Growth performance and physiological response of rabbit bucks to oral administration of white radish juice in a hot humid environment

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ABSTRACT

Background and Objectives: White radish root is rich in phytochemicals with high antioxidant properties, which are needed for the amelioration of heat stress in tropical rabbit production. This study investigated the effect of oral administration of white radish root juice (WRRJ) on growth performance, physiological response, and blood profile of rabbit bucks in a hot humid environment.

Methodology: Eighteen rabbit bucks were randomly allotted into 3 treatments of 6 bucks per treatment: 0 mL of WRRJ (control), 5 mL of WRRJ, and 10 mL of WRRJ, in an 8-week experiment. Data were collected on feed intake (FI), body weight gain (BWG), and feed conversion ratio (FCR). Rectal temperature (RT), respiratory rate (RR), heart rate (HR), and ear temperature (ET) were measured using standard procedures. Blood samples were collected for hematology and selected serum biochemical analysis.

Main Results: The FI, BWG, and FCR were similar ($P > 0.05$) among the treatments. Range of values obtained for RT (38.3 ± 0.30 to 39.6 ± 0.21 °C), RR (171.5 ± 5.83 to 236.0 ± 2.39 breaths/min), HR (149.0 ± 3.84 to 176.0 ± 7.48 beats/min) and ET (35.5 ± 0.76 to 37.9 ± 0.86 °C) were statistically ($P > 0.05$) similar among the treatments. However, in the 7th week of the experiment, RT of bucks given 10 mL WRRJ (39.6 ± 0.21 °C) was higher ($P < 0.05$) than RT of bucks on 5 mL WRRJ (38.5 ± 0.36 °C). No significant ($P > 0.05$) variation was observed in the hematological parameters and serum biochemical indices among the treatments except in the total protein of rabbits on 10 mL WRRJ (5.3 ± 0.25 g/dL), which differ significantly ($P < 0.05$) from 7.0 ± 0.24 g/dL (5 mL WRRJ) but similar to 6.5 ± 0.07 g/dL (control) at the onset of the experiment. The heterophil lymphocyte ratio of 0.48 ± 0.03, 0.43 ± 0.05, and 0.36 ± 0.05 were observed for the control, 5, and 10 mL WRRJ treatments, respectively at the 8th week of the experiment.

Conclusion: Administration of WRRJ at 5 and 10 mL twice weekly offered no significant antioxidant effect on the growth performance, physiological response, and blood profile of rabbit bucks.

Keywords: Rabbit buck, blood profile, rectal temperature, white radish root, heat stress

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INTRODUCTION

A tropical environment is characterized by high ambient temperature coupled with high humidity, thereby resulting in the extended exposure of animals to heat stress, which in turn impairs the physiological homeostasis, metabolic activities, and reproductive performance of the animal. This state of tropical environmental conditions is further compounded by the effect of global warming, making livestock production more challenging in the tropics. Rabbits are highly sensitive to high ambient temperature (Maertens and Gidenne, 2016) due to their dense fur, few functional sweat glands, and poor thermoregulatory system, which prevent heat loss (Marai *et al.,* 2002; Yagci *et al.,* 2006; Oladimeji *et al*., 2022). They perform optimally in 18–21 °C thermo-neutral zone and 27.8 temperature-humidity index (Marai *et al*., 2002). Temperatures outside the thermo-neutral zone result in heat stress. Like other homoeothermic animals, rabbits can regulate their body temperature through physical, morphological, biochemical, and behavioral processes to maintain a relatively constant body core temperature (Marai and Habeeb, 1994).

High ambient temperature activates stress response, which comes at the expense of rabbits' optimal productive and reproductive performance. Depression in feed intake, increase in body temperature, pulse rate and respiration (Adriaan Bouwknecht *et al*., 2007; Shebl *et al*., 2008), alteration in packed cell volume, red blood cell, glucose, and total protein (Okab *et al*., 2008), deregulation in thyroid and stress hormone, albumin, globulin, total lipid, and glucose levels (Marai *et al*., 2008) had all been reported in heat-stressed rabbits. Heat stress promotes oxidative free radical production, resulting in oxidative stress, which impairs the normal physiological condition of rabbits. Accumulation of reactive oxygen species and its metabolites in a biological system overwhelms the endogenous antioxidant defense system. Rabbit bucks are negatively affected by the increase in reactive oxygen species generated during heat stress, consequently affecting male fertility. Enhancing antioxidant defense via exogenous administration of antioxidant substrate and/or its precursors has been recommended (Jimoh *et al*., 2018).

In recent decades, research has been channeled towards finding natural sources of antioxidants in the mitigation of heat stress in livestock production. White radish (*Raphanus sativus*) is an Indian traditional plant, the family Brassicaceae, also known as white radish. It is a root vegetable, and its different parts are reported to have high medicinal values (Manivannan *et al.,* 2019). The radish contains polyphenolics such as vanillic, sinapic, catechin, protocatechuic, coumaric, syringic, caffeic, ferulic, and gallic (Magied *et al.,* 2016). Studies have revealed that flavonoids like kaempferol glycosides and peroxidases are also phytochemical constituents of radish (Hashimoto *et al*., 2006), making it a potential source of natural antioxidants (Wang *et al*., 2004). Antioxidant properties in radish, may not be unconnected to the presence of biologically-active compounds that are able to modulate the activity of cellular enzymes, such as glutathione-S-transferase and quinone reductase, which facilitates more efficient and rapid removal of reactive oxygen species (Lugasi *et al*., 2005). Antimicrobial (Esaki and Onozaki, 1982), anticarcinogenic (Hecht *et al*., 2000), and antimutagenic properties (Hashem and Saleh, 1999) have all been reported in radish. According to Kapoor (1990), radish has been previously used as an appetizer, digestive stimulant, and as a laxative for the treatment of stomach disorders. The important hypocholesterolemic and hypoglycemic role of white radish roots and leaves was earlier reported by Magied *et al*. (2016). In addition, the extract of radish was found to increase the serum high-density lipoprotein in normal rats (Taniguchi *et al.,* 2007), caused epithelium repair, prevented colon mucosa cells against lipid peroxidation and increased enterocytes in rats with a high-fat diet (Sipos *et al.,* 2002). Radish reportedly protects cells by strengthening antioxidants like catalase and glutathione (Chaturvedi, 2008). These antioxidant properties of radish prevented oxidative stress (Salah-Abbès *et al.,* 2009).

