PSM
Veterinary Research

Research Article 2022 | Volume 7 | Issue 1 | 43-54

Open Access

Article Information

Received: April 6, 2022

Accepted: April 25, 2022

Online first: April 29, 2022

Published: April 30, 2022

Running title: Influence of Feed Restriction on Mule Ducks

Keywords
Behavior,
Ducks,
Feeding regime,
Performance,
Welfare.

Authors' Contribution
FAMA conceived and designed the study; collected and analysed data; performed experiments; wrote, and revised the paper.

How to cite
Ahmed, F.A.M., 2022. Early Feed Restriction Can Affect the Behavior and Welfare of Mule Ducks. PSM Vet. Res., 7(1): 43-54.

***Correspondence**
Fatma A.M. Ahmed
Email:
ftm_abushanief@yahoo.com

Early Feed Restriction Can Affect the Behavior and Welfare of Mule Ducks

Fatma A.M. Ahmed*

Animal Behaviour and Husbandry Department, Faculty of Veterinary Medicine, Sohag University, Sohag, 82524, Egypt.

Abstract:
The analysis of feeding behavior is crucial for animal farming and output. This study aimed to determine the influence of the feeding regime on behavior, welfare indices, as well as growth performance of Mule ducks. The study employed 48 one-day-old Mule ducklings, each wing labelled and housed in two groups of 24 ducklings. The first group received ad libitum feed while the second group received a feed restriction (FR) regime. The feed restriction caused increased feeding, gentle and severe feather pecking, and decreased standing, resting, and preening. At 7 weeks of age, the mean walking score differed between the ad libitum and limited feed groups, as did the mean standing score at 5 and 7 weeks. The feather score changed significantly with age (P0<001). The cleanliness of the nostrils decreased with age, whereas scores for the neck and rump increased. Most duck welfare measures concerning cleanliness and gait have decreased in the feed restriction group, except for nostrils. The breast and undertail scores statistically increased at 3–7 weeks, then fell from 5 to 7 weeks. The number of ducks with 1 and 2 gait scores increased with age, whereas ducks with the same footpad scores decreased. Most of the ducks had a feather quality score of zero, whereas ducks with a score of one increased with increasing age, but none of them had a head feather quality score of two at any age. In terms of cleanliness, As the ducks aged, the proportion of ducks scoring 1 increased, with the exception of nostrils and neck, where the proportion of ducks scoring 1 fell from 5 to 7 weeks. Except for nostril cleanliness and gait, the feed restriction group had significantly lower welfare scores. At 2–4 weeks of age, the feed restriction group had a considerably greater mean body weight than the ad libitum group, but at 5–7 weeks, the difference was reversed. At all ages, except for two weeks, the feed restriction group's mean body weight gain was lower than the open food access group's at all ages. On average, the feed conversion ratio was higher in the restricted group at 4 weeks than at 3, 5, and 7 weeks. A small feed restriction may help animals gain weight and have a good feed conversion ratio, which helps keep feed costs down and prevent metabolic syndrome. It is possible to set up a feed restriction plan that will improve ducks' welfare but not hurt their health scores.

INTRODUCTION

Ducks are one of the most adaptable animals, surviving in a wide range of climates and free of common poultry diseases like leukosis, infectious bronchitis, Marek's disease, and many other respiratory disorders. The best meat-to-fat ratio is achieved when they are 7 to 8 weeks old, when they are routinely butchered (Erisir *et al.,* 2009). Egypt's poultry industry is a significant source of animal protein (Abdel Gaied and Bakri, 2009). Several strains of meat-and egg-producing ducks have arisen in Egypt, alongside native Egyptian breeds (Taha *et al.,* 2013). Waterfowl output accounts for approximately 7% of total poultry output, with ducks accounting for roughly 4%. According to Guémené et al. (2012), ducks are used for a variety of products, including meat, eggs, down, feathers, and foie gras.

Because feed represents over 70 percent of the total cost in chicken farms, numerous feed regimes have been studied in various studies (Willems *et al.,* 2013). Ad libitum feeding was found to be detrimental to broiler welfare by raising growth rates, increasing body fat deposition, and increasing mortality (Zubair and Leeson, 1996). As a result, there is a pressing urgency to step up attempts to address some of these issues while also lowering feed costs (Sarvestani *et al.,* 2006).

There has been a lot of research that shows that restricting the amount of food that animals eat can help them stay healthy, keep their bodies in better shape, and save money on feeding costs (Sahraei, 2012; Sahraei and Hadloo, 2012).

It has been established that quantitative feed limitation reduces body weight and delays breeding age (Krishnappa *et al.,* 1992; Fattori *et al.,* 1993). When it comes to obtaining the same body weight as unrestrained birds, the scheduling, length, and intensity of feed restrictions all play a pivotal role (Boostani *et al.,* 2010). Initial feed restriction has a number of advantages, including cost savings from enhanced feed conversion, a reduction in early mortality syndrome, a reduction in death setbacks, a reduction in the incidence of ascites, and a reduction in skeletal disease. De Jong et al. (2005) raised concerns about animal welfare because of issues like severe competition, feed pecking, inconvenient walking, and frustration, which can make it hard for animals to get around and make them more stressed.

