Fayoum Journal of Agricultural Research and Development
https://fjard.journals.ekb.eg

Article

Productive Performance, Kidney Function, Hematological Parameters, Carcass Traits, and Feed Cost as Affected by Fasting Regime of Egyptian Baladi Rabbits During Hot Conditions

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Abstract: This study aimed to assess the effect of the fasting regimes on kidney function, hematological parameters, productive performance, carcass traits, and feed cost of Egyptian Baladi rabbits during hot conditions. Forty rabbits (49 days, 810±15 g) were randomly distributed into four equal groups (N=10). NF non-fasting rabbits serve as the control; intermittent fasting (IF) is fasting one day/week for six weeks; the third group, prolonged fasting (PF), was fasted a separate two days/week for six weeks, while the fourth group, mixed fasting (MF), was fasted one day/week for three weeks only, then fasted a separate two days/week for another three weeks. Initial body weight, weekly body weights, feed intake, and mortality rate were recorded, with blood samples collected post-slaughter. Our results revealed no significant differences between fasting regimes and weekly body weights. The highest value of final body weight was observed with PF, followed by MF, and the lowest weight was recorded with NF. However, the fasting regimes significantly reduced body weight gain initially, with PF showing the lowest gain. Total feed intake decreased notably in all fasting groups, especially in MF. Kidney function improved in fasting rabbits, with significantly lower urea levels in IF and MF groups ($p < 0.05$). Carcass weight and dressing percentage did not differ across groups, though PF and MF rabbits had the highest dressing percentages. The study concluded that fasting regimes did not adversely affect productive performance and instead reduced feed costs while enhancing kidney function. These findings suggest that intermittent or mixed fasting could be a viable strategy for improving rabbit health and economic efficiency in hot climates without compromising carcass quality.

Keywords: Baladi Rabbits, Carcass traits, Fasting regime, Kidney function, Productive performance.

Received: 21 April 2025
Revised: 24 April 2025
Accepted: 28 April 2025

1. Introduction

Rabbits (*Oryctolagus cuniculus*) are considered an important and healthy source of animal protein compared to all other meat animals. Furthermore, they are extremely prolific and develop quickly. In addition, it is important in solving part of the meat shortage problem around the world (North et al., 2019; El-Sabrout et al., 2020). Moreover, rabbits are related to human scientific research like digestibility trials, and drug resistance trials in which digestive physiology, and absorption criteria are vital parameters. For doing these kinds of research works, a clear idea about the topography and biometry of the digestive tract is very much essential (Nath et al., 2016).

However, rabbit breeding faced major problems like the availability of animal feed being limited by decreased green fields from land conversion to residences, industries, transportation, etc., resulting from population growth, lack of grass, increasing feed costs, and global climate change (Habib et al., 2016). In addition, rabbits are very sensitive to heat stress; they have difficulty eliminating excess body heat, and they are susceptible to important diseases that can reduce their productivity, causing severe economic losses and high mortality rates. It also causes numerous physiological problems in rabbits, including oxidative stress, disrupted endocrine control, decreased immunological function, and reproductive difficulties, particularly during the hot months, which lead to financial failures (Liang et al., 20222 and Ayyat et al., 2024).

The Baladi rabbits are well-adapted to the Egyptian climate. These native breeds are especially tolerant of rough, dry temperatures, feed with low-quality feed, and resistant to local diseases, facilitating sustained meat production in hard situations (Badr et al., 2019).

Many benefits of fasting in growing rabbits have been reported by many authors, including improved digestive efficiency, altered body energy retention partitioning to protein rather than fat, and decreased mortality and morbidity from digestive issues (Abou-Hashim et al., 2023). According to Visioli et al. (2022), fasting can be conveniently subdivided into three categories, depending on the time: alternate-day fasting, time-restricted feeding, and whole-day fasts. Fasting has been practiced among different species.

