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Nutritive and Economic Value of Hydroponic Barley Fodder in Kuroiler Chicken Diets

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Abstract:*An experiment was conducted in Kampala to assess the nutritive and economic value of hydroponic barley fodder produced using locally available materials on the growth rateof Kuroiler chicken. One-day oldmale chicks were brooded together, given basal feed and vaccinated. At three weeks age, acompletely randomized design was used to assign chicks to 5 study groups each with three replicatesrunning for 9 weeks. Group 1 (control) was fed on 100% basal feed; groups 2, 3, 4, & 5 were fed on 25% hydroponic barley fodder (HBF) +75% basal; 50% HBF+50% basal; 75% HBF+25% basal and 100% HBF respectively. Barley was sprouted on site. Nutritional profile of barley grain and fodder were analyzed using proximate analysis. Analysis of variance was performed using SPSS version 24, differences among means determined using Tukey post hoc test and LSD test atP = 0.05. Second-degree polynomial regression was used to predict the precise inclusion percentage ofHBF for maximum growth rate. Group 2 attained the highest mean live weight of 3.349±0.039Kg. Optimal inclusion percentagewas 23% while cost of HBFproduction reduced by 63%.However, group 4scored the highest gross margin of 50% and benefit cost ratio of 2.0.*

Key words: *Experiment, Hydroponic barley fodder, Kampala, Kuroiler*

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I. Introduction

The demand for poultry production has rapidly increased worldwide mostly attributed to the escalating per capita consumption of eggs and white meat. In Kampala, production is driven by ready market for poultry products, high turnover and the recent global health concerns promoting poultry products as a healthier source of protein than red [1]. Under intensive systems, feeds account for 60-70% of the total cost of production [2].Liberalization of the feed market in Uganda has resulted into many small-scale processors infiltrating the market supplying expensive substandard poultry feeds with limited alternatives for farmers [3]. In East Africa, hydroponic barley fodder has been produced as poultry feed using low cost greenhouse mesh and timber with plastic and aluminum to reduce cost of poultry production [4]. However, limited information is available on the nutritive and economic effect of fodder produced under such conditions on poultry production. The study therefore aimed to evaluate the effect of including locally sprouted hydroponic barley fodder in Kuroiler chicken diets on growth rate and economic efficiency. The information generated from the study provided insight into the potential of using locally available materials to produce hydroponic barley fodder production and its value in poultry production.

II. Methodology

Experimental Site: An experiment was conducted at Kyanja Agricultural Resource Centre in Nakawa division, Kampala for 12 weeks including the brooding period. The area experiences an average relative humidity of 89%; winds of 5 miles per hour; temperatures range from 17- 27℃ and annual precipitation of 117.5- 169.3mm that come in two seasons between April and May and Sept to November [5]. The experiment was conducted during the April- May rainy season.

The sample size was calculated using the G-Power statistical package considering effect size of 0.45; α error probability of 0.05; power of 0.95; Numerator degrees of freedom of 10; with 5 groups and one covariate. This generated a sample size of 90 birds. Day-old male kuroiler birds were purchased from Chick Master in Mukono district and sexed to confirm that they were all males. They were handled and transported as recommended by the NRC guidelines [6].All chicks were brooded together for the first three weeks.The poultry house was made of timber from the ground to 1.5M height and 2.5M wire mesh to the roof on all side of the house.

Brooding Stage: The brooding house was disinfected and dustedfor ecto-parasite control two weeks in advance. The wire mesh was covered with tarpaulin to reduce draught. The internal brooding area was surrounded by a cardboard fence 16 inches high and 6 feet in diameter. Dry wood shavings to 10cm thickness were used under the deep litter system covered with a thin layer of newspapers for the first 3 days. The brooder was pre-heated to 37℃ and monitored with a mercury thermometer. Upon arrival, birds were placed into the brooder in which four round stoves were evenly distributed using briquettes to provide heating. Light was also provided for 24 hours for the first 3 weeks.All birds were vaccinated against Marek's', New Castle Disease, Infectious bronchitis and Infectious bursal diseases which are common in the area.Commercially formulated feed from Ugachick Poultry Breeders was used as the basal for the first three weeksfed once a day at 9:00am. Hydroponic barley fodder was introduced after the brooding stage on day 21 of the experiment as recommended by Peer and Leeson [7].Amount of basal feed given during the brooding period was weighed daily as per their age and body weight.

