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Research Article

Effect of different combinations of by-products on the technical-economic performance of broilers in Côte d'Ivoire

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Abstract

This study was carried out to evaluate the effect of different combinations of local by-products in growth-finishing rations on the zootechnical parameters of broilers. 225 chicks of the COOB 500 strain, aged 18 days and weighing an average of 605.63 g, were divided into 5 groups of 45 subjects. Each batch of chickens was fed a specific diet, comprising the commercial control and rations R4, R5, R6 and R7. In these rations, maize was partially replaced by 10% cashew apples combined with 10% mango peel, 10% cashew apples combined with 10% mango kernels, 10% mango peel combined with 10% mango seeds, 6% cashew apples combined with 7% mango peel and 7% mango kernels. Soya meal was also partially replaced by 10% cottonseed meal in each of these diets. Chickens were reared on these diets from day 19 to day 45. On day 45, the weight and average daily gain of the chickens fed the RT diet were significantly ($p < 0.05$) higher than those of the other batches. Among the diets containing by-products, chickens in batches R5 and R4 had the highest average daily weights and gains. On the other hand, chickens in batch RT had the lowest feed conversion indices. The use of by-products reduced production costs per kilogram of feed and increased gross margins in the R5 and R4 diets compared with the RT control. Dried cashew apple in combination with dried mango skin or almond and cottonseed meal could reduce production costs and improve the profitability of broiler farms.

Keywords: Broiler chicken, Zootechnical performance

Introduction

Poultry farming plays an important role in meat production in Côte d'Ivoire. It accounts for around 44% of total national meat production [1], as poultry farming is the fastest growing agricultural sub-sector in developing countries [2]. In developing countries, eggs and chicken are considered an important source of animal protein [3]. Most regions have seen significant growth in poultry production and consumption, which can be partly explained by changes in diet, health problems and the price of poultry products [4]. Poultry farming, and broiler farming in particular, is a short-cycle activity that produces good-quality, low-cost protein in just 45 days. Since 1960, global chicken production has increased considerably, more than that of any other type of meat in developed and developing countries [5]. In 2017, broiler meat production reached 109,056,179 tonnes of carcass equivalent, around one and a half times that of beef and eleven times that of sheep meat [6]. However, the high cost of inputs is a major obstacle to the profitability of poultry production [7].

In fact, feed represents the largest share of poultry production costs. According to [8], feed accounts for 60-65% of total production costs in broiler production. This is due to the unavailability of many commonly used feed ingredients, caused by human-animal competition for access to feed resources [9]. According to [10]. To bridge the gap between protein demand and animal productivity, it is essential to exploit other local food resources that are not intended for human consumption [11]. Extensive research has therefore been carried out to assess the suitability of various ingredients as alternative sources of protein and energy for poultry. Much attention has been paid to the evaluation of agricultural plant wastes and by-products as potential ingredients for poultry diets [12]. Materials derived from agricultural or industrial wastes have been used to solve the problem of feed shortage in the poultry industry [13]. In this sense, the agricultural vocation of Côte d'Ivoire could be an asset in solving this problem. In recent years, the country has developed not only the coffee and cocoa sectors, but also other agricultural products such as cashew nuts, cotton and mangoes. It is now the world's leading producer of cashew nuts, with national production of around 1.028 172 tonnes in 2022 [14]. It is also Africa's leading producer of mangoes, with annual production of around 180,000 tonnes [15]. However, while these crops play an important role in the country's exports, they also generate large quantities of by-products that represent significant post-harvest losses. According to the Global Business Network Programme, the Ivorian government estimates the volume of agricultural waste at 15-17 million tonnes per year. This waste represents a potential source of nutrients that can be used for animal feed, particularly in poultry farming, to solve the growing problem of competition between humans and animals for the same products, particularly maize, the price of which is constantly rising [16]. In this context, cashew apples, cottonseed meal and mango peel and almond, which are rich in nutrients, can be used as animal feed [17]. In Côte d'Ivoire, cashew apples, cottonseed meal and mango waste are still underutilised. Using these agricultural by-products could reduce the cost of livestock feed. It would also solve the problem of post-harvest losses and provide an additional source of income for farmers. The aim of this project is to evaluate the effect of combining different by-products in rations on the zootechnical performance of broiler chickens.

