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# Impact of Replacing Different Levels of *Panicum maximum* in Rabbit Diets on Growth Performance, Hemato-Biochemical Profile, and Histological Responses of Some Internal Organs

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## ABSTRACT

There has been an interest in alternative sources in rabbit feeding. Therefore, the current study aimed to estimate the health status, growth performance, hemato-biochemical, and histological picture of some important internal organs in growing Newziland rabbits as a result of replacing different levels of *Panicum maximum* (PM) in its pelleted diet. A total of 35 weaned rabbits (20 males and 15 females) aged 5 weeks were purchased with an average body weight of 839.7 ± 7.05 g and 771.20 ± 9.19 g for males and females, respectively. Randomly, five equal rabbit groups were formed (7 rabbits in each group). The first group (control) was fed a basal diet without PM. The second, third, fourth, and fifth groups were fed pelleted diets containing PM with a replacing percent of 25%, 50%, 75%, and 100% of clover hay, respectively. All groups were fed *ad libitum* of pelleted feed for two months. The blood was aspirated individually three times, including at the beginning of the experiment (as zero time), after one month, and at the end of the experiment, respectively. The whole blood was used for the measurement of hemoglobin concentration, hematocrit percentage, erythrocytes, and total leukocyte counts. At the experimental end, in each group, 3 male rabbits were sacrificed and their internal organs including liver, kidney, cecum, and rectum were collected for histopathology. The live body weight was significantly affected by sex where males were heavier than females, also feed conversion ratio, growth rate, and feed intake were significantly affected by feeding on different levels of PM. Blood hemoglobin, hematocrit, and the total leukocytic count had a non-significant effect while the erythrocyte count increased significantly in all experimental groups. There were insignificant changes in plasma total protein, albumin, globulin, ALT, AST, creatinine, and glucose concentrations when different levels of PM were added. furthermore, the plasma total cholesterol and triglycerides were significantly decreased in rabbits fed PM, 75% and 100% when compared with 25%, 50%, and control groups. Finally, replacement PM instead of clover hay in pelleted diets till 75% was found to be the safety and optimum percentage for biological and healthy rabbits.

**Keywords:** Growth, Hemato-biochemical, Histopathology, *Panicum maximum*, Rabbits

## INTRODUCTION

In Egypt, clover hay is the main source of fibers in pelleted rabbit diets. Two million feddans were planted by clover hay in Egypt (EMA, 2003). Recently, the cultivated wheat area has increased at the expense of Berseem area which has led to an increase in the price of rabbit rations (Abo EL-Maaty et al., 2014). The trend to non-traditional feed ingredients has reduced the cost of feeding and prevented pollution problems (Abdel-Magid et al., 2008). Thus, rabbit producers have a tendency to use new feed alternatives that maintain performance and reduce costs (Refaie et al., 2020). In tropical developing countries, rabbits are considered a good source of meat. *Panicum maximum* (PM, guinea grass) as a forage generally contains appreciable amounts of protein, fiber, fat, and metabolizable energy that can support the growth and production of rabbits (Meddugu et al., 2012).

*Panicum maximum* as a fiber source in the diet of growing rabbits, also called Guinea grass, buffalo grass, or zacate Guinea, It is a promising feed resource with high quality, containing 10.5% Crude Protein (CP), 2.5% Ether Extract (EE), 30.4% Crude Fiber (CF), and 7.5% ash (Ironkwe and Ukanwoko, 2016; Liu et al., 2018). Moreover, it is easily adapted to the environment with a rapid growth rate. Udeh et al. (2007) stated that feed intake in rabbits fed PM increased when compared with other forages as Centrosema pubescents and Sidaacuta. Similarly, Amata and Okorodudu (2016) reported higher weight gain values in rabbits fed concentrate diet plus PM (1:2) than rabbits fed diets concentrated with Myrianthus arboreus or Gmelina arborea.

Moreover, Ezea et al. (2014) recorded better weight gain in pregnant rabbits and their litters when fed concentrate mixed with forage containing PM. The hematological parameters (RBCs and WBCs) are of healthy diagnostic



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importance for the clinical evaluation of animals, particularly nutrient deficiency, internal organs damage, and animal defense mechanisms. Therefore, the current study aimed to examine the effect of feeding PM at different levels instead of clover hay in growing New Zealand rabbits regarding growth performance, hemato-biochemical measurements, and histopathological evaluation of some internal organs.

## MATERIALS AND METHODS

### Ethical approval

The present study was affirmed by the Ethics of Animal Experiments Committee, Desert Research Center, Egypt.

### Animal, design, and alimentation

A total of 35 growing New Zealand White rabbits (20 males and 15 females, 35 days old) were purchased from Maryout Research Station, Desert Research Center, and weighed individually then randomly divided into 5 groups. Then, 7 rabbits per group were distributed on 3 cages (the first cage contained 2 male rabbits, the second cage contained 2 male rabbits, and the third cage contained 3 female rabbits). Five groups fed diets containing different levels of PM were grounded and thoroughly mixed with other feed ingredients with a replacing percent of 0%, 25%, 50%, 75%, and 100% of clover hay. Rabbits were Adapted to the newly pelleted diet containing PM by gradually mixing with the basal diet through three successive days and continued feeding for 8 weeks. Water was supplied *ad libitum* along with the experiment. The rabbits were reared in the same house with optimum management of ambient temperature, ventilation, lighting, and humidity in 15 cages (each cage measured 30 × 50 × 40 cm) and fed a pelleted diet formulated according to de Blas and Mateos (2010). The ingredient and diet analyses were performed according to the Association of Official Analytical Chemists (AOAC, 2006).

### *Panicum maximum* preparation

The whole plants except roots were thoroughly washed with distilled water then dried in a hot air oven at 50-60°C for 40 hours with constant rotation and aeration. After that dried plants were cut into small pieces, subsequently ground and sieved at 0.5 mm then kept in hermetically closed plastic containers, stored in a cool environment, analyzed according to AOAC (2006), and used in the experimental diets. Chemical compositions of PM are shown in Table 1.

**Table 1.** Proximate chemical compositions of *Panicum maximum*

| Ingredient | Composition (%) |
|---|---|
| Dry matter | 92.07 |
| Crude Protein | 8.55 |
| Ash | 10.85 |
| Ether Extract | 7.45 |
| None Detergent Fibers | 60.95 |
| Acid Detergent fibers | 40.10 |
| Acid Detergent Lignin | 5.65 |

### Experimental diet

The diet composition covered the requirement of growing rabbits (AMD, 1996). All diets contained almost 17% CP with 2500 kcal DE/kg (Table 2).

### Growth performance

At the beginning of the experiment, rabbits were individually weighed and selected according to the nearest ± 2.0 g for each group using Top Pan Sensitive Balance (J. Liang Int. Ltd., U.K.). This weighing was done before fresh feeding and watering in the morning and the procedure was repeated weekly. Weight gain for each rabbit was calculated weekly by subtracting the present weight from that of the previous week. The daily weight gain was obtained by dividing the total weight gain by the number of study days (56-days). On a group basis, the weekly feed intake (FI) was obtained by subtracting the residual feed from the offered one. The following equation represents the average daily feed intake per rabbit

$$\text{FI/rabbit/day} = \frac{\text{FI/replicate/week}}{\text{Number of rabbits consumed feed daily during the week}}$$

Feed conversion ratio (FCR) was estimated as the amount of feed consumed (g)/body weight gain (g). The relative growth rate (GR, %) was calculated using the following equation:

Growth rate (GR) = Final weight - initial weight/initial weight × 100



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**Table 2.** Composition of diet ingredients for New Zealand White rabbits

| Ingredient | G1 | G2 | G3 | G4 | G5 |
|---|---|---|---|---|---|
| Clover Hay (12%) | 30 | 22.50 | 15 | 7.5 | -- |
| Panicum maximum | - | 7.50 | 15 | 22.50 | 30 |
| Wheat bran | 21.71 | 21.71 | 21.71 | 21.71 | 21.71 |
| Barley grains ,Ground | 20 | 20 | 20 | 20 | 20 |
| Soybean meal (44% CP) | 13.5 | 13.5 | 13.5 | 13.5 | 13.5 |
| Yellow corn, ground | 10 | 10 | 10 | 10 | 10 |
| Wheat straw | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 |
| Dl-Methionine | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 |
| Premix* | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 |
| Na Cl | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 |
| Di calcium phosphate | 1.19 | 1.19 | 1.19 | 1.19 | 1.19 |
| CaCO3 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 |
| Total (kg) | 100 | 100 | 100 | 100 | 100 |
| **Calculated values*** | | | | | |
| Crude protein (%) | 17.24 | 17.26 | 17.12 | 17.39 | 16.51 |
| ME, kcal/kg diet | 2520 | 2523 | 2538 | 2516 | 2633 |
| Crude fiber (%) | 12.00 | 13.14 | 14.25 | 15.67 | 14.31 |
| Ether extract (%) | 2.59 | 2.45 | 2.33 | 1.65 | 1.43 |
| Calcium (%) | 1.1 | 1.21 | 1.32 | 1.43 | 1.45 |
| Available phosphorus | 0.42 | 0.46 | 0.52 | 0.58 | 0.61 |
| Lysine (%) | 0.82 | 0.84 | 0.87 | 0.95 | 0.95 |
| Methionine | 0.60 | 0.59 | 0.59 | 0.58 | 0.56 |

G1: Control, 0% *Panicum maximum,* G2: 25% *Panicum maximum,* G3: 50% *Panicum maximum,* G4: 75% *Panicum maximum,* G5: 100% *Panicum maximum*,*The premix (Vitamins and Minerals) was added at a rate of 3 kg per ton of diet and supplied the following per kg of diet (as mg or I.U. per kg of diet): Vitamin A 12000 I.U., Vitamin D3 2000 I.U., Vitamin E 40 mg, Vitamin K3 4 mg, Vitamin B1 3 mg, Vitamin B2 6 mg, Vitamin B6 4 mg, Vitamin B12 0.03 mg, Niacine 30 mg, Biotine 0.08 mg, Pantothenic acid 12 mg, Folic acid 1.5 mg, Choline chloride 700 mg, Mn 80 mg, Cu 10 mg, Se 0.2 mg, I 40 mg, Fe 40 mg, Zn 70 mg, and Co 0.25mg. ME: Metabolizable energy. *According to Feed Composition Tables for animal and poultry feedstuffs used in Egypt (2001).

### Blood samples collection

In the early morning, blood samples (about 3 ml) were obtained from the lateral ear vein of an individual rabbit and collected in Eppendorf with anticoagulant (Cal-heparin - 5000 IU). This collection was done at the beginning, after one month, and end of the experiment.

### Hematology profile

The collected heparinized blood samples were investigated for blood hemoglobin (Hb, g/dl) concentration, hematocrit percentage (Ht, %), erythrocyte (RBCs), and total leukocyte counts (WBCs) (Jain, 1993). In the next step, plasma was separated by centrifuged blood samples at 3000 rpm for 15 minutes. and stored at -20ºC until different biochemical tests were applied.

### Biochemical tests

All biochemical parameters of plasma including total protein (TP, g/dl), albumin (A, g/dl), creatinine (CRE, mg/dl), urea nitrogen (PUN, mg/dl), total cholesterol (CHO, mg/dl), triglycerides (TG, mg/dl), and glucose (GLU, mg/dl) concentrations were determined. Globulin was calculated by subtracting albumin from total protein. Moreover, plasma enzymatic activities of alanine amino-transaminase (ALT, µl/l) and aspartate amino-transferase (AST, µl/l) were determined using commercial kits (Diamond Diagnostics, Halliston, MA, USA).

### Histopathological examination

At the end of the experiment (13 weeks of age), three rabbits were collected from each group and sacrificed. Liver, Kidney, Cecum, and Rectum samples were collected, then fixed in formalin saline 10% for 24 hours, Washed under tap water, dehydrated by serial dilutions of alcohol (methyl, ethyl, and absolute ethyl), cleared in xylene, and embedded in paraffin in a hot air oven at 56°C/24 hours. tissue sectioning was done by sledge microtome at a thickness of 4 microns then collected on glass slides, and stained by hematoxylin and eosin stain to be examined by light electric microscope (Photolab, Nikon camera, Japan, Mescher, 2016).

