Effect of hybrid rice varieties on growth and development of broilers and ducks

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A R T I C L E   I N F O

Article history:
Received 23 March 2020
Received in revised form 29 May 2020
Accepted 1 June 2020
Available online 14 November 2020

Keywords:
Hybrid rice
Broiler
Mallard duckling
Mallard duck

A B S T R A C T

Three experiments (Exp. 1, n = 144 broilers [Ross × Ross]; Exp. 2, n = 118 mallard ducklings [Anas platyrhynchos]; and Exp. 3, n = 75 mature mallard ducks) were conducted to determine the effects of 3 levels of unmilled hybrid rice on growth performance and organ and gastrointestinal tract development. The dietary treatments were 1) corn-soybean meal (basal), 2) basal + 5% hybrid rice, and 3) basal + 10% hybrid rice for Exp. 1 to 3, respectively. One bird from each pen in Exp. 1 (n = 24) and all the birds in Exp. 2 (n = 118) and Exp. 3 (n = 75) were randomly selected and euthanized to determine linear measurements and organ and gastrointestinal tract weight. In Exp. 1 and 2, birds fed 10% rice experienced slower growth ($P < 0.05$) than birds fed the basal diet. In Exp. 3, the addition of rice did not affect growth performance. Rice addition did not affect organ length or weight ($P > 0.05$) in Exp. 1. However, birds fed 5% rice had significantly increased ($P < 0.05$) pancreas, ileum, and jejunum weights in Exp. 2, and 10% rice significantly increased ($P < 0.05$) liver weight in Exp. 3. The addition of 10% unmilled rice to broiler and duck diets may reduce growth performance.

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1. Introduction

Rice is a significant part of Louisiana’s farm income. In 2018, the gross farm value generated by all rice production was $379.6 million with approximately 436,000 acres planted (LSU AgCenter Staff, 2018). Approximately 59% of the crop was a Clearfield variety or hybrid. In 2018, the Louisiana Agriculture Center reported that 42,292 acres of Clearfield XL 745 rice were planted and accounted for 9.7% of rice crops in Louisiana. In addition to producing grain, these agronomic rice fields provide habitat and food for migrating waterfowl.

By planting multiple hybrid-rice varieties, farmers have a better chance to increase yield, quality, and profit. Hybrid rice has been designed to combat invasive weeds such as red rice (Oryza sativa var.) and to be moderately resistant to sheath blight, blast, and straighthead (Deliberto and Salassi, 2010). Hybrid rice is known to be a more abrasive or hairy rice than conventional rice varieties (Mayer, 2012). The abrasiveness has been known to cause faster wear on milling equipment but it has unknown effects on waterfowl. Waterfowl are known to consume hybrid waste grain or waste rice (rice not picked up or spilled in the harvest and transportation process). Waste rice is a high-energy food source that can be easily and quickly consumed by waterfowl (Ringelman, 1990).

The diet preference of waterfowl, however, may be controlled by many factors, including negative energy balances, hunting or dominance pressures, digestion inhibitors, blood-glucose levels, levels of swelling in the digestive tract, or, for pen-reared ducks, relative distance of the pans from the pen door (Duke, 1986; Dabbert and Martin, 1994).

Agricultural fields, especially rice fields, provide an important economic benefit to Louisiana in the form of hunting revenue. By leasing agricultural fields that waterfowl utilize for food sources and habitat, the landowner can add a revenue source. In 2017, there...
were over 46,900 × (1 ± 12%) active duck hunters and 1,083,900 × (1 ± 18%) ducks harvested in Louisiana (Raftovich et al., 2018). Gross farm value from hunting leases for waterfowl in Louisiana from 2017 to 2018 was $52.4 million (LSU AgCenter Staff, 2018). The 2011 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation stated for Louisiana that trip- and equipment-related expenditures for waterfowl hunting generated about $3.0 billion in total economic output (Cabrera et al., 2015). Jeopardizing either of these (rice/hunting) enterprises would be economically damaging to the farmer.

