

Effects of different housing systems on body development in crossbred F1 rabbit does

Avaliação de diferentes sistemas de alojamento sobre o desenvolvimento corporal de coelhas mestiças F1

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Highlights

Housing systems influenced body development in crossbred F1 rabbit does.

Body weight increased progressively with age.

Daily weight gain varied with the number of does per housing system.

Abstract

This study evaluated the effects of different housing systems on body development in female rabbits (does). A total of 24 crossbred F1 does (½ New Zealand White and ½ California) were used. The experiment was carried out at the Rabbit Farming Unit of the Federal Institute of Minas Gerais, Bambuí Campus, from July 2020 to February 2021. A completely randomized design (CRD) was used, with three housing treatments: T1 – individual cage, T2 – enriched cage for two does, and T3 – collective pen with four does. The normality of the response variable (Y) was verified using the Shapiro-Wilk test, and homogeneity of variances with Bartlett's test, followed by analysis of variance (ANOVA), all at a 5% significance level. Body development was assessed using the following parameters: weight at first insemination, final weight, weight at 120, 150 and 180 days of age, total weight gain, and daily weight gain from 120-150 and 150-180 days. The CRD was applied to the initial parameters (weight at first

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insemination, final weight), while the other variables followed a split-plot design, with housing system as the main factor and age (days) as the subplot factor. Housing system had no effect on final weight but significantly influenced weight at first insemination. Housing systems affected body weight only at 180 days of age. Total weight gain was not affected by housing system, except for daily gain from 120-150 days, where significant differences were found. Overall, housing systems significantly influenced the body development of rabbit does, demonstrating their importance in production management.

Key words: Animal welfare. Enriched cages. Collective housing systems.

Resumo

O presente estudo teve como objetivo avaliar os efeitos de diferentes sistemas de alojamento sobre o desenvolvimento corporal de coelhas, utilizando para isso 24 matrizes mestiças F1 (1/2 Nova Zelândia Branca e 1/2 Califórnia). O experimento foi conduzido nas instalações do setor de Cunicultura do Instituto Federal Minas Gerais, Campus Bambuí, durante o período de julho de 2020 a fevereiro de 2021. O delineamento experimental adotado foi o inteiramente casualizado (DIC), com três tratamentos (alojamentos) distintos: T1 - Gaiola individual, T2 - Gaiola enriquecida para duas coelhas e T3 - Baia coletiva (quatro coelhas por baia). Para a aplicação da análise de variância (ANOVA), foi verificada a normalidade da variável de interesse (Y) por meio do teste de Shapiro-Wilk, bem como a homogeneidade da variância utilizando o teste de Bartlett ao nível de 5% de significância. O desenvolvimento corporal das coelhas foi avaliado considerando os parâmetros: peso na primeira inseminação, peso final, peso aos 120, 150 e 180 dias de idade, ganho de peso e ganho de peso diário nos intervalos de 120 a 150 dias e de 150 a 180 dias. O DIC foi empregado para os parâmetros iniciais (peso na primeira inseminação, peso final), enquanto os demais parâmetros seguiram um DIC em parcela subdividida (*Split-Plot*), com os tipos de alojamento sendo os tratamentos principais e a idade (dias) das coelhas como tratamentos secundários. Os resultados revelaram que os alojamentos não exercem influência sobre o peso final das coelhas, mas houve uma diferença estatisticamente significativa no peso na primeira inseminação entre os diferentes tipos de alojamento. Em relação ao peso, os alojamentos apresentaram efeito, apenas aos 180 dias de idade. Já para o ganho de peso, os sistemas não influenciaram estatisticamente. Apenas no período de 120 a 150 dias os sistemas afetaram de forma significativa no ganho de peso diário. Em conclusão, os sistemas de alojamento desempenharam um papel significativo no aprimoramento do desenvolvimento corporal das coelhas, evidenciando sua influência marcante nesse contexto.

Palavras-chave: Bem-estar animal. Gaiolas inteligentes. Sistemas coletivos.

Introduction

Rabbit farming has the potential to play a strategic role in Brazil, especially in terms of economic, social, and environmental sustainability (Machado, 2024). This is due to its ability to make efficient use of limited space, take advantage of agricultural by-

products, supply nutrient-rich meat, generate valuable by-products, and contribute to food production, income generation, and employment opportunities for small-scale producers (Bonamigo et al., 2017; Bruxel, 2019; Machado & Ferreira, 2011; Khan et al., 2022).

