JWPR
Journal of World's Poultry Research

2023, Scienceline Publication
J. World Poult. Res. 13(2): 261-267, June 25, 2023

Research Paper, PII: S2322455X2300029-13

DOI: https://dx.doi.org/10.36380/jwpr.2023.29

Effects of Replacing Maize by Proso Millet on Performance of Broiler Chickens

Melad Anwar Khalil *, Hassan Adham Tarsha, and Riad Jamil Kussaibati

Department of Animal Production, Faculty of Veterinary Medicine, Hama University, Hama, Syria

*Corresponding author's E-mail: meladkhlel@hotmail.com

Received: 26 February 2023
Accepted: 17 April 2023

ABSTRACT

The continual rise in the cost of poultry feed ingredients, the fluctuations in price and the comparatively insufficient maize supply have prompted a search for less expensive alternatives. This research study was carried out to investigate the impact of a partial or total replacement of maize with proso millet on performance parameters of broiler chickens, including live body weight, feed conversion ratio, mortality rate and carcass yield. An experiment was carried out using 160 one-day-old broiler chicks of a commercial breed. The chicks were randomly assigned to 5 groups of 32. They consumed different isoprotein and isocaloric diets in which maize was replaced by proso millet at 0, 25, 50, 75, or 100% inclusion rates as T1, T2, T3, T4 and T5. Results showed that all broiler chickens fed on diets containing different rates of millet instead of maize significantly improved live body weight, feed conversion ratio, and carcass yield for females and males compared to T1. Additionally, it was observed that there was a significant decrease in the relative weight of the liver for females and males compared to T1. The use of millet in diets did not negatively affect the broilers' health, and the mortality rate was low throughout the experiment. These results confirmed that maize could be replaced by proso millet in broiler chicken diets up to 100%.

Keywords: Body weight, Broiler chickens, Feed conversion ratio, Maize, Proso millet

INTRODUCTION

Most diets used globally to feed chickens are composed of maize and soybean meal. Maize has been recognized as a source of energy. However, the increasing demand and competition between humans and animals and the diversity of its industrial uses for biofuel production raised the prices of maize especially in the drier regions (Ranum et al., 2014). Consequently, the cost of producing poultry diets, which accounts for about 70% of the total production costs, increased (Dei, 2017). This encouraged researchers to study the possibility of replacing maize with cereals that are rich in energy and do not need large amounts of water for cultivation. It was found that millet grains can be used as a substitute for maize, and it could partially or completely replace maize in poultry diets (Baurhoo et al., 2011).

More than 20 varieties of millet have been cultivated around the world at different times (A Millet Atlas, 2006). The most common are proso, pearl, finger, kodo, foxtail, little, and barnyard millet varieties (Habiyaremye et al., 2017).

Millet is a fast-growing cereal plant that is widely grown in warm countries and regions with poor soils, periodic rainfall, and high temperature (Maidala and Abdullahi, 2016).

The most important characteristic of millet is the potential to cultivate it after the main crops such as wheat, barley and sunflower due to its short productive season and its high efficiency in resisting drought (Nielsen and Vigil, 2017). In addition, proso millet is considered to be of a high nutritional value and its applications are varied between human and bird nutrition and industrial purposes (Das et al., 2019). It is one of the most important crops suitable for rain-fed agriculture as it has a shallow root system (90-120 cm) and a short productive season (60–90 days). This makes it an exceptional crop for lands with rainfed farming systems (Rajasekaran et al., 2023).

