EVALUATION OF HYDROPONIC BARLEY (HORDEUM VULGARE) FODDER ON GROWTH PERFORMANCE IN NEW ZEALAND WHITE RABBIT

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CERTIFICATION

This is to certify that we have read this research paper entitled **'Evaluation of Hydroponic Barley *(Hordeum Vulgare)* Fodder on Growth Performance in New Zealand White Rabbit'** by Muhammad Muqles Bin Rozman, and in our opinion it is satisfactory in terms of scope, quality and presentation as partial fulfilment of the requirement for the course DVT 5436 – Research Project.

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DEDICATIONS

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ABBREVIATIONS

Ca	-	Calcium
CF	-	Crude fiber
CP	-	Crude protein
DM	-	Dry matter
EE	-	Ether Extract
HB	-	Hydroponic barley
OM	-	Organic matter
NDF	-	Neutral detergent fiber
ADF	-	Acid detergent fiber

ABSTRACT

An abstract of the research paper presented to the Faculty of Veterinary Medicine, Universiti Malaysia Kelantan, in partial requirement on the course DVT 5436 – Research Project. Barley is the world's fourth most significant cereal crop, with over 100 countries growing it and using it as animal feed. China is the Asian's largest producer of barley, while Malaysia is a net importer. However, the production of barley and the efficiency of the barley used as rabbit feed in Malaysia has never been investigated. Thus, this study was carried out to evaluate the production of barley grown using a hydroponic system and assess the growth performance of New Zealand White (NZW) rabbit. Barley fodder was produced using the hydroponic system in Malaysia's environmental conditions. Several parameters were taken to assess the growth of the fodder. The fodder was harvested on day 6 and was not influenced by Malaysia's environmental conditions. The growth performance of the NZW rabbit was assessed by replacing a commercial diet with hydroponic barley (HB). Rabbit fed with a commercial diet has a significant increase in body weight compared to rabbits fed with a combination of HB and commercial feed. In conclusion, HB can be alternative feed for rabbit farming in Malaysia.

Keywords: *Body weight, Commercial feed, HB, Malaysia, NZW rabbit*

ABSTRAK

Abstrak kertas penyelidikan yang dibentangkan kepada Fakulti Perubatan Veterinar, Universiti Malaysia Kelantan, untuk memenuhi sebahagian daripada keperluan kursus DVT 5436 - Projek Penyelidikan. Barli merupakan tanaman bijirin keempat paling penting di dunia, dengan lebih daripada 100 negara menghasilkan dan menggunakannya sebagai makanan haiwan. China adalah pengeluar barli terbesar di Asia, manakala Malaysia adalah pengimport bersih. Walau bagaimanapun, pengeluaran barli dan penggunaan barli sebagai makanan arnab di Malaysia tidak pernah diselidik. Oleh itu, kajian ini dijalankan untuk menilai pengeluaran barli yang ditanam menggunakan sistem hidroponik dan menilai prestasi pertumbuhan arnab New Zealand White (NZW). Makanan berasaskan barli dihasilkan menggunakan sistem hidroponik dalam keadaan persekitaran Malaysia. Beberapa parameter telah diambil untuk menilai pertumbuhan tanaman. Makanan ini dituai pada hari ke-6 dan tidak dipengaruhi oleh keadaan persekitaran Malaysia. Prestasi pertumbuhan arnab NZW dinilai dengan menggantikan diet komersial kepada barli hidroponik (HB). Arnab yang diberi makan dengan diet komersial mempunyai peningkatan berat badan yang ketara berbanding arnab yang diberi makan dengan gabungan HB dan makanan komersial. Kesimpulannya, HB boleh menjadi makanan alternatif untuk penternakan arnab di Malaysia.