Despite the potential health benefits of white radish root, there is a dearth of information on its *in vivo* utilization, especially in livestock animals. The bulk of the beneficial effects of white radish were reported in rats, while there remains limited information on the potential effects of white radish on rabbit buck performance and physiological responses. This research was therefore conducted to determine the heat stress mitigating influence of white radish root juice (WRRJ) on growth, blood profile, and physiological responses of matured rabbit buck during the hot season. Therefore, it was hypothesized that WRRJ could suppress the heat stress effect by sustaining the production and other physiological responses of matured rabbits during the hot period.

MATERIALS AND METHODS

The experimental procedure of this study was approved by the Institutional Ethics Committee of the Department of Animal Physiology, Federal University of Agriculture, Abeokuta, Nigeria. Also, the guidelines for animal research of the Nigeria Institute of Animal Science (NIAS) were followed.

Experimental Site and Meteorological Observations

The research was conducted at the COLANIM farm, Federal University of Agriculture, Abeokuta, Ogun State, Nigeria. The farm is located within 7°10’N and 3°2’E at an altitude of 76 m above sea level in the rainforest zone of southwestern Nigeria. The study was carried out during the hot season in Nigeria from January to March for 8 weeks. Ambient temperature and relative humidity of the hutches’ microclimate were recorded daily at 8.00, 13.00, and 18.00 hours using a thermo-hygrometer. Temperature-humidity index (THI) was calculated according to Marai *et al.* (2001) using the mathematical model: $THI = T – ((0.31 – 0.31 \times RH) \times (T – 14.4))$; where T = dry bulb temperature in degrees Celsius (°C), and RH = relative humidity percentage divided by 100.

White Radish Sourcing and Processing

Freshly harvested white radishes were sourced from a farm in Ogun State, Nigeria. The leaves were separated from the tubers, and the tubers were properly washed, cut into pieces, and blended in an electric blender. A muslin cloth was used to extract the juice. The extracted radish juice was poured into a clean bottle and stored at −20 °C until needed, according to Ghozy and Tag Al Deen (2019). The weight of radish roots used in this study varies from 273 to 765 g, while the juice recovery from the samples ranges from 70 to 85%.

Experimental Animals, Design and Management

A total of 18 crossbred (New Zealand White × Chinchilla) rabbit bucks (4 months old) were allotted in a completely randomized design into 3 treatment groups, with each treatment having 3 replicates of 2 bucks each: Treatment 1 - control group (the bucks were not given WRRJ), Treatments 2 and 3 received 5 and 10 mL of WRRJ, respectively. The rabbits were housed in hutches made of wire mesh, framed with wood, measuring 60 cm × 90 cm × 60 cm. Each hutch was provided with a feed and water trough for concentrates and water, respectively. Commercial grower’s mash of 17% crude protein and metabolizable energy (ME) of 2,800 kcal/kg and drinking water was provided *ad libitum.* The WRRJ was carefully administered to the rabbits orally twice weekly via drenching with the aid of a clean and sterile syringe, according to the dose assigned to each treatment (T1: 0 mL, T2: 5 mL, and T3: 10 mL). The choice of 5 and 10 mL was informed by our earlier *in vitro* study, where WRRJ exhibited high antioxidant and free radical scavenging properties. However, the frequency of administration (twice/week) employed in this study was based on safety measures because of the spicy taste and pungent odor of the juice (Majekodunmi, Unpublished data). The experiment commenced in January 2022 and continued for 8 weeks, which terminated in March 2022.

Data Collection

Growth performance

The body weight of rabbits in each replicate was monitored weekly using a sensitive scale and the weight gain was calculated as the difference between the final weight and the initial weight for the week. Feed intake was measured as the difference between the feed offered and leftovers weekly. Feed conversion ratio (FCR) was calculated as the ratio of weight gain to feed intake.

Physiological responses

Measurements of the heart rate (HR), respiratory rate (RR), rectal temperature (RT), and ear temperature (ET) of individual rabbits were taken twice a week between 13.00 and 14.00 hours for 8 weeks of the experiment. The HR of the rabbit per minute was taken with a stethoscope placed on the chest region of the animal. The RR was taken as the number of breaths per minute by visually counting the flank movement per minute. The RT was measured with a digital thermometer (0.1 °C accuracy) inserted into the rectum until it beeped. The infrared thermometer was used to measure the skin temperature on the ear.

Hematology and serum analysis

At the start (day 0) and the end (day 56) of the experiment, blood samples were collected into labeled sterile vacuum tubes containing ethylene-diamine-tetra-acetic acid (EDTA) and labeled sterile sample bottles without anticoagulant for hematological and serum biochemical analysis respectively from each rabbit in all the treatments from the ear vein using a sterilized disposable syringe and needle. Hemoglobin (Hb) concentration, packed cell volume (PCV), red blood cell (RBC), and white blood cell (WBC) counts and the differentials (heterophils, lymphocytes, eosinophils, monocytes, and basophils) were determined as described by Feldman *et al.* (2000). Heterophil-lymphocyte ratio (H/L) was calculated from the values of heterophils and lymphocytes. Blood constants, mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC) were calculated from Hb, PCV, and RBC using appropriate formulae as described by Jain (1986). Serum total protein, albumin, aspartate aminotransferase (AST), alanine aminotransferase (ALT), and malondialdehyde (MDA) concentration were determined using the spectrophotometric method from the specific reagent kits (RANDOX Laboratories Ltd, UK), with a spectrophotometer (visible spectrophotometer 721D Axiom Medical Ltd, UK). Globulin concentration was obtained by subtracting albumin values from the total protein.