Furthermore, fasting could reduce the cost of feedstuff, which accounts for 70% of total production costs; it may enhance the rabbit's oxidative status. It is considered a useful process before animal slaughter for reducing carcass pollution and increasing meat hygiene, and quality. Moreover, it plays a good role in avoiding excessive fattening and reproduction troubles, especially in rabbit females. In addition, fasting could reduce the incidence of digestive pathologies (Larour et al., 2002; Gidenne et al., 2009).

According to Hardiany et al. (2021), intermittent fasting is defined as having no or extremely low caloric intake during regular times less than 24 hours. Another fasting regimen, known as prolonged fasting, is performed for more than one day.

In this context, we applied three regimes of fasting intermittent fasting IF, prolonged fasting PF, and mixed fasting MF the combination (IF+PF) to evaluate the effect of those regimes of fasting on kidney function, hematological parameters, productive performance, carcass traits, and feed cost of Egyptian Baladi rabbits during hot conditions.

2. Materials and Methods

2.1. Study location and time periods

The current study was conducted at Cairo University's Faculty of Agriculture's El-Samman Rabbit Research Development (R&D) Unit. A total of 40 growing Egyptian Baladi rabbits with an average body weight (810±15 g) and an average age (49 days) were randomly distributed into four equal group (N= 10). The first group NF non-fasting rabbits serves as the control, the second group IF intermittent fasting: (fasting one day/week for six weeks), the third group PF prolonged fasting: (fasting a separate two days/week for six weeks), while the fourth group MF mixed fasting (fasting one day/week for three weeks only, then fasting a separate two days/week for another three weeks).

2.2 Ethical of approval

The present study was designed and performed according to the guidelines of Cairo University's Institutional Animal Care and Use Committee (CU-IACUC) the approval NO (CU-IIF-4724).

2.3. Housing and managerial conditions

Rabbits were housed in commercial galvanized wired cages batteries (60x60x40 cm), which were supplied with feeders for feeding and stainless steel nipples for drinking (fresh water was available ad libitum). Ambient temperatures (AT, °C) ranged between 38 to 41ºC, and relative humidity (RH%) ranged between 60 to 65% during experimental periods. The temperature humidity index (THI) was calculated according to Marai et al. (2002) as follows: THI = db°C – [(0.31 - .31 (RH/100) (db°C – 14.4)] where: RH: relative humidity in present db: average daily ambient temperature (dry bulb) of the rabbitry in degree Celsius. The obtained THI in this study ranged between (35.4-37.7). The THI values were classified as absence of heat stress (<27.8), moderate heat stress (27.8-28.8 °C), severe heat stress (28.9-29.9 °C) and very severe heat stress (>30.0 °C). The rabbits in the present study suffer from very severe heat stress.

Rabbits were fed pelleted commercial diets with a chemical composition of 17% CP and 2552 kcal DE/kg diet formulated to meet recommended nutrient requirements of growing rabbits according to NRC (1977).

2.4. Growth measurements and carcass traits

Initial body weight, weekly body weights, feed intake, and mortality rate (=0) were recorded during experimental periods. Weighing was carried out before offering the morning meal. Body weight gain, feed conversion, and feed cost were calculated. At the end of the experiment, randomly four rabbits from each group after being fasted for 12 hours were slaughtered by severing the carotid arteries and jugular veins, skinned, and eviscerated for measuring carcass parameters. After the removal of the visceral organs and head, the remaining part was measured as carcass weight, and this was later expressed as a percentage of the fasted weight to get the dressing percentage Fielding (1991).

2.5. Blood samples

Blood samples of rabbits were collected after slaughtered .Approximately 10 mL of fresh blood sample was collected. Each blood sample was divided into two aliquots:

2.5.1. One with heparin for measuring hematological variables. Hemoglobin (Hb, g/dL) concentration, red blood cell (RBC) count ($\times 10^6/\mu L$), mean corpuscular hemoglobin (MCH) amount (pg) and percentage of red cell distribution width (RDW %) were determined using a hematological analyzer (HA-CLINDIAG, China).