In conjunction with the constant drive for enhanced farm animal welfare, research is needed to establish management solutions that maximize welfare while also ensuring system resilience (Babington and Campbell, 2022). A key purpose of the current research was to examine how the feed regimen affected Mule ducks' behavior and various welfare indicators, as well as their growth performance.

MATERIALS AND METHODS

The research was done at SVU, Department of Animal Behavior and Management, Faculty of Veterinary Medicine in Egypt.

Animals and housing

This study used 48 one-day-old Mule ducklings from local farms in Egypt's Assiut Governorate. The Mule ducks were raised on a nearby farm in large, well-ventilated pens. The ground in the pens was covered with sawdust. The Faculty of Veterinary Medicine, SVU, Qena, Egypt, approved all housing and experimental protocols. The ducklings were divided into two groups of 24 each and had their wings individually tagged.

The birds were placed in 12-floor enclosures at random. The ducks were housed in two similar chambers, and each contained 12 pens. Each pen was one meter wide, one-meter long, and two-meters high. The ducklings were separated into two equal groups, with the first receiving ad libitum feed and the second receiving a feed restriction (FR). Each group was then subdivided into three duplicates, with 16 ducklings in each. All birds were kept in total confinement until 49 days old, but had unrestricted access to feed from 1 to 7 days, with water being provided at all times. The final stocking density was around 11 ducks per square meter. From days 8 to 49 of the study, ad libitum feeding was used in half of the pens, while a restricted diet (the FR group) was used in the other half of the pens from days 8 to 49 of the study. The length and time of the restriction were chosen based on previous research on growth control in chickens (Trocino *et al.,* 2015).

The FR groups got 80% of what the ad libitum birds got the day before. The birds were fed a beginning ration (22% CP and 2900 Kcal/kg) until they were 15 days old, then a finisher ratio (18% CP and 3180Kcal/kg) until they were 49 days old. At fourteen days of age, ducklings were floor-brooded at 33°C for three days and then gradually cooled to room temperature (21°C) by electric heaters at 14 days of age, with 24 hours of continual light provided by incandescent bulbs. Natural ventilation was used to keep the relative humidity in the pen between 50 and 70%.

Behavioral observation

Ducks were counted prior to each thirty-minute observation session to determine what proportion of the total ducks in the observation area were doing the various behaviors mentioned in the ethogram (Table 1), which was then used for data analysis. The birds' behavioral patterns were monitored using the instantaneous scanning sampling method every 10 minutes, according to the specified ethogram (Table 1). The hour interval was kept twice a day (Altmann, 1974), from 08:00 to 10:00 a.m. and 14:00 to 16:00 a.m., for three days per week (at 3 to 7 weeks of age). The observation was carried out by one individual who was stationed 1.5 meters ahead of every group and waited 10 minutes for the birds to acclimate (Karcher et al., 2013). Each pen was scored six times each hour, for a total of 12 scans every day. The result is shown as the proportion of ducks doing certain behaviors (Mahmoud et al., 2015).

Table 1. Definition of recorded behaviors, adapted from (Liste *et al.,* 2012; Barrett *et al.,* 2019)

Behavior	**Description**
Feeding	Pecking and scratching the ground, material intake (e. g. feed, roughage or litter).
Drinking	Having the beak in touch with the drinker.
Walking	The body moves horizontally or vertically, without engaging in any other type of behaviour, such as running, walking, leaping, or hopping.
Standing	Stand with a stretched neck while not engaged in other activities.
Resting	Sit or lie down on the ground while not doing any other activities.
Preening	Using the beak to manipulate the bird's own feather.
Gentle feather pecking (GFP)	Repetition of a gentle nibble on the feathers. The recipient is usually unresponsive and stay in place near the pecker. (Daigle, 2017).
Severe feather pecking (SFP)	Pecks at the feathers with force, speed, and singularity. As the feather is captured and forcefully pulled, the recipient may take a step backward from the performer. The feather is sometimes pulled and consumed.

Welfare assessment

At the 3rd, 5th, and 7th weeks, the welfare of 48 one-day-old ducklings was assessed. Individual ducks were scored within each group using a modified grading rubric system (Karcher *et al.,* 2013) and the "American Humane Certified Meat Ducks" (Common/Domestic Ducks) "Animal Welfare Standards Audit Tool" (American Humane Association, 2019). (Table 2: Individual characteristics were rated (nostril and feather cleanliness) on a "0 to 1" or "0 to 2" scale, with 0 being the best condition and 1 or 2 being the worst. The best condition was 0; the worst was 1 or 2.

Table 2. Scores and definitions for duck welfare indicators.

