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Potential use of fish meal (*Sardinella maderensis*), snail meal (*Achatina fulica*) and African Locust Beans (*Parkia biglobosa*) in Japanese quails diets: zootechnical and nutritional performance

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Abstract

The effects of the consumption of formulated (A1, A2 and A3) and commercial (AT) feeds on the zootechnical and nutritional performance of quail (Coturnix japonica) were studied. The experiment involved 80 1-day-old quails. At the end of the experiment which lasted 9 weeks, the quantities of food ingested per day by quail A1, A2, A3 and AT were respectively 25.27±0.02 g, 25.34± 0.08g, 23.83±0.11g and 23.85±0.08g. A3 and AT quails had the highest mass gains with respective values of 3.65±0.22 and 3.64±0.17 g/d. The best feed efficiency after the growth phase was observed with quail fed with growth feed formulated A3 (6.52 ± 0.05). The carcass yields of the quails fed with the formulated growth foods A1, A2, A3 and commercial AT are respectively 63±0.01; 66±0.01; 64±0.03 and 64±0.03%. The highest mortality rate (10%) was found with quails fed A1 and A2 formulated growth feed. In short, among the formulated feeds, feed A3 had a better impact, similar or even greater than that of commercial feed AT on the zootechnical performance of the Japanese quail studied.

Keywords: Animal feeding; Nutritional performance; Zootechnical performance; Japanese quail

1. Introduction

Poultry farming is growing all over the world and has very significant development potential in Africa. In Côte d'Ivoire, this sector is undergoing a very significant evolution, to the point that in the space of 4 years, poultry meat production, which was 20,000 tonnes in 2011, was more than 40,000 tonnes in 2015 [1]. In 2015, the poultry sector generated a turnover of nearly 240 billion CFA francs, generating 170 thousand jobs, of which 50 thousand direct and 120 thousand indirect. It is also the main market for agricultural products (corn, soybeans) and agribusiness by-products, including cotton and soybean meal [1] The sector will continue to evolve with the addition of new bird species, such as the Japanese quail (*Coturnix coturnix japonica*), whose breeding already provides high quality food proteins for human consumption [2]. Quail rearing is economically viable and technically feasible because quails reach sexual maturity at 6 weeks of age, are quite resistant to various diseases, and easily adapt to various breeding conditions [2]. However, feed is a major component, significantly affecting return on investment as the cost of feeding represents around 65-70% of total production costs [3]. Consequently, the main challenge for the sustainability and profitability of quail farming remains linked to controlling the costs of feed, the main needs of which are mainly energy and protein. In Côte d'Ivoire, soybean meal and fish meal, which are the conventional sources of protein, are becoming expensive and very scarce for poultry feed. This forced nutritionists to explore the food potential of various non-conventional protein sources abounding in Ivorian flora and fauna.

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The Ivorian flora is richly endowed with native fruit trees whose different parts of the fruit are potential sources of nutrients. *Parkia biglobosa*, know as African locust bean (ALBs) and also locally called Néré, is a valuable tree species found in the Sudanese savannas, providing medicine and food to local inhabitants [4]. Indeed, its fruits (pods) have a high nutritional value, whose edible parts (pulp and seeds) are used as ingredients in various foods. Many workers [5] have reported the nutritional adequacy of the *P. biglobosa* seeds with a proximate composition of 30.00% protein, 15.00% fat, 4.00% crude fiber, 2.00% ash and 49.00% carbohydrate. According to Gernah et al. [6], the pulp of the powdered fruit contains more carbohydrates (67.30%) than the seeds, but above all total carotenoids (49,175µg/100g), vitamin C (191.20mg/100g) minerals (4.18%) and crude fiber (11.75%).

Animal protein sources, on the other hand, are unconventional animal feed resources that are not traditionally used to formulate feeds for livestock. These food resources include earthworms, locusts, termites, maggots, caterpillars, cockroaches and snails [7]. Snails, members of the mollusc phylum and found in freshwater, seas and land, are very abundant during periods of heavy rainfall [8]. Several works are reported on the use of snails as protein supplements in aquaculture [9] and poultry diets [7,10].