### Statistical analysis

In this experiment, three factors were studied. The first factor was the replacing level of PM (0%, 25%, 50%, 75%, and 100%) in pelleted diet, the second was animal gender, and the third factor was the animal age and their interactions. Data were analyzed by one-way analysis of variance (ANOVA), followed by Duncan's multiple range tests (Duncan, 1955) for significant between means ($p \leq 0.05$) by SAS (2009), Version 9.2.



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## RESULTS AND DISCUSSION

### Growth performance

***Total feed intake and feed conversion efficiency***

According to Table 3, the calculated values of daily weight gain reported as 16.16, 16.52, 16.04, 15.97, and 15.71 grams/rabbit for 0%, 25%, 50%, 75%, and 100% groups, respectively, which was almost similar among groups. However, weekly weight gain values showed minor differences across experimental groups (113.14, 115.70, 112.26, 111.83, and 109.82 grams/rabbit for 0%, 25%, 50%, 75%, and 100% groups, respectively). On the other hand, final live body weight had highly significant differences among groups where rabbits fed 25% and 50% PM recorded the higher values of final body weight (1758.85 and 1738.76 gram/rabbit), compared to 75% (1726.75 grams/rabbit) and 100% groups (1709.72 grams/rabbit). The higher final live body weight of rabbits on 25% and 50% diets could be due to the high efficient utilization of nutrients by the rabbits.

**Table 3.** The productive performance of growing New Zealand White rabbits fed different levels of *Panicum maximum* in their diets

| Traits | Sex | Experimental groups | | | | | Overall mean |
|---|---|---|---|---|---|---|---|
| | | Control | 25% PM | 50% PM | 75% PM | 100% PM | |
| Initial body weight | M | $854.5^{a} \pm 1.43$ | $846.3^{b} \pm 2.61$ | $840.8^{b} \pm 5.59$ | $827.3^{b} \pm 9.84$ | $829.8^{b} \pm 8.826$ | $839.7^{A} \pm 7.05$ |
| | F | $748.3^{B} \pm 3.08$ | $759.7^{a} \pm 3.46$ | $785.7^{a} \pm 7.87$ | $782.7^{a} \pm 3.66$ | $779.7^{a} \pm 8.44$ | $771.2^{B} \pm 9.19$ |
| Average | | $809 \pm 4.46$ | $809.14 \pm 2.78$ | $817.14 \pm 6.25$ | $808.14 \pm 6.66$ | $808.29 \pm 8.18$ | $810.3^{B} \pm 8.02$ |
| Final body weight | M | $1928^{b} \pm 6.79$ | $1937^{a} \pm 2.66$ | $1898^{ab} \pm 2.62$ | $1882^{ab} \pm 2.52$ | $1856^{c} \pm 3.65$ | $1900^{A} \pm 1.92$ |
| | F | $1485^{b} \pm 2.64$ | $1520^{a} \pm 1.86$ | $1525^{a} \pm 3.58$ | $1517^{a} \pm 2.43$ | $1513^{a} \pm 1.36$ | $1512^{B} \pm 1.91$ |
| Average | | $1738 \pm 4.8$ | $1758 \pm 2.57$ | $1738 \pm 2.41$ | $1726 \pm 2.55$ | $1709 \pm 2.01$ | $1734^{A} \pm 1.58$ |
| Total weight gain | M | 1073.5 | 1091 | 1057 | 1055 | 1026 | 1060.5 |
| | F | 736.7 | 760.3 | 739.3 | 734.3 | 733.3 | 740.78 |
| Average | | 905.1 | 925.65 | 898.15 | 894.65 | 879.65 | 900.64 |
| Weekly weight gain | M | 134.2 | 136.375 | 132.125 | 131.875 | 128.25 | 132.565 |
| | F | 92.087 | 95.037 | 92.412 | 91.787 | 91.662 | 92.597 |
| Average | | 113.143 | 115.706 | 112.268 | 111.831 | 109.826 | 112.581 |
| Daily weight gain | M | 19.17 | 19.482 | 18.875 | 18.839 | 18.321 | 18.937 |
| | F | 13.155 | 13.577 | 13.212 | 13.112 | 13.095 | 13.23 |
| Average | | 16.162 | 16.529 | 16.043 | 15.975 | 15.708 | 16.083 |
| Total feed intake | M | 5676 | 6108 | 6550 | 6674 | 7070 | 6415.6 |
| | F | 5520 | 5839 | 5818 | 5993 | 6918 | 6017.6 |
| Average | | 5598 | 5973.5 | 6184 | 6333.5 | 6994 | 6216.6 |
| Feed conversion ratio | M | 5.287 | 5.6 | 6.196 | 6.326 | 6.743 | 6.03 |
| | F | 7.493 | 7.68 | 7.869 | 8.161 | 9.434 | 8.127 |
| Average | | 6.39 | 6.64 | 7.032 | 7.243 | 8.088 | 7.078 |

PM: *Panicum maximum*, M: Males, F: Females, $^{a,b}$: Means on the same row not followed by the same letter are significantly different ($p < 0.05$). $^{A,B}$: Means on the same column not followed by the same letter are significantly different ($p < 0.05$).

Concerning the effect of gender type, males recorded higher values for final body weight (1928, 1937, 1898, 1882, and 1856 grams for 0%, 25%, 50%, 75%, and 100% groups, respectively) versus female values (1485, 1520, 1525, 1517, and 1513 grams for 0%, 25%, 50%, 75%, and 100% groups, respectively). The results for the total weight gain followed the same trend as that of the final body weight where rabbits fed 25% and 50% diets had significantly higher ($p < 0.05$) total weight gain (925.65 and 898.15 grams/rabbit) while those on 75% and 100% diets had the lowest total weight gain (894.65 and 879.65 grams/rabbit). In harmony with the current results, Mahrous et al. (2012) reported that sex plays a significant role in feed intake, body weight, and feed conversion ratio where males had higher values than females which could be attributed to the anabolic effect of male androgen hormone. Moreover, Zapletal et al. (2020) reported that age and sex were significantly affecting live body weight (LBW) where males were higher in LBW at 49 and 63 days than females. In contrast, Iyeghe-Erakpotobor et al. (2001) reported that female rabbits grew slightly faster than male ones. Iyeghe-Erakpotobor and Adeyegun (2012) observed that weight gain was higher for female than male rabbits fed 10% and 20% groundnut forage meal. On the other hand, Laxmi et al. (2009) showed that there were no significant differences between male and female rabbits in body weights at ages 4, 8, and 16 weeks. Salisu and Iyeghe-Erakpotobor (2014) stated that both the age and sex of rabbits did not influence nutrient intake and digestibility. Bello et al. (2016) and Okanlawon et al. (2020) mentioned that sex did not significantly influence the growth performance parameters of rabbits.

Regarding total feed intake, there was a significant difference $p < 0.05$ among all groups when compared with control where total feed intake per rabbit increased with the increase of dietary PM level ($p < 0.05$). Rabbits fed diet 0% PM (control group) had the lowest total feed intake/rabbit and the superior feed conversion ratio followed by 25%, 50%, 75%, and 100% PM. Total feed intake averages recorded 5598, 5973.5, 6184, 6333.5, and 6994 grams/rabbit/56 days for 0%, 25%, 50%, 75%, and 100% PM , respectively. In this respect, this trend could be attributed to the acceptability, palatability of PM, and subsequent optimal utilization of the feed consumed by the experimentally growing rabbits.



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Feed conversion ratio results showed that rabbits on 75% and 100% recorded poor feed conversion ratio, compared to those in 25% and 50% groups. This suggests poorer feed conversion of these levels of PM in pelleted diets may be due to the dry matter digestibility values for the rabbits fed 75% and 100% diets which were lower, compared to those on 25% and 50% diets. Concerning the effect of type of gender, results presented in Table 3 indicated that final body weight and feed conversion ratio values were higher for males (1900 grams and 6.03, respectively) than females (1512 grams and 8.12, respectively). On the contrary, Lazzaroni et al. (2009) reported that female rabbits had higher feed intake than males. Iyeghe-Erakpotobor and Adeyegun (2012) observed that feed intake was higher for female than male rabbits fed 10% and 20% groundnut forage meal.

### Hemoglobin, hematocrit, and erythrocyte count

Table 4 exhibited blood hemoglobin concentration (Hb) values were non-significant, 9.86, 9.91, 9.95, and 9.85 g//dl in growing rabbits fed pelleted diets containing graduated levels of PM, 25%, 50%, 75%, and 100%, respectively, compared to the control group (9.93 g/dl).

Concerning the effect of gender and age, the statistical analysis revealed that males had higher average values of hemoglobin concentration (10.20 g/dl) than females (9.63 g/dl). Age followed the same trend where the advancement of age led to a significant increase in blood hemoglobin concentration, 9.83, 10.0, and 9.91 g/dl at 5, 9, and 13 weeks, respectively. The interaction of sex and age was significantly affected by blood hemoglobin concentration where average Hb values for males and females were recorded as 10.09 and 9.56g/dl at week 5, 10.29 and 9.71g/dl at week 9, and 10.21 and 9.61g/dl, at week 13, respectively (Table 4). Regarding the effect of replacement different levels of PM on hematocrit percentage (Ht), there were no significant differences in hematocrit values, 33.51, 33.79, 33.32, and 33.70 g//dl in growing rabbits fed 25%, 50%, 75%, and 100% PM, respectively, when compared to the control group (33.51%). Statistical analysis indicated that males had the higher overall mean (34.28%) than females (32.86%), while there were no significant differences in blood hematocrit percentage with the advancement of age, 33.15%, 33.83%, and 33.72% at 5, 9, and 13 weeks, respectively. The interaction of sex and age was significantly affected by blood hematocrit percentage where average Ht values recorded 33.91% and 32.40% at week 5, 34.50%, and 33.16% at week 9, and 34.44% and 33.01% were recorded at week 13 for males and females, respectively (Table 4).

**Table 4.** Effect of replacing different levels of *Panicum maximum* instead of clover hay in pelleted diets on hemoglobin, hematocrit, and red blood cells count of growing New Zealand White rabbits