Experimental Design: A completely randomized design (CRD) was used to assign 90 Kuroiler chicks at three-week age to 5 study groups each group with three replicates. Each group had 18 birds in replicates of 6 birds. The growth rate was considered the responsive variable and measured against different percent levels of hydroponic barley fodder inclusion in each diet. This experiment was conducted for 12 weeks including the brooding period. The experimental design used was developed from the one originally described by Peer and Leeson [7].

Sprouting Hydroponic Barley Fodder: Barley grain (*Hordeum vulgare L,*) was obtained from this center. It was sprouted in a unit measuring 6M length; 5M width and 4M height; the wall on all sides was built to 1.5M from the ground using plastered bricks and timber while 2.5M to the roof was made of wire mesh. Wooden slanting racks mounted with wooden slates of 2-inch thickness and 2 square feet area covered with black DPC polyethene were used as growing surfaces. Seeds were soaked for 4 hours;after which grains were placed in the gunny bags resting ontop the wooden slates. Seeds were spread inside the bags to a 1.5cm thickness. Sprouts were removed from the bags and spread directly onto the growing surface to a thickness of 1.5cm after the incubation period of48 hours. Watering was done every 6 hours using a knapsack spray pump throughout the experiment ensuring that the seeds flood and water is completely drainedin 30 minutes. Fodder was harvested at day 4, separated manually using hands before feeding chicken.In this experiment, commercially formulated feeds were used as the basal. According to the feed manufacturers, the basal feed contained the nutrients listed in Table 1 as per the label on the bags: -

Table 1: Nutritional Composition of Basal Feed as per Manufacturer's Label

Ingredient	Units	Starter (0-4 Weeks)	Finisher (5-12 weeks)
Metabolizable Energy	Kcal	3,100	3,200
Crude Protein	%	21	18
Crude Fiber	%	5	5
Crude fat	%	5	5
Ash	%	12	12.9
Calcium	%	1	1
Phosphorus	%	0.75	0.73
Vitamin A	IU/Kg	12,000	12,000
Vitamin D	IU/Kg	2,000	2,000
Vitamin E	IU/Kg	20	20

Experimental Treatments and Treatment Groups: Five treatment groupswere used in the study each with different inclusion level of hydroponic barley fodder and basal feed as shown in Table 2.

Table 2: Experimental Treatment Groups

GROUP	INCLUSION %	FEEDING RATE
GROUP 1	100% Basal Feed	Based on average weight per week
GROUP 2	75% Basal feed and 25% Hydroponic Barley Fodder	
GROUP 3	50% Basal and 50% Hydroponic Barley Fodder	
GROUP 4	25% Basal and 75% Hydroponic Barley Fodder	
GROUP 5	100% Hydroponic Barley Fodder	