However, no study to our knowledge has been reported on the simultaneous use of the ALBs (seed and pulp) meals as well as snail meal in the diet of quails. The aim of this research was to study the effect of a substitution of soybean meal and fish meal by the ALBs (seed and pulp) meals and snail meal respectively on growth and carcass characteristics in Japanese quail.

2. Material and methods

2.1. Description of the Study Site

The Japanese quail feeding trial was carried out in an experimental poultry farm located in the village of Akouai-Santai (Bingerville) in Côte d'Ivoire. This site is located at an altitude of 26m above sea level, ambient temperatures vary from 24.1 to 27 °C with rainfall between 57 and 266mm.

2.2. Sources of Feed Ingredients and Diet Formulation

Yellow maize (*Zea mays*), African carob fruits, snails, fish and red oil were purchased from local product suppliers (Adjamé, Côte d'Ivoire). Before being used, the biological material was dried, ground and packaged according to the procedures described by N'Gbo et al. [11]. The vitamin complex, methionine, lysine and salt were supplied by Koudijs. Six diets (isocaloric and iso-nitrogen), including three starting and three finishing, have been formulated to meet the nutritional requirements of Japanese quail as prescribed by the National Research Council [12]. The ingredients and chemical composition of these diets are shown in Table 1. Two diets (start-up and finish) serving as control were purchased from poultry input suppliers.

2.3. Bird Feeding and Management

Eighty (80) of 1day-old quails (mean initial body weight 7.46 ± 0.12g) used in the feeding trial were purchased from the experimental farm in Akouai Santai village (Bingerville, Côte d'Ivoire). These quails were then assigned to four dietary treatments (n = 20) according to a completely randomized plan and fed for 2 weeks (start-up phase), then 7 weeks (growth phase) with adequate diets. Every day at 5 p.m., food and water containing vitamin (VMD-Amin special) and a dewormer (Norfloxacin 20%) were provided ad libitum with a lighting cycle of 12 hours (7 p.m. to 7 a.m.) planned.

2.4. Growth Performance and Nutrient Digestibility

Following the determination of each bird's initial body weight (IBW), each quail's body weight was measured twice weekly on an electronic balance (dynamic scales (VICON-412, ACCULAB Sartoruis group, USA) as part of the growth and health monitoring routine. The body weight gain (BWG) of each bird over the experimental period was computed using the equation: BWG = final body weight –initial body weight. Daily feed intake (DFI) of each quail was computed using the equation: DFI (g) = feed offered – feed refusals; with feed offered weighed in the morning and refusal weighed the following day in the morning. Feed conversion ratio (FCR) was computed using the equation: FCR = feed intake (g) / weight gain (g). At the end of the two combined phases (9 weeks), one bird per replicate were randomly taken and housed individually in a cage to determine the nutrient digestibility. The faecal samples were collected daily for three days and analyzed in triplicate for moisture by the oven-drying method (930.15) and crude protein by Kjeldahl method (990.03) as described by AOAC [14]. As for the feed proximate composition, it was adopted from previously published data [13]. All of these data made it possible to determine feed efficiency ratio (FER), protein efficiency ratio (PER) and the digestible crude protein (DCP), as described by Alade 15].

Table 1 Gross composition of experimental diets

Ingredients (g/100g)	Starter Diet			Finisher Diet		
	A1	A2	A3	A1	A2	A3
Yellow corn	56	56	56	58	58	58
ALB (*Parkia biglobosa*) pulp flour	3	3	3	3	3	3
ALB (*Parkia biglobosa*) seed meal	20.8	20.8	20.8	19	19	19
Fish (*Sardinella maderensis*) meal	15	-	7.5	14,5	-	7,25
Snail (*Achatina fulica*) meal	-	15	7.5	-	14,5	7,25
Shell	2	2	2	2,2	2,2	2,2
Red oil	2	2	2	2	2	2
Vitamin complex	0.5	0.5	0.5	0,7	0,7	0,7
Salt	0.3	0.3	0.3	0,3	0,3	0,3
Lysine	0.25	0.25	0.25	0,2	0,2	0,2
Methionine	0.15	0.15	0.15	0,1	0,1	0,1
Total	100	100	100	100	100	100
Chemical composition*						
ME (kcal/kg)	2836.1	2983.7	2946.2	3000,1	3019,6	3058,5
Crude Protein (%)	16.58	18.04	19.72	15,33	16,71	18,36
Crude Fiber (%)	7.42	8.36	9.32	8,27	8,44	8,51