Condition	Score	Definition
Nostril cleanliness	0	Best: Clean and clear air pathways in the nostrils.
	1	Worst: Nostril airway (either side) is obstructed by dust or mucus.
Feather cleanliness	0	Best: Unstained and clean feathers or down.
	1	Worst: Manure adhesion or feather or down staining.
Feather quality	0	Best: Full coverage with down or feathers.
	1	Without blood, feather damage (e.g., short and stubby down/feathers) or bald patch less than 1 cm2.
	2	Worst: Severe feather damage (e.g., blood) or bald patch measuring more than 2 cm2.
Footpads	0	Best: Devoid of sores or embedded dust.
	1	Moderate: Patches are calloused or damaged, but sores do not cover more than half of the pad's surface area and are bloodless.
	2	Worst: More than half of the pads have lesions or callouses, and none of them are bleeding.
Gait	0	Best: Duck waddles and walks freely.
	1	Moderate: Ducks move with a little limp or laboured gait caused by crossed feet or bowlegs.
	2	Worst: Birds are averse to move and only move a limited distance when prompted, often because they have apparent leg abnormalities (severely crossed feet, synovitis or extreme legs bowing).

Productive performance

Estimating growth parameters such as body weight (BW), weight gain (WG), and feed conversion ratio (FCR). The birds were weighed 12 hours after feeding in subgroups of 12 birds per week until the trial ended.

Statistical analysis

Using spreadsheet computer software (Microsoft Excel 2010), the recorded data was processed and entered into the data editor page of IBM SPSS version 22.0. (SPSS Inc., Chicago, Illinois, USA). Repeated measures An ANOVA test with post hoc was used to compare mean scores for more than two independent groups. The mean scores of two unpaired groups were compared using an unpaired t test. Each test was conducted with a 95 percent confidence interval and 0.05 as the p-value.

RESULTS

The effects of the feeding regime on behavior, welfare indices, as well as growth performance of Mule ducks were recorded. Table 3 shows a significant difference at 3–7 weeks of age in mean scores for feeding, drinking, resting, preening, GFP, and SFP between groups that eat freely and those that have restricted feed groups. At 7 weeks, mean walking scores varied significantly between both the ad libitum and restricted feeding groups. At 5 and 7 weeks of age, the mean standing score varied significantly between the ad libitum and feed restriction groups.

There was a significant increase in feather quality traits with an increase in age (Table 4). In terms of cleanliness, there was a significant decrease in nostril scores with an increase in age. Neck scores and rump scores showed a significant increase with increasing age. Breast scores, back scores, and under the tail scores showed significant increases from 3 to 5 weeks and a significant decrease from 5 to 7 weeks of age. Among the health scores, footpad scores showed a significant increase with increasing age. Gait scores increased till 5 weeks of age and then decreased till 7 weeks.

Table 3. Comparative assessment of mean duck behavior scores based on age.

Behavior trait	Mean Score (Mean + SE)								
	3 weeks age			5 weeks age			7 weeks age		
	Ad-libitum	Feed restriction	p-value	Ad-libitum	Feed restriction	p-value	Ad-libitum	Feed restriction	p-value
Feeding	8.57±0.30	11.86± 0.31	<0.0001*	6.62 ± 0.25	7.33 ± 0.29	0.0048*	6.21 ± 0.17	6.01 ± 0.23	<0.0001*
Drinking	14.85±0.36	11.29 ±0.28	<0.0001*	12.97±0.51	9.38±0.25	<0.0001*	13.06±0.53	9.47±0.21	0.0004*
Walking	6.39 ± 0.28	6.42 ± 0.33	0.91	1.73 ± 0.14	1.53 ± 0.12	0.09	1.32 ± 0.13	0.95 ± 0.09	0.004*
Standing	3.26 ± 0.27	3.53 ± 0.33	0.32	2.30 ± 0.29	3.94 ± 0.32	<0.0001*	1.63 ± 0.18	2.04 ± 0.23	0.03*
Resting	32.48 ± 0.60	30.02 ± 0.54	<0.0001*	40.01 ± 0.71	34.41 ±0.62	<0.0001*	44.17 ± 0.83	36.34±0.63	<0.0001*
Preening	4.80 ± 0.11	4.53 ± 0.58	0.0013*	5.70 ± 0.08	5.45 ± 0.08	0.0026*	5.10 ± 0.09	5.84 ± 0.13	<0.0001*
GFP	1.38 ± 0.05	2.06 ± 0.09	<0.0001*	1.62 ± 0.05	4.07 ± 0.1	<0.0001*	1.13 ± 0.03	3.02 ± 0.09	<0.0001*
SFP	0.27 ± 0.02	0.35 ± 0.03	0.0025*	0.74 ± 0.02	0.97 ± 0.03	<0.0001*	0.51 ± 0.03	0.67 ±0.04	<0.0001*

Test applied: Unpaired t test, *indicates statistically significant difference

Table 4. Comparative analysis of mean duck welfare measure scores based on age.