A broiler chick’s diet strongly influences the anatomy and physiology of its gastrointestinal tract (Frikha et al., 2009; Mateos et al., 2012). Poultry and waterfowl have similar gastrointestinal tracts, and many studies conducted on digestive organs focus on poultry (Gabriel et al., 2008; Frikha et al., 2009; de Verdal et al., 2011). Two studies, by de Verdal et al. (2011) and by Nir et al. (1994), concluded that a coarser diet would lead to a larger, better-developed gizzard and a lighter intestine, leading to more efficient digestion of starches and proteins. One of the few pen waterfowl studies showed that a well-developed gizzard actually improves gut motility (Lu et al., 2011). A well-developed gizzard improved performance, digestion, and energy use by effectively breaking down feed and allowing for quick transportation of nutrients to the pancreatic enzyme (Lu et al., 2011). The gastrointestinal tract influences ingestion, digestion, and absorption; any problems in digestion may partially influence growth, survival, or reproduction (Lu et al., 2011). Since hybrid rice is known to be coarser and more abrasive than conventional varieties, consumption by poultry and waterfowl could lead to a better developed digestive system. By having a coarser diet, waterfowl may have an increase in gizzard size, which has been shown to have beneficial effects on overall health in some waterfowl and poultry. Also, if the rice variety attracts or repels the waterfowl from certain fields, this could factor into a farmer’s seed selection process.

Thus, the following experiments were conducted to determine if hybrid rice affected the growth and development of waterfowl and chickens.

2. Materials and methods

All experiments were approved by the McNeese State University Animal Use and Care Committee. Three experiments (Exp. 1, n = 144 broilers; Exp. 2, n = 118 ducklings; Exp. 3, n = 75 mature ducks) were conducted to evaluate the effect of rice variety on chicken, duckling, and duck growth and development. Average initial weights of the chicks and ducks were 34.8, 362.1, and 821 g in Exp. 1, 2, and 3, respectively. Average final BW of the chicks, ducklings, and ducks were 362.1, 446.6, and 1,202.0 g in Exp. 1, 2, and 3, respectively. In Exp. 1 and 2, hatchling chickens (Ross × Ross) and ducklings (mallards) were housed at the McNeese State University School of Agricultural Sciences Poultry Laboratory in Lake Charles, Louisiana. For Exp. 1 and 2, birds were maintained in environmentally controlled (32 °C) Petersime (Petersime Incubator Co., Gettysburg, OH) battery pans (33 cm × 99 cm) with raised wire floors. Continuous fluorescent lighting was provided for the duration of all experiments. All cages and dropping pans were cleaned daily.

In Exp. 3, hatchling mallard ducks (n = 100) were purchased (Metzer Farms, Gonzales, CA) and reared on a commercial duck farm (Chappapeela Farm, Husser, LA) for 30 d and then transported to the McNeese State University Farm in Lake Charles, Louisiana, where they were housed in an open-sided ventilated barn, in pens measuring 110 cm × 170 cm with tri-bar flooring. Diets were formulated to meet or exceed nutritional requirements (Table 1) for hatchling chicks (Exp. 1), ducklings (Exp. 2), and ducks (Exp. 3).

![Table 1](image)

| Item          | Hybrid rice | 0%  | 5%  | 10% |
|--------------|-------------|-----|-----|-----|
| ADG, g       | 11.2        | 10.9 | 10.4 | 0.2 |
| ADFI, g/kg   | 18.2        | 17.9 | 18.3 | 0.3 |
| G:F, g/kg    | 616.0       | 612.0 | 565.0 | 14.0 |
| SEM          | 773.0       | 751.0 | 724.0 | 10.0 |

(NRC 1994). The treatments consisted of 3 levels of unmilled Clearfield XL 745 rice (0%, 5%, or 10%). Chicks, ducklings, and ducks were allotted to dietary treatments: 8 replications of 6 broilers (Exp. 1), 8 replications of 4 or 5 ducklings (Exp. 2), and 3 replications of 8 or 9 ducks (Exp. 3). Treatment diets in mash form and water were provided ad libitum throughout the experiment. Average daily gain (ADG), average daily feed intake (ADFI), and gain-to-feed ratio (G:F) were determined weekly and for the entire