ALB: African Locust Bean; ME: Metabolizable Energy; *: Values adopted from previously published data [13]

2.5. Mortality rate, Carcass yield and Egg laying rate

Mortality was recorded daily and the mortality rate was calculated for the entire experimental period. At the end of this experimental period, twelve quails (3 birds per treatment) were randomly selected and starved for approximately 18 hours, but with ad libitum access to drinking water. Immediately after fasting, the final body weight (FBW) of each quail was measured. Each quail was then killed by cervical dislocation, left to bleed, scalded in hot water and plucked. All viscera were then removed and carcass mass was determined. The egg-laying rate was also determined according to the method of Hantanirina et al [16].

2.6. Experimental design and Statistical analysis

The experimental design used for this study was completely randomized design (CRD). All data collected were subjected to one-way analysis of variance (ANOVA) using the General Linear Model (GLM) procedure of STATISTICA software (StatSoft, Inc. 2011). The differences among means of different groups was detected by Duncan's multiple range test [17] at 5% level of significance [18].

3. Results

3.1. Zoo-technical and nutritional performance

The BWG of quails fed on formulated A1, A2, A3 and trade AT feeds at launch stage were respectively 3.10 ± 0.11, 3.22 ± 0.16; 3.23 ± 0.04 and 3.24 ± 0.04 g / day. They were uniform statistically (P ≥0.05) (Table 2). The mass gain of quails fed on growth feed A1, A2, A3 and trade feed were 3.37 ± 0.04; 3.47 ± 0.05; 3.65 ± 0.22 and 3.64 ± 0.17 g / day. Those of the quails fed on the formulated A3 and trade AT feeds were statistically the same (P ≥0.05). However, quails fed on A1 and A2 formulated growth feeds had statistically different mass gain (P<0.05) (Table 3).

DFI by quails fed both on formulated A1, A2, A3 and Trade feeds were respectively 12.01 ± 0.05 g, 12.13 ± 0.03 g; 11.53 ± 0.10 g and 11.54 ± 0.07 g at launch stage. Those fed on starter feeds A1 and A2 are the same statistically (P ≥0.05). It was the same quantities for launch feeds A3 and trade AT. However, the amount of feed ingested per day by quails fed on A1 and A2 startup formulated feeds was statistically higher (P<0.05) than quails fed on launch formulated A3 and trade AT feeds (Table 2). The amount of feed ingested per day by quails fed on growth feed was respectively 25.27 ± 0.02 g, 25.34 ± 0.08 g, 23.83 ± 0.11 g and 23.85 g± 0.08 g. Those fed on A3 formulated growth and trade AT feeds were the same statistically (P ≥0.05). These amounts of feed ingested per day were statistically lower than those fed on A1 and A2 growth feeds (P<0.05). Both feeds gave statistically the same amount of feed ingested per day (P ≥ 0.05) (Table 3).

The FCR for quails fed on starter formulated A1, A2, A3 and trade AT feeds are respectively 3.87 ± 0.10; 3.76 ± 0.13; 3.56 ± 0.08 and 3.56 ± 0.05. However, quails fed on A3 formulated and AT trade feeds are statistically lower than those fed on starter formulated A1 and A2 feeds as far as the FCR concerned (Table 2). The FCR for quails fed on formulated growth A1, A2, A3 and trade AT feeds are respectively 7.49 ± 0.15; 7.30 ± 0.020; 6.52 ± 0.05 and 6.55 ± 0.01. Those fed on formulated growth A3 and AT trade feeds are statistically equal (P≥0.05). They are statistically lower than the FCR of quails fed on A1 and A2 growth feeds (P<0.05) (Table 3).