Growing societal concern for animal welfare has led to increasing demand for innovative production systems that promote better welfare outcomes. In 2021, the European Parliament published updated legislation mandating the gradual replacement of cages with more suitable alternatives by 2027 (European Parliament, 2021). In response, researchers have been investigating modern housing systems, including collective pens that allow rabbits greater freedom of movement (Machado & Ribeiro, 2019a; Pinotti et al., 2019; Van Damme et al., 2023b; Zomeño et al., 2023).

Evidence suggests that housing female rabbits (does) in individual wire cages compromises their behavioral and psychological well-being (Huang et al., 2021). Reflecting this, cage use in European rabbit farming has progressively declined since 2023 in compliance with European Parliament guidelines (Menezes et al., 2022). Larger, less restrictive spaces have been increasingly emphasized as alternatives to traditional cages (Lima, 2019), and collective housing for does has gained prominence in recent years (Zomeño et al., 2018; Szendrő et al., 2019). Part-time collective housing in particular has the potential to enhance welfare by offering more space and social interactions, which foster more natural behavior expression and improve overall quality of life (Cervera et al., 2017).

However, collective housing also poses management challenges, especially due to hierarchical conflicts among does, which can result in high culling rates (Machado & Fras, 2017). To address this issue, researchers have tested semi-group systems, in which does alternate between collective and individual housing. This helps

mitigate aggression, which tends to intensify in the days immediately before and after kindling (Bill et al., 2020; Braconnier et al., 2020; Machado et al., 2023; Van Damme et al., 2022, 2023a; Zomeño et al., 2018; Szendrő et al., 2019).

Given the growing demand for alternative production systems, the present study evaluated the body development of crossbred F1 rabbit does (½ New Zealand and ½ California) under different housing conditions. The findings provide pioneering data to guide the transition toward more ethical housing systems without compromising production performance.

Material and Methods

This study was conducted at the Rabbit Farming Unit of the Federal Institute of Minas Gerais, Bambuí Campus, from July 2020 to February 2021, with the study protocol previously approved by the Animal Use Ethics Committee (CEUA-IFMG), under protocol number 11/2020. According to the Bambuí-MG weather station, the average minimum temperature during the study period was 20.64 °C, and the maximum 22.23 °C.

Twenty-four crossbred F1 does (½ New Zealand and ½ California) were used, with eight housed in floor pens with beddings (four per pen), eight in four enriched cages (two per cage), and eight in individual cages, which are traditionally used in this production system.

The pens measured 200 x 130 cm with an 80 cm high wire frame and were equipped with nipple drinkers and tubular feeders, similar to those used in poultry production. The 3-centimeter-thick rice hull

bedding was replaced monthly or whenever saturation occurred. The enriched cages measured 100 x 70 x 50 cm and included a footrest, a second-level platform, and a PVC tunnel, and the individual cages (80 x 60 x 40 cm) contained a footrest. All cages contained semi-automatic feeders and

nipple drinkers. All does were fed the same commercial diet, formulated to meet their nutritional requirements, and provided ad libitum throughout the experiment.

Figure 1 illustrates the housing systems used in this study.