![Table 2](image)

| Day 0 to 4 | 0%  | 5%  | 10% |
|------------|-----|-----|-----|
| ADG, g     | 11.2 | 10.9 | 10.4 |
| ADFI, g/kg | 18.2 | 17.9 | 18.3 |
| G:F, g/kg  | 616.0 | 612.0 | 565.0 |

1 Unmilled Clearfield XL 745 rice (ME 2,940 kcal/kg, 7.3% crude protein, 0.24% lys).
2 Contained 50.7% Lys-SO4 (Evenik-Degussa Corp., Kennasaw, GA).
3 The vitamin premix used provided per kilogram of diet: vitamin A (vitamin A palmitate), 4,500 IU; vitamin D3, 450 IU; vitamin E (vitamin E acetate), 50 IU; vitamin K (menadione sodium bisulfite), 1.5 mg; vitamin B12, 0.02 mg; vitamin H (biotin), 0.6 mg; folacin (folic acid), 6 mg; niacin, 50 mg; vitamin B6, 13.4 mg.
4 The mineral premix used provided per kilogram of diet: copper (CuSO4·5H2O), 4.0 mg; iodine (KI), 1.0 mg; iron (FeSO4·7H2O), 60 mg; manganese (MnSO4·H2O), 60 mg; selenium (Na2SeO3), 0.1 mg; zinc (ZnSO4·7H2O), 44 mg; calcium (CaCO3), 723 mg.
5 It contains 600,000 mg/kg of choline.

1 ADG – average daily gain; ADFI – average daily feed intake; G:F – gain-to-feed ratio.
2 Within a row, means with different superscripts differ significantly (P < 0.05).
3 Data are means of 8 replications of 6 birds per replication with an initial and final BW of 34.8 and 362.1 g, respectively.
experimental period (d 11, 14, and 35 in Exp. 1, 2, and 3, respectively).

After a 24-h feed withdrawal, birds were euthanized via carbon dioxide and placed in labeled Whirl-Pak bags for further dissection and analyses. In Exp. 1, 24 birds were euthanized at d 11. In Exp. 2, a total of 118 birds were euthanized ($n = 24$ at d 14 and 21) and $n = 70$ at d 28. In Exp. 3, 75 birds were euthanized at d 35. All samples were stored for 14 d at $3^\circ C$ until dissection and evaluation. At a later date, bird carcasses were allowed to warm to room temperature, and then gastrointestinal tracts (crop [broilers only], esophagus, proventriculus, duodenum, jejunum, ileum) and organs (heart, gizzard, liver, pancreas) were dissected and cleaned of digesta for linear measurements and weights.

Growth data were analyzed by analysis of variance (ANOVA) procedures appropriate for a completely randomized design (Exp. 1) using the GLM procedures of SAS (SAS Inst. Inc., Cary, NC) at the significance level ($P < 0.05$). In Exp. 2 and 3, growth data were analyzed using and randomized complete block design in a one-way ANOVA in the SPSS program at the significance level ($P < 0.05$). Tukey’s Honestly Significant Difference (HSD) test was

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**Fig. 1.** Average daily gain (ADG) of hatchling ducks from 0 to 7 d (A), 7 to 14 d (B), 14 to 21 d (C) of age in Exp. 2. The ADG data are means of 8 replications of 4 or 5 ducks per replication with an initial and final BW of 31.8 and 446.6 g, respectively. The inclusion of 10% hybrid rice decreases ADG ($P < 0.05$) in (A) and (B).
used to find difference among treatments, and significance was considered at $P < 0.05$.

3. Results

In Exp. 1, birds fed 10% rice experienced slower growth ($P < 0.05$) than birds fed the basal diet from 0 to 4 d and 0 to 7 d (Table 2). However, when compared to birds fed 5% rice, birds receiving 10% rice had an increased ($P < 0.05$) ADG from d 7 to 11 and overall (d 0 to 11). Average daily feed intake was greater ($P < 0.05$) in birds fed the basal and 10% rice diets from d 0 to 7, d 7 to 11, and d 0 to 11. Birds fed diets containing 10% rice were less efficient ($P < 0.05$) from d 0 to 7.