| Traits | Age | Sex | Experimental groups | | | | | Overall mean |
|---|---|---|---|---|---|---|---|---|
| | | | Control | 25% PM | 50% PM | 75% PM | 100% PM | |
| Hemoglobin , (g/dl) | Initial | M | 10.09$^{a}$ ± 0.2 | 10.12$^{a}$ ± 0.2 | 10.1$^{a}$ ± 0.2 | 10.1$^{a}$ ± 0.2 | 10.05$^{a}$ ± 0.2 | 10.09$^{A}$ ± 0.2 |
| | | F | 9.89$^{a}$ ± 0.23 | 9.46$^{a}$ ± 0.23 | 9.63$^{a}$ ± 0.23 | 9.69$^{a}$ ± 0.23 | 9.14$^{a}$ ± 0.23 | 9.56$^{B}$ ± 0.23 |
| | Average | | 9.99 ± 0.41 | 9.79 ± 0.41 | 9.86 ± 0.41 | 9.89 ± 0.41 | 9.60 ± 0.41 | 9.83$^{NS}$ ± 0.41 |
| | Med | M | 10.23$^{a}$ ± 0.2 | 10.17$^{a}$ ± 0.2 | 10.33$^{a}$ ± 0.2 | 10.29$^{a}$ ± 0.2 | 10.45$^{a}$ ± 0.2 | 10.29$^{A}$ ± 0.2 |
| | | F | 9.58$^{a}$ ± 0.23 | 9.64$^{a}$ ± 0.23 | 9.51$^{a}$ ± 0.23 | 9.77$^{a}$ ± 0.23 | 10.07$^{a}$ ± 0.23 | 9.71$^{B}$ ± 0.23 |
| | Average | | 9.90 ± 0.41 | 9.90 ± 0.41 | 9.92 ± 0.41 | 10.03 ± 0.41 | 10.06 ± 0.41 | 10.00$^{NS}$ ± 041 |
| | Final | M | 10.25$^{a}$ ± 0.2 | 10.28$^{a}$ ± 0.2 | 10.26$^{a}$ ± 0.2 | 10.24$^{a}$ ± 0.2 | 10.03$^{a}$ ± 0.2 | 10.21$^{A}$ ± 0.2 |
| | | F | 9.56$^{a}$ ± 0.23 | 9.49$^{a}$ ± 0.23 | 9.62$^{a}$ ± 0.23 | 9.62$^{a}$ ± 0.23 | 9.78$^{a}$ ± 0.23 | 9.61$^{B}$ ± 0.23 |
| | Average | | 9.90 ± 0.41 | 9.90 ± 0.41 | 9.94 ± 0.41 | 9.93 ± 0.41 | 9.90 ± 0.41 | 9.91$^{NS}$ ± 0.41 |
| Hematocrit, ( %) | Initial | M | 33.92$^{a}$ ± 0.57 | 33.92$^{a}$ ± 0.57 | 34.27$^{a}$ ± 0.57 | 34.26$^{a}$ ± 0.57 | 33.20$^{a}$ ± 0.57 | 33.91$^{A}$ ± 0.57 |
| | | F | 32.40$^{a}$ ± 0.65 | 32.44$^{a}$ ± 0.65 | 32.48$^{a}$ ± 0.65 | 32.92$^{a}$ ± 0.65 | 31.67$^{a}$ ± 0.65 | 32.40$^{B}$ ± 0.65 |
| | Average | | 33.12 ± 0.61 | 33.18 ± 0.61 | 33.37 ± 0.61 | 33.59 ± 0.61 | 32.43 ± 0.61 | 33.15$^{NS}$ ± 0.61 |
| | Med | M | 34.89$^{a}$ ± 0.57 | 34.47$^{a}$ ± 0.57 | 34.21$^{a}$ ± 0.57 | 34.32$^{a}$ ± 0.57 | 34.60$^{a}$ ± 0.57 | 34.50$^{A}$ ± 0.57 |
| | | F | 33.25$^{a}$ ± 0.65 | 33.00$^{a}$ ± 0.65 | 32.95$^{a}$ ± 0.65 | 33.36$^{a}$ ± 0.65 | 33.25$^{a}$ ± 0.65 | 33.16$^{B}$ ± 0.65 |
| | Average | | 34.07 ± 0.61 | 33.73 ± 0.61 | 33.60 ± 0.61 | 33.84 ± 0.61 | 33.92 ± 0.61 | 33.83$^{NS}$ ± 0.61 |
| | Final | M | 34.56$^{a}$ ± 0.57 | 34.25$^{a}$ ± 0.57 | 34.40$^{a}$ ± 0.57 | 34.75$^{a}$ ± 0.57 | 34.22$^{a}$ ± 0.57 | 34.44$^{A}$ ± 0.57 |
| | | F | 33.27$^{a}$ ± 0.65 | 33.02$^{a}$ ± 0.65 | 32.74$^{a}$ ± 0.65 | 33.11$^{a}$ ± 0.65 | 32.92$^{a}$ ± 0.65 | 33.01$^{B}$ ± 0.65 |
| | Average | | 33.91 ± 0.61 | 33.63 ± 0.61 | 33.57 ± 0.61 | 33.93 ± 0.61 | 33.60 ± 0.61 | 33.72$^{NS}$ ± 0.61 |
| Erythrocytic count , ($X10^6/mm^3$) | Initial | M | 5.24$^{b}$ ± 0.14 | 5.45$^{a}$ ± 0.14 | 5.56$^{a}$ ± 0.14 | 5.59$^{a}$ ± 0.14 | 5.50$^{a}$ ± 0.14 | 5.48$^{A}$ ± 0.14 |
| | | F | 4.58$^{b}$ ± 0.16 | 4.92$^{a}$ ± 0.16 | 4.98$^{a}$ ± 0.16 | 5.08$^{a}$ ± 0.16 | 4.95$^{a}$ ± 0.16 | 4.98$^{B}$ ± 0.16 |
| | Average | | 5.16 ± 0.15 | 5.18 ± 0.15 | 5.27 ± 0.15 | 5.33 ± 0.15 | 5.22 ± 0.15 | 5.23 ± 0.15 |
| | Med | M | 5.29$^{b}$ ± 0.14 | 5.60$^{a}$ ± 0.14 | 5.55$^{a}$ ± 0.14 | 5.69$^{a}$ ± 0.14 | 5.61$^{a}$ ± 0.14 | 5.70$^{A}$ ± 0.14 |
| | | F | 4.29$^{b}$ ± 0.16 | 5.09$^{a}$ ± 0.16 | 4.99$^{a}$ ± 0.16 | 5.38$^{a}$ ± 0.16 | 5.12$^{a}$ ± 0.16 | 5.11$^{B}$ ± 0.16 |
| | Average | | 5.24 ± 0.15 | 5.34 ± 0.15 | 5.30 ± 0.15 | 5.38 ± 0.15 | 5.36 ± 0.15 | 5.40$^{*}$ ± 0.15 |
| | Final | M | 5.29$^{b}$ ± 0.14 | 5.90$^{a}$ ± 0.14 | 5.59$^{a}$ ± 0.14 | 5.67$^{a}$ ± 0.14 | 5.41$^{a}$ ± 0.14 | 5.57$^{A}$ ± 0.14 |
| | | F | 4.51$^{b}$ ± 0.16 | 5.09$^{a}$ ± 0.16 | 4.99$^{a}$ ± 0.16 | 4.89$^{a}$ ± 0.16 | 5.12$^{a}$ ± 0.16 | 4.98$^{B}$ ± 0.16 |
| | Average | | 5.05 ± 0.15 | 5.49 ± 0.15 | 5.29 ± 0.15 | 5.28 ± 0.15 | 5.26 ± 0.15 | 5.30$^{*}$ ± 0.15 |

PM: *Panicum maximum*, M: Males, F: Females, Initial: 5 weeks of age, Med: 9 weeks of age, Final: 13 weeks of age, $^{a,b}$: Means on the same row not followed by the same letter are significantly different ($p < 0.05$). $^{A,B}$: Means on the same column not followed by the same letter are significantly different ($p < 0.05$). *: Significant ($p < 0.05$), NS: Non-significant ($p > 0.05$).



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There was a significant increase in RBCs (5.34, 5.29, 5.33, and 5.28 × $10^6$/$mm^3$) in all treated groups with different levels of PM (25%, 50%, 75%, and 100%, respectively), compared to the control group (5.15 × $10^6$/$mm^3$). Concerning the effect of sex, results indicated that males had the highest value (5.58 × $10^6$/$mm^3$) than females (5.02 × $10^6$/$mm^3$). Concerning the effect of advanced age on RBCs, there were significant differences between RBCs values, 5.23, 5.40, and 5.30 × $10^6$/$mm^3$ at 5, 9, and 13 weeks, respectively. The interaction of sex and age was significantly affected by RBCs count where average RBCs values recorded 5.48 and 4.98 at week 5, 5.70 and 5.11 at week 9 while at 13 weeks the recorded values were 5.57 and 4.98 × $10^6$/$mm^3$ for males and females, respectively (Table 4).

These findings were in agreement with those of Nuhu (2010), Olatunji et al. (2016), and Abo El-Haded et al. (2017) who stated that hematological parameters (Hb, Ht, RBCs, and WBCs) showed non-significant differences in growing rabbits fed diets with graded levels of *Moringa Oleifera* for 8 weeks. Recently, Refaie et al. (2020) observed that rabbits fed pelleted diets containing different levels of PM, 15%, 30%, and 45% had no significant effect on Hb and Ht. In another study, Adegun et al. (2018) studied the effect of replacement different levels of PM fodder (0%, 0.5%, 1%, 1.5%, and 2%) with a concentrate on hematological parameters of Yankasa rams and found that 2% PM had the highest Ht and RBCs values, 32.08 ± 0.3% and 10.17 ± 0.21 × $10^6$ /µl, respectively, while 0.5% PM had the lowest values. Addass et al. (2012) reported both age and sex were significantly affected by hematological parameters in chickens, where the group aged 150 days recorded the highest WBCs and Ht while those aged 90 days indicated higher RBCs value. Furturmore, Isaac et al. (2013) observed that the males had the highest values of RBCs, Hb, Ht, and WBCs than females, all recorded hematological parameters values were within the normal physiological range for healthy rabbits (Archetti et al., 2008; Etim et al., 2014; Abo El-Haded et al., 2017).

**Leukocytes count responses**

Table 5 showed WBCs count values had no significance differences, 6.56, 6.74, 6.73, 6.59, and 6.64 × $10^3$/$mm^3$ in 0%, 25%, 50%, 75%, and 100% PM respectively. These results were in agreement with those of Adegun et al. (2018) who reported non-significant differences in WBCs count of Yankasa rams fed PM at levels of 0%, 0.5%,1%, 1.5%, and 2.0%. Additionally, Jiwuba et al. (2016) found that WBCs count and neutrophil percentage were not influenced by the supplementation of PM at different levels of 0%, 20%, 40%, and 60% into fufu sieviate meal based diets ($p > 0.05$).

On the contrary, Jiwuba (2014) and Salem et al. (2020) found WBCs increased significantly in growing rabbits fed *Moringa Oleifera* leaf meal (MOLM) at 10, 20, and 30% for seven weeks. Refaie et al. (2020) recorded fewer WBCs count in rabbits fed 45% PM. in this study all recorded WBCs values ranged 5.50-7.5 × $10^3$/$mm^3$ which fall within the normal physiological range of healthy rabbits, 4.5-11 × $10^3$/$mm^3$ (RAR, 2009). Concerning the effect of sex, females had WBC's values, 6.91 × $10^3$/$mm^3$ higher than males, 6.39 × $10^3$/$mm^3$. Concerning the effect of age, there were differences between WBC's values with the advancement of age, 6.31, 6.83, and 6.80 × $10^3$/$mm^3$ at 5, 9, and 13 weeks, respectively. The interaction between sex and age was significantly ($p \leq 0.05$) affect WBC's values which recorded 6.08 and 6.53 at 5 weeks, 6.60 and 7.10 at 9 weeks while at 13 weeks recorded 6.50 and 7.10 × $10^3$/$mm^3$ for males and females, respectively.

**Table 5.** Effect of replacing different levels of *Panicum maximum* instead of clover hay in pelleted diets on the total leukocytic count of growing New Zealand White rabbits

| Traits | Age | Sex | Experimental groups | | | | | Overall mean |
|---|---|---|---|---|---|---|---|---|
| | | | Control | 25% PM | 50% PM | 75% PM | 100% PM | |
| White blood cells count , (WBC's X$10^3$/$mm^3$) | Initial | M | $5.99^a \pm 0.16$ | $6.01^a \pm 0.16$ | $6.03^a \pm 0.16$ | $5.97^a \pm 0.16$ | $6.01^a \pm 0.16$ | $6.08^B \pm 0.16$ |
| | | F | $6.18^a \pm 0.18$ | $6.12^a \pm 0.18$ | $6.12^a \pm 0.18$ | $6.18^b \pm 0.18$ | $6.17^a \pm 0.18$ | $6.53^A \pm 0.18$ |
| | Average | | 6.04 ± 0.17 | 6.50 ± 0.17 | 6.40 ± 0.17 | 6.10 ± 0.17 | 6.60 ± 0.17 | 6.31 ± 0.05 |
| | Med | M | $6.67^a \pm 0.16$ | $6.62^a \pm 0.16$ | $6.82^a \pm 0.16$ | $6.52^a \pm 0.16$ | $6.55^a \pm 0.16$ | $6.60^B \pm 0.16$ |
| | | F | $7.05^a \pm 0.18$ | $7.12^a \pm 0.18$ | $7.15^a \pm 0.18$ | $7.15^a \pm 0.18$ | $6.97^a \pm 0.18$ | $7.10^A \pm 0.18$ |
| | Average | | 6.90 ± 0.17 | 6.90 ± 0.17 | 6.98 ± 0.17 | 6.83 ± 0.17 | 6.61 ± 0.17 | $6.83^* \pm 0.05$ |
| | Final | M | $6.45^a \pm 0.16$ | $6.54^a \pm 0.16$ | $6.47^a \pm 0.16$ | $6.54^a \pm 0.16$ | $6.36^a \pm 0.16$ | $6.50^B \pm 0.16$ |
| | | F | $7.02^a \pm 0.18$ | $7.12^a \pm 0.18$ | $7.12^a \pm 0.18$ | $7.16^a \pm 0.18$ | $6.98^a \pm 0.18$ | $7.10^A \pm 0.18$ |
| | Average | | 6.73 ± 0.17 | 6.83 ± 0.17 | 6.80 ± 0.17 | 6.85 ± 0.17 | 6.70 ± 0.17 | $6.8^* \pm 0.05$ |

PM: *Panicum maximum*, M: Males, F: Females, Initial: 5 weeks of age, Med: 9 weeks of age, Final: 13 weeks of age, $mm^3$: cubic milliliter, a,b: Means on the same row not followed by the same letter are significantly different ($p < 0.05$). A,B: Means on the same column not followed by the same letter are significantly different ($p < 0.05$). *: Significant ($p < 0.05$)

**Plasma biochemical parameters**

***Plasma proteins responses***

There was a similarity between determined values of treated groups and control group where TP values recorded 6.33, 6.21, 6.12, 6.15, and 5.99 g/dl; Albumin values (A) recorded 2.99, 2.90, 2.85 2.76, and 2.83 g/dl; Globulin values (G) recorded 3.35, 3.37, 3.42, 3.49, and 3.24 g/dl, and albumin/globulin (A/G) ratio recoded 0.89, 0.86, 0.83, 0.79, and 0.87% for 0%, 25%, 50%, 75%, and 100% PM, respectively.