2.5.2. One without any additives for serum separation. Clear blood serum samples were analyzed for total protein urea (mg/dL), and creatinine (mg/dL) were determined by using commercial test kits (Spectrum Biotechnology, Egypt) and a spectrophotometer (T80 UV/VIS PG instrument Ltd., Lutterworth, UK).

2.6. Statistical analysis

The results of experiment were statistically analyzed using SAS (2014) according to the following model: $Y_{ij} = \mu + Ft_i + e_{ij}$, where Y_{ij} = any individual observation of j^{th} animal within i^{th} fasting regime , μ = overall mean, Ft_i = effect of i^{th} fasting regime (i: 1-4), e_{ij} = experimental error. The level of significant differences between treatments means was tested by Duncan's (1995) multiple range test.

Studies involving animals, humans, endangered species, or regulated materials must include statements regarding ethical approval. Specify the institutional review board or ethics committee that granted approval and provide the corresponding approval code or reference number.

Declare any restrictions on the availability of materials or information at submission, as full disclosure is expected for published work. When proprietary materials are used, describe suitable alternatives where possible.

3. Results

3.1. Effect of fasting on productive performance

The obtained results of weekly body weight are presented in Table 1. The weekly body weights did not differ significantly among fasting groups. The highest value of final body weight was observes with PF followed by MF and the lowest one was observed with control group. .

Table 1. Effect of fasting regime on weekly body weight

Item	NF	IF	PF	MF	± SE	*p*-value
BW1**(g)**	814.5	813.0	812.0	817.0	34.44	1.00
BW2 **(g)**	996.0	938.5	916.5	955.5	35.75	0.46
BW3**(g)**	1093.0	1013.5	998.5	1047.0	34.22	0.23
BW4 **(g)**	1183.0	1114.0	1121.0	1125.5	32.22	0.42
BW5 **(g)**	1269.5	1207.0	1199.5	1219.5	30.60	0.38
BW6 **(g)**	1326.0	1277.0	1282.0	1295.0	30.93	0.68
BW7 **(g)**	1394.5	1397.5	1419.5	1412.0	27.72	0.91

[1]There is no any significant difference in weekly BW between control group and treated groups. BW: body weight, NF: non-fasting, IF (intermittent fasting), PF (prolonged fasting), and MF (mixed fasting).

The fasting process had a significant inverse impact on body weight gain from the 1st to 2nd weeks in all fasting regimes where PF had the lowest weight gain and NF had the biggest weight gain (Table 2). After that the weight gain did not differ between fasting group at the period from (2-3) and (4-5) weeks. Nevertheless, the weight gain increased significantly through the fasting groups at the period from 5 to 7 weeks. Also the total weight gain insignificantly increased with all fasting rabbits and the fourth group MF had the greatest total weight gain compared to control and other fasting groups (Figure 1).

Additionally, the weekly feed intake was significantly higher in the control group than in all fasting groups during all fasting weeks. Furthermore, the MF regime showed highly significant differences ($p < 0.001$) in the amount of feed intake compared to all other fasting regimes (Table 3). Furthermore, there weren't any significant differences between the IF and PF groups through the period from the 3rd week till the end of the experiment. The fasting program significantly reduces the total feed intake, as presented in Figure 1.