To cite this paper: Khalil MA, Tarsha HA, and Kussaibati RJ (2023). Effects of Replacing Maize by Proso Millet on Performance of Broiler Chickens. *J. World Poult. Res.*, 13(2): 261-267. DOI: https://dx.doi.org/10.36380/jwpr.2023.29

Through the research conducted on millet, it was found that the gross energy content of millet was similar to, or slightly better, than that of maize (4331, 4325 kcal/ kg respectively; Khalil et al., 2022). The true metabolisable energy (ME) corrected for nitrogen (TMEN) of maize is 3,350 Kcal/kg compared to 3,300 - 3,450 Kcal/kg for pearl millet (Cisse et al., 2017). The protein concentration of millet is higher than that of maize, but has similar apparent digestible amino acid coefficients (Vasan et al., 2008). For proso millet, the category on which this research was conducted, protein content may vary from 12.4 to 17%, with a high content of amino acids, especially sulfur amino acids (methionine and cysteine; Das et al., 2019). Moreover, millet is also considered rich in fat, and contains a higher percentage of fibers compared to other cereals, polyphenols and other nutraceutical compounds (Habiyaremye et al., 2017). Millet also contains a lot of bioactive compounds that have a beneficial effect on health, such as phenolics and dietary fiber together with micronutrients (carotenoids and tocopherols). They have antioxidant properties which are important to reduce the harmful effects of oxidation (Liang and Liang, 2019). The inclusion of millet grains in animal feed has gained momentum in recent years. It has been demonstrated that millets have the potential to be used as an alternative source of energy in poultry diets (Hassan et al., 2021). Therefore, this research aimed to study the possibility of replacing maize with proso millet (*Panicum miliaceum L*) in broiler chicken diets and its effect on production performance.

MATERIALS AND METHODS

Ethical approval

This research was carried out as a part of PhD researches in poultry nutrition at the Faculty of Veterinary Medicine, department of animal production after the approval of the Ethics Committee of the Faculty of Veterinary Medicine, Hama University, Syria, under the registration number 540, on 3/17/2021 in compliance with all local animal welfare legislation.

Experimental design

A total of 160 unsexed one-day-old Hubbard broiler chickens (39.25 ± 0.75 g at hatch) were used in this study. The chickens purchased from Al-Masri hatchery in Damascus city, Syria. Broiler chickens were randomly divided into five treatment groups with 4 replicates of 8 chicks each. The experimental period was divided into 3 phases: starter (days 1-10), grower (days 11-24), and finisher (days 25-42).

The diets used were formulated to meet the nutritional specifications recommended by the breed producer according to the management guide (Hubbard, 2007). All diets were offered as mash form-and formulated to be isoprotein and isocaloric by adjusting oil and soybean meal content to compensate for lower metabolizable energy (ME) and relatively higher protein content of millet, compared to maize. Millet replaced maize in the diets at 0%, 25%, 50%, 75%, and 100% inclusion rates as T1, T2, T3, T4 and T5 respectively. The composition and analysis of the experimental diets are shown in Table 1.

Housing and management

Broiler chickens were raised in open-sided housing conditions with litter floors. Feed and water were offered *ad-libitum* throughout the trial period.House temperatures (indoors) started at 33 °C and thereafter reduced by 0.5 °C per day until 24 °C was attained on day 19. Continuous lighting was provided for 24 hours in the first three days and then 22 hours of lighting and 2 hours of darkness pattern was adopted for the rest of the experimental period.

Vaccination schedule

The broiler chickens were vaccinated with Spain's HIPRAVIAR vaccinations as follows: on day 7 Newcastle disease plus Infectious bronchitis (B1, H120) by eye drops through intraocular route, on day 14 Infectious bursal disease (CH/80) by drinking water, on day 21 and 35 Newcastle disease (Clone 30) by eye drops.

Experimental procedures

The experiment lasted for 6 weeks. Live body weight (LBW), feed consumption and feed conversion ratio (FCR) were estimated every week (WK). Mortality rate was daily recorded. Feed conversion was calculated based on the relationship between feed intake and weight gain.

Carcass yield

At day 42 of age, the feed was removed for 6 hours before slaughter in order to ensure emptiness of the digestive tract. Six male and six female broilers were randomly taken from each group-and carcass yield was estimated. Prior to slaughter, the LBW of each bird was recorded and the percentage weight of the carcass relative to LBW was calculated. In addition, the liver, breast and thigh meat weights were calculated.

