited the lowest weight (630.6 g), below the commercial threshold of 750 g, while spring females also remained slightly underweight (757.6 g). This suggests a reduced ability of these groups to capitalize on late-growth conditions under increasing heat stress (Gacem *et al*., 2009). Conversely, autumn was characterized by high live weights despite a more moderate average daily gain (ADG), particularly in females (13.0 g/d) and males (12.2 g/d). This suggests compensatory early growth during the initial developmental phases, a phenomenon already described in local populations subjected to agroclimatic variations (Zerrouki *et al*., 2018). This performance distribution indicates that winter females combine high growth rate with optimal final biomass, making S8 a particularly advantageous slaughter window, with an estimated carcass yield between 58 and 62% of live weight (Dalle *et al*., 2024). Autumn females, despite slightly lower performance, show good adaptability in less favorable conditions (Gidenne., 2023), while spring males appear to be more penalized at the end of their growth, their optimum occurring around S10, likely due to increasing thermal stress (Lebas *et al*., 2019). Overall, these results highlight the phenotypic plasticity of the local rabbit in the face of agroclimatic variations and argue in favor of differentiated breeding management according to sex and season. with a particular appreciation of winter births for females (Fortun *et al*., 2021).

Live weight and carcass yield

In Table 2 mean values show significant variability depending on season and sex, as confirmed by the two-way analysis of variance (sex × season) ($p<0.05$). Analysis of the correlations between live weight and carcass traits reveals a direct, positive and highly significant relationship between total body mass at slaughter and the amount of muscle tissue recoverable as carcass (Table 1, Fig 1 and 2). These results confirm that live weight is a reliable indicator of carcass yield in domestic rabbits, consistent with the findings of Larzul and Gondret (2005).

Correlation between live weight and hot carcass weight

Correlation remains positive and highly significant ($r = 0.742$; $p<0.001$), although slightly lower than that observed for cold carcass weight. This difference is attributable to post-mortem moisture loss resulting from cooling and muscle contraction, leading to a reduction in weight between the two states (Fig 3). Similar observations



(■ = Female LW8; ▲ = Male LW8; - - = Commercial slaughter threshold at 12.5 g/day; Shaded area = Commercial window W7-W10).

Fig 2: Average daily gain (g/day) between weeks 7 and 10 and live weight at week 8 (g) of local rabbits according to the season-sex interaction.

Table 2: Average live weight, carcass weight and yield by season and sex.

Season	Sex	Live weight (g)	Hot carcass weight (g)	Cold carcass weight (g)	Cold yeild (%)
Autumn	M	1249.9±218.7	569.0±66.0	509.2±63.2	40.7±7.8
Autumn	F	1170.8±150.3	524.2±95.3	489.9±96.2	41.8±3.1
Winter	M	1213.8±217.8	543.6±107.1	496.2±91.0	40.9±2.0
Winter	F	1695.4±247.5	888.8±143.2	800.0±134.9	47.2±3.9
Spring	M	1294.9±232.3	554.9±135.2	538.2±141.5	41.6±8.3
Spring	F	1463.9±274.8	647.4±152.0	611.9±162.2	41.8±4.8

have been reported by Zhao *et al*. (2024), highlighting that muscle water retention is a key determinant of final carcass mass. Seasonal effects are also confirmed.

In winter, hot carcass weights reach their peak values (888.8±143.2 g for females), reflecting the positive influence of moderate climatic conditions on muscle growth and tissue water stability. In spring, correlations remain strong, supported by a balanced diet and a steady growth rate. Conversely, in autumn, the relationship is weaker, likely due to fluctuating thermal conditions and increased metabolic stress, which affect energy conversion and carcass quality.

Regarding sex, the correlation is higher in females ($r = 0.759$; $p<0.001$) than in males ($r = 0.495$; $p<0.01$), reflecting greater weight stability before and after chilling. This difference is attributable to the higher intramuscular lipid content and superior water retention observed in females, consistent with the findings of Benali *et al*. (2025). Overall, these results demonstrate that live weight is a reliable predictor of meat production performance.

Correlation between live weight and cold carcass weight

The Pearson correlation test reveals a very strong linear relationship between live weight and cold carcass weight ($r = 0.867$; $p<0.001$), indicating that the heaviest rabbits at slaughter consistently yield the most developed carcasses (Fig 4). However, this relationship varies by season: the correlation peaks in winter, reflecting the beneficial effect of stable thermal conditions on muscle growth and weight retention. Females in winter show the best performance, with an average cold carcass weight of 800.0±134.9 g, reflecting enhanced metabolic and muscular efficiency. In the spring, the relationship remains high, suggesting an optimal balance between growth and moderate water loss. In the autumn, the correlation is weaker, likely due to slowed post-weaning growth and climatic variations affecting energy utilization and tissue composition.

The cold carcass weight observed in the present study is consistent with the findings of Kouadio *et al*. (2023), who reported that cold carcass weight followed the trend in live weight at slaughter, with no significant change in carcass yield.