Keywords: *Body weight, Commercial feed, HB, Malaysia, NZW rabbit*

1.0 Introduction

In terms of both production volume and area under cultivation, barley *(Hordeum vulgare)* is the fourth-most important grain in the world today. It has excellent adaptations and is extremely adaptable in every way. In actuality, it is the cereal that is most versatile. The majority of the world's barley is grown outside of areas where cereals like maize and rice may thrive. Today, there are numerous commercial uses for barley. Animal feed is the main use for barley production. As a feed ingredient, barley is equally nutritious as corn. Barley has a high carbohydrate content and a comparatively low protein, calcium, and phosphorus content. Small levels of the B vitamins are also present.After being steam rolled or put through a grinding process, the entire barley kernel is used as feed. Malt sprouts and brewing byproducts are also included in animal feed. Due to its increased weight and superior kernel yield, two-rowed barley is determined to be the most frequently used type for animal feed (Zhou, 2009).

The term "hydroponics" refers to a method of growing plants in nutrient solutions with or without the use of an inert medium to give mechanical support, such as gravel, vermiculite, rockwool, peat moss, sawdust, coir dust, coconut fibre, etc. The majority of hydroponic systems work automatically to regulate the amount of water, nutrients, and photoperiod in accordance with the needs of various plants (Sharma et. al., 2018).

Like ruminants, rabbits have generally been considered sufficient to adapt to low-energy, low-protein diets with a high fibre content. Regardless of age or physiological condition, rabbits are often given fresh grass or bad quality hay. In fact, the unique digestive physiology, with caecotrophy and intensive caecal fermentation, enables rabbits to benefit from feedstuffs with low energy value and variable nutritional

qualities and helps to meet maintenance requirements for vitamins and amino acids. However, under intensive rearing conditions, a diet deficient in protein and energy cannot meet the high nutritional needs of the commercial genotypes used today (Blas and Mateos, 2010).

2.0 Research Problem

The rabbit industry in Malaysia is relatively new. However, it has grown in popularity due to numerous government-sponsored campaigns and incentives to promote its development and food security in Malaysia. Feed is the single most critical factor in rabbit production. Commercial feed or concentrate diets are expensive for farmers and thus resulting in a high cost of production. Thus, barley is potential feed that can be used as rabbit feed as opposed to other expensive rabbit feed on market but has never investigated in Malaysia.

3.0 Research Questions

3.1 Does barley germinate under a hydroponic system in Malaysia's environmental conditions?

3.2 Does hydroponic barley improve the growth performance of the New Zealand White rabbit?

4.0 Research Hypothesis

4.1 Barley will grow using a hydroponic system in Malaysia's environmental conditions.

4.2 Hydroponic barley can improve the growth performance of the New Zealand White rabbit.

5.0 Research Objectives

5.1 To observe the germination of barley cultivated under a hydroponic system in Malaysia's environmental conditions.

5.2 To assess the growth performance of New Zealand White rabbits fed with hydroponic barley.

6.0 Literature Review

6.1 Distribution and Growth Condition of Hydroponic Barley

In ancient times, barley was probably first cultivated in the highlands of Ethiopia and Southeast Asia. It is thought to have existed in places as far back as 5000 BC in Egypt, 3500 BC in Mesopotamia, 3000 BC in northwestern Europe, and 2000 BC in China. Through the 16th century, barley was the primary bread plant used by the Hebrews, Greeks, Romans, and a large portion of Europe. The production of barley has historically been significant worldwide. With an annual production of 20,489,088 tonnes, the Russian Federation is the largest producer of barley worldwide (Lammas and Shitikova, 2021)

One of the four main feed grains, barley, is essential in livestock diets. For ruminants, the grain can serve as a significant source of energy, protein, and fibre. For pigs, the grain can serve as a significant supply of both energy and protein. The most widely used grains in Australia are barley and wheat, which together make up around 60% of all cereal grains fed to cattle. The other cereal grains used by the animal industry were oats (20%), sorghum (10%), and triticale (10%) (Dung et. al., 2009).

In semi-arid areas with light soils, barley is inexpensive, simple to grow, and offers excellent weed suppression and erosion management. It can also be used to cover gaps in short rotations or as a crop to protect topsoil in dry circumstances worldwide. It can absorb excess subsoil moisture to help reduce the production of saline seeps and is more salt tolerant than other small grains. Dry, cool climates are best for producing

barley. Its short growing season allows it to be grown farther north as a spring covered crop than any other cereal grain. Like no other cereal crop, it can also produce more biomass in less time (Clark, 2007).