Statistical analysis

Data were analyzed by one-way analysis of variance (ANOVA) using the SPSS statistical package (IBM SPSS Statistics 25.0). The significance of difference between means was determined by the method of Least Significance Difference (LSD). Statistical significance was accepted when $p < 0.05$.

Table 1. Ingredient composition of broiler chicken's diets for a period of 42 days

Item	Starter (days 0-10)					Grower (days 11-24)					Finisher (days 25-42)				
	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5
Maize (%)	57.6	43	28.5	14.9	0	62.5	46.6	31.55	15.5	0	66.5	50.5	33.2	16.5	0
Proso millet (%)	0	14.5	29	42.7	57.6	0	16.1	31.4	47.5	63.5	0	15.9	33.2	50.5	67.2
Soybean meal (46%)	37.4	36.95	36.45	36	35.4	32	31.4	30.9	30.3	29.6	28.9	28.35	27.8	27.1	26.5
Sun flower oil (%)	0.3	0.81	1.27	1.68	2.16	0.8	1.25	1.66	2.17	2.52	0.53	1.08	1.65	2	2.48
Dicalcium phosphate (%)	2.4	2.4	2.4	2.4	2.4	2.2	2.2	2.2	2.2	2.2	1.89	1.9	1.9	1.9	1.9
Limestone (%)	0.89	0.93	0.98	0.94	1.03	1.12	1.09	0.99	0.99	0.81	0.97	1.06	1.06	0.83	0.77
L-Lysine (70%)	0.29	0.3	0.3	0.3	0.31	0.29	0.29	0.29	0.3	0.33	0.22	0.24	0.24	0.24	0.24
DL-Methionine (99%)	0.31	0.29	0.28	0.26	0.25	0.28	0.26	0.24	0.23	0.21	0.23	0.21	0.19	0.17	0.15
L-Thrionine, (100%)	0.06	0.07	0.07	0.07	0.1	0.06	0.06	0.05	0.06	0.08	0.01	0.01	0.01	0.01	0.01
Choline chloride (60%)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Salt (%)	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Sodium bicarbonate (%)	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Minerals[a] + Vitamins[b] (%)	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Chemical analyses															
Crude protein (%)	22.7	22.7	22.7	22.7	22.7	20.6	20.6	20.6	20.6	20.6	19.5	19.5	19.5	19.5	19.5
ME, Kcal/Kg	2928	2930	2929	2930	2929	3000	2999	2999	3000	2999	3024	3024	3026	3025	3025
Total Lysine (%)	1.44	1.45	1.44	1.44	1.45	1.29	1.29	1.3	1.3	1.3	1.16	1.17	1.17	1.17	1.2
Total Methionine (%)	0.67	0.65	0.64	0.6	0.6	0.61	0.59	0.58	0.6	0.6	0.54	0.53	0.51	0.5	0.5
Total (Met+Cys) (%)	1.08	1.08	1.08	1.08	1.08	0.99	0.99	0.99	0.99	0.99	0.9	0.9	0.9	0.9	0.9
Calcium (%)	1.06	1.08	1.1	1.1	1.1	1.09	1.07	1.03	1	1	0.95	0.98	0.98	0.9	0.9
Available Phosphorus (%)	0.47	0.47	0.5	0.5	0.5	0.44	0.44	0.44	0.44	0.44	0.39	0.39	0.4	0.4	0.4

[a]Trace mineral premix provides the following in grams per ton of diets: CU: 16, I: 1.28, FE: 21, MN: 120.9, SE: 0.3, ZN: 112.5. [b]Vitamin premix provides the following in grams per ton of diets: A: 12, D3: 10, E: 175, K: 3.25, B1: 3.5, B2: 8.8, B3: 65, B5: 20, B6: 4.4, B7: 0.22, B9: 2.2, B12: 0.017.

RESULTS

The effect of the inclusion of millet in experimental diets on live body weight (LBW) in the different ratios is presented in Table 2. The result showed that the LBW at the end of the experiment was greater ($P < 0.05$) for T5 as compared to T1, T2, T3 but, similar to T4. Live body weight for groups fed diets of T2, T3, T4 and T5 was higher (7.5, 12, 17 and 20 %, respectively) as compared to those fed with control basal diet T1.