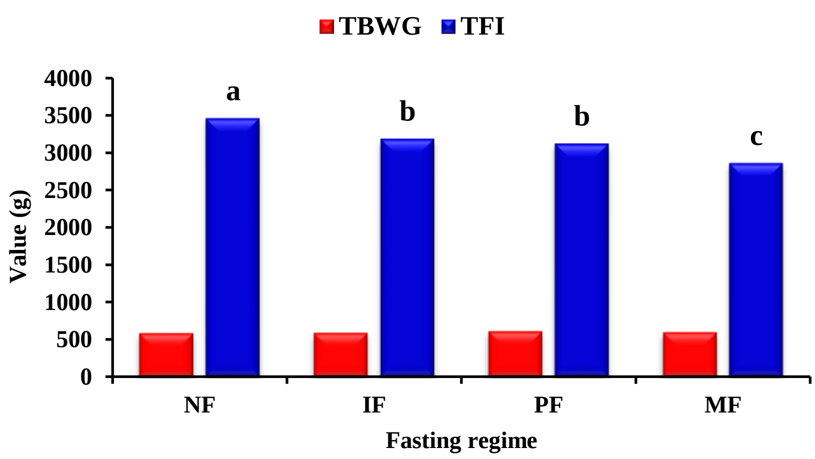

Figure 1. Impact of fasting regime on TBWG: total body weight gain and TFI: total feed intake. a, b and c significant differences ($p<0.05$). NF: non-fasting, IF (intermittent fasting), PF (prolonged fasting), and MF (mixed fasting).

Table 2. Effect of fasting regime on weekly body weight gain

Item	NF	IF	PF	MF	± SE	*p*-value
BWG_{1-2} (g/w)	181.5^{a}	125.5^{b}	104.5^{b}	138.5^{b}	12.22	0.001
BWG_{2-3} (g/w)	97.0	75.0	82.0	91.5	7.10	0.15
BWG_{3-4} (g/w)	90.0^{b}	100.5^{ab}	122.5^{a}	78.5^{b}	9.57	0.02
BWG_{4-5} (g/w)	86.5	93.0	78.5	94.0	7.04	0.39
BWG_{5-6} (g/w)	56.5^{b}	70.0^{ab}	82.5^{a}	75.5^{a}	5.31	0.01
BWG_{6-7} (g/w)	68.5^{b}	120.5^{ab}	137.5^{a}	117.0^{ab}	17.69	0.05
TBWG (g)	580.0	584.5	607.5	595.5	25.05	0.87

*a, and b letters mean there is a significant difference in weekly BWG between control group and treated groups. BWG: Body weight gain, TBWG: total Body weight gain, NF: non-fasting, IF (intermittent fasting), PF (prolonged fasting), and MF (mixed fasting).

Table 3. Effect of fasting regime on weekly feed intake

Item	NF	IF	PF	MF	± SE	*p*-value
FI_{1-2} (g/w)	620.50^{a}	522.0^{b}	511.0^{bc}	489.5^{c}	10.25	<.0001
FI_{2-3} (g/w)	592.0^{a}	500.58^{b}	446.5^{c}	415.5^{c}	13.05	<.0001
FI_{3-4} (g/w)	562.5^{a}	562.5^{a}	543.5^{a}	466.5^{b}	11.64	<.0001
FI_{4-5} (g/w)	600.5^{a}	558.0^{b}	552.0^{b}	547.0^{b}	10.91	0.01
FI_{5-6} (g/w)	542.0^{a}	547.5^{a}	556.5^{a}	473.0^{b}	8.60	<.0001
FI_{6-7} (g/w)	546.0^{a}	499.0^{b}	514.5^{b}	472.5^{c}	8.93	<.0001
TFI (g)	3463.5^{a}	3189.58^{b}	3124.0^{b}	2864.0^{c}	32.94	<.0001

*a, b and c letters mean there is a significant difference in weekly FI between control group and treated groups. FI: feed intake, TFI: total feed intake NF: non-fasting, IF (intermittent fasting), PF (prolonged fasting), and MF (mixed fasting).

The results of weekly feed conversion (FC) and feed costs showed that the FC at the first and second weeks of the experiment significantly increased with the prolonged fasting PF, while at the period from 2nd to 3rd weeks there weren't any significant differences on FC between NF, IF and PF groups. However, the percentage of FC significantly decreased in (MF). Additionally, the fasting process did not influence on FC in all experimental rabbits from the 3rd till 5th weeks. Our findings showed that different fasting regimes significantly (p <0.0001) reduced the feed costs and the mixed fasting program reduce the costs up to 31% (Table 4).