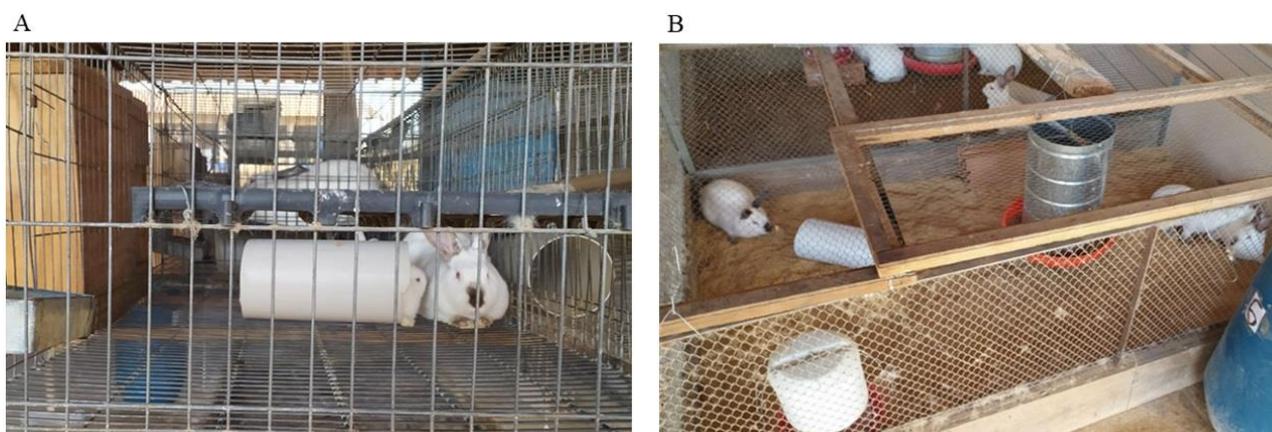


Figure 1. Evaluated housing systems: (A) enriched cages and (B) collective pens.

Body development was assessed using the following parameters: weight at first insemination, final weight, weight at 120, 150 and 180 days of age, weight gain from 120-150 days and 150-180 days, and daily weight gain during the same intervals. The initial parameters (weight at first insemination and final weight) were analyzed using a CRD, with housing system as the main factor. The remaining parameters were evaluated in a split-plot design, with housing system as the main factor and age of the does as the subplot factor.

The CRD consisted of three experimental treatments: T1 – individual cage, T2 – enriched cage with two does, and

T3 – collective pen. Each treatment included eight replicates, each corresponding to one doe. Parametric assumptions were verified by testing normality with the Shapiro-Wilk test and homogeneity of variances with Bartlett's test, followed by one- and two-way ANOVAs. When differences were significant at a 5% level, Tukey's test was applied for multiple comparisons, also at 5% significance.

Results and Discussion

Table 1 presents the ANOVA results for final body weight and weight at first insemination (30 weeks of age) in relation to doe housing systems.

Table 1
Comparison of housing systems for final body weight and body weight at first insemination

Housing system	Final weight (g)	Weight at 1 st insemination (g)
Individual cage	3838.57 ± 307.76	4015.43 ± 308.16 A
Paired housing	4023.33 ± 321.37	3864.71 ± 326.28 A
Collective pen	3661.88 ± 254.56	3408.75 ± 348.97 B

*Different letters within a column indicate significant differences according to Tukey's test ($p < 0.05$).

The F-test indicated no significant differences in final body weight among the housing systems at the 5% level, suggesting that housing type did not affect the final weight of the does.

By contrast, there were significant differences in body weight at first insemination across housing systems. The lower weight recorded in the collective pen is likely due to the higher activity levels of the does, driven by greater space for movement and social interaction, often involving agonistic disputes (fights). Moreover, subordinate does may have been prevented from accessing feeders, limiting their feed intake. These findings are consistent with Machado et al. (2019b), who found that does in collective cages had lower weights at first insemination.

Supporting this trend, Machado et al. (2020) reported an average body weight of 4230.90 g at first insemination in individually housed crossbred does, reinforcing the tendency for reduced weights in group

housing systems. These outcomes highlight the negative impact of collective housing on body weight at insemination. Since rabbit does require optimal body condition for their first mating or insemination, which is critical for maintaining weight in later reproductive cycles and improving longevity, this finding represents a challenge for production efficiency.

Table 2 presents the two-way ANOVA results for body weight, weight gain, and daily weight gain.

Body weight increased over time across all the housing systems. Consistent with Mondin et al. (2021), the does achieved different weights at different stages. Body weight was highest at 180 days, as confirmed by Tukey's test (5% level). Interaction effects revealed that, at 180 days, the mean body weight of individually housed does was statistically similar to that of does housed in pairs, whereas collective pens yielded the lowest weights.