FER of quail fed on both starter formulated A1, A2, A3 and feeds trade AT are respectively 0.26 ± 0.02; 0.27 ± 0.01; 0.28 ± 0.02 and 0.28 ± 0.03. Those fed on A3 and AT starter formulated feeds are statistically equal (P≥0.05). It is same for quails fed on A1 and A2 starter feeds. FER of quail fed on A3 and AT starter feed were statistically higher (P≤0.05) than those fed on A1 and A2 starter one (Table 2). Feed efficiencies of quail fed on A1, A2, A3 and trade AT growth feeds were respectively 0.13 ± 0.03; 0.14 ± 0.01; 0.15 ± 0.01 and 0.15 ± 0.02. Quails fed on formulated A3 and AT growth feeds are higher (P<0.05) than quails fed on A1 and A2 growth feeds statistically (Table 3).

The PER of quails fed on A1, A2, A3 and trade AT starter feeds were respectively 3.87 ± 0.18, 4.36 ± 0.21; 4.89 ± 0.14 and 5.07 ± 0.31. Those fed on A3 and AT starter feeds are equal statistically (P≥0.05). They are higher (P<0.05) than quails fed on A1 and A2 starter feeds statistically (Table 2). PER of quails fed on A1, A2, A3 formulated growth and trade AT feeds were respectively 2.50 ± 0.48, 3.09 ± 0.36; 3.65 ± 0.47 and 3.56 ± 0.26. Those fed on A3 and AT growth feeds are equal statistically (P≥0.05). They are higher (P<0.05) than quails fed on A1 and A2 formulated growth feeds statistically (Table 3).

DCP use of quails fed on A1, A2, A3 and trade AT starter feeds are respectively 72.27 ± 1.39%, 77.79 ± 2.93%; of 80.13 ± 0.57% and 80.91 ± 1.50%. Those fed on A2, A3 and AT starter feeds are equal statistically (P≥0.05). They are higher (P<0.05) than quails fed on A1 starter feed statistically (Table 2). This same observation is made at the level of quails fed with growth food (Table 3).

Table 2 Zootechnical and nutritional parameters of Japanese quails in captivity fed with starter feeds

Parameters	A1	A2	A3	AT
BWG (g)	3,100±0,012a	3,220±0,006b	3,230±0,006b	3,240±0,010b
DFI (g)	12,010±0,006b	12,130±0,006c	11,530±0,006a	11,540±0,006a
FCR	3,870±0,017c	3,760±0,006b	3,560±0,010a	3,560±0,010a
FER	0,258±0,001a	0,265±0,001b	0,280±0,001c	0,280±0,001c
PER	3,865±0,002a	4,355±0,001b	4,885±0,001c	5,070±0,015d
DCP (%)	72,268±0,001a	77,790±0,001b	80,136±0,002c	80,911±0,001d

BWG = body weight gain; DFI = Daily feed intake; FCR=Feed conversion ratio; FER=feed efficiency ratio; PER=protein efficiency ratio; DCP=digestible crude protein; The same letter on the same line means that there is no significant difference between the values at P<0.05

Table 3 Zootechnical and nutritional parameters of Japanese quails in captivity fed with growth feeds

Parameters	A1	A2	A3	AT
BWG (g)	3,370±0,000[a]	3,470±0,012[b]	3,650±0,006[c]	3,640±0,000[c]
DFI (g)	25,270±0,006[a]	25,340±0,006[b]	23,830±0,006[c]	23,850±0,000[d]
FCR	7,490±0,010[d]	7,300±0,000[c]	6,520±0,000[a]	6,550±0,006[b]
FER	0,133±0,000[a]	0,136±0,001[b]	0,153±0,001[c]	0,152±0,001[c]
PER	2,495±0,001[a]	3,087±0,001[b]	3,651±0,001[d]	3,555±0,002[c]
DCP (%)	54,580±0,006[a]	63,960±0,000[b]	72,270±0,006[d]	71,436±0,001[c]

BWG = body weight gain; DFI = Daily feed intake; FCR=Feed conversion ratio; FER=feed efficiency ratio; PER=protein efficiency ratio; DCP=digestible crude protein; The same letter on the same line means that there is no significant difference between the values at P<0.05

3.2. Mortality rate, Carcass yield and Egg laying rate

The carcass yields of quail fed with newly formulated growth feed (A1, A2, A3) and commercial feed (AT) at the end of the experiment were respectively 63±0.01; 64±0.01; 66 ± 0.03 and 64 ± 0.03%. Those of the quails fed with growth feed A2 and commercial feed AT are statistically (P≥0.05) identical. They are statistically lower (P≤0.05) than the carcass yields of quails fed with the newly formulated feed A3, which has the highest carcass yield (Table 4).