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Concerning the effect of sex, the obtained results indicated that plasma TP, A, and G concentrations were influenced significantly by sex where male rabbits had higher values, 6.39, 2.94, and 3.45 g/dl than females, 6.03, 2.78, and 3.22 g/dl, respectively. The calculated A/G ratio was not influenced significantly by the type of gender where the value was similar, 0.88 and 0.89 in male and female rabbits, respectively. Regarding the effect of age, Table 6 showed that the age positively affected TP and G where total protein increased significantly ($p < 0.05$) with the advancement of age, 6.05, 6.14, and 6.35 g/dl at 5, 9, and 13 weeks, respectively. Globulin increased significantly ($p < 0.05$) with the advancement of age, 3.13, 3.47, and 3.41 g//dl at weeks 5, 9, and 13, respectively, while albumin decreased significantly ($p < 0.05$) with the advancement of age, 2.92, 2.82, and 2.88 g/dl at weeks 5, 9, and 13, respectively, and subsequently A/G ratio decreased significantly ($p < 0.05$) with the advancement of age, 0.93, 0.90, and 0.86% at weeks 5, 9, and 13, respectively. The interaction of sex and age could significantly ($p \leq 0.05$) influence total proteins where average TP values recorded 6.32 and 5.89 at week 5, 6.29, and 6.15 at week 9 while recorded 6.57 and 6.04 g/dl at week 13 for males and females, respectively. Average albumin values were recorded 2.98 and 2.86 at week 5, 2.89, and 2.75 at week 9 while at week 13 the values were recorded as 2.96 and 2.72 g/dl for males and females, respectively. Average globulin values recorded 3.34 and 3.03 at week 5, 3.4 and 3.3 at week 9, while at 3.61 and 3.32 g/dl at week 13 for males and females, respectively (Table 6). In the same vein, Makanjuola et al. (2014) stated that the serum TP, A, and G concentrations of broiler chickens were not affected by the dietary supplementation of *Moringa oleifera* leaf meal (up to 0.6%). On the contrary, Adegun et al. (2018) found TP, A, and G of Yankasa rams increased significantly when fed PM fodder at 0%, 0.5%,1%, 1.5%, and 2%.

**Table 6.** Effect of replacement different levels of *Panicum maximum* instead of clover hay in pelleted diets on plasma total proteins, albumin, globulin concentrations, and albumin/globulin ratio of growing New Zealand White rabbits

| Traits | Age | Sex | Experimental groups | | | | | Overall mean |
|---|---|---|---|---|---|---|---|---|
| | | | Control | 25% PM | 50% PM | 75% PM | 100% PM | |
| Total protein (g/dl) | Initial | M | 6.28$^{a}$ ± 0.14 | 6.17$^{a}$ ± 0.14 | 6.03$^{a}$ ± 0.14 | 6.15$^{a}$ ± 0.14 | 6.23$^{a}$ ± 0.14 | 6.32$^{A}$ ± 0.14 |
| | | F | 5.95$^{a}$ ± 0.16 | 6.01$^{a}$ ± 0.16 | 6.06$^{a}$ ± 0.16 | 5.99$^{a}$ ± 0.16 | 6.10$^{a}$ ± 0.16 | 5.89$^{B}$ ± 0.16 |
| | Average | | 6.43 ± 0.15 | 5.96 ± 0.15 | 5.85 ± 0.15 | 5.96 ± 0.15 | 6.06 ± 0.15 | 6.05 ± 0.15 |
| | Med | M | 6.35$^{a}$ ± 0.14 | 6.34$^{a}$ ± 0.14 | 6.26$^{a}$ ± 0.14 | 6.14$^{a}$ ± 0.14 | 6.26$^{a}$ ± 0.14 | 6.29$^{A}$ ± 0.14 |
| | | F | 6.01$^{a}$ ± 0.16 | 6.33$^{a}$ ± 0.16 | 6.16$^{a}$ ± 0.16 | 6.22$^{a}$ ± 0.16 | 6.10$^{a}$ ± 0.16 | 6.15$^{B}$ ± 0.16 |
| | Average | | 6.17 ± 0.15 | 6.21 ± 0.15 | 6.20 ± 0.15 | 6.18 ± 0.15 | 5.93 ± 0.15 | 6.14$^{*}$ ± 0.15 |
| | Final | M | 6.30$^{a}$ ± 0.14 | 6.50$^{a}$ ± 0.14 | 6.53$^{a}$ ± 0.14 | 6.24$^{a}$ ± 0.14 | 6.43$^{a}$ ± 0.14 | 6.57$^{A}$ ± 0.14 |
| | | F | 6.01$^{a}$ ± 0.16 | 6.19$^{a}$ ± 0.16 | 6.22$^{a}$ ± 0.16 | 6.05$^{a}$ ± 0.16 | 6.10$^{a}$ ± 0.16 | 6.04$^{B}$ ± 0.16 |
| | Average | | 6.38 ± 0.15 | 6.46 ± 0.15 | 6.31 ± 0.15 | 6.31 ± 0.15 | 5.99 ± 0.15 | 6.35$^{*}$ ± 0.015 |
| Albumin (g/dl) | Initial | M | 3.08$^{a}$ ± 0.08 | 2.88$^{a}$ ± 0.08 | 2.88$^{a}$ ± 0.08 | 2.94$^{a}$ ± 0.08 | 2.90$^{a}$ ± 0.08 | 2.98$^{A}$ ± 0.08 |
| | | F | 2.93$^{a}$ ± 0.09 | 2.71$^{a}$ ± 0.09 | 2.78$^{a}$ ± 0.09 | 2.88$^{a}$ ± 0.09 | 2.69$^{a}$ ± 0.09 | 2.86$^{B}$ ± 0.09 |
| | Average | | 3.06 ± 0.08 | 2.90 ± 0.08 | 2.90 ± 0.08 | 2.92 ± 0.08 | 2.94 ± 0.08 | 2.92 ± 0.08 |
| | Med | M | 2.97$^{a}$ ± 0.08 | 2.87$^{a}$ ± 0.08 | 2.80$^{a}$ ± 0.08 | 2.85$^{a}$ ± 0.08 | 2.94$^{a}$ ± 0.08 | 2.89$^{A}$ ± 0.08 |
| | | F | 2.80$^{a}$ ± 0.09 | 2.80$^{a}$ ± 0.09 | 2.69$^{a}$ ± 0.09 | 2.76$^{a}$ ± 0.09 | 2.69$^{a}$ ± 0.09 | 2.75$^{B}$ ± 0.09 |
| | Average | | 2.90 ± 0.08 | 2.90 ± 0.08 | 2.74 ± 0.08 | 2.75 ± 0.08 | 2.75 ± 0.08 | 2.82$^{NS}$ ± 0.08 |
| | Final | M | 3.10$^{a}$ ± 0.08 | 2.98$^{a}$ ± 0.08 | 3.01$^{a}$ ± 0.08 | 2.69$^{a}$ ± 0.08 | 2.91$^{a}$ ± 0.08 | 2.96$^{A}$ ± 0.08 |
| | | F | 2.80$^{a}$ ± 0.09 | 2.76$^{a}$ ± 0.09 | 2.80$^{a}$ ± 0.09 | 2.55$^{a}$ ± 0.09 | 2.69$^{a}$ ± 0.09 | 2.72$^{B}$ ± 0.09 |
| | Average | | 3.00 ± 0.08 | 2.90 ± 0.08 | 2.90 ± 0.08 | 2.62 ± 0.08 | 2.80 ± 0.08 | 2.88$^{NS}$ ± 0.08 |
| Globulin (g/dl) | Initial | M | 3.02$^{b}$ ± 0.13 | 3.29$^{a}$ ± 0.13 | 3.15$^{a}$ ± 0.13 | 3.21$^{a}$ ± 0.13 | 3.33$^{a}$ ± 0.13 | 3.34$^{A}$ ± 0.13 |
| | | F | 3.12$^{b}$ ± 0.15 | 3.31$^{a}$ ± 0.15 | 3.28$^{a}$ ± 0.15 | 3.11$^{a}$ ± 0.15 | 3.41$^{a}$ ± 0.15 | 3.03$^{B}$ ± 0.15 |
| | Average | | 3.37 ± 0.14 | 3.16 ± 0.14 | 3.46 ± 0.14 | 3.51 ± 0.14 | 3.52 ± 0.14 | 3.13 ± 0.14 |
| | Med | M | 3.38$^{b}$ ± 0.13 | 3.46$^{a}$ ± 0.13 | 3.36$^{a}$ ± 0.13 | 3.29$^{a}$ ± 0.13 | 3.32$^{a}$ ± 0.13 | 3.40$^{A}$ ± 0.13 |
| | | F | 3.21$^{b}$ ± 0.15 | 3.29$^{a}$ ± 0.15 | 3.47$^{a}$ ± 0.15 | 3.46$^{a}$ ± 0.15 | 3.41$^{a}$ ± 0.15 | 3.30$^{B}$ ± 0.15 |
| | Average | | 3.29 ± 0.14 | 3.37 ± 0.14 | 3.41 ± 0.14 | 3.37 ± 0.14 | 3.11 ± 0.14 | 3.47$^{*}$ ± 0.14 |
| | Final | M | 3.20$^{b}$ ± 0.13 | 3.52$^{a}$ ± 0.13 | 3.52$^{a}$ ± 0.13 | 3.55$^{a}$ ± 0.13 | 3.52$^{a}$ ± 0.13 | 3.61$^{A}$ ± 0.13 |
| | | F | 3.21$^{b}$ ± 0.15 | 3.43$^{a}$ ± 0.15 | 3.42$^{a}$ ± 0.15 | 3.50$^{a}$ ± 0.15 | 3.41$^{a}$ ± 0.15 | 3.32$^{B}$ ± 0.15 |
| | Average | | 3.39 ± 0.14 | 3.59 ± 0.14 | 3.40 ± 0.14 | 3.59 ± 0.14 | 3.09 ± 0.14 | 3.41$^{*}$ ± 0.14 |
| Albumin/globulin (%) | Initial | M | 0.91$^{a}$ ± 0.05 | 0.93$^{a}$ ± 0.05 | 0.97$^{a}$ ± 0.05 | 0.95$^{a}$ ± 0.05 | 0.95$^{a}$ ± 0.05 | 0.92$^{A}$ ± 0.05 |
| | | F | 0.91$^{a}$ ± 0.05 | 0.96$^{a}$ ± 0.05 | 0.97$^{a}$ ± 0.05 | 0.96$^{a}$ ± 0.05 | 0.90$^{a}$ ± 0.05 | 0.95$^{A}$ ± 0.05 |
| | Average | | 0.91 ± 0.05 | 0.95 ± 0.05 | 0.97 ± 0.05 | 0.95 ± 0.05 | 0.92 ± 0.05 | 0.93 ± 0.05 |
| | Med | M | 0.90$^{a}$ ± 0.05 | 0.84$^{b}$ ± 0.05 | 0.84$^{b}$ ± 0.05 | 0.87$^{b}$ ± 0.05 | 0.89$^{b}$ ± 0.05 | 0.87$^{A}$ ± 0.05 |
| | | F | 0.90$^{a}$ ± 0.05 | 0.86$^{b}$ ± 0.05 | 0.78$^{b}$ ± 0.05 | 0.81$^{b}$ ± 0.05 | 0.83$^{b}$ ± 0.05 | 0.86$^{A}$ ± 0.05 |
| | Average | | 0.90 ± 0.05 | 0.85 ± 0.05 | 0.81 ± 0.05 | 0.82 ± 0.05 | 0.91 ± 0.05 | 0.90$^{*}$ ± 0.05 |
| | Final | M | 0.91$^{a}$ ± 0.05 | 0.80$^{b}$ ± 0.05 | 0.86$^{b}$ ± 0.05 | 0.77$^{b}$ ± 0.05 | 0.89$^{b}$ ± 0.05 | 0.86$^{A}$ ± 0.05 |
| | | F | 0.86$^{a}$ ± 0.05 | 0.81$^{b}$ ± 0.05 | 0.86$^{b}$ ± 0.05 | 0.70$^{b}$ ± 0.05 | 0893$^{b}$ ± 0.05 | 0.86$^{A}$ ± 0.05 |
| | Average | | 0.90 ± 0.05 | 0.81 ± 0.05 | 0.90 ± 0.05 | 0.73 ± 0.05 | 0.91 ± 0.05 | 0.86$^{*}$ ± 0.05 |

PM: *Panicum maximum*, M: Males, F: Females, Initial: 5 weeks of age, Med: 9 weeks of age, Final: 13 weeks of age, g/dl: grams per deciliter. $^{a,b}$: Means on the same row not followed by the same letter are significantly different ($p < 0.05$). $^{A,B}$: Means on the same column not followed by the same letter are significantly different ($p < 0.05$). *: Significant ($p < 0.05$), NS: Non-significant ($p > 0.05$).



