

Original Research Paper

The Impact of Prebiotic Supplementation on Growth, Carcass Traits and Meat Quality of Rabbit

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Abstract

The growing concern over antimicrobial resistance and the restrictions on antibiotic growth promoters have increased interest in alternative feed additives such as prebiotics. Mannan-oligosaccharides (MOS) and β -glucans, derived from yeast cell walls, have been reported to enhance gut health, immune function, growth performance, and product quality in livestock. However, their efficacy in rabbits remains inconsistent, warranting further investigation. Therefore, this study evaluated the effects of different dietary inclusion levels of a prebiotic based on MOS and β -glucans on growth performance, mortality, and meat quality traits in growing rabbits. A total of 80 weaned rabbits (initial body weight: 679.68 ± 150.86 g) were randomly assigned to four dietary treatments in a completely randomized design, with 20 rabbits per treatment. The experimental diets consisted of a control diet without supplementation and three diets supplemented with 2% (D1), 3% (D2), or 4% (D3) of the MOS and β -glucan prebiotic. Rabbits were reared from 5 to 11 weeks of age with free access to feed and water. Growth performance parameters, including body weight, average daily gain (ADG), feed intake (FI), feed conversion ratio (FCR), and mortality rate, were recorded weekly. Meat color characteristics were evaluated at slaughter. The results showed that dietary supplementation with MOS and β -glucans had no significant effect ($p > 0.05$) on body weight, ADG, FI, FCR, or mortality throughout the experimental period. Although numerical differences were observed among treatments, these variations were not statistically significant. In contrast, meat color was affected by prebiotic supplementation. Rabbits receiving the 3% prebiotic diet exhibited significantly higher redness ($a^* = 6.95 \pm 0.31$) and lower yellowness ($b^* = 4.68 \pm 0.33$) than the other groups, indicating improved color stability and potentially greater consumer acceptance. In conclusion, supplementation with a MOS and β -glucan prebiotic at inclusion levels of 2-4% did not enhance growth performance or reduce mortality in growing rabbits under the conditions of this study. However, the improvements observed in meat color traits suggest a positive effect on certain aspect of meat quality. These findings contribute to the understanding of yeast-derived prebiotics in rabbit nutrition and indicate that their benefits may be more evident in product quality than in growth performance, emphasizing the need for further studies to determine optimal inclusion rates and underlying mechanisms.

Key words: rabbit, prebiotic, growth rates, FCR

المخلص

أدت المخاوف المتزايدة بشأن مقاومة مضادات الميكروبات والقيود المفروضة على استخدام محفزات النمو بالمضادات الحيوية إلى زيادة الاهتمام بالبدائل الغذائية مثل البريبايوتيك. وقد أظهرت الدراسات أن المانان-أوليغوسكاريدات (MOS) والبيتا-غلوكانات (β -glucans)، المستخلصة من جدران الخلايا الخميرية، يمكن أن تحسن صحة الأمعاء، ووظائف الجهاز المناعي، والأداء الإنتاجي، وجودة المنتجات الحيوانية. ومع ذلك، لا تزال نتائج استخدامها في تغذية الأرانب متباينة، مما يستدعي إجراء المزيد من الدراسات. لذلك هدفت هذه الدراسة إلى تقييم تأثير مستويات مختلفة من البريبايوتيك المعتمد على MOS والبيتا-غلوكانات على الأداء النمائي، ونسبة النفوق، وبعض صفات جودة اللحم لدى الأرانب النامية. تم توزيع 80 أرنبًا مقطوعًا بمتوسط وزن ابتدائي بلغ 679.68 ± 150.86 غرامًا عشوائيًا على أربع معاملات غذائية وفق تصميم عشوائي كامل، بمعدل 20 أرنبًا لكل معاملة. شملت المعاملات نظامًا غذائيًا شاهدًا دون إضافة البريبايوتيك، وثلاثة أنظمة غذائية مدعمة بنسبة 2% (D1)، و3% (D2)، و4% (D3) من خليط MOS والبيتا-غلوكانات. رُبيت الأرانب من عمر 5 إلى 11 أسبوعًا مع توفير العلف والماء بحرية. وتم تسجيل مؤشرات الأداء الإنتاجي أسبوعيًا، بما في ذلك وزن الجسم، ومتوسط الزيادة اليومية في الوزن (ADG)، واستهلاك العلف (FI)، ومعامل التحويل الغذائي (FCR)، ونسبة النفوق. كما تم تقييم خصائص لون اللحم عند الذبح. أظهرت النتائج أن إضافة MOS والبيتا-غلوكانات إلى العليقة لم يكن لها تأثير معنوي ($P > 0.05$) على وزن الجسم أو متوسط الزيادة اليومية أو استهلاك العلف أو معامل التحويل الغذائي أو نسبة النفوق خلال فترة التجربة. وعلى الرغم