Hydroponic BarleyFeeding Experiment: At three-weeks, chicks were weighed & randomly assigned to the 5 treatment groups each of 18 birds in three replicates of 6 birds. They were individually weighed using a generic electronic kitchen digital weighing scale.This ensured that birds were of similar initial weight, age and sex to control for these as confounding factors. Thereafter birds were weighted weekly for the rest of the experimental period. Each bird was assigned an identification number written on a masking tape that was loosely strapped around one leg that was regularly adjusted as the birds grew older. Hydroponic barley fodder (HBF) was therefore introduced after the brooding period and fed to birds from 3 weeks (21 days) of the experiment for the next 9 weeks. Where mortality occurred, there was no replacement. Individual weight gain, amount of feed given per week; left-over feed and cost of feed consumed were recorded weekly using standard data record sheets attached. Basal feed and hydroponic barley fodder were weighed according to the treatment groups every morning and given to birds separately. The experiment was terminated after 12weeks by slaughtering the birds for sale.Basal feed was given at 9:00am and Hydroponic barley fodder (HBF) given at 12:00 noon to ensure full utilization. HBF was produced on-site, harvested at day 4 of sprouting and manually separated with hands into smallerportions then placed in plastic feeding containers.Birds were allowed a 4 - day's adjustment periodwhen HBF was introduced at the onset of the feeding experiment which was part ofweek 4 of the study.All unconsumed feed was removed every morning, weighed and recorded. Birds were fed as per average body weight.

Nutritionalcomposition of hydroponic barley fodder and original barley grain was determined using proximate analysis. The method partitioned nutrients into six components including: moisture content, ash, crude protein, carbohydrate, crude fat and crude fiber [8]. Nine barley grain samples each weighing 1kg were collected and submitted to Makerere University College of food science and technology laboratory for proximate analysis. Three (3kg) grain samples were picked from each of the bags sampled. These were collected from the top, middle and bottom of each of the nine bags of barley used. The three samples from each bag were thoroughly mixed before one kilogram was sampled for the laboratory analysis. Hydroponic fodder harvested at day 4 from each of these grain samples were also submitted for analysis. Proximate analysis was run on these samples in triplicate [7]. Dietary fiber was determined using the method described by Kirk and Sawyer [9].Carbohydrate content was determined using the method of Nielsen [10]. Moisture content was determined using the method of AOAC [11] Ash content was the inorganic residue obtained after burning off the organic matteras recommended by AOAC [12].Crude protein was determined using the Kjeldahl method described by Kirk and Sawyer [9]. Crude fat was determined using the Soxhlet apparatus [12].

Estimation of Feeding Costs: The economic value of using hydroponic barley fodder in chicken feed was assessed using gross margin ratio to measure how efficiently labor and raw materials were used in the production process. The benefit cost analysis was the tool used to determine the profitability of production. Revenue generated from sale of dressed birds in each group at the end of the experiment was also recorded. The cost of barley grain, water and labor required to sprout one kilogram of hydroponic barley fodder was calculated and recorded. Amount of HBF required to produce one Kg of meat was also calculated and recorded. The parameters used in assessing the economic value of including HBF in Kuroiler chicken diets included: - feed cost per unit of body weight gain, gross margin obtainable after sale of birds per kilogram and subsequent benefit cost ratio [13].They were used for comparison between groups.

Data Analysis: Proximate analysis was used to determine the nutritional profile of the original barley grain and 4-day hydroponicbarley fodder sprouts.The T-test was used to analyze significant difference in nutritional profile achievedby sprouting barley for 4 days in comparison to the grain.Weekly individual weight gainper group wassubjected to one-way analysis of variance (ANOVA) to evaluate effect of 4-day hydroponic barley fodder sprouts on weight gain. Analysis of variance was performed using SPSS version 24 and differences among the means were determined using Tukey post hoc test andLeast significant difference test (LSD) with the level of significance defined at P= 0.05[7]. To further predict accurate inclusion percentage of HBF required to give the highest growth rate and a breakpoint for the optimum requirement was estimated using a second-degree polynomial regression analysis. All statistical analysis was done using SPSS version 24.0 [14].The economic benefit of using HBFwas calculated to determine cost efficiency in each group using gross margin and benefit-cost ratio.

Ethical Issues: The experimental design and all procedures conducted were based on animal welfare principles recommended by the National Research councilto avoid any discomfort or pain [15]. Sound animal husbandry practices were used to provide systems of care that permitted the birds to grow mature and express their species-specific behavior. Adequate veterinary care was provided to ensure proper animal health and research assistants involved in the study were trained and motivated to achieve high-quality animal care throughout the experiment. A program was put in place for disease prevention, surveillance, diagnosis and treatment. [15].Birds were slowly acclimatized to handling by frequent exposure to kind and gentle handling by research personnel; starting at 2 weeks age to ease handling at later stages of the study and to increase feed efficiency as well as body weight gain [16].