Table 2
Comparison of housing systems from 120 to 180 days of age for body weight, weight gain, and daily weight gain

Housing system	Weight (g)			P-value
	120 (d)	150 (d)	180 (d)	
Individual cage	3228.00 ± 237.04 C	3706.43 ± 326.91 B	3883.57 ± 331.52 aA	
Paired housing	3102.00 ± 365.81 C	3636.88 ± 444.65 B	3764.43 ± 349.78 abA	0.01
Collective pen	2991.00 ± 242.470 C	3288.00 ± 286 B	3415.38 ± 347.54 bA	0.01
Housing system	Weight gain (g)			P-value
	120-150 (d)	150-180 (d)	Mean	
Individual cage	478.43 ± 139.09	177.43 ± 155.67	327.93	
Paired housing	505.75 ± 178.39	-11.29 ± 173.38	247.23	0.01
Collective pen	297 ± 155.69	127.38 ± 178.08	212.19	0.06
Mean	427.06 A	97.84 B		
Housing system	Daily weight gain (g)			P-value
	120-150 (d)	150-180 (d)		
Individual cage	15.43 ± 4.49 abA	6.11 ± 5.37 B		
Paired housing	17.25 ± 3.83 aA	-0.39 ± 5.98 B		0.01
Collective pen	9.58 ± 5.02 b	4.39 ± 6.14		0.03

*Different uppercase letters in rows and lowercase in columns indicate significant differences according to Tukey's test (p<0.05). Int.: Interaction between housing system and age (days).

For weight gain (g), differences were only significant between 120-150 days and 150-180 days, with the highest gains recorded in the 120-150 day period. The interaction between housing and age was not significant, indicating consistent housing effects over time. Notably, does housed in pairs experienced weight loss between 150 and 180 days. As reported by Ferreira and Santiago (1999) and Trocino et al. (2015), this may be due to increased stocking density or the challenges of group housing. The sharp growth observed in individually and pair-housed does in the previous period (120-150 days) also suggests possible compensatory effects. These results emphasize the need to consider housing conditions, social dynamics, and available space when assessing doe weight gain over time.

Daily weight gain also varied by housing system between 120 and 150 days. The means for does housed alone and in pairs were statistically similar; however, in the following period (150-180 days), daily weight gains declined substantially, with some animals even losing weight in these housing systems.

According to Oliveira et al. (2003), lower stocking density is associated with higher daily weight gains, consistent with the results obtained here for the 120-150 day period. By contrast, Brandalise et al. (2020) reported daily weight gains of 30.02 ± 18.78 grams in adult female rabbits, values similar to those found in the present study for the same age period (120-150 days), although the does in their study were not pregnant. Lazzaroni et al. (2009) observed average daily gains of 27.8 ± 5.31 g in Carmagnola Grey does, while Marciano et al. (2019) recorded 13.75 g in Lionhead does, close to values reported here

for the 120-150 day period. Collectively, these studies illustrate the considerable variability in growth performance depending on breed.

Conclusions

Overall, housing systems significantly affected body development, particularly in terms of weight at first insemination, weight at 180 days, and daily weight gain between 120 and 150 days of age. Based on the parameters evaluated, the findings indicate that housing two does per cage may be the most advantageous option for F1 crossbreds ($\frac{1}{2}$ New Zealand White \times $\frac{1}{2}$ California). Although certain differences were observed when compared with individual cages, paired housing offers the benefit of reduced space requirements and lower costs by accommodating two animals together. Unlike collective housing, it also minimizes the risk of aggressive interactions, fostering productive efficiency and a more stable social environment.

References

- Bill, J., Rauterberg, S. L., Herbrandt, S., Ligges, U., Kemper, N., & Fels, M. (2020). Agonistic behavior and social hierarchy in female domestic rabbits kept in semi-groups. *Journal of Veterinary Behavior*, 38(4), 21-31. doi: 10.1016/j.jveb.2020.03.004
- Bonamigo, A., Duarte, C., Winck, C. A., & Sehnem, S. (2017). Produção da carne cunícula no Brasil como alternativa sustentável. *Revista em Agronegócio e Meio Ambiente*, 10(4), 1247-1270. doi: 10.17765/2176-9168.2017v10n4p1247-1270