Table 4. Effect of fasting regime on weekly feed conversion and feed costs

Item	NF	IF	PF	MF	± SE	*p*-value
FC_{1-2} (%)	3.5^{b}	4.9^{ab}	5.4^{a}	3.7^{b}	0.49	0.03
FC_{2-3} (%)	6.3^{a}	7.1^{a}	5.9^{ab}	4.8^{b}	0.45	0.01
FC_{3-4} (%)	7.1	6.0	4.7	6.3	0.62	0.08
FC_{4-5} (%)	8.3	6.3	7.3	6.0	0.85	0.25
FC_{5-6} (%)	11.1^{a}	7.9^{b}	7.1^{b}	6.5^{b}	0.99	0.01
FC_{6-7} (%)	10.9^{a}	5.0^{b}	4.4^{b}	4.8^{b}	1.56	0.02
TFC (%)	6.0^{a}	5.6^{ab}	5.2^{bc}	4.9^{c}	0.23	0.01
F-cost (L.E)	84.0^{a}	78.7^{ab}	73.0^{bc}	68.5^{c}	3.25	0.01

*a, b and c letters mean there is a significant difference in weekly FC and feed-cost between control group and treated groups. . Fc: feed conversion ratio, TFC: total feed conversion ratio, F-cost: feed cost, NF: non-fasting, IF (intermittent fasting), PF (prolonged fasting), and MF (mixed fasting).

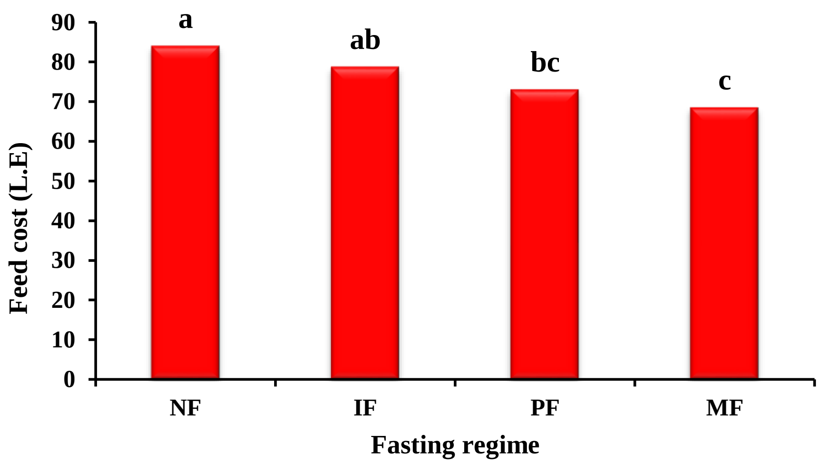

Figure 2. Impact of fasting regime on feed cost (L.E) a, b, and c significant differences (p<0.05). NF: non-fasting, IF (intermittent fasting), PF (prolonged fasting), and MF (mixed fasting).

3.2. Effect of fasting on kidney function

The effect of fasting on kidney function is presented in Figure 3. Our findings showed that urea levels significantly decreased with IF and MF compared to the control group. Furthermore, in comparison to the non-fasting group all fasting regime s enhanced kidney functions (p < 0.05) by reducing Creatinine levels and the lowest value recorded with mixed fasting regime.