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### Liver and kidney functions

#### *Alanine amino transaminase and aspartate aminotransferase enzymes*

The obtained results in Table 7 indicated that there was a similarity between the values of treated groups and those of the control group where ALT values recorded 13.04, 13.21, 13.11, 13.3, and 13.53 µl/l. The corresponding values for AST were 52.91, 53.20, 53.25, 53.38, and 53.45 µl/l for 0%, 25%, 50%, 75%, and 100% PM, respectively. Regarding the effect of sex, the obtained results indicated that plasma ALT and AST concentrations were not significantly affected by sex where ALT values recorded 13.11 and 13.15 µl/l while AST values recorded 53.28 and 53.30 µl/l for males and females, respectively. Regarding the effect of age, Table 7 showed no significant differences in both ALT and AST values with the advancement of age where ALT values were 13.14, 13.15, and 13.49 µl/l at 5, 9, and 13 weeks, respectively while AST values were 53.35, 53.23, and 53.21 µl/l at 5, 9, and 13 weeks, respectively. The interaction between sex and age insignificantly affects both ALT and AST values where average ALT values were recorded 13 and 13.18 at week 5, 13.17 and 13.14 at week 9, and 13.16 and 13.12 µl/l at week 13 for males and females, respectively. Average AST values recorded 53.2 and 53.14 at week 5, 53.33 and 53.33 at week 9 while at week 13 the reported values were 53.30 and 53.43 µl/l for males and females, respectively (Table 7). These results were in line with those of Ghomsi et al. (2017). They reported that there were insignificant differences among rabbits fed 0%, 25%, and 50% *Moringa oleifera* leaf meal (MOLM) instead of soya bean meal regarding ALT and AST enzyme activities which means the proper functioning of the liver, kidney, and muscles. Olatunji et al. (2016) and Abo El-Haded et al. (2017) reported that both ALT and AST enzymes activities were not affected by rabbits fed diets containing *Moringa oleifera* leaf meal up to 20%. Omer et al. (2018) reported that albumin, AST, and creatinine concentrations were not affected in rabbits when replaced 50% of Berseem hay (BH) by agriculture by-products, such as Mung bean husks (MBH), soybean vein hay (SBVH), or peanut vein hay (PVH) in their diets while TP and globulin increased significantly.

**Table 7.** Effect of replacement different levels of *Panicum maximum* instead of clover hay in pelleted diets on plasma ALT, AST, CHO, and TG concentrations of growing New Zealand White rabbits

| Traits | Age | Sex | Experimental groups | | | | | Overall mean |
|---|---|---|---|---|---|---|---|---|
| | | | Control | 25% PM | 50% PM | 75% PM | 100% PM | |
| ALT (µl/l) | Initial | M | $12.99^{a}$ ± 0.46 | $12.98^{a}$ ± 0.46 | $12.96^{a}$ ± 0.46 | $12.92^{a}$ ± 0.46 | $13.36^{a}$ ± 0.46 | $13.00^{A}$ ± 0.46 |
| | | F | $12.95^{a}$ ± 0.54 | $12.98^{a}$ ± 0.54 | $12.95^{a}$ ± 0.54 | $13.45^{a}$ ± 0.54 | $13.47^{a}$ ± 0.54 | $13.18^{A}$ ± 0.54 |
| | Average | | 12.97 ± 0.50 | 13.10 ± 0.50 | 12.92 ± 0.50 | 13.10 ± 0.50 | 13.20 ± 0.50 | 13.14 ± 0.50 |
| | Med | M | $12.96^{a}$ ± 0.46 | $12.92^{a}$ ± 0.46 | $13.15^{a}$ ± 0.46 | $13.21^{a}$ ± 0.46 | $13.22^{a}$ ± 0.46 | $13.17^{A}$ ± 0.46 |
| | | F | $13.08^{a}$ ± 0.54 | $13.03^{a}$ ± 0.54 | $13.17^{a}$ ± 0.54 | $13.15^{a}$ ± 0.54 | $13.17^{a}$ ± 0.54 | $13.14^{A}$ ± 0.54 |
| | Average | | 13.02 ± 0.50 | 13.40 ± 0.50 | 13.30 ± 0.50 | 13.30 ± 0.50 | 13.64 ± 0.50 | $13.15^{NS}$ ± 0.50 |
| | Final | M | $12.97^{a}$ ± 0.46 | $12.92^{a}$ ± 0.46 | $12.92^{a}$ ± 0.46 | $13.11^{a}$ ± 0.46 | $13.42^{a}$ ± 0.46 | $13.16^{A}$ ± 0.46 |
| | | F | $13.03^{a}$ ± 0.54 | $13.05^{a}$ ± 0.54 | $13.12^{a}$ ± 0.54 | $13.17^{a}$ ± 0.54 | $13.27^{a}$ ± 0.54 | $13.12^{A}$ ± 0.54 |
| | Average | | 13.12 ± 0.50 | 13.13 ± 0.50 | 13.10 ± 0.50 | 13.50 ± 0.50 | 13.74 ± 0.50 | $13.49^{NS}$ ± 0.50 |
| AST (µl/l) | Initial | M | $53.01^{a}$ ± 1.00 | $53.04^{a}$ ± 1.00 | $53.14^{a}$ ± 1.00 | $53.12^{a}$ ± 1.00 | $53.23^{a}$ ± 1.00 | $53.20^{A}$ ± 1.00 |
| | | F | $53.97^{a}$ ± 1.15 | $53.19^{a}$ ± 1.15 | $53.05^{a}$ ± 1.15 | $53.37^{a}$ ± 1.15 | $53.18^{a}$ ± 1.15 | $53.14^{A}$ ± 1.15 |
| | Average | | 52.50 ± 1.07 | 53.30 ± 1.07 | 53.20 ± 1.07 | 53.70 ± 1.07 | 53.95 ± 1.07 | 53.35 ± 1.07 |
| | Med | M | $53.06^{a}$ ± 1.10 | $53.19^{a}$ ± 1.00 | $53.08^{a}$ ± 1.00 | $53.17^{a}$ ± 1.00 | $53.15^{a}$ ± 1.00 | $53.33^{A}$ ± 1.00 |
| | | F | $53.07^{a}$ ± 1.15 | $53.01^{a}$ ± 1.15 | $53.43^{a}$ ± 1.15 | $53.08^{a}$ ± 1.15 | $53.08^{a}$ ± 1.15 | $53.33^{A}$ ± 1.15 |
| | Average | | 53.11 ± 1.07 | 53.10 ± 1.07 | 53.05 ± 1.07 | 53.22 ± 1.07 | 53.10 ± 1.07 | $53.23^{NS}$ ± 1.07 |
| | Final | M | $53.01^{a}$ ± 1.00 | $53.14^{a}$ ± 1.00 | $53.59^{a}$ ± 1.00 | $5334^{a}$ ± 1.00 | $53.02^{a}$ ± 1.00 | $53.30^{A}$ ± 1.00 |
| | | F | $53.11^{a}$ ± 1.15 | $53.08^{a}$ ± 1.15 | $53.41^{a}$ ± 1.15 | $53.09^{a}$ ± 1.15 | $53.18^{a}$ ± 1.15 | $53.43^{A}$ ± 1.15 |
| | Average | | 53.13 ± 1.07 | 53.21 ± 1.07 | 53.50 ± 1.07 | 53.21 ± 1.07 | 53.30 ± 1.07 | $53.21^{NS}$ ± 1.07 |
| CHO (mg/dl) | Initial | M | $86.61^{a}$ ± 1.04 | $84.36^{b}$ ± 1.04 | $84.08^{b}$ ± 1.04 | $83.18^{b}$ ± 1.04 | $80.64^{b}$ ± 1.04 | $84.57^{A}$ ± 1.04 |
| | | F | $83.02^{a}$ ± 1.21 | $81.93^{b}$ ± 1.21 | $79.22^{b}$ ± 1.21 | $79.22^{b}$ ± 1.21 | $78.51^{b}$ ± 1.21 | $80.94^{B}$ ± 1.21 |
| | Average | | 83.91 ± 1.12 | 83.14 ± 1.12 | 82.05 ± 1.12 | 81.20 ± 1.12 | 79.57 ± 1.12 | 82.75 ± 1.12 |
| | Med | M | $82.71^{a}$ ± 1.04 | $81.57^{b}$ ± 1.04 | $80.91^{b}$ ± 1.04 | $78.46^{b}$ ± 1.04 | $80.19^{b}$ ± 1.04 | $81.40^{A}$ ± 1.04 |
| | | F | $79.11^{a}$ ± 1.21 | $77.52^{b}$ ± 1.21 | $77.81^{b}$ ± 1.21 | $77.61^{b}$ ± 1.21 | $78.51^{b}$ ± 1.21 | $78.71^{B}$ ± 1.21 |
| | Average | | 80.41 ± 1.12 | 79.54 ± 1.12 | 79.40 ± 1.12 | 78.03 ± 1.12 | 78.35 ± 1.12 | $80.05^{*}$ ± 1.12 |
| | Final | M | $79.73^{a}$ ± 1.04 | $79.09^{b}$ ± 1.04 | $78.57^{b}$ ± 1.04 | $78.38^{b}$ ± 1.04 | $78.69^{b}$ ± 1.04 | $78.79^{A}$ ± 1.04 |
| | | F | $78.52^{a}$ ± 1.21 | $76.61^{b}$ ± 1.21 | $75.52^{b}$ ± 1.21 | $76.25^{b}$ ± 1.21 | $75.51^{b}$ ± 1.21 | $76.28^{B}$ ± 1.21 |
| | Average | | 78.62 ± 1.12 | 75.60 ± 1.12 | 76.54 ± 1.12 | 77.31 ± 1.12 | 76.60 ± 1.12 | $76.53^{*}$ ± 1.12 |
| TG (mg/dl) | Initial | M | $66.10^{a}$ ± 1.11 | $65.19^{b}$ ± 1.11 | $65.98^{b}$ ± 1.11 | $65.02^{b}$ ± 1.11 | $65.38^{b}$ ± 1.11 | $66.85^{A}$ ± 1.11 |
| | | F | $63.41^{a}$ ± 1.30 | $63.65^{b}$ ± 1.30 | $62.75^{b}$ ± 1.30 | $62.75^{b}$ ± 1.30 | $62.77^{b}$ ± 1.30 | $62.10^{B}$ ± 1.30 |
| | Average | | 65.25 ± 1.20 | 66.72 ± 1.20 | 66.86 ± 1.20 | 65.90 ± 1.20 | 62.60 ± 1.20 | 65.50 ± 1.20 |
| | Med | M | $64.06^{a}$ ± 1.11 | $63.64^{b}$ ± 1.11 | $63.31^{b}$ ± 1.11 | $63.63^{b}$ ± 1.11 | $63.33^{b}$ ± 1.11 | $64.09^{A}$ ± 1.11 |
| | | F | $61.35^{a}$ ± 1.30 | $60.78^{b}$ ± 1.30 | $61.33^{b}$ ± 1.30 | $61.48^{b}$ ± 1.30 | $60.77^{b}$ ± 1.30 | $61.34^{B}$ ± 1.30 |
| | Average | | 62.20 ± 1.20 | 61.20 ± 1.20 | 62.22 ± 1.20 | 62.05 ± 1.20 | 63.40 ± 1.20 | $62.21^{*}$ ± 1.20 |
| | Final | M | $64.16^{a}$ ± 1.11 | $63.74^{b}$ ± 1.11 | $63.78^{b}$ ± 1.11 | $63.32^{b}$ ± 1.11 | $63.30^{b}$ ± 1.11 | $64.04^{A}$ ± 1.11 |
| | | F | $62.21^{a}$ ± 1.30 | $61.48^{b}$ ± 1.30 | $61.21^{b}$ ± 1.30 | $62.30^{b}$ ± 1.30 | $61.77^{b}$ ± 1.30 | $61.99^{B}$ ± 1.30 |
| | Average | | 63.13 ± 1.20 | 62.11 ± 1.20 | 62.49 ± 1.20 | 62.31 ± 1.20 | 62.53 ± 1.20 | $62.51^{*}$ ± 1.20 |