Mortality rate during the experiment is shown in Table 2. During the trial period, there was no observable sign of morbidity, but mortality occurred fortuitously within the first week of chicks' life. At the end of the experiment, cumulative mortality was 6.25, 0, 6.25, 6.25 and 6.25% for T1, T2, T3, T4 and T5 respectively. This may be due to stress or mechanical injury during handling and transportation, and there was no significant difference in mortality percentage among the treatments.

Feed conversion ratio was significantly ($P < 0.05$) improved from the first week until the end of the experiment. Overall FCR at six weeks of age, and the value was higher for T1 and T2 than T3, T4 and T5 (Table 3). A significant ($P < 0.05$) improvement in FCR was recorded in the groups fed with diets T2, T3, T4 and T5 as compared to the control group T1. In general, the highest level of millet showed the best FCR compared to other groups.

The results concerning carcass yield and liver weight, expressed as a percentage of the live body weight, are demonstrated in Table 4. The results showed that the carcass yield of broiler chickens fed with diets T4 and T5 was significantly higher ($p < 0.05$) than T1 in males, and a significant ($P < 0.05$) improvement was recorded in T5 as compared to T1 in females, with no difference between the other groups. Similarly, for the breast and thigh meat, T5 recorded the highest value for the breast meat, and T4 recorded the highest value for the thigh meat with significant difference ($p < 0.05$) compared to T1 in females. However, in males the highest value for the breast meat was recorded in T2, and the highest value for thigh meat was recorded in T4 with a significant difference ($p < 0.05$) compared to T1. It was also noted that the percentage of liver decreased linearly and significantly ($p < 0.05$) with increasing inclusion rates of millet.

Table 2. Live body weight of Hubbard broiler chickens (g) ± SEM fed on diets containing different levels of millet

Age (week) \ Treatments	T1	T2	T3	T4	T5
1	158.55 ^{a} ± 3.31	156.45 ^{a} ± 2.5	160.33 ^{ac} ± 20	167.66 ^{bc} ±1.86	168.39 ^{b} ± 2.66
2	383.39 ^{a} ± 6.9	396.1 ^{ac} ± 6.93	405.97 ^{bc} ± 9.05	411.78 ^{bc} ± 4.5	395.71 ^{ac} ± 5.57
3	757.23 ^{a} ± 13.15	779.48 ^{ac} ± 16.37	808.62 ^{bc} ± 15.32	819.97 ^{b} ± 9.59	822 ^{b} ± 12.44
4	1193.1 ^{a} ± 23.91	1234.45 ^{ac} ± 27.51	1281.59 ^{bc} ± 26.22	1355.63 ^{d} ± 16.13	1386.48 ^{d} ± 20.54
5	1737.97 ^{a} ± 31.93	1799.23 ^{a} ± 60.9	1867.62 ^{ab} ± 55.69	1948.63 ^{b} ± 35.81	2001.1 ^{b} ± 51.5
6	2257.35 ^{a} ± 38.57	2426.29 ^{ab} ± 79.22	2528.83 ^{bc} ± 75.33	2648.81 ^{cd} ± 55	2714.4 ^{d} ± 67.85
Mortality (%)	6.25 ± 3.6	0	6.25 ± 3.6	6.25 ± 3.6	6.25 ± 3.6

[abcd]Means within each row with the different superscripts are significantly different ($p < 0.05$). T1: inclusion rate of millet 0% (control), T2: inclusion rate of millet 25%, T3: inclusion rate of millet 50%, T4: inclusion rate of millet 75%, T5: inclusion rate of millet 100%. SEM: Standard Error of Mean

Table 3. Feed conversion ratios in Hubbard broiler chickens ± SEM fed on diets containing different levels of proso millet.