III. Results and Discussion

The study showed that locally available materials could be used to produce HBF comparable to the one produced using conventional automated systems up to day 7 as seen in pictures C and D in Table 3. The study also revealed that each kilogram of barley grain produced 4.1kg of hydroponic barley fodder (HBF) by day four of sprouting and 6.8kg at day seven. This increase could have been attributed to softening of the seed coat resulting into the large uptake of water during the process of soaking and germination which agrees with [17].

Table 3: Observations in Sprouting Hydroponic Barley Fodder

Sprouting Day	Observation	Image of Growth
Day 1	Each kilogramof seeds imbibed water and increased weight to 1.8 kilograms after 4 hours of soaking.	
Day 2	Small white roots: 2-3 radicals are seen protruding from the grains and measure between 1.2- 2.3 cm.	
Day 3	The roots became elongated and small green shoots started sprouting. The green shoots had a height of 0.6- 1.4 cm while elongated roots measured 2.5-3.6 cm. The water could still drain freely through the seeds on the tray**.**	
Day 4	The green shoots had a height of 2.8-4.3 cmwith short green shoots at the top (A).The roots grew into a white mat-like mass with filamentous roots entangled together at the base. The mat can easily be lifted and rolled up like a carpet (B). Fresh weight of hydroponic fodder increased 4 times from the original barley grain and each kilogram of barley grain seeded produced 4.1kg of hydroponic fodder by day 4 of sprouting.	

		
Day 7	The Shoots grew to a height of 16.2 to 21.3cm while the root mass has a thickness of 2.4cm. (C). The roots are fully developed forming a thick white mat at the base that cannot be easily separated. (D)	 

Nutrient Composition of locally sprouted 4-day hydroponic barley fodder sprouts: Results indicated that in terms of nutritional profile, hydroponic barley fodder was more nutritious than the whole dry grain.Generally,nutrients available in HBFwerehigher than those in dry whole barley grain. A paired t-test was used to evaluate the level of significance for the two samples. There was a statistically significant difference (p= 0.000) in the nutritional profile of the original barley grain when compared to the sprouted grain. Increased moisture content observed, in turn activated hydrolytic enzymes within the seeds which then broke down starch, protein and fat into simple sugars, amino acids and free fatty acids respectively as reported by Sneath and McIntosh [18]. The decrease in carbohydrate despite increase in crude protein; crude fat; crude fiber and ash could be described by alterations in the proportion of nutrients during sprouting. This concurred with the similar reports [19].

Table 4: Nutrient Composition of Locally Sprouted Hydroponic Barley Fodder and Original Grain

Nutrient	Barley Grain Mean ± SEM (G/100g)	Hydroponic Barley Fodder (4-Day Sprouts) Mean ± SEM (G/100g)	P Value
Crude Protein	6.85 ± 0.0172^{a}	23.45 ± 0.0106^{b}	0.000
Moisture Content	11.38 ± 0.0249^{c}	80.58 ± 0.2102^{d}	0.000
Ash	0.58 ± 0.00784^{e}	2.12 ± 0.0179^{f}	0.000
Crude Fat	0.02 ± 0.0016^{g}	1.10 ± 0.032^{h}	0.000
Carbohydrate	79.98 ± 0.148^{i}	14.95 ± 0.0266^{j}	0.000
Dietary Fiber	3.04 ± 0.0171^{k}	6.11 ± 0.0238^{l}	0.000
$^{a-l}$*Means with different superscripts in the same row are significantly different (P=0.05)*			