Duck welfare measure	Mean Score (Mean + SE)			p-value
	3 weeks age	5 weeks age	7 weeks age	
Feather quality				
Neck	0.18 ± 0.02[a]	0.64 ± 0.04[b]	8.22 ± 0.16[c]	<0.0001*
Back	4.50 ± 0.06[a]	13.55 ± 0.17[b]	3.30 ± 0.03[c]	<0.0001*
Wings	2.20 ± 0.02[a]	16.84 ± 0.16[b]	8.29 ± 0.07[c]	<0.0001*
Tail	4.66 ± 0.06[a]	58.49 ± 0.04[b]	14.26 ± 0.03[c]	<0.0001*
Cleanliness				
Nostril	1.61 ± 0.05[a]	0.93 ± 0.03[b]	0.61 ± 0.03[c]	<0.0001*
Neck	0.74 ± 0.03[a]	1.52 ± 0.02[b]	3.06 ± 0.05[c]	<0.0001*
Breast	1.38 ± 0.01[a]	5.40 ± 0.06[b]	4.58 ± 0.06[c]	<0.0001*
Back	1.68 ± 0.02[a]	4.03 ± 0.04[b]	2.76 ± 0.03[c]	<0.0001*
Rump	0.385 ± 0.03[a]	1.14 ± 0.04[b]	5.64 ± 0.10[c]	<0.0001*
Under the tail	7.70 ± 0.06[a]	27.28± 0.26[b]	3.72 ± 0.03[c]	<0.0001*
Health Score				
Gait	3.79± 0.04[a]	4.26 ± 0.05[b]	1.22 ± 0.01[c]	<0.0001*
Footpad	0.45 ± 0.03[a]	0.74 ± 0.04[b]	1.74 ± 0.03[c]	<0.0001*

Test applied: Repeated measures ANOVA with Post Hoc, *indicates a statistically significant difference, Values superscripted with a different letter are statistically different.

Table 5, shows significantly decreased duck welfare measure scores in the feed restriction group, except for nostril cleanliness and gait scores, which are significantly increased.

Table 6, displays the distribution of ducks with each welfare score according to age. In feather quality, the majority of ducks showed a score of 0. None of them had a score of 2 in head feather quality at all ages. The proportion of ducks with score 1 increased with increasing age, which was statistically significant. Also, in cleanliness, there was a significant increase in the number of ducks with a score of 1 with increasing age, except in the neck and nostrils, which showed a decrease in the proportion of ducks with a score of 1 at 5 and 7 weeks, respectively. Among the health scores, the number of ducks with gait scores of 1 and 2 went up, but the number of ducks with footpad scores of 1 and 2 went down with age.

Table 5. Comparative analysis of mean duck welfare scores based on feeding regimes.

Duck welfare measure	Mean Score (Mean + SE)		p-value
	Ad-libitum	Feed restriction	
Feather quality			
Neck	0.64 ± 0.04	0.18± 0.02	<0.0001*
Back	13.55 ± 0.17	4.50 ± 0.06	<0.0001*
Wings	16.28 ± 0.16	2.22± 0.02	<0.0001*
Tail	58.49 ± 0.87	4.66 ± 0.07	<0.0001*
Cleanliness			
Nostril	0.93 ± 0.01	1.61 ± 0.01	<0.0001*
Neck	1.42 ± 0.02	0.74 ± 0.01	<0.0001*
Breast	5.40 ± 0.06	1.38± 0.02	<0.0001*
Back	4.03 ± 0.04	1.68 ± 0.02	<0.0001*
Rump	1.136 ± 0.01	0.38 ± 0.01	<0.0001*
Under the tail	27.29 ± 0.26	7.70 ± 0.07	<0.0001*
Health Score			
Gait	3.79 ± 0.04	4.26 ± 0.05	<0.0001*
Footpad	0.45 ± 0.01	0.74 ± 0.02	<0.0001*

Test applied: Unpaired t test, *indicates statistically significant difference

Table 6. Distribution of ducks with each welfare scores based on age.

Welfare measure	Percentage of ducks (%)									p-value
	3rd week age			5th week age			7th week age			
	Welfare Scores									
	0	1	2	0	1	2	0	1	2	
Feather quality										
Head	98.3	1.7	0	98.5	1.5	0	98.2	1.8	0	<0.0001*
Neck	89.1	6.4	4.5	97.1	1.9	0.4	93.1	6.9	0	<0.0001*
Back	94.5	3.4	2.1	84.7	7.3	8.0	66.1	15.4	18.5	<0.0001*
Wings	89.5	8.4	2.1	82.1	14	3.8	40.1	43.4	16.5	<0.0001*
Tail	95.9	4.1	0	89.0	9.7	0.3	48.4	45.3	6.3	<0.0001*
Cleanliness										
Nostril	80.2	19.8		76.5	23.5		82.3	18		<0.0001*
Neck	94.6	5.4		96.7	3.3		94.4	5.6		<0.0001*
Breast	92.1	7.9		91.2	8.8		73.6	26		<0.0001*
Back	91.6	8.4		91.4	8.6		82.4	18		<0.0001*
Rump	91.0	8.1		96.3	3.7		95.5	4.5		<0.0001*
Under the tail	82.3	17.7		41.6	58.4		17.4	83		<0.0001*
Health Score										
Gait	95.1	4.4	0.5	82.4	16.6	1.0	80.2	17.6	2.2	<0.0001*
Footpad	33.3	51.3	16.4	54.1	36.8	9.1	42.7	40.7	16.7	<0.0001*

*Indicates statistically significant difference.