PM: *Panicum maximum*, M: Males, F: Females, Initial: 5 weeks of age, Med: 9 weeks of age, Final: 13 weeks of age, mg/dl: Milligrams per deciliter, ALT: Alanine amino transaminase, AST: Aspartate aminotransferase, CHO: Cholesterol, TG: Triglycerides, $^{a,b}$: Means on the same row not followed by the same letter are significantly different ($p < 0.05$), $^{A, B}$: Means on the same column not followed by the same letter are significantly different ($p < 0.05$). *: Significant ($p < 0.05$), NS: Non-significant ($p > 0.05$).



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### Plasma total cholesterol and triglycerides responses

The obtained results in Table 7 indicated that total cholesterol (CHO) and triglycerides (TG) values were not influenced significantly in rabbits fed 25% and 50% PM but decreased significantly in rabbits fed 75% and 100% PM. Moreover, there was a similarity between values of treated and control groups where CHO values recorded 80.98, 79.43, 79.33, 78.85, and 78.17 mg/dl and the corresponding values of TG were 63.53, 63.34, 63.86, 63.42, and 62.84mg/dl for 0%, 25%, 50%, 75%, and 100% PM, respectively. Regarding the effect of sex, the obtained results indicated that plasma CHO and TG concentrations differed significantly regarding sex. The CHO values were recorded at 81.59 and 78.64 mg/dl while TG values were 64.99 and 61.81 mg/dl for males and females, respectively.

Regarding the effect of age, Table 7 showed that age had a significant effect on CHO and TG levels where CHO recorded 82.75, 80.05, and 76.53 mg/dl at weeks 5, 9, and 13, respectively. The corresponding values of TG were 65.50, 62.21, and 62.51 mg/dl at weeks 5, 9, and 13, respectively. The interaction between sex and age showed a significant ($p < 0.05$) effect on CHO and TG values where there were significant differences among the different sexes and ages. Average CHO values recorded 84.57 and 80.94 at week 5, 81.40 and 78.71 at week 9 while 78.79 and 76.28 mg/dl at week 13 for males and females, respectively. Average TG values recorded 66.85 and 62.1 at week 5, 64.09 and 61.34 at week 9 while 64.04 and 61.99 mg/dl at week 13 for males and females, respectively (Table, 7).

These results coincided with Jiwuba et al. (2016) who mentioned that the Moringa leaf meal diet could reduce serum cholesterol in rabbits producing the lean meat**.** Abo El-Haded et al. (2017) found that plasma total cholesterol level was lower ($P < 0.05$) in rabbits fed 19% *Moringa Oleifera* leaf meal diet when compared with those fed 12.5% or the control diet indicating that Moringa Oleifera leaf meal has a cholesterol-lowering effect. Salem et al. (2020) also found the feeding of growing rabbits with different levels of *Moringa Oleifera* leaf meal (10%, 20%, and 30%) significantly decreased total cholesterol ($p < 0.05$) and non-significantly increased triglycerides ($p > 0.05$), compared with the control group**.**

### Plasma urea nitrogen, glucose, and creatinine responses

The obtained results in Table 8 indicated that plasma urea nitrogen (PUN) increased significantly (24.32 and 23.2 mg/dl) for rabbits fed 75% and 100% PM, respectively, compared to 22.24, 22.14, and 21.28, mg/dl for 25% and 50% PM, and control groups, respectively. Regarding the effect of sex, PUN values recorded non-significant results of 22.2 and 22.18 mg/dl for males and females, respectively. Regarding the effect of age, Table 8 showed that age had a significant effect on PUN levels where recorded the values of 21.25, 22.22, and 23.6 mg/dl at weeks 5, 9, and 13, respectively.

As shown in Table 8, the interaction between sex and age showed a significant ($p < 0.05$) effect on PUN values where there were non-significant differences among the sexes but there were significant differences among different stages of age. Average PUN values were recorded 21.28 and 21.23 at week 5, 22.23 and 22.22 at week 9 while at week 13 recorded 23.1 and 23.1 mg/dl for males and females, respectively. Regarding plasma GLU and CRE, there was a similarity between values of treated groups and those of the control group where GLU values were 115.5, 115.11, 115.1, 115.46, and 115.37 mg/dl, and the corresponding values for CRE were 1.01, 1, 1.01, 1.02, and 0.92 mg/dl for 0%, 25%, 50%, 75%, and 100% PM, respectively.

Regarding the effect of sex, the obtained results indicated that plasma GLU and CRE concentrations were not significantly affected by sex where GLU values recorded 115.4 and 115.1 mg/dl, while CRE values recorded 0.99 and 1 mg/dl for males and females, respectively. Regarding the effect of age, Table 8 showed that the age had an insignificant effect on GLU and CRE levels where GLU recorded 115.1, 115.32, and 115.35 mg/dl at weeks 5, 9, and 13, respectively. The corresponding values of CRE were 1, 0.99, and 0.98 mg/dl at weeks 5, 9, and 13, respectively. The interaction of sex and age insignificantly influence GLU and CRE values in rabbits. Average GLU values were recorded as 115.36 and 114.8 at week 5, 115.34, and 115.31 at week 9 while 115.5 and 115.2 mg/dl at week 13 for males and females, respectively. Average CRE values recorded 1.01 and 1.01 at 5 weeks, 0.99 and 0.99 at week 9 while they were measured as 0.98 and 0.99 mg/dl for males and females at week 13, respectively (Table 8).

Similiarly, Jiwuba et al. (2016) found that plasma creatinine showed non-significant ($p > 0.05$) differences among rabbits fed a diet containing 0%, 10%, 20%, and 30% *Moringa Oleifera* leaf meal. Abo El-Haded et al. (2017) found that plasma creatinine and urea nitrogen levels were not significantly affected ($p > 0.05$) by a diet with 12.5 % or 19 % *Moringa Oleifera* leaf meal in rabbits. Selim et al. (2021) reported the different dietary supplementation with *Moringa Oleifera* (5, 10, or 15 g/kg diet) did not affect ($p > 0.05$) the serum urea and creatinine concentrations. Finally, the obtained results revealed that all values of determined blood biochemical parameters fall within the range of normal values for New Zealand White rabbits which were recently determined by Özkan and Pekkaya (2019). According to the results of the current study, PM used in rabbit pelleted diet up to 100% had no significant effect on the creatinine and urea nitrogen levels which means PM had no adverse effects on the kidney functions.



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**Table 8.** Effect of replacement different levels of *Panicum maximum* instead of clover hay in pelleted diets on plasma Blood Urea Nitrogen, Glucose, and Creatinine concentrations of growing New Zealand White rabbits

| Traits | Age | Sex | Experimental groups | | | | | Overall mean |
|---|---|---|---|---|---|---|---|---|
| | | | Control | 25% PM | 50% PM | 75% PM | 100% PM | |
| PUN (mg/dl) | Initial | M | $20.83^{b} \pm 0.75$ | $21.97^{a} \pm 0.75$ | $21.91^{a} \pm 0.75$ | $22.45^{a} \pm 0.75$ | $21.94^{a} \pm 0.75$ | $21.28^{A} \pm 0.75$ |
| | | F | $21.22^{b} \pm 0.87$ | $21.97^{a} \pm 0.87$ | $21.97^{a} \pm 0.87$ | $22.97^{a} \pm 0.87$ | $21.91^{a} \pm 0.87$ | $21.23^{A} \pm 0.87$ |
| | Average | | 21.02 ± 0.81 | 22.22 ± 0.81 | 22.20 ± 0.81 | 22.71 ± 0.81 | 22.12 ± 0.81 | 21.25 ± 0.81 |
| | Med | M | $21.41^{b} \pm 0.75$ | $21.90^{a} \pm 0.75$ | $21.70^{a} \pm 0.75$ | $24.29^{a} \pm 0.75$ | $23.03^{a} \pm 0.75$ | $22.23^{A} \pm 0.75$ |
| | | F | $21.17^{b} \pm 0.87$ | $21.95^{a} \pm 0.87$ | $21.87^{a} \pm 0.87$ | $24.79^{a} \pm 0.87$ | $22.71^{a} \pm 0.87$ | $22.22^{A} \pm 0.87$ |
| | Average | | 21.29 ± 0.81 | 21.92 ± 0.81 | 21.70 ± 0.81 | 24.54 ± 0.81 | 22.87 ± 0.81 | $22.22^{*} \pm 0.81$ |
| | Final | M | $20.91^{b} \pm 0.75$ | $22.73^{a} \pm 0.75$ | $22.33^{a} \pm 0.75$ | $28.84^{a} \pm 0.75$ | $24.54^{a} \pm 0.75$ | $23.10^{A} \pm 0.75$ |
| | | F | $22.18^{b} \pm 0.87$ | $22.46^{a} \pm 0.87$ | $22.69^{a} \pm 0.87$ | $28.48^{a} \pm 0.87$ | $24.71^{a} \pm 0.87$ | $23.10^{A} \pm 0.87$ |
| | Average | | 21.54 ± 0.81 | 22.59 ± 0.81 | 22.51 ± 0.81 | 25.70 ± 0.81 | 24.62 ± 0.81 | $23.60^{*} \pm 0.81$ |
| GLU (mg/dl) | Initial | M | $115.49^{a} \pm 0.55$ | $115.20^{a} \pm 0.55$ | $115.07^{a} \pm 0.55$ | $115.53^{a} \pm 0.55$ | $115.50^{a} \pm 0.55$ | $115.36^{A} \pm 0.55$ |
| | | F | $114.94^{a} \pm 0.64$ | $114.91^{a} \pm 0.64$ | $114.96^{a} \pm 0.64$ | $114.96^{a} \pm 0.64$ | $115.24^{a} \pm 0.64$ | $114.8^{A} \pm 0.64$ |
| | Average | | 115.71 ± 0.59 | 114.95 ± 0.59 | 115.01 ± 0.59 | 115.24 ± 0.59 | 115.37 ± 0.59 | $115.10^{NS} \pm 0.59$ |
| | Med | M | $115.36^{a} \pm 0.55$ | $115.20^{a} \pm 0.55$ | $115.20^{a} \pm 0.55$ | $115.44^{a} \pm 0.55$ | $115.52^{a} \pm 0.55$ | $115.34^{A} \pm 0.55$ |
| | | F | $115.31^{a} \pm 0.64$ | $115.70^{a} \pm 0.64$ | $114.96^{a} \pm 0.64$ | $115.45^{a} \pm 0.64$ | $115.24^{a} \pm 0.64$ | $115.31^{A} \pm 0.64$ |
| | Average | | 115.33 ± 0.59 | 115.40 ± 0.59 | 115.03 ± 0.59 | 115.44 ± 0.59 | 115.40 ± 0.59 | $115.32^{NS} \pm 0.59$ |
| | Final | M | $115.45^{a} \pm 0.55$ | $115.20^{a} \pm 0.55$ | $115.52^{a} \pm 0.55$ | $115.89^{a} \pm 0.55$ | $115.44^{a} \pm 0.55$ | $115.50^{A} \pm 0.55$ |
| | | F | $115.45^{a} \pm 0.64$ | $114.96^{a} \pm 0.64$ | $114.99^{a} \pm 0.64$ | $115.73^{a} \pm 0.64$ | $115.24^{a} \pm 0.64$ | $115..20^{A} \pm 0.64$ |
| | Average | | 115.45 ± 0.59 | 114.98 ± 0.59 | 115.25 ± 0.59 | 115.71 ± 0.59 | 115.34 ± 0.59 | $115.35^{NS} \pm 0.59$ |
| CRE (units) | Initial | M | $1.02^{a} \pm 0.01$ | $1.02^{a} \pm 0.01$ | $1.02^{a} \pm 0.01$ | $1.01^{a} \pm 0.01$ | $0.99^{a} \pm 0.01$ | $1.01^{A} \pm 0.01$ |
| | | F | $1.01^{a} \pm 0.02$ | $1.01^{a} \pm 0.02$ | $1.02^{a} \pm 0.02$ | $1.01^{a} \pm 0.02$ | $0.99^{a} \pm 0.02$ | $1.01^{A} \pm 0.02$ |
| | Average | | 1.03 ± 0.01 | 1.03 ± 0.01 | 1.03 ± 0.01 | 1.04 ± 0.01 | 0.97 ± 0.01 | 1.00 ± 0.01 |
| | Med | M | $1.01^{a} \pm 0.01$ | $1.01^{a} \pm 0.01$ | $1.01^{a} \pm 0.01$ | $1.01^{a} \pm 0.01$ | $0.99^{a} \pm 0.01$ | $0.99^{A} \pm 0.01$ |
| | | F | $1.02^{a} \pm 0.02$ | $0.99^{a} \pm 0.02$ | $1.01^{a} \pm 0.02$ | $1.01^{a} \pm 0.02$ | $0.98^{a} \pm 0.02$ | $0.99^{A} \pm 0.02$ |
| | Average | | 1.02 ± 0.01 | 1.00 ± 0.01 | 1.01 ± 0.01 | 1.02 ± 0.01 | 0.89 ± 0.01 | $0.99^{NS} \pm 0.01$ |
| | Final | M | $0.99^{a} \pm 0.01$ | $0.98^{a} \pm 0.01$ | $0.98^{a} \pm 0.01$ | $1.01^{a} \pm 0.01$ | $0.94^{a} \pm 0.01$ | $0.98^{A} \pm 0.01$ |
| | | F | $0.99^{a} \pm 0.02$ | $0.98^{a} \pm 0.02$ | $1.00^{a} \pm 0.02$ | $1.01^{a} \pm 0.02$ | $0.93^{a} \pm 0.02$ | $0.99^{A} \pm 0.02$ |
| | Average | | 0.99 ± 0.01 | 0.98 ± 0.01 | 0.99 ± 0.01 | 1.01 ± 0.01 | 0.91 ± 0.01 | $0.98^{NS} \pm 0.01$ |