Statistical Analysis

Data generated were subjected to one-way analysis of variance (ANOVA) using SAS software (SAS, 1999). Treatment means were compared using the Duncan option of the software and considered significantly different at P < 0.05. The statistical model was as follows: $y_{ij} = \mu + A_i + e_{ij}$, where y_{ij} is the traits of interest, μ is an overall mean, A_i is the effect of i^{th} level of WRRJ (i = 0, 5, 10), and e_{ij} is the random error.

RESULTS AND DISCUSSION

The ambient temperature, relative humidity, and THI observed during the study are presented in Table 1. The lowest temperature (23.02 °C) and highest humidity (85.07%) were recorded in the morning, while the highest temperature (33.23 °C) and the lowest humidity (39.76%) were observed in the evening. The THI ranged from 22.74 to 29.64, with the highest recorded in the evening. The average temperature (29.54 °C) during this study is higher than the temperature range (18–21 °C) of thermal comfort for rabbits (Marai *et al.*, 2002; El Sabry *et al.*, 2021). Likewise, the THI, which is an indicator of the thermal comfort of an animal in confinement, increased from 22.74 in the morning to 29.35 and 29.64 in the afternoon and evening, respectively. According to Marai *et al.* (2002) the optimal THI for rabbit husbandry is 27.8, while THI 29.0–30.0 indicate severe heat stress. The observed THI in this study indicated the absence of heat stress in the morning but severe heat stress in both the afternoon and evening.

Table 1 Summary of meteorological observations during the experiment

Climatic factor	08:00 h	13:00 h	18:00 h	Average
Relative humidity (%)	85.07 ± 1.96	43.39 ± 2.16	39.76 ± 2.53	56.33 ± 2.06
Ambient temperature (°C)	23.02 ± 0.49	32.54 ± 0.17	33.23 ± 0.30	29.54 ± 0.42
Temperature-humidity index	22.74 ± 1.65	29.35 ± 1.26	29.64 ± 1.71	27.20 ± 1.03

The results of the growth performance characteristics are presented in Table 2. No significant (P > 0.05) variations and no particular trend of the effect of WRRJ were observed on the growth performance characteristics of the rabbit bucks among treatments. Similarity observed in the feed intake, weight gain, and FCR of rabbit bucks in the control and WRRJ groups in this study is an indication of no detrimental effect of WRRJ on growth performance. This result is in agreement with those obtained by Abedo *et al.* (2012), who fed rabbits diet supplemented with 1.5% radish seed. Similarly, Moram *et al*. (2015) did not find significant improvement in feed intake, weight gain, and feed efficiency of healthy male albino mice orally administered radish root juice. On the contrary, El-Tohamy *et al.* (2010) observed that radish seed meal supplementation improved feed intake, final weight, and FCR of rabbits compared to those in the control. In the study of Anwar *et al.* (2020), dietary supplementation of 100–400 mg/kg of radish leaf extract could not reverse the negative effect of atorvastatin administration on the body weight of rabbits. In obese rats, oral administration of red radish root juice (1–3 mL/kg BW/day) significantly reduced feed intake and body weight gain (Ghozy and Tag Al Deen, 2019).

The results of the thermoregulatory indices of the rabbit bucks are presented in Table 3. The observed range of RR (171.5 ± 5.83 to 236.0 ± 2.39 breaths/min), HR (149.0 ± 3.84 to 176.0 ± 7.48 beats/min), and ET (35.5 ± 0.76 to 37.9 ± 0.86 °C) were statistically (P > 0.05) similar among the treatments across the week. The RT, which ranged from 38.3 ± 0.30 to 39.6 ± 0.21 °C, were not significantly (P > 0.05) influenced by the treatments across the week except at week 7, with rabbits on 10 mL WRRJ having the highest value (39.6 ± 0.21 °C) compared with (38.5 ± 0.36 °C) recorded for rabbits on 5 mL WRRJ. However, the observed RT in this study is within the range of 38.6 to 40.1 °C estimated for rabbits by Robertshaw (2004). The RR observed in this study is higher than the values reported by Iyeghe-Erakpotobor et al. (2013) in their study on the physiological performance of rabbits in a sub-humid tropical environment. The high RR recorded in this study is an indication of thermal stress. Rabbits maintain heat balance in hot environments by increasing their respiratory activity, thereby losing more heat via evaporation from the respiratory tract. This could explain the high RR observed in this study. However, no effect of the WRRJ was observed in the respiratory response of the rabbit bucks, which may be due to the dosage and frequency (twice/week) of WRRJ administration. The ranges of values recorded for RR, HR, and RT in this study are within the range indicated for rabbits by Willmer *et al.* (2000).

Table 2 Effect of oral administration of white radish root juice on growth performance of rabbit bucks

Treatment	Initial weight (g)	Final weight (g)	Total feed intake (g)	Total weight gain (g)	FCR	Mortality*
Control	1,945.0 ± 33.30	3,028.0 ± 44.00	5,720.0 ± 160.00	1,082.5 ± 20.60	5.3 ± 0.20	0
5 mL WRRJ	1,947.5 ± 111.00	2,998.0 ± 143.00	5,038.0 ± 217.00	1,050.0 ± 58.20	4.8 ± 0.14	0
10 mL WRRJ	1,922.5 ± 108.00	2,941.0 ± 116.00	5,301.0 ± 349.00	1,018.8 ± 36.20	5.2 ± 0.37	0
P-value	0.977	0.854	0.216	0.571	0.400	ND

Note: WRRJ = white radish root juice, FCR = feed conversion ratio. *Absolute values, ND = not determined.