In table 7, there is a significantly higher mean body weight among the feed restriction group than the ad libitum group at 2–4 weeks of age, whereas there was a significantly lower mean body weight among the feed restriction group than the ad libitum group at 5–7 weeks. At all ages, with the exception of two weeks, when it was significantly higher, mean body weight gain was markedly smaller in the feed restriction group than in the free food access group. At 4 weeks, the feed conversion ratio was significantly larger in the group with feed restriction than it was in the ad libitum group, whereas at 3, 5 and 7 weeks it was significantly lower.

Table 7. Comparative analysis of mean duck performance scores based on feeding regime and age.

Duck performance	2 weeks	3 weeks	4 weeks	5 weeks	6 weeks	7 weeks
Body weight (gm)						
Ad-libitum	256.39 ± 1.54	501.71±2.62	1012.58 ± 4.15	1452.87 ± 5.8	1956.16± 6.62	2332.36±7.06
Feed restriction	269.93 ± 1.54	528.09±3.13	1021.21±4.97	1021.21±4.15	1912.22 ± 5.97	2228.98±7.1
p-value	<0.0001*	<0.0001*	0.04*	<0.0001*	<0.0001*	<0.0001*
Body weight gain (gm)						
Ad-libitum	116.78±6.89	168.45 ±36.78	516.78 ± 24.54	452.65 ± 29.59	501.08 ± 34.54	389.89 ±33.92
Feed restriction	134.22±10.21	167.87± 39.59	489.12 ± 19.49	406.03 ± 32.51	489.63 ± 33.72	321.98 ± 42.86
p-value	<0.0001*	<0.0001*	<0.0001*	<0.0001*	0.103	<0.0001*
Feed conversion ratio						
Ad-libitum	0.09 ±0.21	2.68± 0.48	4.71± 1.31	6.71± 2.79	8.11± 2.31	1.51 ± 0.15
Feed restriction	0.06±0.21	2.31 ± 0.15	7.41± 2.71	4.39 ± 0.69	8.51 ±1.29	0.04 ± 0.41
p-value	0.29	<0.0001*	<0.0001*	<0.0001*	0.29	<0.0001*

Test applied: Unpaired t test, *indicates statistically significant difference

DISCUSSION

As an important aspect of duck farm inspections and investigations, animal welfare examinations are performed on a regular basis. Animal-based metrics are commonly used in such evaluations, as they are regarded to represent a more realistic portrayal of the animal's true status of welfare (Blokhuis *et al.,* 2003). The core aim of this study was to find out the influence of feeding regime (early feed restriction regime vs. ad libitum) on behavior, some welfare indices, and growth performance of Mule ducks.

Feed limitation over an extended period of time may be harmful, resulting in undesirable habits including feather pecking and a reduction in performance (Bentley *et al.,* 2020). It is possible, however, to implement a feed restriction paradigm that increases duck skeletal health while avoiding other potential negative implications. Feather pecking and a decrease in productivity (Bentley *et al.,* 2020). However, a feed restriction paradigm that promotes duck skeletal health while avoiding other potential negative consequences is achievable. At 7 weeks of age, mean walking and standing scores varied significantly between the ad libitum and feed restriction groups. It may be due to the significantly lower calorie supply for the ducks, which compelled them to restrict their movement. In addition, there were significant differences in mean scores for GFP and SFP between ad libitum and feed restriction groups at 3 weeks, 5 weeks, and 7 weeks of age. SFP is hypothesized to emerge from investigatory GFP that becomes more powerful and causes feather removal as well as further plumage and/or tissue injury (Dalton *et al.,* 2013). When evaluated in turkeys demonstrating SFP, it was linked to less active behavior, such as extended reclining durations and far less frequent standing behavior. SFP outbreaks in poultry can be caused by a number of issues, but the most common one is a chicken's foraging behavior because it doesn't get enough stimulation from the environment (Dixon *et al.,* 2008), which can be caused by not having enough food.

Feathers are intricate physiological integumentary components that are replenished by birds on a regular basis. Birds are unable to fly, forage, or attract a mate if their feathers are not in good shape (Pennycuick, 1975). A significant increase in feather quality traits was noted with an increase in age in the said study. This may probably be due to the advantages conferred by the breed of the ducks employed, along with the right balance of feed, locomotion, and ambient housing facilities maintained during the study period. However, in cleanliness, there was a significant decrease in nostril scores with an increase in age. Restricted access to troughs, baths, and showers may be a possible reason for the effect that was seen.

Gait is a complicated feature that necessitates the convergence of sensory perception, stability, conformation, and precise motor control, and assessments of inheritance for poultry gait are modest (Duggan *et al.,* 2017). The use of a visual gait score, which is a qualitative evaluation of each bird's walking ability, is used to reduce the prevalence of inappropriate gait in breeding flocks. The present study demonstrated increased gait scores increased till 5 weeks of age, with a further decline till 7 weeks. The changes in skeletal muscle growth with increasing age may be a probable reason for the observed effect (Brickett *et al.,* 2007). To figure out why ducks have different walking abilities, researchers will use methods like methods such as computed tomography (CT) and bone ashing (Zhong *et al.,* 2012; Van Wyhe *et al.,* 2014). These methods will let them look at ducks' shapes and bones so that they can figure out what causes them to walk in different ways.