Mean Weight Gain: At 3 weeks age, birds had average live weight between 0.355 - 0.370 Kg which was recorded as baseline data and the feeding experiment began. The mean live weights per week are presented in Table 5. The studyobserved increase in mean live weight of Kuroilers in the groups with HBF inclusion levels between 25-75% during the entire experiment. This weight gain could have been attributed to increased bioavailability of amino acids, simple sugars and fatty acids; concurring with a report by Saidi and Omar [20]. The highest final live weight of 3.349±0.039Kg was observed in the treatment group with inclusion levels of 75% Basal + 25% HBF. Finishing live weights at 12 weeks were higher than the standard weight of 2.5kg for

Kuroilers on conventional feed under intensive systems [21].This can beascribed to increased bioavailability of essential nutrients, vitamins and mineralsoptimal for meat and egg production.The study indicated that weight gained decreased with increasing percentage inclusion of hydroponic barley fodder in kuroiler chicken diets as seen in Table 5.

However, complete replacement of basal feed with HBF as seen in group 5 could not support the expected production traits among Kuroiler chicken. Stunted growth and poor health were observed among these birds probably due to significant losses in carbohydrate paired with increased dietary fiber content which reduces digestibility of HBF when given independently [7]. This therefore implies that hydroponic barley fodder does not have the nutritional capacity to completely replace conventional basal feeds. HBF utilization was greatly improved when HBF was fed in combination with basal feed; which agreed with Saidi and Omar [20]. This was also reported by Mwangi and Mbugua [22] who conducted a similar study with various chicken breeds in Kenya and recommended that even local chicken cannot thrive on this diet alone unlike claims that promote independent use of this fodder.

Second-degree polynomial regression analysis predicted 23% HBF inclusion level as the optimum percent inclusion to maximize growth rate among kuroiler chicken.This analysis showed a significant negative curvillinear correlation between mean weight gained and percentage inclusion of hydroponic barley fodder. Broken line analysis predicted as seen in Fig. 1. The coefficient of determination was $R^{2 =}$ 0.960 which implies a strong relationship between the two variables.

Table 5: Mean Live Weight (Kg) of Kuroiler Chickenduring Experiment

	Group1[Control] n=18	Group2 n=18	Group3 n=18	Group 4 n=18	Group5 n=18	p Value
Week of Study	**Mean± SEM**	**Mean± SEM**	**Mean± SEM**	**Mean± SEM**	**Mean± SEM**	
Week 3(Baseline)	0.370±0.004^{a}	0.369±0.004^{a}	0.364±0.004^{a}	0.363±0.004^{a}	0.355±0.004^{a}	0.104
Week 4	0.665±0.009^{b}	0.666±0.008^{b}	0.622±0.015^{b}	0.615±0.012^{b}	0.532±0.010^{b}	0.000
Week 5	0.992±0.015^{c}	0.978±0.010^{c}	0.895±0.023^{c}	0.872±0.020^{c}	0.622±0.015^{b}	0.000
Week 6	1.259±0.019^{d}	1.121±0.023^{c}	1.072±0.028^{c}	1.037±0.025^{d}	0.647±0.014^{b}	0.000
Week 7	1.356±0.021^{d}	1.380±0.038^{d}	1.258±0.033^{d}	1.260±0.030^{e}	0.678±0.012^{b}	0.000
Week 8	2.112±0.043^{e}	1.871±0.079^{e}	1.712±0.051^{e}	1.612±0.047^{f}	0.778±0.032^{b}	0.000
Week 9	2.229±0.041^{e}	2.142±0.060^{f}	1.905±0.051^{f}	1.855±0.039^{g}	0.900±0.038^{b}	0.000
Week 10	2.673±0.051^{f}	2.526±0.040^{g}	2.437±0.061^{g}	2.393±0.044^{h}	1.0361±0.040^{c}	0.000
Week 11	2.902±0.334^{g}	2.906±0.026^{h}	2.849±0.043^{h}	2.636±0.039^{i}	1.174±0.045^{d}	0.000
Week 12	3.278±0.036^{h}	3.349±0.039^{i}	2.998±0.052^{h}	2.766±0.062^{i}	1.320±0.039^{e}	0.000
^{c}Figures in the same column with the same superscripts are not significantly different *^{ac}Figures in the same column with different superscripts are significantly different*						