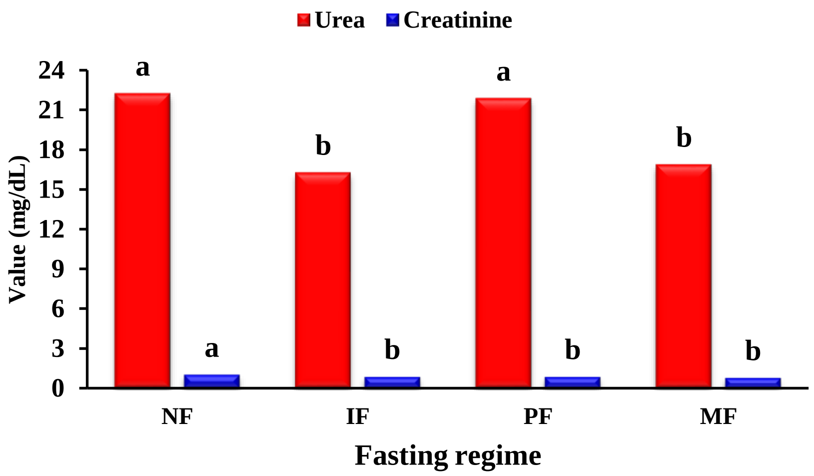

Figure 3. Impact of fasting regime on kidney function groups a and b significant differences (p<0.05). NF: non-fasting, IF (intermittent fasting), PF (prolonged fasting), and MF (mixed fasting).

3.3. Effect of fasting on hematological parameters

Figure 4 presents the impact of different fasting regime on some hematological variables. Our results showed that the values of hematological parameters were ranged within the normal range. However, fasting regime had a non-significant inverse impact on RBC count, hemoglobin level and mean corpuscular hemoglobin (MCH). Furthermore, fasting processes increase the percentage of red cell distribution width (RDW%) and the highest value was observed with prolonged fasting.

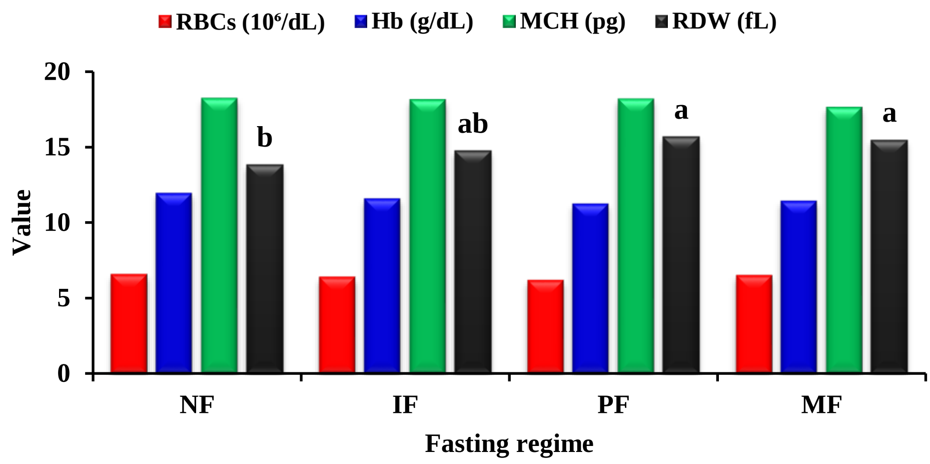

Figure 4. Impact of fasting regime on hematological parameters a and b significant differences (p<0.05). RBC: red blood cell, Hb: hemoglobin, MCH: mean corpuscular hemoglobin, RDW: red cell distribution width, NF: non-fasting, IF (intermittent fasting), PF (prolonged fasting), and MF (mixed fasting).

3.4. Effect of fasting on carcass traits

The fasting program resulted in substantial (p<0.05) changes in rabbit body weight before and after slaughter. The control group had the highest weight relative to the other groups. Furthermore, carcass weight and dressing out percentage did not differ across experimental groups. However, the fasting rabbits (PF and MF) had the highest dressing out percentage. Furthermore, fasting regime did not affect organs weight, except stomach weight in (MF), which was lower than in all other groups and intestine weights in (PF) was greater than all other groups (Table 5).