Materials and Methods

Collection of by-products

This work required the use of four by-products. These were cashew apples from the department of Tanda, and mango peels and kernels from the COBEKO mango processing plant in Korhogo. The cotton cake came from COTRAF Sa, also in Korhogo. These various by-products underwent several treatments before being incorporated into the diet of the broilers used in this trial. Cashew apples were cut and dried. The mango peels were washed, pulped and dried. The mango seeds were kneaded with a knife to remove the remaining flesh and then crushed to extract the almond. The almond was then cut into small pieces, soaked in water for 24 hours, boiled at 100°C for 30 minutes and dried. Finally, the cottonseed meal was purchased as granules in 50 kg plastic bags. All these by-products were dried at an ambient temperature of 30°C to 35°C for different periods of time until a constant weight was obtained. After drying, each by-product was ground and stored in plastic bags.

Formulation of experimental diets

Four (4) rations, identified as R4, R5, R6 and R7, were made up of the different by-products. In each of these experimental rations, soybean meal, which is a source of protein, was partially replaced by cottonseed meal at a rate of 10%. However, for corn, which is the main energy source in the food, it has been partially substituted in different proportions depending on the ration formulated. The proportion of maize substituted in formulated rations and the proportion of substitute by-products are as follows:

R4: 20% corn substituted with 10% cashew apple + 10% mango peel

R5: 20% corn substituted by 10% cashew apple + 10% mango almond

R6: 20% corn substituted by 10% mango peel + 10% mango almond

R7: 20% corn substituted by 6% cashew apple + 7% mango peel+ 7% mango almond.

After formulation, each of the four (4) rations was subjected to a bromatological analysis to determine their chemical composition. The dry matter, ash, protein, fat and fibre contents of the samples were determined using [18] method. Raw cellulose was obtained by the WEENDE method [19]. Official methods of analysis. 17th Ed. Association of Official Analytical Chemists. Gaithersburg, Maryland, USA The metabolizable energy of each sample was calculated using the formula of [20]. Calcium, magnesium and sodium content was determined using an atomic absorption spectrophotometer according to the [18]. Official methods of analysis. 17th Ed. Association of Official Analytical Chemists. Gaithersburg, Maryland, USA method. For phosphorus, its quantification was done by spectrophotometer according to [21]. The commercial food used as a control has been identified as RT. Only the nutritional composition indicated on the label was considered (Table 2). All chicks were subjected to the prophylaxis program provided by the hatchery.

Table 1. *Centesimal composition of the ingredients of experimental diets formulated*

Ingredients	R4	R5	R6	R7
Maize	43	43	43	43
Cashew apple (%)	10	10	-	6
Mango peel (%)	10	-	10	7
Mango almond (%)	-	10	10	7
Wheat bran (%)	4	4	4	4
Soybean meal (%)	16	16	16	16
Cotton meal (%)	10	10	10	10
Fish flour (%)	2	2	2	2
Shellfish (%)	0.25	0.25	0.25	0.25
Vitamin- mineral premix (%)	3.5	3.5	3.5	3.5
Salt (%)	0.25	0.25	0.25	0.25
Oil (%)	1	1	1	1
Total (%)	100	100	100	100

Table 2. *Chemical composition of the rations used in the study*

Chemical composition	RT	R4	R5	R6	R7
Dry matter	-	88.03	87.47	91.37	84.40
Crude protein (%)	17	21 .88	20.13	19.25	19.25
Fat (%)	5	2.508	2.948	4.69	537
Ash	13	7.84	7.22	5.35	4.98
Crude cellulose (%)	4.7	7.68	7.56	7.96	7.88