In Exp. 2, there was no difference ($P > 0.10$) in ADG between birds fed the basal diet and 5% rice during all growth phases (Fig. 1). However, 10% rice decreased ($P < 0.05$) growth and ADFI during the same periods (Fig. 2). Feed intake data were not reported past 14 d and growth data past 21 d because of bird removal for intestinal tract and organ analyses.

In Exp. 3, there was no difference ($P > 0.10$) for ADG, ADFI, and feed efficiency at any time in the experiment for birds receiving 0 or 5% rice (Table 3). In week 5, ducks receiving 10% rice had a lower feed efficiency ($P < 0.05$) compared to ducks fed the basal diet.

In Exp. 1, there was no difference ($P > 0.10$) in linear measurements (Table 4) or organ weights (Table 5). In Exp. 2, there was no difference ($P > 0.10$) in linear measurements (Tables 6 and 7).

However, birds fed 10% rice had shorter ($P < 0.05$) ileum lengths than birds fed 5% rice when harvested at d 28 (Table 8). Organ weights were not different at d 14 or 21 (Tables 9 and 10). Ducks fed 5% rice had heavier ($P < 0.05$) pancreas and ileum weights when harvested at d 28 (Table 11). Jejunum weights of ducks fed 10% rice were lighter ($P < 0.05$) compared to ducks consuming diets with 5% rice.

In Exp. 3, ducks fed 10% rice had heavier ($P < 0.05$) livers than ducks fed the basal diet (Table 12). There was no difference ($P < 0.05$) in organ length between treatments (Table 13).

4. Discussion

This study investigated the effects of feeding unmilled rice at 3 levels in growing and adult broilers, ducklings, and ducks. Anecdotal evidence suggests that hybrid rice varieties which are planted to resist pests and weed pressure may reduce feed palatability and thus feed intake of waterfowl that winter in or near rice fields. Because rice is an important human food staple, most animal feeding studies focus on feeding byproducts of rice (e.g., bran, straw, hulls), and limited research has been conducted on feeding whole or ground rice to animals. Cromwell et al. (2005) found no adverse effects when pigs were fed ground glufosinate herbicide-tolerant rice or conventional rice to pigs. Our study found that, regardless of rice inclusion, birds (broilers, ducklings, and ducks) grew at a similar rate and that there were no

Fig. 2. Average daily feed intake (AFDI) of hatchling ducks from 0 to 7 d (A), 7 to 14 d (B) of age in Exp. 2. The data are means of 8 replications of 4 or 5 ducks per replication with an initial and final BW of 31.8 and 446.6 g. The inclusion of 10% hybrid rice decreases ($P < 0.05$) ADFI in (A) and (B).
Table 3
Growth performance of mature ducks.1

| Item        | Hybrid rice | SEM |
|-------------|-------------|-----|
| Day 0 to 7  |             |     |
| ADG, g      | 26.60       | 5.8 |
| ADFI, g/kg  | 102.93      | 10.24 |
| G:F, g/kg   | 260.00      | 279.00 |
| Day 7 to 14 |             |     |
| ADG, g      | 9.43        | 1.11 |
| ADFI, g/kg  | 111.04      | 107.19 |
| G:F, g/kg   | 87.00       | 117.00 |
| Day 14 to 28|            |     |
| ADG, g      | 7.80        | 1.11 |
| ADFI, g/kg  | 102.03      | 105.44 |
| G:F, g/kg   | 72.78       | 61.07 |
| Day 28 to 35|            |     |
| ADG, g      | 10.58       | 1.73 |
| ADFI, g/kg  | 48.41       | 46.61 |
| G:F, g/kg   | 194.00      | 195.00 |

ADG = average daily gain; ADFI = average daily feed intake; G:F = gain-to-feed ratio.

1 One bird per pen was randomly selected for gastrointestinal tract evaluation. Data are means of 3 birds per treatment. No difference (P > 0.10).

Table 4
Broiler organ lengths (cm) at 11 d of age (n = 24).1

| Organ       | Hybrid rice | SEM |
|-------------|-------------|-----|
| Esophagus   | 8.0         | 0.7 |
| Duodenum    | 18.7        | 1.4 |
| Jejunum     | 41.5        | 3.5 |
| Ileum       | 42.7        | 3.8 |

1 One bird per pen was randomly selected for gastrointestinal tract evaluation. Data are means of 3 birds per treatment. No difference (P > 0.10).