Age (week) \ Treatments	T1	T2	T3	T4	T5
1	1.00 ^{a}	1.00 ^{a} ± 0.01	0.98 ^{b}	0.95 ^{c}	0.90 ^{d}
2	1.45 ^{a}	1.39 ^{b} ± 0.01	1.35 ^{c}	1.35 ^{c} ± 0.01	1.38 ^{b}
3	1.62 ^{a}	1.58 ^{b} ± 0.01	1.46 ^{c}	1.39 ^{d}	1.36 ^{e}
4	1.85 ^{a}	1.83 ^{b} ± 0.01	1.78 ^{c} ± 0.01	1.59 ^{d}	1.54 ^{e} ± 0.01
5	1.92 ^{a} ± 0.01	1.88 ^{b} ± 0.01	1.88 ^{b} ± 0.01	1.87 ^{b}	1.87 ^{b}
6	1.98 ^{a} ± 0.01	1.95 ^{b} ± 0.01	1.95 ^{b}	1.92 ^{c} ± 0.01	1.89 ^{d}
Cumulative	1.74 ^{a} ± 0.018	1.72 ^{ab} ± 0.011	1.69 ^{b} ± 0.006	1.63 ^{c} ± 0.01	1.61 ^{c} ± 0.004

[abcde]Means within each row with the different superscripts are significantly different ($p < 0.05$). T1: inclusion rate of millet 0% (control), T2: inclusion rate of millet 25%, T3: inclusion rate of millet 50%, T4: inclusion rate of millet 75%, T5: inclusion rate of millet 100%. SEM: Standard Error of Mean

Table 4. Carcass meat yield and liver of Hubbard broilers chickens (%) ± SEM fed on diets containing different levels of proso millet

Items / Treatments	[1]Carcass (%)		[1]Breast meat (%)		[1]Thigh meat (%)		[1]Liver (%)	
	Female	**Male**	**Female**	**Male**	**female**	**Male**	**female**	**Male**
T1	$75.72^{a} \pm 0.74$	$75.16^{a} \pm 0.44$	$24.21^{a} \pm 0.91$	$23.42^{a} \pm 0.39$	$17^{a} \pm 0.24$	$16.92^{a} \pm 0.23$	$2.26^{a} \pm 0.14$	$2.10^{a} \pm 0.15$
T2	$75.74^{a} \pm 0.39$	$76.1^{ab} \pm 0.66$	$24.36^{ab} \pm 1.23$	$25.64^{b} \pm 0.93$	$18.1^{b} \pm 0.54$	$17.72^{ab} \pm 0.21$	$1.89^{b} \pm 0.07$	$1.81^{b} \pm 0.55$
T3	$76.57^{ab} \pm 0.58$	$76.31^{ab} \pm 0.38$	$26^{ab} \pm 1.01$	$25.6^{b} \pm 0.41$	$17.37^{ab} \pm 0.35$	$18.04^{ab} \pm 0.52$	$1.80^{b} \pm 0.08$	$1.91^{ab} \pm 0.93$
T4	$76.8^{ab} \pm 0.34$	$76.91^{b} \pm 0.62$	$24.93^{ab} \pm 1$	$24.89^{ab} \pm 0.43$	$18.33^{b} \pm 0.17$	$18.7^{b} \pm 0.5$	$1.80^{b} \pm 0.05$	$1.8^{b} \pm 0.05$
T5	$77.34^{b} \pm 0.52$	$76.65^{b} \pm 0.13$	$27.06^{b} \pm 0.33$	$25.46^{b} \pm 0.38$	$18.16^{b} \pm 0.38$	$17.89^{ab} \pm 0.46$	$1.76^{b} \pm 0.08$	$1.86^{ab} \pm 0.06$

[ab]Means within each column with different superscripts are statistically different ($p < 0.05$). T1: inclusion rate of millet 0% (control), T2: inclusion rate of millet 25%, T3: inclusion rate of millet 50%, T4: inclusion rate of millet 75%, T5: inclusion rate of millet 100%. SEM: Standard Error of the Mean

DISCUSSION

Broiler chicken's performance was found to be enhanced when the replacement ratio of maize with proso millet was increased. The higher crude protein digestibility and the greater oil content, either in treatment diets or in millet compared to that of the control diet or maize, could be the reasons for improvement the performance (Khalil et al., 2022).