The study by Brahmantiyo *et al*. (2021) highlights the genetic superiority of the HyLa line selected for heat resilience over the NN line, which is more sensitive to heat stress. These lines were evaluated under controlled tropical conditions, where high temperatures amplify differences in carcass performance. Regarding sex, the correlation is more pronounced in females ($r = 0.934$; $p<0.001$) than in males ($r = 0.625$; $p<0.01$), underscoring their greater weight uniformity and superior muscle retention capacity. These differences are attributed to endocrine and metabolic factors, such as improved protein utilization and higher anabolic activity, as reported by Martínez-Paredes *et al*. (2022).

An adjusted coefficient of determination of $R^2 = 0.749$, indicating that nearly 75% of the variability in cold carcass weight is explained by live weight at slaughter. This result is comparable to those reported by Abdel-Rahman *et al*. (2023), who observed coefficients exceeding 0.85 between these two variables in rabbits of similar breeds.

Seasonal and sex-related effects on cold carcass yield

Cold carcass yield appears to be a particularly stable parameter, showing little influence from season, sex, or live weight (Fig 5). This low variability aligns with the observations of Moumen *et al*. (2016) regarding the local Aurès rabbit; they reported relatively constant slaughter yields despite significant variation in live weight, suggesting that the proportion of marketable mass remains generally predictable. Furthermore, recent methodological studies indicate that post-mortem stages particularly chilling tend to diminish individual differences, reinforcing the view that cold yield reflects a standardized fraction of the carcass (Croda-Andrade *et al*., 2022). Similarly, variations related to breed or sex can lead to structural differences in tissue distribution that may affect cooling weight loss (Derewicka *et al*., 2021).

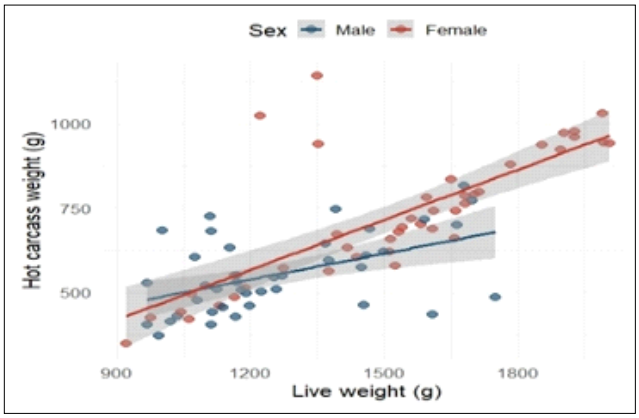


Fig 3: Correlation between live weight and hot carcass weight.

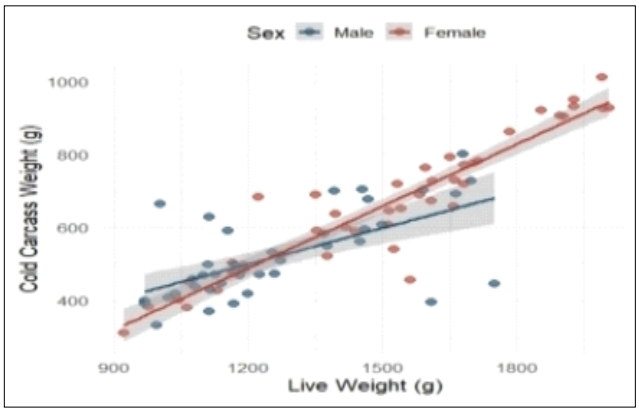


Fig 4: Correlation between live weight and cold carcass weight according to sex.

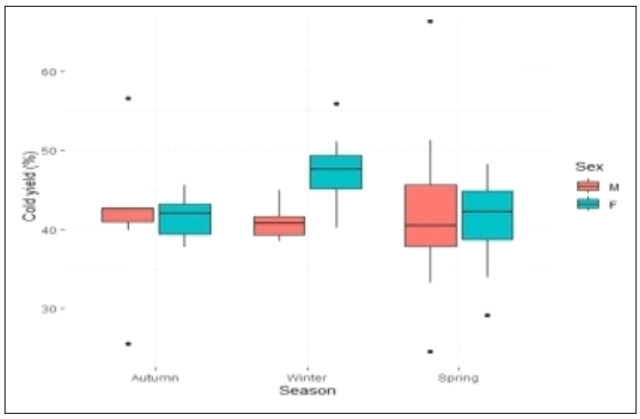


Fig 5: Effect of sex and season on cold carcass yield.

CONCLUSION

This study analyzes the combined influence of season and sex on the growth and carcass performance of local rabbit populations. The results demonstrate clearly superior performance during winter, characterized by higher asymptotic weights and cold carcass weights, highlighting a strong correlation between weight gain and meat yield potential. Conversely, hot and cold carcass yields remain constant and independent of season, sex and live weight, revealing remarkable stability in the face of biological or climatic variations. This robustness improves the predictability of final yield and reinforces the value of these indicators for slaughter planning and the technical-economic optimization of the rabbit industry.

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Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Informed consent

All animal procedures for experiments were approved by the Committee of Experimental Animal Care and Handling Techniques were approved by the University of Animal Care Committee.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

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