The daily laying rates of quails fed with newly formulated A1, A2, A3 and commercial AT feeds obtained during the 8th and 9th weeks of rearing are respectively 10.71±0.30; 13.89±0.50; 20.68±1 and 21.43±0.50%. The decreasing order of these daily laying rates obtained during the 8th and 9th weeks of rearing is as follows: daily laying rate with feed AT = daily laying rate with feed A3 > daily laying rate with feed A2 > daily laying rate with feed A1. (Table 4).

The mortality rates of quails fed on A1, A2, A3 and AT trade growth feeds are respectively 10%; 10%; 5% and 5%. The quails fed on A3 formulated and AT trade growth feeds provided statistically the same mortality rates (P≥0.05) than quails fed on growth feed A1 and A2. These mortality rates are statistically lower than those of quails fed on labeled growth feeds A1 and A2 (P≤0.05) (Table 4).

Table 4 Carcass, Egg laying rate and mortality rate

Parameters	A1	A2	A3	AT
Carcass Yield (g)	63±0.01d	64±0.01c	66±0.03a	64±0.03b
Egg laying rate (%)	10,71±0,30c	13,89±0,50b	20,68±1a	21,43±0,50a
Mortality Rate (%)	10a	10a	5b	5b

4. Discussion

Quails fed the newly formulated (A1, A2, A3) and commercial (AT) diets had significant (p ≤ 0.05) body mass gains (BWG) during captive rearing. This situation shows that the foods studied contain nutrients favorable to their weight gain. The mass gains especially of quails fed with A3 (formulated) and commercial AT (control) feeds are greater than those of quails fed with newly formulated A1 and A2 feeds. This result suggests that nutrients favorable to good weight growth and palatability of quails are more abundant, varied and well balanced in A3 (formulated) and commercial AT feeds than newly formulated A1 and A2 feeds. This result corroborates the work of Peyman et al. [19] and those of Seven et al. [20] who also obtained a good increase in the mass gains of quails fed with diets based on soybean meal substituted with fava beans during their captive breeding.

These nutritional qualities are effectively reflected in good feed consumption indices (FCR) obtained with A3 (formulated) and commercial AT (control) foods. Indeed, Leclercq and Beaumont [21] were able to show that as the protein content of the food increases, the consumption index decreases and the gain in mass increases. Also, Gongnet and Vias-Franck [22] pointed out that the best indices of consumption are obtained with a high rate of protein efficiency (PER). However, those of foods A3 and AT are indeed the highest (4.885±0.001 and 5.070±0.015%). This justifies the best consumption indices obtained with these foods. The newly formulated A3 feed consists mainly of fish and snail animal proteins. This combination of animal proteins is a very important formulation factor which brings the zootechnical characteristics of quails fed with this feed closer to those of quails fed with commercial feed. This combination could also have an influence on the palatability of animals bred in captivity. The large quantities of A3 and AT feeds ingested (FI) by these quails could justify this state of affairs. The amount of food consumed could therefore also have an influence on the weight growth of quail.

Indeed, Agwunobi and Ekpenyong [23] showed that, the more the subjects consume a lot of food, the more they gain in mass and present a better food efficiency coefficient (FER). This was rightly demonstrated in the course of this work. The mass gains of quails fed with A3 and commercial AT feeds (respectively 3.650±0.006 g and 3.640±0.000 g) are similar to those obtained by some authors [24,25] at the end of their captive quail breeding. These mass gains are on the other hand superior to those of the same animals bred in captivity by many authors [26,27,28,29].