The timing of physiological processes, the rate of reproductive structure expansion and survival, and evaporation function all play a role in how agricultural crops in Malaysia are impacted by climate change. Temperature increases have an impact on moisture availability through evaporation; typically, evaporation rises by 5% for every 1ºC increase in the average annual temperature. Long-term limitations of water and other resources are anticipated as a result of climate change, and these shortages will also deteriorate soil conditions, cause pest and disease outbreaks among animals and crops, and cause the sea level to increase, among other effects (Siwar et. al., 2019). Due to the lack of barley production, Malaysia typically imports barley from other countries.

6.2 Chemical Composition and Nutritive Value of Hydroponic Barley

For the long-term viability of the products and productivity in the production of rabbits, the nutritional value of hydroponically grown barley must be evaluated. The chemical composition of HB (Table 1), which includes dry matter (DM), organic matter (OM), crude protein (CP), crude fibre (CF), ether extract (EE), digestible energy (DE), neutral detergent fibre (NDF), and acid detergent fibre (ADF), was suitable for substituting concentrate feed for rabbits. The changes in HB's nutritional value may be caused by the growth period, the conditions and techniques of cultivation, as well as chemical methods (Mohamed et. al., 2021).

Table 1: Chemical composition of HB

Chemical Composition	Nutritive value
Dry matter (DM)	14 – 18 %
Organic matter (OM)	87 – 92 %
Crude protein (CP)	10 – 20 %
Crude fibre (CF)	8 – 17 %
Ether extract (EE)	2 – 5 %
Digestible energy (DE)	7 – 11 mJ /Kg
Neutral detergent fibre (NDF)	26 – 36 %
Acid detergent fibre (ADF)	14 – 17 %

6.3 New Zealand White Rabbit as Animal Model

The original breeds from which New Zealand White (NZW) rabbits were created are unknown. Their bodies are well-balanced, with slender and muscular faces and round cheeks. Their back feet are large and long, while their front pectoral muscles are small and short. Their ears are long and erect. The white variety's average body weight is up to 5 kg (Wanjala et. al., 2016).

Due to its sturdy and compact meat, the NZW rabbit is a meat-producing type. The NZW rabbit was well-known for its ability to produce commercial meat. It grew rapidly, had a high carcass quality, a high fertility rate, and a high maternity rate (Lukefahr et al., 2022).

There are currently 33,701 rabbits in Malaysia, including pets and broilers. The Persatuan Penternak Arnab Pedaging Kelantan (PETAK) and other associations make Kelantan the state with the most active rabbit production in Malaysia. The average monthly production of rabbit meat is close to 1,000 kg, with a selling price of roughly RM35 per kg. This is a profitable endeavour because there is actually a rising demand for rabbit meat as a substitute for protein sources like beef, mutton, and chicken (Raj et. al., 2021).

6.4 Influence of Hydroponic Barley on Growth Performance

Recently, rabbit production has accelerated, primarily to meet the growing demand for fresh meat for human consumption and provide farmers with additional income. As a result, extensive research has been conducted to improve rabbits' product performance and quality. Several feeding strategies have been developed over the last two decades to ensure animal feed's safe and economical use. Additionally, numerous studies have been conducted to determine the effect of HB on rabbit growth performance (Abdel-Wareth et al., 2020).

According to Nagani (2019), the rabbits fed HB with the addition of anaerobic probiotics have higher final body weights, total body weight gains, daily body weight gains, and feed conversion ratios than the other rabbit groups that were put to the test. The body weight increase of New Zealand White rabbits fed a diet containing vegetated fenugreek seeds and/or barley grain on rice straws and their combination is higher than that of rabbits fed a diet consisting just of clover (Sekken et. al., 2012).