من ملاحظة بعض الفروق العددية بين المعاملات، فإن هذه الفروق لم تكن ذات دلالة إحصائية. في المقابل، تأثرت بعض خصائص لون اللحم بإضافة البريبايوتيك؛ حيث أظهرت الأرناب التي تلقت عليقة تحتوي على 3% من البريبايوتيك ارتفاعاً معنوياً في درجة الاحمرار ($a^* = 6.95 \pm 0.31$) وانخفاضاً في درجة الاصفرار ($b^* = 4.68 \pm 0.33$) مقارنة بالمجموعات الأخرى، مما يشير إلى تحسن ثبات اللون واحتمال زيادة تقبل المستهلك للحم. في الختام، لم تؤد إضافة البريبايوتيك القائم على MOS والبيتا-غلوكانات بمستويات تتراوح بين 2% و 4% إلى تحسين الأداء النمائي أو خفض نسبة النفوق لدى الأرناب النامية في ظروف هذه الدراسة. ومع ذلك، فإن التحسن الملحوظ في بعض صفات لون اللحم يشير إلى وجود تأثير إيجابي على جوانب معينة من جودة اللحم. وتسهم هذه النتائج في تعزيز المعرفة حول استخدام البريبايوتيك المشتق من الخمائر في تغذية الأرناب، كما تشير إلى أن فوائده قد تكون أكثر وضوحاً في تحسين جودة المنتج النهائي مقارنة بتحسين الأداء الإنتاجي، مما يستدعي إجراء المزيد من الدراسات لتحديد المستويات المثلى للإضافة وفهم الآليات المسؤولة عن هذه التأثيرات.

الكلمات المفتاحية: الأرناب، البريبايوتيك، معدلات النمو، استهلاك العلف

Introduction

Commercial rabbit production represents an important sector of animal agriculture due to rabbits' high reproductive potential, rapid growth rate, efficient feed utilization, and ability to produce lean meat with high nutritional value. Rabbit meat is characterized by a high protein content, low fat and cholesterol levels, and a favorable fatty acid profile, making it increasingly attractive to health-conscious consumers. Consequently, besides productive performance, carcass traits and meat quality have become key indicators of profitability and sustainability in rabbit production systems. Parameters such as carcass yield, meat color, oxidative stability, and sensory characteristics directly influence consumer acceptance and market value (Kumar et al., 2023).

Despite the economic importance of rabbit production, digestive disorders remain a major challenge for the industry. Enteric diseases caused by pathogenic bacteria are among the leading causes of mortality and poor productive performance in growing rabbits. Such infections impair nutrient utilization, reduce growth rate, worsen feed efficiency, and increase production costs. Furthermore, bacterial contamination may compromise food safety and negatively affect the quality of rabbit products intended for human consumption (Gallois et al., 2008; Bivolarski and Vachkova, 2013; Ismail et al., 2017).

For several decades, antibiotics and chemotherapeutic agents have been widely incorporated into animal feeds for disease prevention and growth promotion. However, the extensive therapeutic and subtherapeutic use of antibiotics in livestock has contributed to the emergence and dissemination of antimicrobial-resistant bacteria, raising major concerns for both animal and public health. Furthermore, consumer demand for antibiotic-free animal products and concerns regarding antibiotic residues in meat have intensified the search for natural and sustainable alternatives capable of maintaining animal health, productive performance, and product quality (Ben Rhouma et al., 2020).

Among these alternatives, prebiotics have received considerable attention because of their beneficial effects on gastrointestinal health and host physiology. Prebiotics are non-digestible feed ingredients that selectively stimulate the growth and activity of beneficial intestinal microorganisms, thereby improving gut microbial balance and intestinal function (Roberfroid et al., 2010). Mannan-oligosaccharides (MOS) and β -glucans, derived mainly from yeast cell walls, are among the most extensively studied prebiotic compounds in animal nutrition. These bioactive compounds have been shown to improve intestinal integrity, modulate immune responses, enhance nutrient digestibility, and strengthen antioxidant defenses, which may contribute to improved health and productive performance in rabbits (Ebeid et al., 2023).