Table 5
Broiler organ weights (g) at 11 d of age (n = 24).1

| Organ       | Hybrid rice | SEM |
|-------------|-------------|-----|
| Liver       | 13.0        | 1.1 |
| Heart       | 16.5        | 0.2 |
| Gizzard     | 2.8         | 1.2 |
| Crop        | 2.2         | 0.2 |
| Pancreas    | 1.3         | 0.1 |
| Esophagus   | 1.4         | 0.2 |
| Proventriculus | 3.0     | 0.2 |
| Duodenum    | 4.0         | 0.6 |
| Jejunum     | 7.1         | 0.7 |
| Ileum       | 7.3         | 1.2 |

1 One bird per pen was randomly selected for gastrointestinal tract evaluation. Data are means of 3 birds per treatment. No difference (P > 0.10).

detrimental effects from feeding 10% rice. Even though ducklings fed 10% rice had a reduced average daily growth, there were no differences in the ducks' ultimate overall growth. A potentially limiting factor for feed consumption may be the unhulled seed or whole grain. However, if the unhulled rice is ingested, it may limit the unhulled rice may promote an increase in pregastric gizzard development that would be more efficient in grinding the whole grains. Previous studies have reported an increase in gizzard and duodenum weight when geese were fed whole-corn diets at 28 and 70 d of age (Lu et al.)

Table 7
Duckling organ lengths (cm) at 21 d of age (n = 24).1

| Organ       | Hybrid rice | SEM |
|-------------|-------------|-----|
| Duodenum    | 15.1        | 0.9 |
| Jejunum     | 50.3        | 2.0 |
| Ileum       | 47.7        | 2.2 |

1 One bird per treatment was randomly selected for gastrointestinal tract evaluation. Data are means of 3 birds per treatment. No difference (P > 0.10).

Table 8
Duckling organ lengths (cm) at 28 d of age (n = 70).1

| Organ       | Hybrid rice | SEM |
|-------------|-------------|-----|
| Esophagus   | 17.3        | 0.5 |
| Duodenum    | 24.3        | 1.0 |
| Jejunum     | 49.8        | 1.8 |
| Ileum       | 47.5        | 1.8 |

1 Within a row, means with different superscripts differ significantly (P < 0.05).

1 One bird per pen was randomly selected for gastrointestinal tract evaluation. Data are means of 8 replicates of 3 or 4 birds per pen.

Table 9
Duckling organ weights (g) at 14 d of age (n = 24).1

| Organ       | Hybrid rice | SEM |
|-------------|-------------|-----|
| Liver       | 11.4        | 1.6 |
| Heart       | 3.0         | 0.4 |
| Gizzard     | 18.8        | 1.5 |
| Pancreas    | 1.0         | 0.1 |
| Esophagus   | 3.3         | 0.5 |
| Proventriculus | 2.3     | 0.8 |
| Duodenum    | 4.8         | 0.5 |
| Jejunum     | 6.1         | 0.7 |
| Ileum       | 6.7         | 1.1 |

1 One bird per pen was randomly selected for gastrointestinal tract evaluation. Data are means of 3 birds per treatment. No difference (P > 0.10).

Table 10
Duckling organ weights (g) at 21 d of age (n = 24).1

| Organ       | Hybrid rice | SEM |
|-------------|-------------|-----|
| Liver       | 15.6        | 1.4 |
| Heart       | 4.7         | 0.4 |
| Gizzard     | 28.9        | 2.2 |
| Pancreas    | 1.0         | 0.02 |
| Esophagus   | 4.3         | 0.6 |
| Proventriculus | 3.6     | 0.5 |
| Duodenum    | 6.6         | 0.5 |
| Jejunum     | 8.7         | 1.0 |
| Ileum       | 9.1         | 1.2 |

1 One bird per pen was randomly selected for gastrointestinal tract evaluation. Data are means of 3 birds per treatment. No difference (P > 0.10).
5. Conclusion