The use of HB as a replacement concentrate feed in growth rabbit diets increased economic return and decreased overall feed costs (Nagani, 2019). With a short growth period of 7 to 10 days, HB only needs a minimal area to produce (Mooney, 2005). Furthermore, HB enhanced economic effectiveness, feed conversion ratio, and body weight gain (Fayed, 2011). In this study, simple approach is established in HB production and provides alternative feed sources for rabbit farming in Malaysia. This innovative approach is aimed to boost the rabbit farming industry in Malaysia.

7.0 Materials and Methods

7.1 Production of Hydroponic Barley fodder

The experiment was conducted for 28 days using barley seeds, which were obtained from commercial feed supplier. For the HB cultivation, the seeds were weighed and placed in a saltwater container within 30 minutes. Then, the seeds were transferred into freshwater for 12 hours at room temperature. Later, the seeds were moved into the new container and watered to promote radicle growth until harvest. The fodders were monitored for the growth rate, temperature, and humidity during the cultivation.

7.2 Evaluation of growth performance of New Zealand White Rabbit

An experiment was carried out in Animal Research Lab (ARL), Faculty of Veterinary Medicine, University Malaysia Kelantan (UMK), under the approval of the Animal Care and Use Ethics Committee (UMK/FPV/ACUE/FYP/010/2022).

The experiment was conducted for 21 days (4 days as an adaption period and 17 days as a growth trial) using eight female weaned mixed New Zealand White Rabbits, about 35 days of age, which were obtained from a Nasa Rabbit Farm. The initial average body weight of the rabbits were recorded. All rabbits were divided into two dietary groups composed of four rabbits each : (A) Restricted feed (10% of body weight) with a ratio of 1: 3; commercial pellets: HB, and (B) restricted commercial pellets (10% of body weight) served as a control group. The quantities of feed were adjusted weekly based on body weight). Water was supplied ad libitum in a bottle drinker. The feeds were offered to the rabbit twice daily in the morning and at night

7.3 Statistical Analysis

A descriptive statistic was used to analyse the data obtained from the parameter HB fodder production to determine the mean, and standard error mean (SEM). An Independent T-test was used to analyse the input to determine the type of diet given and the growth performance of the New Zealand White (NZW) rabbit in this study. Both of the tests were performed using the SPSS Version 27 software.

8.0 Results

8.1 Production of Hydroponic Barley

Production of HB was set up during the night. The growth rate of HB fodder was closely observed every four hours during germination and 12 hours for sprouts. The daily observation was made until the fodder was ready to be harvested on day 6. The initial weight of seed, fresh weight of fodder, temperature and humidity were recorded throughout this project (Table 2). On average, 80 g of seeds produced about 650 g of fresh grass on day 6^{th} of harvesting. The mean recorded morning and night temperatures and humidities were 28.52 °C, 28.47°C, 81.33% and 82.17 %, respectively.

8.2 Evaluation of growth performance of New Zealand White rabbit

Bodyweights of the rabbits were taken on Day 1 before the animals were fed specific diets. The quantity of feed was changed weekly based on weekly body weight data obtained. The growth performances of rabbits, including initial, day 8, day 15 and final body weight, total weight and daily weight gain, were presented in Table 3. The present study revealed almost similar findings of total and daily weight gains ($p>0.05$) in both treatment groups. However, slightly higher weight gain was observed in the group of rabbits fed with a commercial diet. There was no significant weight gain was observed in the group of rabbits that received a combination of commercial pellet and barley fodder.

Table 2: Weight of seed and fodder, average temperature and humidity among pots

Parameter	Pot						Mean	SEM
	A	B	C	D	E	F		
Initial weight of seed (g)	80.0	80.0	80.0	80.0	80.0	80.0	80.00	0.00
Fresh weight of fodder (g)	650.4	649.9	653.1	650.1	650.1	649.7	650.55	0.52
Average morning temperature (°C)	28.6	28.6	28.5	28.4	28.5	28.5	28.52	0.03
Average night temperature(°)	28.2	28.2	28.3	28.6	28.6	28.9	28.47	0.11
Average morning humidity (%)	80	80	81	82	82	83	81.33	0.49
Average night humidity (%)	84	84	83	81	81	81	82.17	0.70