Table 3 Effect of oral administration of white radish on stress response in rabbit bucks

Treatment	Week of experiment								
	1	2	3	4	5	6	7	8	Mean
RR									
Control	190.5 ± 5.95	204.5 ± 4.92	176.5 ± 10.20	227.0 ± 3.76	225.0 ± 3.27	230.0 ± 3.12	229.5 ± 4.66	218.5 ± 13.9	212.7 ± 3.32
5 mL WRRJ	198.0 ± 4.72	199.5 ± 6.99	175.5 ± 7.61	225.0 ± 3.61	232.0 ± 4.34	225.5 ± 2.92	226.0 ± 6.55	210.5 ± 10.2	211.5 ± 3.10
10 mL WRRJ	194.5 ± 2.82	206.8 ± 4.77	171.5 ± 5.83	220.3 ± 4.45	236.0 ± 2.39	228.8 ± 2.78	229.8 ± 3.69	215.5 ± 9.84	212.9 ± 3.11
P-value	0.535	0.655	0.899	0.476	0.095	0.546	0.846	0.884	0.947
HR									
Control	169.0 ± 8.13	163.0 ± 4.83	159.5 ± 6.99	155.5 ± 3.58	150.0 ± 3.55	159.5 ± 8.05	158.5 ± 6.63	159.0 ± 6.92	159.3 ± 2.21
5 mL WRRJ	157.0 ± 5.49	160.5 ± 2.87	160.0 ± 2.62	156.0 ± 5.55	149.0 ± 3.84	154.5 ± 3.29	162.5 ± 5.34	150.0 ± 4.84	156.2 ± 1.57
10 mL WRRJ	169.0 ± 5.44	161.5 ± 3.31	158.0 ± 1.89	154.0 ± 4.88	156.3 ± 3.30	160.3 ± 5.19	176.0 ± 7.48	151.3 ± 3.29	160.8 ± 1.82
P-value	0.338	0.895	0.947	0.953	0.318	0.754	0.165	0.434	0.217
RT									
Control	39.3 ± 0.21	39.3 ± 0.18	39.2 ± 0.14	39.1 ± 0.24	39.2 ± 0.23	39.1 ± 0.22	39.0 ± 0.18[ab]	38.5 ± 0.37	39.1 ± 0.08
5 mL WRRJ	39.0 ± 0.14	38.8 ± 0.24	39.1 ± 0.17	38.3 ± 0.30	39.1 ± 0.12	39.0 ± 0.14	38.5 ± 0.36[b]	39.3 ± 0.17	38.9 ± 0.08
10 mL WRRJ	39.0 ± 0.20	39.0 ± 0.18	38.9 ± 0.15	38.8 ± 0.33	39.3 ± 0.16	39.1 ± 0.20	39.6 ± 0.21[a]	39.1 ± 0.09	39.1 ± 0.07
P-value	0.442	0.175	0.499	0.214	0.782	0.989	0.039	0.093	0.107
ET									
Control	37.2 ± 0.47	36.2 ± 0.66	37.9 ± 0.86	37.7 ± 0.62	37.3 ± 0.58	36.5 ± 0.85	36.7 ± 0.51	37.1 ± 0.59	37.1 ± 0.23
5 mL WRRJ	37.5 ± 0.38	36.1 ± 0.48	37.3 ± 0.60	37.0 ± 0.77	37.6 ± 0.50	37.0 ± 1.47	36.5 ± 0.69	37.4 ± 0.50	37.1 ± 0.26
10 mL WRRJ	37.2 ± 0.93	36.4 ± 0.53	37.0 ± 0.41	36.6 ± 0.65	37.7 ± 0.48	35.5 ± 0.76	36.6 ± 0.80	37.1 ± 0.77	36.8 ± 0.24
P-value	0.929	0.922	0.647	0.494	0.821	0.614	0.983	0.892	0.608

Note: [ab] Means in the same column of the trait with different superscripts are significantly different ($P < 0.05$). WRRJ = white radish root juice, RR = respiratory rate (breaths/min), HR = heart rate (beats/min), RT = rectal temperature (°C), ET = ear temperature (°C).

The hematological results of the experimental animals are shown in Table 4. No significant (P > 0.05) variations were observed in all the hematological parameters both at the onset and at the 8th week of the experiment. Though not significantly different from the control, a numerical reduction was observed in the H/L values among the treatment groups at day 56 of the study compared with the baseline values, with rabbits on 10 mL WRRJ having the lowest H/L value. This is an indication of the potential mitigating effect of WRRJ. The present results on hematology align with that of Moram *et al.* (2015) which showed statistically similar values of hematological parameters for male albino mice in control and those given radish root juice (8 mL/kg body weight). In contrast to the present finding, Salah-Abbès *et al.* (2008) reported that RBC, WBC count, platelet count, and Hb concentration in the blood of Balb/c mice given radish extract (15 mg/kg body weight) was significantly higher than that of control mice. The results of Mohammed *et al.* (2008) showed that methanolic and aqueous extracts of radish seeds ameliorated the negative effects of carbon tetrachloride injection on PCV, RBC, and Hb concentration in albino Wistar rats. The above reports on rodents suggests radish possess bioactive substances that can influence blood cell components which were not evident in this study probably due to the dosage of WRRJ, frequency of administration, and the level of heat stress experienced by the rabbits.