Footpad scores are utilized as an animal welfare measure in research studies and on farms (Weber Wyneken *et al.,* 2015). Foot pad dermatitis (FPD) is a key problem for food safety, farm yields, and financial viability, on top of the ramifications for animal welfare (Shepherd and Fairchild, 2010). A significant decrease in footpad scores was noted in the studied ducks with increasing age. This is most likely due to the balance achieved in the current study due to the balance of feed intake, locomotion, and housing conditions. However, many contradictory results have also been reported. The incidence and intensity of FPD are known to increase with both bird age and weight (Leishman *et al.,* 2021). With passing time, the weight of poultry increases with age. The intensity of FPD and body weight gain have been reported to have a positive correlation (0.22) (Da Costa *et al.,* 2014). The prevalence of FPD was found to increase by 3.6 percentage for every additional kilogram of body weight, regardless of the gender of the flock. The bigger birds are usually older and tend to spend much more time on the litter, which can contribute to FPD progression (Tullo *et al.,* 2017). Affected birds are reported to be less active and exhibiting less behavioral variety (Weber Wyneken *et al.,* 2015). This could cut down on how much food the animals eat, which could slow down their growth rate and body weight, as well as make them more likely to get contact dermatitis and die (Mayne *et al.,* 2007).

Many research studies on poultry have found that restricting feed not only lowers feed costs, but also improves feed conversion ratio, whilst lowering fat content (Benyi *et al.,* 2009). It also aids in the normalization of the animal's digestion, which makes it a great study model with fewer complicated morbidities (Keenan *et al.,* 1999). Despite the fact that research on how food restrictions affect ducks hasn't been very extensive, a report said that male Pekin ducks were able to grow faster and have better overall body composition when they had unlimited access to food (Wu *et al.,* 2012). On the other hand, a long time without food could be bad, causing bad habits like feather picking and pecking and less productivity (Bentley *et al.,* 2020).

The present study implied a significantly higher mean body weight among the Feed Restriction group than the Ad Libitum group at 2-4 weeks of age, whereas there was a significantly higher mean body weight among the group with free access to food than the feed restriction group at 5-7 weeks. In animals that were underfed, compensatory growth was seen, and refeeding these animals made them grow faster in order to make the physiological and psychological links work together again (Kholya *et al.,* 2017).

The feed restriction group's mean body weight growth was lower than the ad libitum groups at all ages except for two weeks, when it was significantly higher. Negative growth was observed after a restricted diet, indicating that the level of dilution used was insufficient to provide the dietary requirements for weight gain or maintenance. The feed restriction groups exhibited a significantly greater FCR at 4 weeks than the ad libitum group, but a lower ratio at 3–7 weeks. Feed restriction has been shown to boost FCR, caloric effectiveness, and reduce broiler mortality (Novel *et al.,* 2009). However, the decreased feed conversion ratio in the following week may be attributed to the induction of a stress mechanism in the gut that could have led to higher corticosterone concentrations associated with less output (Fraley *et al.,* 2013). Because the mucosal surface is so close to the intestinal contents, stressors in the digestive system can cause alterations in the intestinal mucosa rather rapidly. Xu et al. (2002) stated that bigger crypts and shorter villus may not be able to get enough nutrients and perform well.

CONCLUSION

Overall, our findings imply that a little feed limitation may not have a negative influence on production targets and may even have some physiological benefits. Hence, it is necessary to establish a feed limitation strategy that will increase duck welfare without compromising the health scores. In the future, more long-term studies could help figure out how the important variables in this study affect the behavior, health scores, and welfare of Mule ducks, and economic, social, and animal welfare solutions need to be found.

ACKNOWLEDGMENT

The authors would like to thank Animal Behaviour and Husbandry Department, Faculty of Veterinary Medicine, Sohag University, Sohag, for the support.

CONFLICT OF INTEREST

None declared.

REFERENCES

Abdel Gaied, S., Bakri, H.H., 2009. An economic evaluation for the impacts of spreading of bird flu on poultry sector in Egypt. World J. Agric. Res., 5: 264-9.

Altmann, J., 1974. Observational study of behavior: sampling methods. Behaviour., 49: 227-67.

American Humane Association, 2019. American Humane Certified™ Animal Welfare Standards for Ducks (Meat and Egg Layers) (Revised June 2019).

Babington, S., Campbell, D.L., 2022. Water for domestic ducks: The benefits and challenges in commercial production. Front. Anim. Sci., 3.

Barrett, L., Malecki, I., Blache, D., 2019. Differences in pre-laying behavior between floor-laying and nest-laying Pekin ducks. Anim., 9: 40.

Benyi, K., Acheampong-Boateng, O., Norris, D., Mathoho, M., Mikasi, M.S., 2009. The response of Ross 308 and Hybro broiler chickens to early and late skip-a-day feed restriction. Trop. Anim. Health Prod., 41: 1707-13.