Beyond their effects on growth performance, prebiotics may also influence carcass characteristics and meat quality. Improved intestinal health and nutrient utilization can enhance muscle deposition and carcass yield, while the antioxidant properties of MOS and β -glucans may reduce lipid oxidation and improve meat color stability. Previous studies have reported positive effects of MOS supplementation on carcass traits and meat quality characteristics in rabbits and other livestock species, although the responses vary according to dietary inclusion level, animal age, and management conditions (Khadeer et al., 2023).

The potential benefits of prebiotics may be particularly important under hot climatic conditions. Rabbits are highly susceptible to heat stress because they possess relatively few sweat glands and have a limited capacity to dissipate excess body heat. In Mediterranean and North African countries, including Tunisia, elevated ambient temperatures frequently challenge rabbit production systems. Heat stress has been reported to reduce feed intake, growth performance, carcass weight, and immune competence while

increasing oxidative stress and negatively affecting meat quality attributes such as color, water-holding capacity, and oxidative stability (Liang et al., 2022; Ebeid et al., 2023). Moreover, oxidative damage induced by heat stress can accelerate meat deterioration and reduce shelf life, thereby affecting consumer acceptance and economic returns (Bejaoui et al., 2023).

Recent evidence suggests that nutraceutical feed additives such as MOS and β -glucans may help alleviate the detrimental effects of heat stress. Through modulation of gut microbiota, enhancement of intestinal barrier function, stimulation of immune responses, and improvement of antioxidant status, these compounds may contribute to maintaining productive performance, carcass quality, and meat characteristics under challenging environmental conditions (Ebeid et al., 2023).

Therefore, the present study was conducted to evaluate the effects of dietary supplementation with a MOS- β -glucan prebiotic on growth performance, carcass traits, and meat quality characteristics of weaned rabbits reared under Tunisian environmental conditions.

Materials and Methods

Experimental design and animal management

The experiment was conducted at the rabbitry of the National Institute of Agronomy, Tunisia, during the summer season under natural heat stress conditions. Ambient temperature and relative humidity were monitored throughout the experimental period using a digital thermo-hygrometer. The average ambient temperature was 27.64 °C, with minimum and maximum values of 21.5 °C and 32.8 °C, respectively. The average relative humidity was 60%, and the mean Temperature-Humidity Index (THI) was 26.11, indicating moderate to severe heat stress conditions for growing rabbits (Marai et al., 2000).

A total of 80 healthy weaned Californian hybrid rabbits (35 days of age) were selected from multiparous does that kindled on the same day. Only clinically healthy rabbits with body weights close to the population mean (679.68 ± 150.86 g) were included in the experiment. Following weaning, the animals were transferred from the maternity unit to the fattening facility and housed in wire-mesh cages measuring 61 × 45 × 22 cm. The stocking density was four rabbits per cage.

The experiment followed a completely randomized design. Rabbits were randomly allocated to four experimental treatments ($n = 20$ rabbits per treatment). The dietary treatments consisted of a control diet without prebiotic supplementation (Control) and three experimental diets supplemented with 2% (D1), 3% (D2), or 4% (D3) prebiotic.

The prebiotic used in this study was a commercial preparation based on mannan-oligosaccharides (MOS) and β -glucans derived from yeast cell walls. The prebiotic was incorporated into the experimental diets (Table 1) as a single combined MOS and β -glucan product at the specified inclusion levels.

Throughout the experimental period, rabbits had ad libitum access to feed and fresh water. A lighting schedule of 16 h light and 8 h darkness was maintained, while ventilation was natural.

Data collection

Body weight, feed intake, and mortality were recorded weekly from 35 to 77 days of age. Growth performance parameters, including average daily gain (ADG), feed intake (FI), and feed conversion ratio (FCR), were subsequently calculated. Carcass characteristics, such as dressing percentage, front part percentage, and hind part percentage, were measured at 11 weeks of age.

Meat quality

Meat color was evaluated on the *Longissimus Dorsi* muscle using a Minolta Chromameter (CR410 Konica Minolta Sensing Inc., Osaka, Japan) operating in the CIE Lab* color space. The instrument was calibrated before each measurement session using the manufacturer's standard white calibration tile. Meat samples were stored at 4 °C and allowed to bloom for 30 min prior to color determination to ensure adequate oxygenation of myoglobin. Three measurements were taken at different locations on the muscle surface of each sample, and the average value was used for statistical analysis. The color parameters recorded were lightness (L^*), redness (a^*), and yellowness (b^*).