Table 5 shows the results of the effect of oral administration of WRRJ on the serum biochemistry of rabbit bucks. Serum glucose, total protein, albumin, globulin, AST, ALT, and MDA showed no significant (P > 0.05) variations among the treatment groups at day 56 of the experiment. Significant variation was observed in the total protein at the onset of the experiment with rabbits on 10 mL WRRJ having the lowest value (5.3 ± 0.25 g/dL) which differed significantly from 7.0 ± 0.24 recorded for rabbits on 5 mL WRRJ. The reduction in serum total protein may be due to a dilution caused by an increase in water consumption (Okab *et al.,* 2008). However, this variation in total protein cannot be attributed to WRRJ since its administration had not commenced. Administration of radish pods, leaves, or seed extract has been reported to influence some biomarkers (AST, ALT, LDH, and creatine kinase) of cardiac function in albino rats (Shah *et al*., 2014) and heart rate (Ghayur and Gilani, 2006) in anesthetized rats. These reports suggest that radishes possess phytochemicals with cardioprotective ability. Younus and Siddiq (2022) in their study on the administration of 100 and 200 mg of radish pod extract reported a significant reduction in rectal temperature of mice 3–5 h after yeast-induced pyrexia. Although no significant effect was recorded in this study, radish root extract has been found to influence glucose levels in the serum of diabetes-induced rats (Dehghani *et al*., 2011; Magied *et al*., 2016). Higher serum glucose values observed at the onset of this study compared with day 56 may be due to the stress of being introduced into unfamiliar surroundings where they were housed individually with no visual and physical contact as against their previous housing condition. Unfamiliar environment and isolation are potent stressors (Serra *et al.,* 2004) and it has been reported that elevated glucose levels in rabbits are generally due to various stress factors (Jenkins, 2008) which might be the result of the decrease in glucose utilization to preserve energy during the stressed conditions.

Several studies (Wang *et al*., 2010; Beevi *et al.,* 2012; Goyeneche *et al*., 2015) have reported different forms of polyphenol constituents in radish when tested *in vitro* for antioxidative activity and have been positively correlated with radical scavenging and reducing ability. Magied *et al.* (2016) reported a reduction in malondialdehyde concentration in the serum of hypercholesterolemic rats administered 200 and 400 mg/kg BW/day of white radish root extract. On the contrary, Atasever *et al.* (2020) showed that oral gavage of fermented radish root (250 and 500 mg/kg) did not affect alanine aminotransferase activity and malondialdehyde concentration in the serum of male albino Wistar rats which support the present finding. The reports highlighted above on improvement in blood constituents following administration of radish extract suggest activity of several bioactive substances in radish which may be dependent on the degree of cellular or systemic stress induction, dosage and frequency of administration.

Table 4 Effect of oral administration of white radish root juice on hematology of rabbit bucks

Parameter	Day 0			P-value	Day 56			P-value	Reference ranges*
	Control	5 mL WRRJ	10 mL WRRJ		Control	5 mL WRRJ	10 mL WRRJ		
PCV (%)	28.0 ± 1.00	30.0 ± 5.00	32.0 ± 8.00	0.879	33.0 ± 1,00	34.0 ± 4.00	38.5 ± 1.50	0.384	33–50
Hb (g/dL)	8.7 ± 0.05	9.8 ± 0.54	10.5 ± 1.30	0.791	10.6 ± 0.40	11.0 ± 1.20	12.8 ± 0.60	0.269	9.4–17.4
RBC ($\times 10^6/\mu L$)	4.2 ± 0.02	4.7 ± 0.54	5.0 ± 1.30	0.798	5.21 ± 0.02	5.8 ± 0.66	6.5 ± 0.19	0.223	3.8–7.9
WBC ($\times 10^3/\mu L$)	2,375 ± 225	2,975 ± 275	3,000 ± 50	0.198	2,425 ± 225	3,650 ± 450	3,675 ± 25	0.089	5–13
Plat ($\times 10^9/L$)	68.0 ± 2.00	76.5 ± 4.50	68.5 ± 9.50	0.605	39.0 ± 4.00	46.0 ± 8.00	57.5 ± 13.50	0.465	20–65
MCV (fL)	66.3 ± 2.06	63.0 ± 3.37	64.0 ± 0.70	0.552	63.3 ± 1.68	58.9 ± 0.20	59.4 ± 0.57	0.098	50–75
MCH (pg)	20.5 ± 0.02	20.6 ± 0.82	20.8 ± 0.07	0.893	21.3 ± 0.69	19.1 ± 0.10	19.7 ± 0.35	0.282	18–24
MCHC (g/dL)	30.9 ± 0.93	32.7 ± 0.46	32.5 ± 0.46	0.076	32.1 ± 0.24	32.1 ± 0.28	33.2 ± 0.26	0.111	27–34
Lym (%)	60.0 ± 1.00	62.5 ± 5.50	63.5 ± 7.50	0.898	66.5 ± 0.50	67.5 ± 2.50	70.5 ± 2.50	0.459	43–80
Het (%)	36.5 ± 0.50	34.0 ± 4.00	32.5 ± 7.50	0.852	32.0 ± 0.00	29.0 ± 2.00	25.0 ± 2.50	0.186	34–70
Mon (%)	2.0 ± 0.00	2.0 ± 1.00	1.5 ± 0.50	0.829	1.5 ± 0.50	1.5 ± 0.50	1.5 ± 0.50	1.000	0–4
Eos (%)	1.5 ± 0.50	1.5 ± 0.50	2.5 ± 0.50	0.385	0.5 ± 0.50	2.0 ± 1.00	2.5 ± 0.50	0.262	0–2
H/L	0.61 ± 0.02	0.55 ± 0.11	0.53 ± 0.18	0.908	0.48 ± 0.03	0.43 ± 0.05	0.36 ± 0.05	0.242	0.3–0.8

Note: WRRJ = white radish root juice, PCV = packed cell volume, Hb = hemoglobin, RBC = red blood cell, WBC = white blood cell, Plat = platelets, MCV = mean corpuscular volume, MCH = mean corpuscular hemoglobin, MCHC = mean corpuscular hemoglobin concentration, Lym = lymphocyte, Het = heterophil, Mon = monocyte, Eos = eosinophil, H/L = heterophil-lymphocyte ratio. *Reference ranges obtained from Medirabbit (2011).