Table 5. Effect of fasting regime on carcass traits

Item	NF	IF	PF	MF	± SE	*p*-value
BWbsl (g)	1510.00^{a}	1398.75^{ab}	1382.5^{b}	1316.25^{b}	37.71	0.02
BWasl (g)	1482.50^{a}	1353.75^{b}	1346.25^{b}	1278.75^{b}	40.71	0.03
Blood weight (g)	27.5	45.0	36.25	37.5	7.02	0.41
Fur weight (g)	250.0^{a}	226.25^{ab}	223.75^{ab}	208.75^{b}	8.30	0.03
Carcass weight (g)	898.75	826.25	846.25	831.25	27.55	0.28
Dressing (%)	59.46	59.17	61.27	63.19	1.61	0.31
GI weight (g)	243.0	251.5	247.0	220.0	8.47	0.10
GI % (g)	16.13	18.0	17.86	16.71	0.54	0.10
Kidney weight (g)	10.0	10.5	10.0	9.0	0.56	0.33
Kidney (%)	0.67	0.76	0.73	0.68	0.04	0.41
Liver weight (g)	48.25	41.5	47.5	40.25	2.76	0.14
Liver (%)	3.19	2.96	3.43	3.06	0.13	0.13
Heart weight (g)	4.75	4.0	4.25	3.75	0.30	0.16
Heart (%)	0.32	0.29	0.31	0.29	0.02	0.67
Spleen weight (g)	1.25	1.0	1.0	1.25	0.18	0.59
Spleen (%)	0.08	0.07	0.07	0.10	0.01	0.44
Lung weight (g)	13.25	11.25	8.0	12.0	2.04	0.35
Lung (%)	0.88	0.80	0.59	0.92	0.15	0.43
Stomach weight (g)	85.75^{a}	84.75^{a}	77.5^{ab}	66.5^{b}	4.57	0.04
Stomach (%)	5.69	6.05	5.62	5.06	0.35	0.30
Caecum weight (g)	91.75	96.0	79.75	80.75	9.58	0.56
Caecum (%)	6.09	6.88	5.72	6.12	0.66	0.66
Intestine weight (g)	65.5^{b}	70.75^{b}	89.75^{a}	72.75^{b}	4.33	0.01

Means sharing the same superscripted small letter in each row are not significantly different according to Duncan's multiple range tests at the p ≤ 0.05probability level. BWbsl: body weight before slaughter, BWasl: body weight after slaughter conversion ratio, GI: Gastrointestinal, NF: non-fasting, IF (intermittent fasting), PF (prolonged fasting), and MF (mixed fasting).

4. Discussion

Many investigations reported that fasting program has an inverse effect on productive performance, country to our results we didn't find a significant effect of fasting on rabbits performance, however, the fasting rabbits tend to be lower in weekly body weight compared to non-fasting rabbits till the 12 weeks of the experiment and at the last week of experiment all fasted rabbits had the biggest body weight compared to the control group. Additionally, body weight gain did not differ between fasting groups at the begging of experiment then we observed that the weight gains were increased significantly through the fasting groups.

These findings agree with previous report by Brecchia et al. (2012) in does rabbits, Also, Hardiany et al. (2023) in New Zealand white rabbits who noted there no effect of intermittent fasting (IF) or prolonged fasting (PF) on rabbit's body weights. In addition to Abou-Hashim et al. (2023) mentioned that there were no significant effects of fasting regimen 12 h/day twice a week or fasted for 48 h each week F48 with 200 mg of prebiotic on final body weight and total body weight gain of growing rabbits. Furthermore, Hardiany et al. (2021) found that fasting did not affect on rabbits body weight this may be due to rabbits eat their feces.

While Sobhy et al. (2008) revealed that rabbits subjected to fasting 10h showed insignificantly decrease in total weight gain by 3.4% compared to control group while rabbits subjected to fasting 24h showed significantly decrease in total weight gain by 20% when compared to control group. An inverse study by Hussein and Abd El-Fattah (2020) they reported that by increasing feed frequency the final weight, total gain and average daily gain were increased significantly (p<0.001).

From our results, we concluded that fasting reduces feed intake significantly epically with a mixed fasting regime and this may be referred to in this type of fasting rabbits gradually adapted to the fasting process which enables them to eat a small amount of feed without losing their body mass. Additionally, the feed cost for all fasted regimes significantly declined especially MF which reduced to 31% (Figure 2). This reduction will be reflected in the breeder's profit.