Table1. Chemical composition of the control diet

Composition	Nutritive value (%)
Humidity	14 %
Crude fibre	16 %
Protein	17 %
Metabolisable Energy	2600 kcal/kg
Ash	9 %
Fat content	3 %
Methionine	0.3 %
Cysteine	0.35 %
Threonine	0.68 %
Tryptophan	0.25 %
Minerals	
Manganese	9 mg/kg
Iron	25 mg/kg
Copper	60 mg/kg
Zinc	15 mg/kg
Cobalt	0.2 mg/kg
Iodine	0.2 mg/kg
Vitamin	
Vit A	11000 UI
Vit D	2000 UI
Vit H	30 mg
Additive	
Robenidine	66 mg/kg

Vit: Vitamin.

Statistical analysis

Data were subjected to analysis of variance using SAS 9.0 and by fitting into the mathematical model:

$$Y_{ij} = \mu + T_{ij} + e_{jj},$$

where Y_{ij} = observation mean; μ = general mean, T_i = effect of i th treatment for j th observation and e_{ij} = random error.

A repeated measure analysis was employed to assess periodic growth performance. Significant differences among the mean values for the three dietary treatments were tested using Duncan's Multiple Range Test.

Results

Performance parameters

The impact of prebiotic treatments on growth traits is presented in Table 2. Generally, throughout the entire feeding period, growth remained comparable among all experimental groups, as the slaughter weight did not exhibit a significant difference ($P > 0.05$). The supplementation with prebiotics showed no discernible effect on mortality ($P > 0.05$).

Table 2. Effect of prebiotic supplementation on Average daily weighs gain and feed conversion ratio of rabbit

	Group I	Group II	Group III	Group IV	P value
ADG 6	49.98±4.38	44.55±4.38	47.36±4.38	47.08±4.38	0.85
FCR 6	1.86±0.26	1.78±0.26	1.58±0.26	1.58±0.26	0.84
ADG 7	54.94±5.25	44.58±5.25	45.44±5.25	47.31±5.25	0.51
FCR 7	1.77±0.21	2.07±0.21	1.86±0.21	1.86±0.21	0.76
ADG 8	16.02±1.76	18.05±1.76	18.91±1.76	19.79±1.79	0.50
FCR 8	7.59 ^b ±0.89	5.58 ^b ±0.89	3.99 ^a ±0.89	4.05 ^a ±0.89	0.04

ADG 9	25.56±2.19	22.61±2.19	23.25±2.19	20.07±2.19	0.40
FCR 9	4.50±0.55	4.35±0.55	4.30±0.55	5.08±0.55	0.74
ADG 10	26.57±2.16	24.49±2.16	27.38±2.16	27.01±2.16	0.78
FCR 10	4.47±0.39	4.24±0.39	4.03±0.39	4.11±0.39	0.87
ADG 11	24.79±3.90	19.31±3.90	18.80±3.90	20.62±3.90	0.69
FCR 11	4.39±2.16	7.46±2.16	4.17±2.16	3.28±2.16	0.56
Mortality	20.00±9.89	15.00±9.89	10.00±9.89	20.00±9.89	0.87

C: control; ADG: Average daily weighs gain; FCR: feed conversion ration

^{a,b} Values with different superscripts within a row differ significantly $p < 0.05$.

No significant differences ($p > 0.05$) in feed conversion ratio (FCR) were observed among treatments during most of the experimental period. However, at week 8, rabbits receiving the 3% and 4% MOS and β -glucan supplementation exhibited significantly lower FCR values (3.99 ± 0.89 and 4.05 ± 0.89 , respectively) compared with the control group (7.59 ± 0.89) ($p < 0.05$). Despite this transient improvement, no significant differences in overall FCR were detected among treatments over the entire fattening period.

Carcass characteristics

Tables 3 and 4 summarize the effects of MOS and β -glucan supplementation on carcass yields and relative organ weights, respectively. No significant treatment effects ($p > 0.05$) were observed for any of the measured carcass or organ parameters. The inclusion of the prebiotic at levels of 2%, 3%, and 4% did not affect carcass yield or the relative weight of internal organs compared with the control group.