Table 5 Effect of oral administration of white radish root juice on serum biochemistry of rabbit bucks

Parameter	Day 0			P-value	Day 56			P-value	Reference ranges*
	Control	5 mL WRRJ	10 mL WRRJ		Control	5 mL WRRJ	10 mL WRRJ		
Glucose (mg/dL)	252.6 ± 49.60	273.0 ± 18.10	204.7 ± 17.10	0.413	135.2 ± 17.50	124.1 ± 36.20	112.7 ± 3.83	0.805	75–140
TP (g/dL)	6.5 ± 0.07[ab]	7.0 ± 0.24[a]	5.3 ± 0.25[b]	0.022	5.8 ± 0.58	5.9 ± 0.45	6.2 ± 0.74	0.900	5.0–7.5
Albumin (mg/dL)	3.5 ± 0.15	3.4 ± 0.03	3.7 ± 0.05	0.232	3.2 ± 0.12	3.5 ± 0.44	3.2 ± 0.39	0.779	2.5–4.0
Globulin (mg/dL)	3.0 ± 3.05	3.6 ± 3.64	1.6 ± 0.21	0.143	2.6 ± 0.70	2.4 ± 0.89	3.0 ± 0.35	0.805	1.5–3.3
AST (U/L)	34.5 ± 1.10	60.4 ± 5.14	63.1 ± 12.9	0.148	71.6 ± 1.06	76.3 ± 24.70	43.9 ± 5.52	0.366	10–98
ALT (U/L)	6.4 ± 0.14	14.7 ± 4.76	12.1 ± 1.85	0.272	28.7 ± 4.83	29.7 ± 6.39	16.9 ± 1.72	0.254	5.5–26.0
MDA (nmol/mL)	24.1 ± 2.95	23.9 ± 0.50	18.3 ± 2.06	0.232	19.1 ± 6.00	20.3 ± 1.53	21.2 ± 1.92	0.927	

Note: [ab] Means in the same row with different superscripts are significantly different ($P < 0.05$). WRRJ = white radish root juice, TP = total protein, AST = aspartate aminotransferase, ALT = alanine aminotransferase, MDA = malondialdehyde concentration. *Reference ranges obtained from Medirabbit (2011).

CONCLUSION

The results of this study demonstrated that twice weekly oral administration of WRRJ at 5 and 10 mL, offered no significant antioxidant effect on rabbit bucks as observed in the heterophil-lymphocyte ratio and malondialdehyde concentration which are indicators of stress. Likewise, no effect was observed in the growth performance, physiological response, and other hematology and serum biochemical indices. Further investigation using higher doses and/or more frequency of administration of WRRJ as an anti-stress is hereby recommended to elucidate its beneficial effect on the production performance of rabbit bucks reared under hot climes.

REFERENCES

Abedo, A.A., F.A.F. Ali, H.A.A. Omer and S.A.M. Ibrahim. 2012. Response of growing rabbits to diets containing different levels of protein and radish (*Raphanus sativus* L) seeds. J. Agric. Sci. 4(3): 281–289. https://doi.org/10.5539/jas.v4n3p281.

Adriaan Bouwknecht, J., B. Olivier and R.E. Paylor. 2007. The stress-induced hyperthermia paradigm as a physiological animal model for anxiety: a review of pharmacological and genetic studies in the mouse. Neurosci. Biobehav. Rev. 31(1): 41–59. https://doi.org/10.1016/j.neubiorev.2006.02.002.

Anwar, O., M. Iqbal, A.M. Khan, S. Tariq and A. Ambreen. 2020. Effect of *Raphanus sativus* (Radish) leaf extract and high doses of atorvastatin on body weight, liver weight and liver/body weight ratio. APMC. 14(4): 313–317. https://doi.org/10.29054/apmc/2020.721.

Atasever, A., D. Yaman Gram, G. Ekebas, N. Ertas Onmaz, M. Senturk, M. Eren and L. Ekici. 2020. Effect of fermented red radish (*Raphanus sativus* L) in carbon tetrachloride-induced liver injury in rats. Thai J. Vet. Med. 50(3): 405–416.

Beevi, S.S., L.N. Mangamoori and B.B. Gowda. 2012. Polyphenolics profile and antioxidant properties of *Raphanus sativus* L. Nat. Prod. Res. 26(6): 557–563. https://doi.org/10.1080/14786419.2010.521884.

Chaturvedi, P. 2008. Inhibitory response of *Raphanus sativus* on lipid peroxidation in albino rats. Evid. Based Complement. Alternat. Med. 5(1): 55–59. https://doi.org/10.1093/ecam/nel077.

Dehghani, F., M. Azizi and M.R. Panjehshahin. 2011. The effects of aqueous extract of *Raphanus sativus* on blood glucose, triglyceride and cholesterol in diabetic rats. IJPT. 10(2): 66–70.

El Sabry, M.I., M.M. Zaki, F.A. Elgohary and M.M. Helal. 2021. Sustainable rabbit production under the global warming conditions in Southern Mediterranean region. World Vet. J. 11(4): 543–548. https://doi.org/10.54203/scil.2021.wvj69.

El-Tohamy, M.M., W.S. El-Nattat and R.I. El-Kady. 2010. The beneficial effects of *Nigella sativa*, *Raphanus sativus* and *Eruca sativa* seeds cakes to improve male rabbit fertility immunity and production. J. Am. Sci. 6(10): 1247–1255.

Esaki, H. and H. Onozaki. 1982. Antimicrobial action of pungent principles in radish root. Nihon Eiyo Shokuryo Gakkai Shi. 35(3): 207–211. https://doi.org/10.4327/jsnfs1949.35.207.