Table 3: Growth performance of rabbit between experimental and control diet

Parameter	Group		P-value
	A	B	
Initial body weight (g)	455.2 ± 5.4	432.2 ± 14.5	0.23
Day 8 body weight (g)	627.6 ± 5.3	618.9 ± 14.4	0.24
Day 15 body weight (g)	800.0 ± 5.5	806.5 ± 14.6	0.23
Final body weight (g)	971.3 ± 14.2	992.4 ± 33.2	0.26
Total weight gain (g)	516.2 ± 10.2	560.3 ± 19.7	0.26
Daily weight gain (g)	24.6 ± 0.5	26.7 ± 1.0	0.27

9.0 Discussion

HB fodder cultivation requires proper medium and environmental conditions such as temperatures and humidities, particularly in tropical countries like Malaysia. However, there is limited data on HB fodder farming in Malaysia. The average fresh weight of HB is one of the crucial parameters in determining the quantity of fodder produced. The fresh weight of HB fodder was not affected by environmental conditions such as temperature and humidity, as shown in this study. If the environmental conditions are ideal in a hydroponic system, the plant is likely to grow as healthily as naturally (Qureshi, 2017). Furthermore, the results supported a review by Jan et al. (2020) who found that almost six days are sufficient from seed germination to a fully grown fodder that is 15–25 cm tall in order to achieve good fodder.

Bodyweight gain is one of the parameters used to evaluate animal growth performance. The present study demonstrated that rabbits fed with a 100% commercial diet showed slightly higher body weight on day 15 and final weight gain than those provided with a combination of commercial pellet and HB. However, the results were not significant ($p>0.05$) and this is indicated the potential of HB fodder as an alternative feeding strategy in rabbit farming, as similar results were obtained. Another study also recommended HB fodder as a concentrate feed replacement in growing rabbit diets as it can increase economic return and decrease total feed cost (Nagadi, 2019). In terms of economics, HB has a short growth period of 7-10 days and only requires a small amount of land area to produce (Mooney, 2005).

The HB growth period with additional supplement and combination of HB with microorganism given during feeding are the factors that influence weight gain that might interfere with this study. During production of barley, only plain water without any nutritional supplements was used. The fodder also fails to offer its full potential to achieve an excellent nutritional composition and is necessary for growing rabbits due to the short duration of harvest time, which is on day 6. Jan et al. (2020) found by adding additional supplements, it is possible to achieve high nutrient content of the feed using hydroponics. Additionally, Nagadi (2019) investigated the impacts of eight-day-old HB with the addition of anaerobic probiotics, showing better final body weights, total body weight gains, daily body weight gains, and feed conversion ratios than the other rabbit groups that were assessed.

10.0 Conclusion

In conclusion, replacing 75% of the commercial diet with HB fodder had no significant effects on rabbits' weight. This study recommends an alternative feeding strategy for rabbit farmers to reduce feed and management costs.

11.0 Recommendations and Future Work

Several limitations were observed during this project. For future studies, it is wise to control the formation of mold. This is because mold can quickly grow in Malaysia's climate and environment. Secondly, this study can be improved by increasing the number of animals used (n=20) to produce significant results on growth performance. In addition, the duration of an experimental study on animals also should be extended by at least three months to produce meaningful results on growth performance based on the type of diet given. Increasing the experiment duration can estimate the maximum growth performance in rabbits.