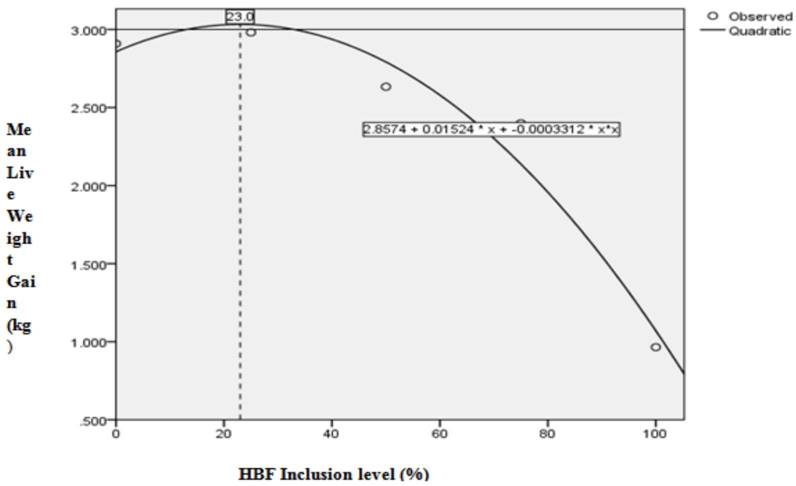

Figure 1: Scatter diagram and regression curve for mean weight gain and percent inclusion of HBF

Cost Efficiency of Kuroiler Production Using Hydroponic Barley fodder: The study showed that it cost 900 Ugx to produceone kilogram of hydroponic barley fodder. Fixed costs such as structure used to grow the fodder and extra storage space were not factored into this calculation. The main inputs considered are variable costsof barley seeds, water and labour used per day in the sprouting process [19]. This was compared to the basal feed obtained from Ugachick poultry breeders which cost 2,180Ugx per kilogram**.**All Kuroiler chickens were sold at the end of the experiment as per individual live body weight, each kilogram valued at 10,000 UGX. The unit cost of meat production reduced with increasing inclusion percentage of HBF from 25-75%inclusion percentage. Group 4 scored the highest gross margin of 50% and BCR of 2.0 at the end of the experiment. Birds in this group attained an average live weight of 2.766 ± 0.062 (kg) and the cost of producing one kilogram of chicken meatin this group was 33.9% less than the control group. Even though the 25% HBF + 75% basal feed group achieved the highest weight gained at the end of the experiment, the cost of meat production was relatively higher in group 2 than that in group 4.Therefore, inclusion of HBF in the diet significantly (P=0.000) increased live weight gain per unit of feed given thus reducing cost of production. However, the cost of meat production increased by 2.5% relative to the control group when inclusion level of HBF reached 100%.

IV. Conclusion and Recommendation

Sprouting barley hydroponically using locally available materials has the potential to enhance the technical and economic viability of this technology among small holder farmers. Development of low-cost equipment for hydroponic fodder production using locally available materials will ensure economic competitiveness of hydroponic fodder relative to alternative feed sources. Hydroponic barley fodder is a viable feed supplement for poultry production with the optimal inclusion for the best growth rateat 23% of total dry matter intake.Its incorporation in Kuroiler chicken diets increased growth rate and decreased production cost per kilogram of chicken meat produced.However, hydroponic barley foddercannot be given as an independent feed; as excessive consumptionresulted into stunted growth and poor health. Consequently, it must be fed in combination with additional dry matter to improve overall utilization of the fodder.More research is required to confirm if this production technique can be replicated in another environment with different weather conditions. In addition, further studies must be conducted using other poultry breeds to provide more concrete evidence on poultry performance usinghydroponic barley fodder with othercost-effective basal feed rations on the market.

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