Bentley, A., Porter, L., Van Blois, L., Van Wyk, B., Vuong, C., Tellez-Isaias, G., Shafer, D., Tucker, Z., Fraley, S., Hargis, B. and Fraley, G., 2020. A feed restriction milieu for Pekin meat ducks that may improve gait characteristics but also affects gut leakiness. Poult. Sci., 99: 39-47.

Blokhuis, H.J., Jones, R.B., Geers R., Miele, M., Veissier, I., 2003. Measuring and monitoring animal welfare: transparency in the food product quality chain. Anim. Welf., 12: 445-55.

Boostani, A., Ashayerizadeh, A., Mahmoodian, F.H., Kamalzadeh, A., 2010. Comparison of the effects of several feed restriction periods to control ascites on performance, carcass characteristics and hematological indices of broiler chickens. Braz. J. Poult. Sci., 12: 170-77.

Brickett, K.E., Dahiya, J.P., Classen, H.L., Annett, C.B., Gomis, S., 2007. The impact of nutrient density, feed form, and photoperiod on the walking ability and skeletal quality of broiler chickens. Poult. Sci., 86: 2117-25.doi:10.1093/ps/86.10.2117

Da Costa, M.J., Grimes, J.L., Oviedo-Rondón, E.O., Barasch, I., Evans, C., Dalmagro, M., Nixon, J., 2014. Footpad dermatitis severity on turkey flocks and correlations with locomotion, litter conditions, and body weight at market age. J. Appl. Poult. Res., 23: 268-279.doi: 10.3382/japr.2013-00848

Dalton, H.A., Wood, B.J., Torrey, S., 2013. Injurious pecking in turkeys: development, causes, and potential solutions. World’s Poult. Sci. J., 69: 865-75.

De Jong, I.C., Fillerup, M., Blokhuis, H.J., 2005. Effect of scattered feeding and feeding twice a day during rearing on indicators of hunger and frustration in broiler breeders. Appl. Anim. Behav. Sci., 92: 61-76. doi: 10.1016/j.applanim.2004.10.022

Dixon, L.M., Duncan, I.J.H., Mason, G., 2008. What's in a peck? Using fixed action pattern morphology to identify the motivational basis of abnormal feather-pecking behaviour. Anim. Behav., 76: 1035-42.

Duggan, B.M., Rae, A.M., Clements, D.N., Hocking, P.M., 2017. Higher heritabilities for gait components than for overall gait scores may improve mobility in ducks. Genet. Sel. Evol., 49: 1-7. doi:10.1186/s12711-017-0317-2

El Kholya, S.Z., El-Tahawy, A.S., 2017. Effects of Early Feed Restriction on Some Welfare Indices and Economic Efficiency of White Pekin and Mule Ducks. Alex. J. Vet. Sci., 52:68-80.

Erisir, Z., Poyraz, O., Onbasilar, E.E., Erdem, E. Oksuztepe, G.A., 2009. Effect of housing system swimming pool and slaughter age on duck performance, carcass and meat characteristics. Anim. Vet. Adv., 8: 1864-1869.

Fattori, T.R., Wilson, H.R., Harms, R.H., Mather, F.B., Miles, R.D., Butcher, G.D., 1993. Response of Broiler Breeder Females to Feed Restriction Below Recommended Levels.: 3. Characterizing the Onset of Sexual Maturity. Poult. Sci., 72: 2044-51.

Fraley, G.S., Coombs, E., Gerometta, E., Colton, S., Sharp, P.J., Li, Q., Clarke, I. J., 2013. Distribution and sequence of gonadotropin-inhibitory hormone and its potential role as a molecular link between feeding and reproductive systems in the Pekin duck (Anas platyrhynchos domestica). Gen. Comp. Endocrinol., 184: 103-110.doi: 10.1016/j.ygcen.2012.11.026

Guémené, D., Shi, Z.D., Guy, G., 2012. Production systems for waterfowl. Alternative systems for poultry: health, welfare and productivity, 128-154.

Karcher, D. M., Makagon, M.M., Fraley, G.S., Fraley, S.M., Lilburn, M.S., 2013. Influence of raised plastic floors compared with pine shaving litter on environment and Pekin duck condition. Poult. Sci., 92: 583-90.

Keenan, K.P., Ballam, G.C., Soper, K.A., Laroque, P., Coleman, J.B., Dixit, R., 1999. Diet, caloric restriction, and the rodent bioassay. Toxicol. Sci., 52(suppl_1): 24-34.doi: 10.1093/toxsci/52.suppl_1.24

Krishnappa, P., Devegowda, G., Ramappa, G.R., Lokanath, B.S., 1992. Effect of restricted feeding on subsequent performance of broiler breeder dams. Indian Poult. Sci., 27: 29-31.