Feldman, B.F., J.G. Zinkl and N.C. Jain. 2000. Schalm's Veterinary Haematology. 5th Edition. Lippincott Williams & Wilkins, Philadelphia, USA.

Ghayur, M.N. and A.H. Gilani. 2006. Radish seed extract mediates its cardiovascular inhibitory effects via muscarinic receptor activation. Fundam. Clin. Pharmacol. 20(1): 57–63. https://doi.org/10.1111/j.1472-8206.2005.00382.x.

Ghozy, S.F.A.E. and R.I. Tag Al Deen. 2019. Effect of fresh red radish roots juice on some biomarker for hypertrophy of adipose tissue in obese rats. Bulletin of the National Nutrition Institute of the Arab Republic of Egypt. 54(2): 1–20. https://doi.org/10.21608/bnni.2020.108366.

Goyeneche, R., S. Roura, A. Ponce, A. Vega-Galvez, I. Quispe-Fuentes, E. Uribe and K.D. Scala. 2015. Chemical characterization and antioxidant capacity of red radish (*Raphanus sativus* L.) leaves and roots. J. Funct. Foods. 16: 256–264. https://doi.org/10.1016/j.jff.2015.04.049.

Hashem, F.A. and M.M. Saleh. 1999. Antimicrobial components of some cruciferae plants (*Diplotaxis harra* Forsk. and *Erucaria microcarpa* Boiss.). Phytother. Res. 13(4): 329–332. https://doi.org/10.1002/(sici)1099-1573(199906)13:4%3C329::aid-ptr458%3E3.0.co;2-u.

Hashimoto, T., Y. Ueda, N. Oi, H. Sakakibara, C. Piao, H. Ashida, M. Goto and K. Kanazawa. 2006. Effects of combined administration of quercetin, rutin and extract of white radish sprout rich in kaemferol glycosides on the metabolism in rats. Biosci. Biotechnol. Biochem. 70: 279–281. https://doi.org/10.1271/bbb.70.279.

Hecht, S.S., P.M. Kenney, M. Wang, N. Trushin and P. Upadhyaya. 2000. Effects of phenethyl isothiocyanate and benzyl isothiocyanate, individually and in combination, on lung tumorigenesis induced in A/J mice by benzo[a]pyrene and 4-(methylnitrosamino)-1-(3-pyridyl)-1-butanone. Cancer Lett. 150(1): 49–56. https://doi.org/10.1016/s0304-3835(99)00373-0.

Iyeghe-Erakpotobor, G.T., O.M. Akinsola, T.T. Samuel and P.F. Pewar, 2013. Growth and physiological responses of rabbit hyla stock in a sub-humid tropical environment. J. Anim. Prod. Res. 25: 25–36.

Jain, N.C. 1986. Schalm's Veterinary haematology. 4th Edition. Lea & Febiger, Philadelphia, USA.

Jenkins, J.R. 2008. Rabbit diagnostic testing. J. Exot. Pet. Med. 17(1): 4–15. https://doi.org/10.1053/j.jepm.2007.12.003.

Jimoh, O.A., E.S. Ayedun, W.A. Oyelade, O.D. Oloruntola, O.T. Daramola, S.O. Ayodele and I.S. Omoniyi. 2018. Protective effect of soursop (*Annona muricata* linn.) juice on oxidative stress in heat stressed rabbits. J. Anim. Sci. Technol. 60: 28. https://doi.org/10.1186/s40781-018-0186-4.

Kapoor, L.D. 1990. Handbook of Ayurvedic Medicinal Plants. CRC Press, Boca Raton, Florida, USA.

Katsuzaki, H., Y. Miyahara, M. Ota, K. Imai and T. Komiya. 2004. Chemistry and antioxidative activity of hot water extract of Japanese radish (daikon). Biofactors. 21: 211–214. https://doi.org/10.1002/biof.552210142.

Lugasi, A., A. Blázovics, K. Hagymási, I. Kocsis and A. Kéry. 2005. Antioxidant effect of squeezed juice from black radish (*Raphanus sativ*us L. *var niger*) in alimentary hyperlipidaemia in rats. Phytother. Res. 19(7): 587–591. https://doi.org/10.1002/ptr.1655.

Maertens, L. and T. Gidenne. 2016. Feed efficiency in rabbit production: nutritional, technico-economical and environmental aspects, pp. 131–151. *In*: Proceeding of the 11th World Rabbit Congress. June 15–18, 2016. Quingdao, China.

Magied, M.M., A.M. Alian, L.A. Fattah, M. Haerrdy and M.T. Hussein. 2016. The protective effect of white and red radish as hypoglycemic and hypocholesterolemic agents. IOSR J. Pharm. Biol. Sci. 11(3): 51–61. https://doi.org/10.9790/3008-1103035161.

Manivannan, A., J.H. Kim, D.S. Kim, E.S. Lee and H.E. Lee. 2019. Deciphering the nutraceutical potential of *Raphanus sativus*—a comprehensive overview. Nutrients. 11(2): 402. https://doi.org/10.3390%2Fnu11020402.

Marai, I.F., M.S. Ayytat and U.M. Abd el-Monem. 2001. Growth performance and reproductive trans at first parity of New Zealand White female rabbits as affected by heat stress and its alleviation under Egyptian conditions. Trop. Anim. Health Prod. 33(6): 451–462. https://doi.org/10.1023/a:1012772311177.

Marai, I.F.M. and A.A. Habeeb. 1994. Thermoregulation in rabbits. Options Mediterraneennes. 8: 33–41.

Marai, I.F.M., A.A.M. Habeeb and A.E. Gad. 2002. Rabbits' productive, reproductive and physiological performance traits as affected by heat stress: a review. Livest. Prod. Sci. 78(2): 71–90. https://doi.org/10.1016/S0301-6226(02)00091-X.