Development of broilers, ducklings, and mature ducks. Growth performance and intestinal tract development were similar in broilers regardless of percentage of rice included in the diet. When ducklings (0 to 28 d of age) were fed diets containing 10% rice, growth and feed intake were decreased. However, birds receiving the 5% rice diet had increased growth and feed intake compared to those fed the basal diet. Mature ducks (30 ± 2 d of age) had similar growth performance regardless of percentage of rice in the diet. Organ development (weights and lengths) differed when ducklings were fed 5% rice, but there was little effect in mature ducks. In Exp. 1 and 2, from 0 to 7 d, birds fed 10% rice had slower growth ($P < 0.05$) than birds fed the basal diet. In Exp. 3, the addition of rice did not affect growth, feed intake, or feed efficiency. The addition of 10% unmilled rice to broiler and duck diets may decrease growth performance.

Author contributions

Frederick M. LeMieux: writing — review and editing, supervision. Courtney P. Villemarette: writing — original draft. Eddie K. Lyons: writing — original draft, supervision. Thomas H. Shields: writing — review and editing. Norman German: writing — review and editing.

Conflict of interest

We declare that we have no financial or personal relationships with other people or organizations that might inappropriately influence our work, and there is no professional or other personal interest of any nature or kind in any product, service and/or company that could be construed as influencing the content of this paper.

Acknowledgements

We would like to thank the Fritz Lang Foundation for providing partial funding for this research.

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Table 11

Duckling organ weights (g) at 28 d of age (n = 70).1

| Organ    | Hybrid rice | SEM  |
|----------|-------------|------|
|          | 0%          | 5%   | 10%  |
| Liver    | 19.0        | 18.8 | 16.8 | 1.2  |
| Heart    | 5.8         | 6.0  | 5.3  | 0.4  |
| Gizzard  | 30.3        | 31.3 | 28.8 | 1.6  |
| Pancreas | 1.1a        | 1.3b | 1.1a | 0.1  |
| Esophagus| 4.1         | 4.1  | 5.4  | 1.4  |
| Proventriculus| 3.6 | 3.4  | 3.4  | 0.3  |
| Duodenum | 6.7         | 6.9  | 6.3  | 0.4  |
| Jejunum  | 8.5b        | 9.7a | 8.1b | 0.6  |
| Ileum    | 8.8a        | 10.3b| 8.4a | 0.7  |

1 Data are means of 8 replicates of 3 or 4 birds per replicate.

Table 12

Mature duck organ weights (g) at 65 d of age (n = 75).1

| Organ    | Hybrid rice | SEM  |
|----------|-------------|------|
|          | 0%          | 5%   | 10%  |
| Gizzard  | 43.8        | 45.4 | 46.0 | 1.8  |
| Liver    | 24.6a       | 26.3a| 27.7b| 1.2  |
| Ileum    | 12.2        | 13.0 | 13.1 | 1.0  |
| Jejunum  | 12.1        | 12.6 | 12.0 | 0.8  |
| Heart    | 11.4        | 11.9 | 12.0 | 0.5  |
| Esophagus| 6.7         | 7.5  | 6.3  | 0.7  |
| Duodenum | 5.0         | 5.5  | 5.2  | 0.4  |
| Proventriculus| 5.0 | 4.5  | 4.6  | 0.5  |
| Pancreas | 1.0         | 1.0  | 1.0  | 0.0  |

1 Data are means of 3 replicates of 8 or 9 ducks per replicate.

Table 13

Mature duck organ lengths (cm) at 65 d of age (n = 75).1

| Organ    | Hybrid rice | SEM  |
|----------|-------------|------|
|          | 0%          | 5%   | 10%  |
| Esophagus| 23.4        | 24.2 | 23.9 | 0.6  |
| Duodenum | 23.9        | 24.5 | 24.4 | 0.9  |
| Jejunum  | 57.0        | 57.7 | 58.2 | 1.6  |
| Ileum    | 53.0        | 53.7 | 54.9 | 1.7  |

1 Data are means of 3 replicates of 8 or 9 ducks per replicate. No difference ($P > 0.10$).
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