Since the millet grains are slightly lower in (ME) in comparison with maize, the addition of sun-flower oil to compensate this shortage was required to maintain the diet's isocaloric, which enhanced the broilers' appetite (Adil et al., 2020). It was found that broiler chickens preferred diets containing higher levels of oil (Bueno et al., 2015). Furthermore, both oil and fat increase the duration of the nutrients remaining in the intestines. That provides a longer time for the enzymes to work. and remain in the digest for more time in contact with the intestinal villi, which leads to improving absorption and reflection of it on FCR (Boroojeni et al., 2011). In addition, significant improvement ($p < 0.05$) can result in the presence of the highest level of amino acid balance, since the synthesis of protein requires an adequate amount of amino acids, the presence of which in millet grains is greater than that found in yellow corn (Manaah and Alkassar, 2021).

The results of this study are similar to what was found by (Baurhoo et al., 2011) who confirmed that replacing maize with millet in broiler diets improved live body weight and feed conversion ratio. In addition, a previous study indicated that the diets based on proso millet recorded the highest value in weight gain and feed consumption without affecting the feed conversion ratio compared to the diets based on yellow maize (Ibitoye et al., 2012). The results of this study follow several studies which also show that broiler chickens fed on diets based on millet and formulated to maintain isocaloric and isoprotein have better performance parameters than those of corn-based diets (Hidalgo et al., 2004; Garcia et al., 2005). It could be stated that the higher nutrient content and low concentrations of anti-nutrients kept the production responses of broiler chickens effective, without causing any adverse effects (Boroojeni et al., 2011). The liver is considered the main site of detoxification and nutrient metabolism; thus, it is suggested that the liver size is dependent on the amount of work it does (Zaefarian et al., 2019). The current study suggests that millet-based diets decreased liver sizes significantly ($p < 0.05$), probably because millet has a low incidence of mycotoxins compared to other cereals such as wheat and maize (Manaah and Alkassar, 2021). Meanwhile, (Rao et al., 2004) show that the total replacement of yellow maize by millet did not influence the relative weight of the liver of broiler chickens at day 42 of age.

The observed improvement in the carcass yield ($p < 0.05$) may be explained by the higher content of amino acids in millet compared to maize, especially sulfur amino acids which are essential for optimum muscle accretion (Tjetjoo et al., 2022). The results of this study are similar to those found in a previous study that showed the percentage of carcass yield was not different between groups of broiler chickens fed on diets containing up to 50% millet, and it was even better than those fed diets without millet (Baurhoo et al., 2011). Likewise, (Rao et al., 2003) reported that breast and thigh muscle were significantly influenced by replacing maize with millet.

CONCLUSION

According to the findings of the present study, proso millet can be considered an exceptional alternative to completely replace of maize in broiler chicken diets without causing any adverse effects on performance, especially in arid and semiarid areas that suffer from water scarcity and where maize cannot be raised. Attending to millet, making more progress in the genetic improvement and the selection of suitable strains, as well as being more productive in applying it in ruminant rations as a rich source of fiber, are recommendations for future studies.

DECLARATIONS

Ethical consideration

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.

Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Authors' contributions

Conceived and designed the experiments, and the supervision by Riad Kussaibati Prof. Dr. Department of Animal Production, Faculty of Veterinary Medicine, Hama University, Hama, Syria. It was also supervised by Hasan Tarsha Ass. Prof. Dr. Department of Animal Production, Faculty of Veterinary Medicine, Hama University, Hama, Syria. the experiment was performed, the data was analyzed and the paper was written by Melad Khalil. Practical works and analysis were performed at the faculty of agriculture, Damascus University, Damascus, Syria. All authors read and approved the final version of the manuscript for publication in the present journal.