- Braconnier, M., Munari, C., Gómez, Y., & Gebhardt-Henrich, S. (2020). Grouping of breeding rabbit does at different time points: effects on fertility, mortality and weight. *World Rabbit Science*, 28(2), 73-80. doi: 10.4995/wrs.2020.13107
- Brandalise, J., Bertipaglia, T., & Gomes, F. (2020). Ganho de peso em coelhos adultos e jovens. *Anuário Pesquisa e Extensão Unoesc Joaçaba*, 5(2020), e26199. <https://periodicos.unoesc.edu.br/apeuj/article/view/26199>
- Bruxel, P. (2019). *Influência do tipo de gaiola no desempenho e bem-estar de coelhas gestantes e lactantes*. Graduação em Zootecnia, Universidade Federal de Santa Catarina, Florianópolis, SC, Brasil.
- Cervera, C., Martínez-Paredes, E., Machado, L., & Villagrà, A. (2017). Producción de conejas en sistemas de alojamiento individual o colectivo en semigrupo. *Anais do Symposium de Cunicultura de ASESCU*, Murcia, Espanha, 42.
- European Parliament (2021). *European Parliament resolution of 10 June 2021 on the European Citizens' Initiative 'End the cage age' (2021/2633 (RSP))*. https://www.europarl.europa.eu/doceo/document/TA-9-2021-0295_EN.html
- Ferreira, W. M., & Santiago, G. S. (1999). Desempenho produtivo de coelhos criados em diferentes densidades populacionais. *Revista Brasileira de Zootecnia*, 28(1), 113-117. doi: 10.1590/S1516-35981999000100016
- Huang, Y., Breda, J., Savietto, D., Debrusse, A. M., Combes, S., & Fortun-Lamothe, L. (2021). Part-time grouping of rabbit does in enriched housing: effects on performances, injury occurrence and enrichment use. *Animal*, 15(12), 100390. doi: 10.1016/j.animal.2021.100390
- Khan, A., Lashari, M. H., & Farooq, U. (2022). Effect of season and housing systems on various physio-behavioral attributes of local breed of rabbits (*Oryctolagus cuniculus*) in Southern Punjab, Pakistan. *Brazilian Journal of Biology*, 82(1), e258816. doi: 10.1590/1519-6984.258816
- Lazzaroni, C., Biagini, D., & Lussiana, C. (2009). Different rearing systems for fattening rabbits: performance and carcass characteristics. *Meat Science*, 82(2), 200-204. doi: 10.1016/j.meatsci.2009.01.011
- Lima, N. G. S. D. (2019). *Coelhario rústicos na agricultura familiar*. Graduação em Zootecnia, Universidade Federal da Grande Dourados, Dourados, MS, Brasil.
- Machado, L. C. (2024). Novo panorama da cunicultura brasileira. *Anais do Seminário Nacional de Ciência e Tecnologia em Cunicultura*, Bambuí, MG, Brasil. http://www.rbc.acbc.org.br/images/RBC_-_Edi%C3%A7%C3%A3o_especial_-_Mar_2024.pdf
- Machado, L. C., Martínez-Paredes, E., & Cervera, C. (2019b). Performance of rabbit does housed in collective pens and individual cages. *World Rabbit Science*, 27(4), 227-235. doi: 10.4995/wrs.2019.11540
- Machado, L. C., & Ferreira, W. M. (2011). *A cunicultura e o desenvolvimento sustentável*. Associação Científica Brasileira de Cunicultura. <http://acbc.org.br/site/index.php/notas-tecnicas/a-cunicultura-e-o-desenvolvimento-sustentavel>