PM: *Panicum maximum*, M: Males, F: Females, Initial: 5 weeks of age, Med: 9 weeks of age, Final: 13 weeks of age, PUN: Plasma urea nitrogen, GLU: Glucose, CRE: Creatinine, mg/dl: Milligrams per deciliter, $^{a,b}$: Means on the same row not followed by the same letter are significantly different ($p < 0.05$). $^{A, B}$: Means on the same column not followed by the same letter are significantly different ($p < 0.05$). *: Significant ($p < 0.05$), NS: Non-significant ($p > 0.05$).

### Histopathology

Weaned and growing rabbits are herbivorous animals that require legumes or fibers sources, such as clover hay to support their bowel (colon) digestion and help the continuous chewing which prevents teeth overgrowth. Any disturbance in the fibers content of rabbit diets (either more or less than normal nutrient requirements) would lead to the inflammation of the colon and rectum accompanied by gases distension, and sudden death. In the current study, an alternative cheaper source of fibers named PM was added into the growing rabbit diets at different levels of 0%, 25%, 50%, 75%, and 100% instead of the clover hay. Therefore, it was of utmost importance to investigate the impact of PM on productive performance and the health status of rabbits regarding CBC, protein, lipid profile, liver, and kidney function tests as well as its histopathological effect on different vital commonly affected tissues, including liver, kidney, colon, and rectum. Liver showed hepatocyte vacuolar degeneration at 0% PM then dilatation in the central and portal vein with diffused hepatocytes vacuolization when rabbits fed 25% PM, then exhibited the normal histological picture at 50%, 75%, and 100% (Figure 1, Table 9).



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Moreover, the kidney exhibited tubular vacuolar degeneration at 0% PM then normal histological structure at 25% PM while at 50% revealed degenerative changes in the lining epithelium of renal tubules at the cortex level, then exhibited no histopathological alteration at 75 and 100% (Figure 2, Table 9). The vacuolar degeneration observed in both liver and kidney of the control group (0% PM) means such lesions may not be related to the PM as mentioned by Molina et al. (2018) who stated that the observed lesions in growing rabbits fed a diet containing Amaranthus dubius as an alternative source of fiber may be attributed to climatic conditions. Moreover, Melillo (2007) reported that the possible biliary stasis or lipidosis might lead to the noticed liver lesions.

Histopathological changes of bowl digestive system were reduced by increasing the level of PM in rabbit diets where the colon exhibited the normal histological picture at 0% PM then indicated diffused goblet cells (mucous degeneration) all over the lining mucosal epithelium at both 25% and 50% PM. At 75%, the results were indicative of few focal infiltrations of the inflammatory cells in lamina propria of mucosa then revealed a normal histological picture at 100% (Figure 3, Table 9).

Rectum had inflammatory cells infiltration in rabbits fed 25, 50, 75, and 100% PM while 0% PM showed normal histological structure (Figure 4, Table 9).

Rabbits fed 100% PM exhibited no histopathological lesions in all investigated organs, liver, kidney, and colon except the rectum showed slight inflammation in mucosal lamina propria, although it indicated the lowest productive performance and biochemical parameters. Similar results were supported by Molina et al. (2018) who observed chronic inflammation in the small intestine as well as hepatic intracytoplasmic perinuclear vacuolization in growing rabbits fed diet containing Amaranthus dubius. Gutiérrez et al. (2002) stated that the fibers act as a substrate for bacterial growth and control the intestinal microbiota to facilitate digestion and prevent digestive disorders in rabbits. Álvarez et al. (2007) reported that mucosal structure was improved when non-detergent fibers decreased from 36-38% to 30-32%. Hall et al. (1997) discussed the mucosal structure and intestinal barrier may be affected by the type of dietary fibers which have an important role in the growth of beneficial microbiota and improvement of the competitive exclusion. García-Ruiza et al. (1997) recorded that the presence of soluble fibers in the diet enhanced intestinal villi growth and enterocytes activity, while the lignified fibers led to lower activity of intestinal cells with structural atrophy and proliferation of Clostridial perfringens. Fabre et al. (2006) recommended that the soluble fibers play an important role in the reduction of Epizootic Rabbit Enteropathy when added at 11-12%.

**Table 9.** Histopathological examinations of vital organs in accordance to replacement of different levels of *Panicum maximum* in pelleted diets of growing New Zealand White rabbits

| **PM (%)**<br>**Organs** | **0%** | **25%** | **50%** | **75%** | **100%** |
|---|---|---|---|---|---|
| Liver (Figure 1) | Vacuolar degeneration was detected in the cytoplasm of the hepatocytes (Figure 1 A). | Intracellular vacuolization was detected in a diffuse manner all over the hepatocytes associated with dilatation in the central and portal vein (Figure 1 B). | There was no histopathological alteration (Figure 1 C) | There was no histopathological alteration (Figure 1 D). | There was no histopathological alteration (Figure 1 E). |
| Kidney (Figure 2) | The lining tubular epithelial cells showed vacuolar degeneration (Figure 2 A). | There was no histopathological alteration (Figure 2 B). | Degenerative change was detected in the tubular lining epithelium at the cortex (Figure 2 C). | There was no histopathological alteration (Figure 2 D). | There was no histopathological alteration (Figure 2 E). |
| Colon (Figure 3) | There was no histopathological alteration as recorded in mucosa, submucosa, muscularis, and serosa (Figure 3 A). | Diffuse goblet cells formation was detected all over the mucosal lining epithelium (Figure 3 B). | There was diffuse goblet cells formation all over the lining mucosal epithelium (Figure 3 C). | Focal few inflammatory cells infiltration was detected in the lamina propria of the mucosal layer (Figure 3 D). | There was no histopathological alteration (Figure 3 E). |
| Rectum (Figure 4) | There was no histopathological alteration as recorded in mucosa, submucosa, muscularis, and serosa (Figure 4 A). | The lamina propria of the mucosal layer showed inflammatory cells infiltration in between the glands (Figure 4 B). | Focal infiltration, as well as aggregation of inflammatory cells, were detected in the lamina propria of the mucosa (Figure 4 C). | There was inflammatory cells infiltration in the lamina propria of the mucosa (Figure 4 D). | Inflammatory cells infiltration was observed in the lamina propria of the mucosa (Figure 4 E). |


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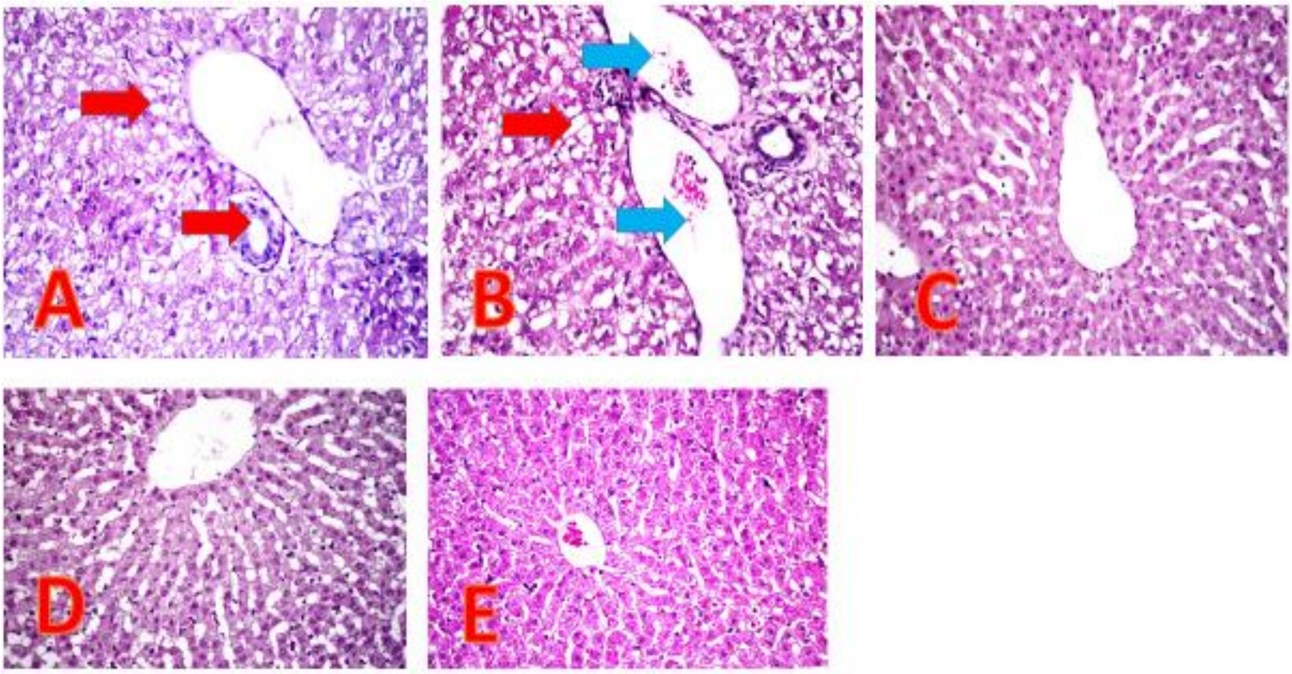