The findings of current study suggested that fasting program enhanced kidney function where, the creatinine levels significantly decreased in all fasting groups additionally, serum urea levels (an indicator of kidney function) were significantly decreased in IF and MF. This reduction could be referred to fasting process did not affect inversely on rabbit mass and this can be observed from the obtain results Table 1 of body weight gain in the current study. The reduction in urea levels in the agreement with Larivière-Lajoie et al. (2023) who recoded a reduction in urea levels till 8 hours of fasting followed by an elevation till 24 hours of fasting in Grimaud rabbits. Also, Abdul Ameer and Hassan (2022) recorded a significant enhancing in creatinine and urea levels after overnight fasting for New Zealand white rabbits. The same observation for urea levels reported by Khalifa et al. (2024) who recorded a significant reduction (p < .01) in urea levels with different fasting duration.

. Similarly, Zeweil et al. (2017) confirmed that fasting for 24h or 48h significantly (P≤ 0.0001) decreased RBCs and Hb concentration compared with those of control (Ad) or with Zn supplementation groups in growing V-line rabbits. Additionally, Peris and Abd El-Latif (2021) reported that hemoglobin, red blood cell (RBC) and platelet levels significantly declined with feed restriction regime for growing rabbits. In the line with our findings Abdul Ameer and Hassan (2022) recorded that after overnight fasting all hematological parameter significantly decreased (P≤0.05). This decrease in hemoglobin content was considered to be owing to the observed decrease in RBC numbers. RDW is associated with fasting and oxidative stress; the elevation of RDW is resulting in impaired erythropoiesis and elevated insulin and indicating chronic inflammation (Dada et al., 2014 and Horne et al., 2021). The increase in RDW in our study indicates that the fasting rabbits in the PF and MF groups faced the highest stress of fasting or heat stress compared to the IF or control groups.

The current study demonstrated that fasting program had no clear effect on carcass parameter or organs weight where the control group had the highest body weights before and after slaughter compared to fasting groups. However, the intermittent fasting (IF) and prolonged fasting (PF) had the highest dressing out percentage.

These results are in agreement with Cornejo-Espinoza et al. (2016) who found that The BW decreased with fasting group compared to non-fasting and the highest reduction found with 12 h of fasting additionally, the carcass yield increased with 12 h of fasting, compared to the control group. Additionally, Bianchi et al. (2008) reported that rabbits fasted for short time had higher live weight compared to medium and long fasted. Also the livers weight and carcass yield were significantly higher in long fasted followed by medium fasted. Peris and Abd El-Latif (2021) observed that carcass weight was not affected by feed restriction. However, FR reduced kidney fat in all restricted groups.

Moreover, Larivière-Lajoie et al. (2024) reported that female rabbits exposed to 4 hours of FWT had a larger gastrointestinal tract weight than male rabbits or females exposed to 11 or 18 hours (P=0.04). Both sexes saw lower stomach content weights after 18 hours of FWT compared to 4 and 11 hours (P=0.002), although caecum weights remained unaffected.

5. Conclusions

We could conclude that fasting regimens under hot conditions could be an important way for reducing the feed costs without compromising rabbit performance or health status. Furthermore, the findings revealed that all fasting programs under hot conditions improved kidney function, with RBC count, hemoglobin level, and mean corpuscular hemoglobin (MCH) levels falling within normal ranges. There was no obvious influence on carcass metrics or organ weight. These findings suggest that intermittent or mixed fasting could be a viable strategy for improving rabbit health and economic efficiency in hot climates without compromising carcass quality.

Funding: Please add: This study didn't receive any funding support.

Acknowledgments: We would like to express our special appreciation and thanks to Professor Nagwa A. Ahmed, Professor of Poultry Physiology, Faculty of Agriculture, Cairo University, and the head of the Rabbit Research Development (R&D) Unit, for their exceptional guidance, valuable advice, and constant support throughout this research.

Conflicts of Interest: The authors declare that there is no conflict of interest.

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