- Machado, L. C., & Frascari, C. C. (2017). Criação de coelhos em sistemas coletivos. *Revista Brasileira de Cunicultura*, 11(1), 1-19. <http://www.rbc.acbc.org.br/artigo/artigos-de-revisao-bibliografica/criacao-de-coelhos-em-sistemas-coletivos>
- Machado, L. C., & Ribeiro, B. O. V. B. (2019a). Intelligent cage for pet rabbits. *Revista Brasileira de Cunicultura*, 16(1), 1-11. <http://www.rbc.acbc.org.br/edicoes/edicao-atual/intelligent-cages-for-pet-rabbits>
- Machado, L. C., Faria, C. D., Geraldo, A., Santos, A. M., Silveira, J. M. M., & Silva, V. D. (2020). Aspectos reprodutivos, produtivos, sanitários e comportamentais de coelhos Nova Zelândia Branco, Botucatu e mestiços. *Revista Brasileira de Cunicultura*, 18(1), 21-41. doi: 10.46342/cunicultura.v1.2020-7
- Machado, L. C., Martínez-Paredes, E., Cervera, C., & Garcia, A. V. (2023). Performance of kits that born in semi-group housing system or individual cages before and after weaning. *Revista Brasileira de Cunicultura*, 23(1), 1-12. doi: 10.46342/cunicultura.v23.2023.1
- Marciano, L. E. A., Araújo, T. de M., Lima, N. R., Fernandes, L. S., & Costa, M. L. L. da. (2019). Desempenho de coelhos alimentados com farinha de *Tenebrio molitor*. *Revista Brasileira de Meio Ambiente*, 6(1), 46-49. doi: 10.5281/zenodo.3233029
- Menezes, I. O. de, Rodrigues, P. G., Zeferino, C. P., Soares, V. E., Fraga, D. H. A. G., Silveira, D. M., Barauna, D. C., Azevedo, M. S. P. de, Milena dos Santos, M., & Barreto, D. R. A. (2022). Behavioral evaluation of rabbits housed in collective pens with environmental enrichment. *Research, Society and Development*, 11(10), e411111030301. doi: 10.33448/rsd-v11i10.30301
- Mondin, C., Trestini, S., Trocino, A., & Di Martino, G. (2021). The economics of rabbit farming: a pilot study on the impact of different housing systems. *Animals*, 11(11), 3040. doi: 10.3390/ani11113040
- Oliveira, M. C. de, Arantes, U. M., & Alves, J. A. (2003). Desempenho produtivo e contagem de linfócitos de coelhos sexados submetidos a duas densidades populacionais. *Ciência Animal Brasileira*, 4(2), 109-115. doi: 10.5216/cab.v4i2.309
- Pinotti, H., Fagian, L. Z., Soares, V. E., Brennecke, K., Santos, I. P., & Zeferino, C. P. (2019). Estudo descritivo do comportamento e preferência de coelhos alojados em gaiolas com enriquecimento ambiental. *Revista Brasileira de Cunicultura*, 16(12), 12-21. <http://www.rbc.acbc.org.br/artigo/artigos-cientificos/estudo-descritivo-do-comportamento-e-preferencia-de-coelhos-alojados-em-gaiolas-com-enriquecimento-ambiental>
- Szendró, Z., Trocino, A., Hoy, S., Xiccato, G., Villagrà, A., & Maertens, L. (2019). A review of recent research outcomes on the housing of farmed domestic rabbits: reproducing does. *World Rabbit Science*, 27(1), 1-14. doi: 10.4995/wrs.2019.10599
- Trocino, A., Filiou, E., Tazzoli, M., Birolo, M., Zuffellato, A., & Xiccato, G. (2015). Effects of floor type, stocking density, slaughter age and gender on productive and qualitative traits of rabbits reared in collective pens. *Animal*, 9(5), 855-861. doi: 10.1017/S1751731114003188

- Van Damme, L. G., Ampe, B., Delezie, E., Rommers, J., & Tuytens, F. A. (2023b). Social behaviour and personality profiles of breeding does housed part-time in group. *Applied Animal Behaviour Science*, 267(10), 106064. doi: 10.1016/j.applanim.2023.106064
- Van Damme, L. G., Delezie, E., Ampe, B., & Tuytens, F. A. (2022). Timing of part-time group housing for farm rabbits: effects on reproductive performance, skin injuries and behaviour. *Applied Animal Behaviour Science*, 252(7), 105656. doi: 10.1016/j.applanim.2022.105656
- Van Damme, L., Delezie, E., Maertens, L., Ampe, B., & Tuytens, F. (2023a). Effect of group size and escape enrichment on reproductive performance of breeding does in part-time group housing. *World Rabbit Science*, 31(1), 47-55. doi: 10.4995/wrs.2023.18616
- Zomeño, C., Birolo, M., Gratta, F., Zuffellato, A., Xiccato, G., & Trocino, A. (2018). Effects of group housing system, pen floor type, and lactation management on performance and behaviour in rabbit does. *Applied Animal Behaviour Science*, 203(6), 55-63. doi: 10.1016/j.applanim.2018.03.002
- Zomeño, C., Bordignon, F., Xiccato, G., Trocino, A., Birolo, M., Menegon, F., Tarakdjian, J., & Di Martino, G. (2023). Role of housing system and season on the carcass and meat quality traits of growing rabbits reared in Italian commercial farms. *World Rabbit Science*, 31(3), 179-189. doi: 10.4995/wrs.2023.19230