Table 3. Effect of prebiotic supplementation on carcass yields of rabbit

	Group I	Group II	Group III	Group IV	P value
Hot carcass yield (%)	56.08±0.94	55.48±0.94	57.24±0.94	56.58±0.94	0.60
Cold carcass yield (%)	54.50±1.00	54.54±1.00	55.55±1.00	55.17±1.00	0.85
Reference carcass yield (%)	47.16±1.23	47.04±1.23	48.31±1.23	47.62±1.23	0.88

Table 4. Effect of prebiotic supplementation on proportion of organs of rabbits

	Group I	Group II	Group III	Group IV	P value
Digestive tract (%)	18.39±0.68	19.00±0.65	19.86±0.65	18.11±0.68	0.15
Coecum (%)	6.40±0.41	7.10±0.39	6.20±0.37	6.31±0.41	0.37
Hind gut (%)	6.20±0.21	6.70±0.20	6.13±0.19	6.02±0.21	0.10
Heart (%)	2.46±0.84	2.61±0.81	2.96±0.77	2.37±0.84	0.95
Reference carcass (%)					
Front	33.50±0.48	34.38±0.48	33.97±0.48	33.46±0.48	0.49
Mid	27.43±0.39	26.22±0.39	26.64±0.39	26.94±0.39	0.19
Hind	39.06±0.30	39.38±0.30	39.38±0.30	39.59±0.30	0.67
Fat scapulaire	0.39±0.68	0.32±0.68	0.37±0.68	0.35±0.68	0.75
Fat périnéal	1.10±0.12	0.81±0.12	0.74±0.12	1.10±0.12	0.09

Meat color characteristics

Physico-chemical meat quality attributes of rabbit strains given different levels of prebiotics are presented in Table 5.

Table 5. Effect of prebiotic supplementation on meat quality of rabbit

	Group I	Group II	Group III	Group IV	P value
L*	48.15 ^b ±0.68	51.45 ^a ±2.48	49.26 ^b ±1.31	49.01 ^b ±0.86	0.0012
a*	6.28 ^b ±0.23	5.46 ^c ±0.23	6.95 ^a ±0.31	6.11 ^b ±0.50	<.0001
b*	7.27 ^a ±0.15	5.58 ^c ±0.27	4.68 ^d ±0.33	6.76 ^b ±0.33	<.0001

^{a,b,c,d} Values with different superscripts within a row differ significantly $p < 0.05$. L*: Lightness, a*: Redness, b*: Yellowness.

Significant differences were observed among the experimental groups for all color parameters (L^* , a^* , and b^*) ($p < 0.01$), indicating that the dietary treatments markedly influenced rabbit meat color characteristics.

The higher L^* value (51.45 ± 2.48) recorded in Group II suggests increased meat lightness, which in rabbits is often associated with lower myoglobin concentration or a higher proportion of oxymyoglobin at the muscle surface. Elevated L^* values may also reflect reduced muscle pigment density or alterations in post-mortem water distribution, both of which can affect light scattering in rabbit muscle.

The a^* parameter, indicative of redness and closely related to myoglobin content and its redox state, was highest in Group III (6.95 ± 0.31). This finding suggests enhanced myoglobin stability and a greater proportion of oxymyoglobin, potentially resulting from improved antioxidant status that limits myoglobin oxidation to metmyoglobin. In contrast, the lower a^* value observed in Group II may reflect increased oxidative processes, leading to myoglobin oxidation and reduced color stability.

Regarding b^* (yellowness), the higher values observed in Groups I and IV may be attributed to increased deposition of dietary pigments (such as carotenoids) in rabbit muscle or to lipid oxidation processes, which are known to promote yellow discoloration. Conversely, the lower b^* values in Group III (4.68 ± 0.33), particularly in Group III, may indicate reduced lipid oxidation and improved oxidative stability, possibly linked to enhanced antioxidant defenses.

Discussion

Given the increasing restrictions on the use of antibiotic growth promoters in animal production, the present study was conducted to evaluate the potential effects of a yeast-derived prebiotic composed of mannan-oligosaccharides (MOS) and β -glucans on the growth performance, health status, and meat quality of growing rabbits reared under natural heat stress conditions. MOS and β -glucans are recognized for their ability to modulate gut microbiota, enhance immune responses, and improve antioxidant status, which may contribute to better animal performance and product quality.

However, under the conditions of the present study, dietary supplementation with the MOS and β -glucan prebiotic did not significantly affect body weight gain, feed intake, feed conversion ratio, or mortality throughout the fattening period. These findings suggest that the beneficial effects commonly attributed to MOS and β -glucans were not sufficient to overcome the physiological constraints associated with heat stress and maintain improvements in growth performance.