The carcass yields of quails fed with A2 and commercial AT feed are statistically ($P \geq 0.05$) identical. On the other hand, they are statistically lower ($P \leq 0.05$) than the carcass yield of quails fed with formulated A3 feed which remains the highest. This situation shows that quails fed with A2 and commercial AT feeds weigh heavily, but stripped of their feathers and viscera (liver, heart, empty gizzard, lungs, kidneys and intestines), they have a reduced carcass mass. This finding suggests that the feathers and viscera of quails fed with these A2 and AT feeds have higher masses than those of quails fed with A3 feed. This would mean that snail powder plays a very important role in the cell metabolism of quail, because the A3 feed has a composite snail and fish powder as its animal protein source. This explanation is also supported by the fact that food A1 whose animal protein source is fish powder did not give good results compared to food A2 whose animal protein source is only snail powder. and which gives a carcass yield similar to that of the control. Also, it is good to note that the equality of carcass yields obtained with quails fed with A2 (formulated) and commercial AT feed could be explained by the presence within them of the same quantities of molecules responsible for the evolution of the weight growth of these birds. The carcass yields of quails fed with formulated feeds A2 and A3 and commercial AT (64% to 66%) are close to those obtained (67%) by Abdel-Azeem [30] after captive breeding of hens.

The quality of the foods studied was also highlighted by the egg-laying rates of the quails. In this study, quails fed the newly formulated, commercial diets laid eggs. This means that the foods studied contain the molecules capable of ensuring egg laying and that the quails are raised in good conditions [31]. However, the low daily laying rates (10.71 - 21.43%) observed in our experience could be explained by the physiological state of the quails during the period of obtaining these eggs. Indeed, the eggs used for the calculation of the daily laying rates in our study were obtained in weeks 8 and 9 corresponding to the period of the start of laying of the quails in our study, as indicated by Reddish et al. [32]. During this period, egg production is relatively low. In addition, the daily laying rates obtained in quails fed with A3 (20.68%) and commercial AT (21.43%) feeds compared to those obtained in quails fed with newly formulated A1 feeds (10 .71%) and A2 (13.89%) show that A3 and AT feeds contain more molecules capable of ensuring egg laying in quails.

Indeed, the synergistic action resulting from the association of several protein sources in the A3 food has already been demonstrated by many researchers including Smith [33] who showed that various protein sources lead to better performance of spawn subjects. The daily egg laying rates obtained in quails in this study are lower than those obtained by Marques et al. [34], Berto et al. [35], Hassan [36] and Abdel-Azeem [30]. who worked respectively on quails during a period ranging from the 6^{th} to the 14^{th} week.

Finally, to test the quality of the newly formulated feeds, we evaluated the mortality rate of the quails. In this study, the quails fed with the newly formulated and commercial feeds succumbed but the mortality rates obtained are low (10%) for the quails fed with feeds A1 and A2 and very low (5%) for the quails fed with with foods A3 and AT. This situation is not attributable to food insofar as quail deaths were obtained only during the first 3 days of the experiment. It could be attributed to stress during transport and handling during the installation of the quails in the compartments of the crate. This behavior suggests that the foods studied were not the cause of the quail deaths. The mortality rates obtained in this work did not exceed the 10% limit recommended by Bres et al. [37], which could be explained by the quality of the environment and the food offered to the quails during the experiment. Indeed, the food ingested by quails contains energy elements, plastic elements and functioning factors which ensured the maintenance of their life as meant by Bres et al. [37].

5. Conclusion

The determination of the zootechnical and nutritional parameters made it possible to report on the growth of the quails and the nutritional efficiency of the various newly formulated feeds during the evaluation. Indeed, these foods all had a positive impact on the zootechnical and nutritional performance of Japanese quail reared in our ambient conditions. The results obtained revealed that the newly formulated diet A3 was more effective than the other two (A1 and A2) because it was at the origin of performances similar or even superior to those of the control diet AT. The mixture of snail and fish meal in equal parts, this synergistic effect of various sources of protein in the A3 feed increased its biological value.

Compliance with ethical standards

Conflict of interest statement

All authors have read, understand and agreed to the submission guidelines, policies and submission declaration of the journal. All authors have approved the manuscript as submitted.

Statement of ethical approval

The study was approved by the Institutional Animal Ethics Committee of University Nangui Abrogoua of Ivory Coast.

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