Marai, I.F.M., A.A.M. Habeeb and A.E. Gad. 2008. Performance of New Zealand White and Californian male weaned rabbits in the subtropical environment of Egypt. Anim. Sci. J. 79(4): 472–480. https://doi.org/10.1111/j.1740-0929.2008.00552.x.

Medirabbit. 2011. Complete blood count and biochemical reference values in rabbits. Available Source: www.medirabbit.com. July 3, 2023.

Mohammed, N.H.SH., A.I. Abelgasim and A.H. Mohammed. 2008. Protective effect of *Raphanus sativus* against carbon tetrachloride induced hepatotoxicity in Wistar albino rats. J. Pharmacol. Toxicol. 3(4): 272–278. https://doi.org/10.3923/jpt.2008.272.278.

Moram, G.S.E., T. El-sayed Kholief and A.T.F. Ahmed. 2015. Antioxidant effect of radish (*Raphanus sativus* L.) and leek (*Allium porrum* L.) juices against hepatotoxicity and nephrotoxicity induced by dimethoate in male albino mice. World J. Pharm. Res. 4(12): 215–246.

Okab, A.B., S.G. El-Banna and A.A. Koriem. 2008. Influence of environmental temperatures on some physiological and biochemical parameters of male New-Zealand rabbit males. Slovak J. Anim. Sci. 41(1): 12–19.

Oladimeji, A.M., T.G. Johnson, K. Metwally, M. Farghly and K.M. Mahrose. 2022. Environmental heat stress in rabbits: implications and ameliorations. Int. J. Biometeorol. 66: 1–11. https://doi.org/10.1007/s00484-021-02191-0.

Robertshaw, D. 2004. Temperature regulation and thermal environment, pp. 962–974. *In*: H.H. Dukes and W.O. Reece, (Eds), Dukes' Physiology of Domestic Animals. 12th Edition. Cornell University Press, New York, USA.

Salah-Abbès, J.B., S. Abbès, Z. Haous and R. Oueslati. 2009. *Raphanus sativus* extract prevents and ameliorates zearalenone-induced peroxidative hepatic damage in Balb/c mice. J. Pharm. Pharmacol. 61(11): 1545–1554. https://doi.org/10.1211/jpp.61.11.0015.

Salah-Abbès, J.B., S. Abbès, Z. Ouanes, Z. Houas, M.A. Abdel-Wahhab, H. Bacha and R. Oueslati. 2008. Tunisian radish extract (*Raphanus sativus*) enhances the antioxidant status and protects against oxidative stress induced by zearalenone in Balb/c mice. J. Appl. Toxicol. 28(1): 6–14. https://doi.org/10.1002/jat.1240.

SAS. 1999. SAS/STAT User's Guide. Version 8 for Windows. SAS Institute Inc., Cary, North Carolina, USA.

Serra, M., M.G. Pisu, I. Floris, S. Floris, E. Cannas, A. Mossa, G. Trapani, A. Latrofa, R.H. Purdy and G. Biggio. 2004. Social isolation increases the response of peripheral benzodiazepine receptors in the rat. Neurochem. Int. 45(1): 141–148. https://doi.org/10.1016/j.neuint.2003.11.013.

Shah, M., G. Shahu, A.K. Tamrakar, S. Malshetthy, S. Janadri and S. Swamy. 2014. Cardiotoxic activity of leaves extract of *Raphanus sativus* Linn. in adult male albino rats. Int. J. Pharm. Phytopharmacol. Res. 4(1): 66–69.

Shebl, H.M., M.A. Ayoub, W.H. Kishik, H.A. Khalil and R.M. Khalifa. 2008. Effect of thermal stresses on the physiological and productive performance of pregnant doe rabbits. Agric. Res. J. 8(1): 15–24.

Sipos, P., K. Hagymási, A. Lugasi, E. Fehér and A. Blázovics. 2002. Effects of black radish root (*Raphanus sativus* L. var *niger*) on the colon mucosa in rats fed a fat rich diet. Phytother. Res. 16(7): 677–679. https://doi.org/10.1002/ptr.950.

Taniguchi, H., R. Muroi, K. Kobayashi-Hattori, Y. Uda, Y. Oishi and T. Takita. 2007. Differing effects of water-soluble and fat-soluble extracts from Japanese radish (*Raphanus sativus*) sprouts on carbohydrate and lipid metabolism in normal and streptozotocin-induced diabetic rats. J. Nutr. Sci. Vitaminol. (Tokyo). 53(3): 261–266. https://doi.org/10.3177/jnsv.53.261.

Wang, L., K. Burhenne, B.K. Kristensen and S.K. Rasmussen. 2004. Purification and cloning of a Chinese red radish peroxidase that metabolise pelargonidin and forms a gene family in *Brassicaceae*. Gene. 343(2): 323–335. https://doi.org/10.1016/j.gene.2004.09.018.

Wang, L.S., X.D. Sun, Y. Cao, L. Wang, F.J. Li and Y.F. Wang. 2010. Antioxidant and pro-oxidant properties of acylated pelargonidin derivatives extracted from red radish (*Raphanus sativus* var. *niger*, *Brassicaceae*). Food Chem. Toxicol. 48(10): 2712–2718. https://doi.org/10.1016/j.fct.2010.06.045.

Willmer, P., G. Stone and J. Johnston. 2000. Environmental Physiology of Animals. 1st Edition. Blackwell Scientific Publications, Oxford, UK.

Yagci, A., B. Zik, C. Uguz and K. Altunbas. 2006. Histology and morphometry of White New Zealand rabbit skin. Indian Vet. J. 83(8): 876–880.

Younus, I. and A. Siddiq. 2022. *Raphanus sativus* L. Var. *caudatus* as an analgesic and antipyretic agent in animal models. Pakistan J. Zool. 54(4): 1643–1648.