Similarly, other studies (Luick et al., 1992; Scapinello et al., 2001; Fonseca et al., 2004; Volek et al., 2007) reported no significant effect of dietary supplementation with MOS or fructo-oligosaccharides on the weight gain of rabbits. Moreover, there were no substantial differences among the groups in average feed intake values for the entire fattening period. In contrary, Abd El-Aziz et al. (2020) improved that dietary supplementation of MOS and IMO had a desirable positive impact on productive and economic efficiency in the rabbit. Also, Attia et al. (2015) and Bovera et al. (2019) found that addition of prebiotic to the diet provided some positive effects on growth performance and health status.

Additionally, the variability in responses reported in the literature suggests that the efficacy of MOS and β -glucans depends on inclusion level, diet composition, health status, and environmental conditions. Similar non-significant effects on growth performance under stressful or suboptimal conditions have been reported in rabbits and other livestock species, indicating inconsistent growth responses to prebiotics (Mancini and Paci, 2021 ; Ebeid et al., 2023).

No significant effects of prebiotic supplementation were observed on carcass traits. Regarding carcass characteristics, our findings were disconsistant with those observed by Abd El-Aziz et al. (2021), Mahrose et al. (2019), and Abo Ghanima et al. (2020). Rabbits in all dietary groups exhibited similar dressing yield, averaging 56%, which aligns well with previously reported values (Marounnek et al., 2007; Rotolo et al., 2014).

Concerning carcass measurements, the obtained results are consistent with Ewuola et al. (2011) finding that the addition of growth promoting additives (dietary prebiotics and probiotics a symbiotic) had no

significant effect on the carcass characteristics measured except the right arms of rabbits. Additionally, Ozsoy and Yalcin (2011) and Rotolo et al. (2014) observed non-significant differences in carcass traits of growing rabbits due to dietary prebiotic oligosaccharides. On the other hand, Attia et al. (2015) reported that Mannan oligosaccharides administered intermittently increased dressing percentage as compared to control. Also, Abdel-Hamid and Farahat. (2016) stated that carcass traits such as live weight, hot and reference carcass weight, percentage of periscapular, and perirenal fat related to reference carcass weight were significantly affected by the dietary MOS supplementation. Tang et al. (2017) found that adding prebiotic from 20 to 52 weeks of age, there were no appreciable variations in the relative weights of heart, liver, ovary, pancreas, and spleen in laying hens fed IMO in diet.

Nevertheless, the observed improvements in meat color parameters at the highest inclusion level indicate that the prebiotic may have exerted positive effects on muscle oxidative stability and certain aspect of meat quality. Therefore, while MOS and β -glucan supplementation did not enhance zootechnical performance under the experimental conditions, it may contribute to improving product quality, which is an increasingly important objective in rabbit production systems. Further studies are needed to determine whether different inclusion levels, supplementation periods, or combinations with other functional feed additives could enhance the efficacy of MOS and β -glucan supplementation, particularly under heat stress conditions.

Overall, these results suggest that dietary treatments modulated rabbit meat color through their effects on myoglobin concentration and redox state, lipid oxidation, and antioxidant capacity. Improvements in redness and reduced yellowness, as observed in Group III, are indicative of better oxidative stability and are generally associated with improved meat quality and consumer acceptance in rabbits.

Meat quality and carcass traits are increasingly recognized as critical parameters in rabbit production because they directly affect consumer acceptance and market value (Kumar et al., 2023). Heat stress is known to negatively affect carcass yield and meat quality by increasing oxidative stress and altering muscle metabolism, leading to poorer color stability and higher lipid oxidation (Ebeid et al., 2023 ; Liang et al., 2022).

The improvement in meat color observed in this study may be related to the antioxidant properties of β -glucans and MOS. These compounds are known to enhance antioxidant enzyme activity, reduce oxidative damage, and improve immune function, which may contribute to better muscle oxidative stability under heat stress conditions. Similar improvements in meat quality traits have been reported with MOS supplementation in rabbits, particularly under challenging environmental conditions (Khadeer et al., 2023).

Conclusion

The supplementation of the MOS and β -glucan prebiotic did not significantly affect growth performance or mortality throughout the fattening period. These findings suggest that, under the environmental and management conditions of the present study, prebiotic supplementation was not sufficient to enhance zootechnical performance in growing rabbits exposed to natural heat stress.

Nevertheless, the observed improvements in meat color characteristics indicate that the prebiotic may exert beneficial effects on specific aspects of meat quality. The discrepancy between growth performance and meat quality responses highlights the complexity of the physiological mechanisms involved in the action of prebiotics.