**Figure 1.** Histopathological findings of liver in accordance to replacement of different levels of *Panicum maximum* in pelleted diets of New Zealand White rabbits. **A:** Liver of rabbits after treatment with 0% *Panicum maximum* showed vacuolar degeneration in the cytoplasm of hepatocytes (red arrow). **B:** Liver of rabbits after treatment with 25% *Panicum maximum* showed dilated portal and central veins (blue arrows) with diffused hepatocytes vacuolization (red arrow). **C, D, E**: Livers of rabbits after treatment with 50%, 75%, 100% *Panicum maximum* showed normal histological findings

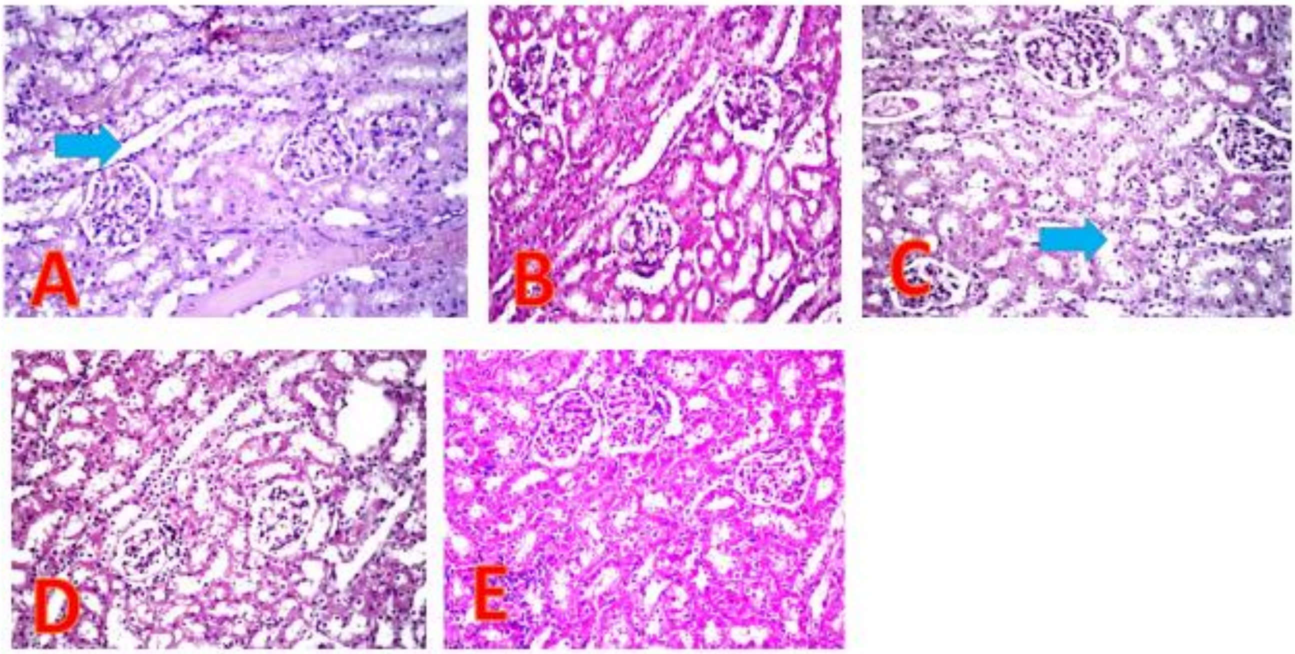


**Figure 2.** Histopathological findings of Kidneys in accordance to replacement of different levels of *Panicum maximum* in pelleted diets of New Zealand White rabbits. **A:** Kidney of rabbits after treatment with 0% *Panicum maximum* showed vacuolar degeneration in The lining tubular epithelial cells (blue arrow). **B, D, E**: kidneys of rabbits after treatment with 25%, 75%, 100% *Panicum maximum* showed no histopathological alteration. **C:** Kidney of rabbits after treatment with 50% *Panicum maximum* showed degenerative change in the tubular lining epithelium at the cortex (blue arrow).



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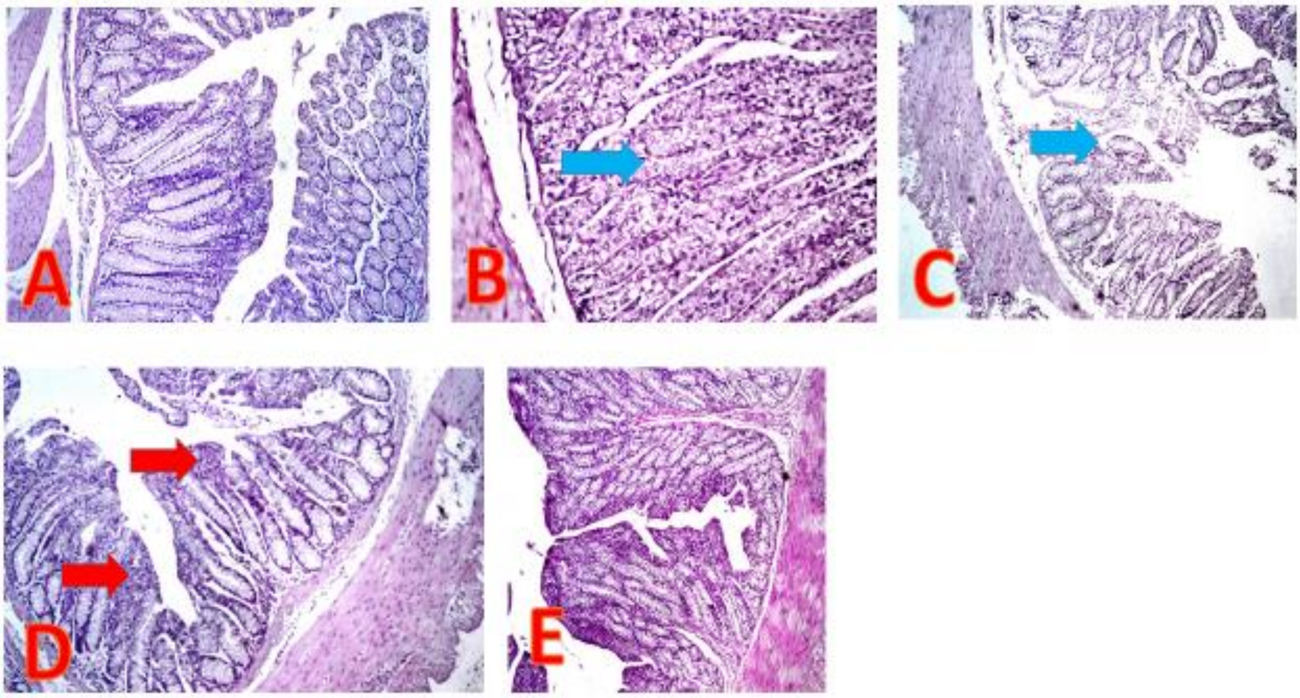


**Figure 3.** Histopathological findings of colons in accordance to replacement of different levels of *Panicum maximum* in pelleted diets of New Zealand White rabbits. **A:** Colon of rabbits after treatment with 0% *Panicum maximum* showed no histopathological alteration in mucosa, submucosa, muscularis, and serosa. **B, C:** Colons of rabbits after treatment with 25%, 50% *Panicum maximum* showed mucous degeneration in the mucosal linning epithelium (blue arrow). **D:** Colon of rabbits after treatment with 75% *Panicum maximum* showed focal few inflammatory cells infiltration in mucosal lamina propria (red arrow). **E:** Colon of rabbits after treatment with 100% showed normal structure

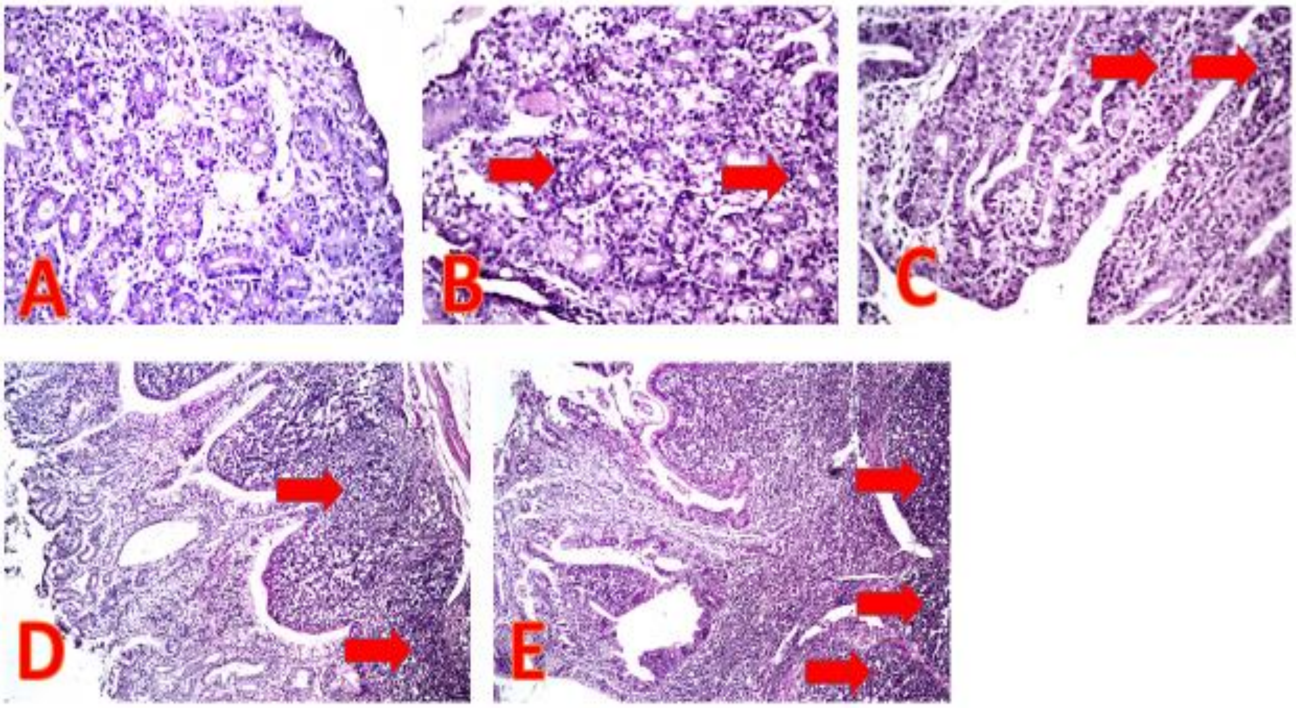


**Figure 4.** Histopathological findings of liver in accordance to replacement of different levels of *Panicum maximum* in pelleted diets of New Zealand White rabbits. **A:** Rectum of rabbits after treatment with 0% *Panicum maximum* showed no histopathological alteration in mucosa, submucosa, muscularis, and serosa. **B, C, D, E:** Rectums of rabbits after treatment with 25%, 50%, 75%, 100% *Panicum maximum* showed inflammatory cells infiltration in the mucosal lamina propria (red arrow).



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## CONCLUSION

The sole aim of venturing into animal production by producers is to make a profit with a reduced cost. The PM is abundant in supply and cheap. Therefore, it was recommended to be an alternative raw material reduced cost of production with an improvement of performance and health status of growing rabbits when replaced the alfalfa hay at levels of 25%, 50%, and75% in rabbits diet. Finally, it was clear that magnified benefit was obtained when rabbits fed 75% PM which nearly had the best values either on the level of the productive, biochemical or histological picture. In addition, there was no record of mortality during the experiment in all groups which may be related to the safety of PM and high standards of zoo hygiene.

## DECLARATIONS

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### Competing interests

With respect to the research, authorship, and/or publications of this article. The authors declare that they have no competing interests.

### Authors' contribution

Abou Sekken designed the experiment, and revised the article; Hossni Abo Eid wrote the article, and discussed it, Disouky Mourad helped field study, collected data, and conducted statistical analysis; Hanan El-Samahy helped laboratory analyses, and tabulation of experimental data; while, Ibrahim El-Folly helped in experiment application, statistical analysis, manuscript writing. All authors have read and approved the final manuscript.

### Ethical considerations

Ethical issues including plagiarism, consent to publish, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy have been checked by the authors.

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