Acknowledgments

The Authors thank the Arab Company for Manufacturing of Agricultural and Veterinary Drugs (ACMAVED) in Damascus, Syria, for the financial support of this work without any influences or interference with the workflow. Thanks for the help in supporting and accomplishing this research.

Availability of data and materials

The raw and analyzed data of this study will be presented to anyone who asks the corresponding author.

REFERENCES

Adil S, Banday MT, Sheikh IU, Khan AA, and Khurshid A (2020). Effect of essential oils as replacement for antibiotic growth promoters in the diet on performance of broiler chicken. SKUAST Journal of Research, 22(1): 74-78. Available at: https://www.indianjournals.com/ijor.aspx?target=ijor:skuastjr&volume=22&issue=1&article=010

A millet atlas: Some identification guidance (2006). Institute of Archaeology University College, London. Available at: http://www.homepages.ucl.ac.uk/~tcrndfu/Abot/Millet%20Handout06.pdf

Baurhoo N, Baurhoo B, Mustafa AF, and Zhao X (2011). Comparison of corn-based and Canadian pearl millet-based diets on performance, digestibility, villus morphology, and digestive microbial populations in broiler chickens. Poultry Science, 90(3): 579-586. DOI: https://www.doi.org/10.3382/ps.2010-00954

Boroojeni FG, Samie AH, Edriss MA, Khorvash M, Sadeghi G, Van Kessel A, and Zentek J (2011). Replacement of corn in the diet of broiler chickens using foxtail millet produced by 2 different cultivation strategies. Poultry Science, 90(12): 2817-2827. DOI: https://www.doi.org/10.3382/ps.2011-01647

Bueno JPR, de mattos Nascimento MRB, Carvalho CMC, de Abreu Fernandes E, Assunção Silva MC, da Silva Martins JM, and Litz FH (2015). Millet and corn oil in sorghum-based diets for broilers. Ciência Rural, 45(12): 2233-2238. DOI: https://www.doi.org/10.1590/0103-8478cr20141200

Cisse RS, Hamburg JD, Freeman ME, and Davis AJ (2017). Using locally produced millet as a feed ingredient for poultry production in Sub-Saharan Africa. Journal of Applied Poultry Research, 26(1): 9-22. DOI: https://www.doi.org/10.3382/japr/pfw042

Das S, Khound R, Santra M, and Santra DK (2019). Beyond bird feed: Proso millet for human health and environment. Agriculture, 9(3): 64. DOI: https://www.doi.org/10.3390/agriculture9030064

Dei HK (2017). Assessment of maize (Zea mays) as feed resource for poultry. In: M. Manafi (Editor), Poultry Science. pp. 1-32. DOI: https://www.doi.org/10.5772/65363

Garcia AR, Batal AB, Dale NM, and Café MB (2005). Evaluation of pearl millet as a grain source for prestarter and starter broiler diets. Poultry Science, 84(Suppl. 1): 96-97. Available at: https://www.scopus.com/record/display.uri?eid=2-s2.0-81555214925&origin=inward&txGid=a9ff62d1e350dd3c815ca21a086aecb5

Habiyaremye C, Matanguihan JB, D'Alpoim Guedes J, Ganjyal GM, Whiteman MR, Kidwell KK, and Murphy KM (2017). Proso millet (*Panicum miliaceum L.*) and its potential for cultivation in the Pacific Northwest, US: A review. Frontiers in Plant Science, 7: 1961. DOI: https://www.doi.org/10.3389/fpls.2016.01961

Hassan ZM, Sebola NA, and Mabelebele M (2021). The nutritional use of millet grain for food and feed: A review. Agriculture & Food Security, 10: 16. Available at: https://link.springer.com/article/10.1186/s40066-020-00282-6

Hidalgo MA, Davis AJ, Dale NM, and Dozier III WA (2004). Use of whole pearl millet in broiler diets. Journal of Applied Poultry Research, 13(2): 229-234. DOI: https://www.doi.org/10.1093/japr/13.2.229

Hubbard SAS (2007). Broiler management guide. Guidelines. Hubbard SAS, Quintin, France. Available at: https://www.winmixsoft.com/files/info/Hubbard%20Broiler%20Management%20Guide.pdf

Ibitoye EB, Olorede BR, Jimoh AA, and Abubakar H (2012). Comparative performance and organ relative weight of broiler chickens fed three sources of energy diet. Journal of Animal Production Advances, 2(5): 233-238.