Further research is warranted to investigate whether different supplementation strategies, including longer administration periods, alternative inclusion levels, or combinations with other functional feed additives, could enhance the efficacy of MOS and β -glucan supplementation. Additional studies conducted under controlled heat stress conditions would also help clarify the mechanisms through which these prebiotics influence animal performance, carcass traits, and meat quality.

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Author's Contributions

Raouia Ben Rhouma designed the study, performed the experiments, and analyzed the data. Naceur M'Hamdi and Aziza Boubaker assisted with manuscript writing and literature review. All authors contributed to the preparation, review, and final approval of the manuscript.

Ethics

The protocols and animal manipulation in this project were approved by the Official Animal Care and Use Committee of the National Institute of Agronomy of Tunisia (Protocol No. 05/15)

References

- Abd El-Aziz AH. Mahrose KM. El-Kasrawy NI. Alsenosy AEA 2021. Yeast as growth promoter in two breeds of growing rabbits with special reference to its economic implications. *Acad. Bras. Cienc*, 93: e20190274.
- Abdel-Hamid TM and Farahat MH 2015. Effect of dietary mannanoligosaccharides on some blood biochemical, haematological parameters and carcass traits in purebred New Zealand White and crossbred rabbits. *Animal Production Science*, 56 :2133-2139.
- Abo Ghanima MM. Abd El-Aziz AH. Noreldin AE. Atta MS. Mousa SA. El-Far AH 2020. β -glucan administration improves growth performance and gut health in New Zealand White and APRI rabbits with different breed responses. *PLoS ONE*, 15: e0234076.
- Attia YA. Hamed RS. Abd El-Hamid AE. Shahba HA. Bovera F 2015. Effect of inulin and mannan-oligosaccharides compared with zinc-bacitracin on growing performance, nutrient digestibility and hematological profiles of growing rabbits. *Animal Production Science*, 55: 80–86. doi:10.1071/ AN13286.
- Abd El-Aziz A. Mahmoud M. Abo ghanima. Eman M. El-Deeb. Sherif Z. Kamel Usama E. Mahrous 2020. Influence of two dietary probiotic oligosaccharides supplementation on productive performance and carcass traits with special attention to their biochemical alterations in two rabbit breeds. *Damanhour Journal of Veterinary Sciences*, 3 (1): 1–7.
- Bejaoui B. Sdiri C. Ben Souf I. Belhadj Slimen I. Ben Larbi M. Sidrine K. Martin P. and M'Hamdi N 2023. Physicochemical Properties, Antioxidant Markers, and Meat Quality as Affected by Heat Stress : A Review. *Molecules* 2023, 28 : 3332. <https://doi.org/10.3390/molecules28083332>
- Ben Rhouma R. Jouini A. Klibi A. Hamrouni S. Boubaker A. Kmiha S. Maaroufi A 2020. Molecular characterization of antimicrobial resistance and virulence genes in *Escherichia coli* strains isolated from diarrheic and healthy rabbits in Tunisia. *World Rabbit*, 28: 81-91 doi:10.4995/wrs.2020.10879 WRS, UPV, 2003.
- Bivolarski BL and Vachkova EG 2013. Morphological and functional events associated to weaning in rabbits. *J Anim Physiol Anim Nutr*. Doi :10. 1111/jpn.12058.
- Bovera F. Lestingi A. Iannaccone F. Tateo A. Nizza A 2012. Use of dietary mannanoligosaccharides during rabbit fattening period: effects on growth performance, feed nutrient digestibility, carcass traits, and meat quality. *Journal of Animal Science*, 90: 3858–3866.
- Ebeid TA. Aljabeili HS. Al-Homidan IH. Volek Z. Barakat H 2023. Ramifications of Heat Stress on Rabbit Production and Role of Nutraceuticals in Alleviating Its Negative Impacts : An Updated Review. *Antioxidants* , 12 :1407. <https://doi.org/10.3390/antiox12071407>.
- Ewuola EO. Amadi CU. Imam TK 2011. Performance evaluation and nutrient digestibility of rabbits fed dietary prebiotics, probiotics and symbiotics. *Int. J. Applied Agric. Apicult. Res*, 7(1): 107-117.
- Fonseca AP. Falcao L. Kocher A. Spring P 2004. Effects of dietary mannanoligosaccharide in comparison to oxytetracyclin on performance of growing rabbits. In *Proceedings of the eighth World Rabbit Congress*. Puebla, Mexico: 829-833.