Appendices A

Appendix A 1: Barley seeds

Appendix A 2: Experimental design was carried out at Animal Research Lab

Appendix A 3: Group A rabbits were fed with HB fodder

Appendix A 4: Commercial diet used for this study

References

Abdel-Wareth, A. A., Al-Kahtani, M. A., Alsyaad, K. M., Shalaby, F. M., Saadeldin, I. M., Alshammari, F. A., Mobashar, M., Suleiman, M. H., Ali, A. H., Taqi, M. O., El-Sayed, H. G., El-Sadek, M. S., Metwally, A. E., & Ahmed, A. E. (2020). Combined supplementation of nano-zinc oxide and thyme oil improves the nutrient digestibility and reproductive fertility in the male Californian rabbits. *Animals*, *10*(12), 2234. https://doi.org/10.3390/ani10122234

Blas, C. D., & Mateos, G. G. (2010). Feed formulation. *Nutrition of the Rabbit*, 222–232. https://doi.org/10.1079/9781845936693.0222

Clark, A. (Ed.). (2007). Overview of Nonlegume Cover Crops. *Managing cover crops profitably* (3rd ed., pp. 77–80). essay, Sustainable Agriculture Research and Education (SARE).

Dung, D. D., Godwin, I. R., & Nolan, J. V. (2010). Nutrient content and in sacco digestibility of Barley Grain and sprouted barley. *Journal of Animal and Veterinary Advances*, *9*(19), 2485–2492. https://doi.org/10.3923/javaa.2010.2485.2492

Fayed, A. M. (2011). Comparative Study And Feed Evaluation Of Sprouted Barley Grains On Rice Straw Versus Tamarix Mannifera On Performance Of Growing Barki Lambs In Sinai. *Journal of American Science*, 7 (1):954-961.

Jan, S., Rashid, Z., Ahngar, T. A., Iqbal, S., Naikoo, M. A., Majeed, S., Bhat, T. A., Gul, R., & Nazir, I. (2020). *Hydroponics – A Review*. https://doi.org/https://doi.org/10.20546/ijcmas.2020.908.206

Lammas, M. E., & Shitikova, A. V. (2021). World barley production. *International Scientific Conference*. https://doi.org/10.26897/978-5-9675-1855-3-2021-153

Lukefahr, S. D., McNitt, J. I., Cheeke, P. R., & Patton, N. M. (2022). *Rabbit production*. CAB International.

Mohamed, E., Hassan, H., & Abdel-Wareth, A. (2021). Potential of hydroponic barley in rabbit diets: Effect on productive performance, nutrient digestibility, microbiological and physiological responses. *SVU-International Journal of Veterinary Sciences*, *4*(3), 12–23. https://doi.org/10.21608/svu.2021.67695.1114

Mooney, J. (2005). Growing Cattle Feed Hydroponically. *Meat and livestock Australia*. 30 pp

Nagadi, S. A. (2019). Replace the sprout barley instead of the concentrated fodder including anaerobic probiotic zad® for growing rabbits. *International Journal of Engineering Research*, *V8*(10). https://doi.org/10.17577/ijertv8is100058

Qureshi, M. U. N. (2017). Comparative study of Hydroponic and Geoponic Systems. *International Journal of Agricultural Science and Research*.

Raj, J., Lau, L., & Lau, J. (2021). Malaysian youths make up over 80pc of rabbit breeders nationwide. *Malaymail*.

Sekken, M. S. M. A., Taie, H. T., & Rabie, S., A. (2012). Utilization of sprouted fenugreek and/or sprouted barley in rabbit feeding. *Egyptian Journal of Nutrition and Feeds*, 15(2): 311-321.

Sharma, N., Acharya, S., Kumar, K., Singh, N., & Chaurasia, O. P. (2018). Hydroponics as an advanced technique for vegetable production: An overview.

Journal of Soil and Water Conservation, *17*(4), 364. https://doi.org/10.5958/2455-7145.2018.00056.5

Siwar, C., Alam, M. M., Murad, W., & Al-Amin, A. Q. (2019). A review of the linkages between climate change, agricultural sustainability and poverty in Malaysia. https://doi.org/10.31219/osf.io/28vwc

Wanjala, F. N., Wanyoike, M. W., & Gachuiri, C. K. (2016). Performance of New Zealand White, California White and their cross under two feeding regimes. *International Journal of Development and Sustainability*, Vol. 5 No. 4, pp. 199-212

Zhou, M. X. (2009). Barley production and consumption. *Advanced Topics in Science and Technology in China*, 1–17. https://doi.org/10.1007/978-3-642-01279-2_1