Khalil MA, Tarsha H, and Kussaibati R (2022). Determination of nutritional values of Proso millet grains produced in Syria in chicken feeding. Journal of Hama University, 5(14): 81-93. Available at: https://hama-univ.edu.sy/ojs/index.php/huj/article/view/1015

Liang S and Liang K (2019). Millet grain as a candidate antioxidant food resource: A review. International Journal of Food Properties, 22(1): 1652-1661. DOI: https://www.doi.org/10.1080/10942912.2019.1668406

Maidala A and Abdullahi IB (2016). Utilization of millet (*Pennisetum Spp*) as an energy source by broiler Chickens: A review. International Journal of Agriculture and Earth Science, 2(7): 18-24. Available at: www.iiardjournals.org/get/IJAES/VOL.%202%20NO.%207%202016/UTILIZATION%20OF%20MILLET.pdf

Manaah SA and Alkassar AM (2021). Effect of replacing maize with normal and soaked in Acetic acid locally pearl millet on the performance of broilers. Annals of the Romanian Society for Cell Biology, 23: 8570-8580. Available at: www.annalsofrscb.ro/index.php/journal/article/view/3572

Nielsen DC and Vigil MF (2017). Water use and environmental parameters influence proso millet yield. Field Crops Research, 212: 34-44. DOI: https://www.doi.org/10.1016/j.fcr.2017.06.025

Rajasekaran R, Francis N, Mani V, and Ganesan J (2023). Proso millet (*Panicum miliaceum L.*). Neglected and Underutilized Crops. Chapter 10, pp. 247-278. DOI: https://www.doi.org/10.1016/B978-0-323-90537-4.00005-3

Rao SV, Raju MV, Reddy MR, and Panda AK (2004). Replacement of yellow maize with pearl millet (Pennisetum typhoides), foxtail millet (*Setaria italica*) or finger millet (*Eleusine coracana*) in broiler chicken diets containing supplemental enzymes. Asian-Australasian Journal of Animal Sciences, 17(6): 836-842. DOI: https://www.doi.org/10.5713/ajas.2004.836

Rao SY, Raju MY, and Panda AK (2003). Replacement of yellow maize with graded levels of pearl millet (*Pennisetum typhoides*) in commercial broiler diets. Indian Journal of Poultry Science, 38(3): 236-242. Available at: https://indianjournals.com/ijor.aspx?target=ijor:ijps&volume=38&issue=3&article=009

Ranum P, Peña-Rosas JP, and Garcia-Casal MN (2014). Global maize production, utilization, and consumption. Annals of the New York Academy of Sciences, 1312(1): 105-112. DOI: https://www.doi.org/10.1111/nyas.12396

Tjetjoo SU, Moreki JC, and Madibela OR (2022). Carcass characteristics of Guinea fowl raised under intensive system and fed diets containing yellow maize, millet and white sorghum as energy sources. Open Journal of Animal Sciences, 12(2): 317-335. DOI: https://www.doi.org/10.4236/ojas.2022.122024

Vasan P, Mandal AB, Dutta N, Maiti SK, and Sharma K (2008). Digestibility of amino acids of maize, low tannin sorghum, pearl millet and finger millet in caecectomized roosters. Asian-Australasian Journal of Animal Sciences, 21(5): 701-706. DOI: https://www.doi.org/10.5713/ajas.2008.70296

Zaefarian F, Abdollahi MR, Cowieson A, and Ravindran V (2019). Avian liver: The forgotten organ. Animals, 9(2): 63. DOI: https://www.doi.org/10.3390/ani9020063