- Gallois M. Le HueröuLuron I. Fortun-Lamothe L. Lalle JP. Gidenne T 2008. Adaptability of the digestive function according to age at weaning in the rabbit: I. Effect on feed intake and digestive functionality. *Animal*, 2: 525–535.
- Ismail AK. Abdien HM. Hamed DM et al 2017. Prevalence of some enteric bacterial infections causing rabbit enteritis and attempts to control rabbit coli enteritis with phytobiotics. *Zagazig Vet J*, 45(1): 91–101.
- Khadeer BS. Prasad Reddy LSSV. Bhaskar Reddy GV. Kumar AVNS. and Naik BR 2023. Influence of Mannan oligosaccharides and Tulasi (*Ocimum sanctum*) on Carcass and Meat Quality Characteristics of Rabbits. *J. Meat Sci*, 18(2): 1-8. DOI:10.48165/jms.2023.18.02.01
- Kumar SA. Kim HJ. Jayasena DD. Jo C 2023. On-Farm and Processing Factors Affecting Rabbit Carcass and Meat Quality Attributes. *Food Science of Animal Resources*, 43(2) :197-219. DOI :10.5851/kosfa. 2023.e5.
- Liang ZL. Chen F. Park S. Balasubramanian B. Liu WC 2022. Impacts of Heat Stress on Rabbit Immune Function, Endocrine, Blood Biochemical Changes, Antioxidant Capacity and Production Performance, and the Potential Mitigation Strategies of Nutritional Intervention. *Front Vet Sci*, 26(9) :906084. DOI : 10.3389/fvets.2022.906084.
- Luick BR. El-Sayaad AE. Cheeke PR 1992. Effect of fructooligosaccharides and yeast culture on growth performance of rabbits. *J. Appl. Rabbit Res*, 15: 1121-1128.
- Mahrose KM. Elhack MEA. Mahgoub SA. Attia FAM 2019. Influences of stocking density and dietary probiotic supplementation on growing Japanese quail performance. *Acad. Bras. Cienc*, 91: e20180616.
- Mancini S and Paci G 2021. Probiotics in Rabbit Farming: Growth Performance, Health Status, and Meat Quality. *Animals*, 11: 3388. <https://doi.org/10.3390/ani11123388>
- Marai IFM. Ayyat MS. Abd El-Monem UM 2000. Young doe rabbit performance traits as affected by dietary zinc, copper, calcium or magnesium supplements under winter and summer conditions of Egypt. *Proceedings of 7th World Rabbit Congress. Valencia. Spain*: 313-320.
- Marounek M. Skrivanova V. Dokoupilova A. Czauderna M. Berladyn 2007. Meat quality and tissue fatty acid profiles in rabbits fed diets supplemented with conjugated linoleic acid. *Veterinary Medicine*, 52: 552-561.
- Özsoy B and Yalçın S. 2011. The effects of dietary supplementation of yeast culture on performance, blood parameters and immune system in broiler turkeys. *Ankara Üniv Vet Fak Derg*, 58: 117-122.
- Roberfroid M. Gibson GR. Hoyles L. McCartney AL. Rastall R. Rowland I. et al 2010. Prebiotic effects: metabolic and health benefits. *Br. J. Nutr*, 104(Suppl. 2) :1–63. doi: 10.1017/S0007114510003363.
- Rotolo L. Gai F. Peiretti PG. Ortoffi M. Zoccarato I. Gasco L 2014. Live Yeast (*Saccharomyces Cerevisiae* Var. *Boulardii*) Supplementation in Fattening Rabbit Diet: Effect on Productive Performance and Meat Quality. *Livestock Science*, 162 :178–184.
- Scapinello C, de Faria HG, Furlan AC and Michelan AC 2001. Effect of the utilization of oligosaccharide mannose and acidifiers on growing rabbits' performance. *Revista Brasileira de Zootecnia*, 30:1272-1277.
- Tang SGH. Sieo CC. Ramasamy K. Saad WZ. Wong HK. Ho YW 2017. Performance, Biochemical and Haematological Responses, and Relative Organ Weights of Laying Hens Fed Diets Supplemented with Prebiotic, Probiotic and Synbiotic. *BMC Veterinary Research*, 13(1): 248.
- Volek Z. Marounek M. Skrivanova V 2007. Effect of a starter diet supplementation with mannanoligosaccharide or inulin on health status, caecal metabolism, digestibility of nutrients and growth of early weaned rabbits. *Animal*, 1: 523-530.