Leishman, E.M., van Staaveren, N., Osborne, V.R., Wood, B.J., Baes, C.F., Harlander-Matauschek, A., 2021. A Cross-Sectional Study on the Prevalence of Footpad Dermatitis in Canadian Turkeys. Front. Anim. Sci., 43. doi:10.3389/fanim.2021.726907

Liste, G., Kirkden, R.D., Broom, D.M., 2012. Effect of water depth on pool choice and bathing behaviour in commercial Pekin ducks. Appl. Anim. Behav. Sci., 139: 123-33.

Mahmoud, U.T., Abdel-Rahman, M., Darwish, M., Applegate, T., Cheng, H. 2015. Behavioural changes and feathering score in heat stressed broiler chickens fed diets containing different levels of propolis. Appl. Anim. Behav. Sci., 166: 98-105.

Mayne, R.K., Else, R.W., Hocking, P.M., 2007. High litter moisture alone is sufficient to cause footpad dermatitis in growing turkeys. Br. Poult. Sci., 48: 538-545. doi: 10.1080/00071660701573045

Novel, D.J., Ng'Ambi, J.W., Norris, D., Mbajiorgu, C.A., 2009. Effect of different feed restriction regimes during the starter stage on productivity and carcass characteristics of male and female Ross 308 broiler chickens. Int. J. Poult. Sci, 8: 35-39.

Pennycuick, C.J., 1975. Mechanics of flight. In: Farner D. S. and King J. R. (eds) Avian Biology. Academic Press: London. 5: 1-75.

Sahraei, M., 2012. Feed Restriction in Broiler Chickens Production: A Review. Glob. Vet., 8: 449-58.

Sahraei, M., Hadloo, M.H., 2012. Effect of Physical Feed Restriction in Finisher Period on Carcass Traits and Broiler Chickens Performance. Glob. Vet., 9: 201-4.

Sarvestani, T.S., Dabiri, N., Agah, M.J., Norollahi, H., 2006. Effect of Pellet and Mash Diets Associated with Biozyme Enzyme on Broilers Performance, Int. J. Poult. Sci., 5: 485-90.

Shepherd, E.M., Fairchild, B.D. 2010. Footpad dermatitis in poultry. Poult. Sci. 89: 2043-2051. doi: 10.3382/ps.2010-00770

Taha, A., Abd El-Ghany, F., Sharaf, M., 2013. Strain and sex effects on productive and slaughter performance of developed local Egyptian and Canadian chicken strains. J. Anim. Poultry Prod., 4: 297-319.

Trocino, A., Piccirillo, A., Birolo, M., Radaelli, G., Bertotto, D., Filiou, E., Petracci, M., Xiccato, G., 2015. Effect of genotype, gender and feed restriction on growth, meat quality and the occurrence of white striping and wooden breast in broiler chickens. Poult. Sci., 94: 2996-3004. doi: 10.3382/ps/pev296.

Tullo, E., Fontana, I., Peña Fernandez, A., Vranken, E., Norton, T., Berckmans, D., Guarino, M., 2017. Association between environmental predisposing risk factors and leg disorders in broiler chickens. J. Anim. Sci., 95: 1512-1520. doi: 10.2527/jas2016.1257

Van Wyhe, R.C., Regmi, P., Powell, B.J., Haut, R.C., Orth, M.W., Karcher, D.M. 2014. Bone characteristics and femoral strength in commercial toms: The effect of protein and energy restriction. Poult. Sci., 93: 943-952.doi:10.3382/ps.2013-03604

Weber Wyneken, C., Sinclair, A., Veldkamp, T., Vinco, L.J., Hocking, P.M., 2015. Footpad dermatitis and pain assessment in turkey poults using analgesia and objective gait analysis. Br. Poult. Sci., 56: 522-530.doi:10.1080/00071668.2015.1077203

Willems, O.W., Miller, S.P., Wood, B.J., 2013. Assessment of residual body weight gain and residual intake and body weight gain as feed efficiency traits in the turkey (Meleagrisgallopavo). Genet. Sel. Evol., 45: 1-8. doi:10.1186/1297-9686-45-26

Wu, L., Guo, X., Fang, Y., 2012. Effect of diet dilution ratio at early age on growth performance, carcass characteristics and hepatic lipogenesis of Pekin ducks. Braz. J. Poult. Sci., 14: 43-9.

Xu, Z.R., Zou, X.T., Hu, C.H., Xia, M.S., Zhan, X.A., Wang, M.Q., 2002. Effects of dietary fructooligosaccharide on digestive enzyme activities, intestinal microflora and morphology of growing pigs. Asian-Aus. J. Anim. Sci., 15: 1784-89.

Zhong, Z., Muckley, M., Agcaoglu, S., Grisham, M.E., Zhao, H., Orth, M., Lilburn, M.S., Akkus, O., Karcher, D.M., 2012. The morphological, material-level, and ash properties of turkey femurs from 3 different genetic strains during production. Poult. Sci., 91: 2736-46.doi:10.3382/ps.2012-02322

Zubair, A.K., Leeson, S., 1996. Changes in body composition and adipocyte cellularity of male broilers subjected to varying degrees of early-life feed restriction. Poult.Sci., 75: 719-28. doi:10.3382/ps.0750719