Calcium (%)	3.44	1.08	1.02	1.06	1.17
Total phosphorus (%)	0.58	0.70	0.57	0.51	0.60
Potassium (%)	-	1.13	1.44	1.41	1.23
Magnesium (%)	-	0.25	0.23	0.26	0.31
Sodium (%)	0.17	1.92	1.82	1.56	1.62
EM (kcal/kg)	2768	3086.35	3146.22	3281.80	3340.99

RT: commercial control ration, R4: 10% cashew apple, 10% mango peel and 10% cottonseed meal ; R5: 10% cashew apple, 10% mango almond and 10% cottonseed meal; R6: 10% mango peel, 10% mango almond and 10% cottonseed meal; R7: 6% cashew apple, 7% mango peel, 7% mango almond and 10% cottonseed meal.

Collection of by-products

The trial was conducted with 225 chicks, 19 days old and weighing an average of 606.17 g, selected after a three-day dietary transition, starting on day 16, between a commercial starter diet and a diet formulated according to the batches formed. The 225 chicks were divided into five batches of 45 chicks, and each batch was subdivided into three according to the assigned ration. A control batch (RT) and four experimental batches (R4, R5, R6 and R7) were formed. The experiment started with chicks aged 19 days and ended on day 45, i.e. a duration of 27 days. All chicks received the same prophylactic treatment.

Data collection and calculation of zootechnical parameters

During the experiment, the amount of food consumed and refused was recorded daily. The animals were weighed individually on an empty stomach, simultaneously on D19, D28, D35 and D45, using an electronic balance. The number of dead chickens was also recorded. The data collected during the experiment were used to calculate several zootechnical parameters, namely individual feed intake (IFI), average weight (AW), average daily gain (ADG) and feed conversion ratio (FCR). As the only factor that differentiated the batches was the feed ration, the economic analysis was carried out based on the feed production cost in relation to the commercial weight at 45 days.

Data analysis

Zootechnical parameters such as IFI, AW, ADG, FCR, were subjected to an analysis of variance (ANOVA) at a significance level of 5%.

Materials and Methods

Results

Individual food consumption (IFI)

The analysis in Table 3 shows the daily feed consumption of the different batches. The individual feed consumption of all batches of chickens increased progressively during the growth-finishing phase. All mean feed intakes from D19 to D45 were significantly different at the 5% level. The feed intake of batch RT (135.13 ± 19.24 g/d) was lower than that of batches R4 and R5, but higher than that of batches R6 and R7. Food consumption by subjects fed rations containing by-products varied from 127.09 to 141.59 g/d. Feed consumption was highest in batches R4 and R5 and lowest in batches R6 and R7.

Food consumption increased significantly during the three periods of the experiment in all lots. There is overall appreciation of feed containing by-products by chickens, as evidenced by the variation in individual food consumption between 127.09 and 141.59 g/y. These results are lower than those of [22] who obtained IFI between 166.4 and 172.37 g/d for 56-day broilers fed with rations containing 5, 10, 15, 20 and 5% rice bran. These values are also higher than those obtained by [23] who observed individual feed intakes (IFI) of 64.1 and 74.4 g/d in broilers fed with corn that was substituted with mango feeds.

Table 3. *Feed consumption (g/d) of different batches of broilers*

	Periods			
Baches	**J19-J28**	**J29-J35**	**J36-J45**	**J19-J45**
RT	116.57 ± 20.29^a	142.48 ± 5.59^a	$148.55 \pm 2{,}43^a$	135.13 ± 19.24^a
R4	118.78 ± 18.96^a	149.75 ± 1.02^b	153.21 ± 4.64^b	139.56 ± 19.94^b
R5	120.71 ± 17.49^a	152.66 ± 5.36^b	154.72 ± 5.15^b	141.59 ± 19.70^b
R6	110.75 ± 20.21^b	$131.56 \pm 13{,}19^c$	144.27 ± 8.46^c	128.56 ± 20.77^c
R7	104.07 ± 21.37^c	135.28 ± 10.33^d	144.37 ± 14.86^c	127.09 ± 24.50^c
P	0.0038	<0.001	<0.001	<0.001

In each column, the means assigned a common letter are not significantly different from each other at $p < 0.05$. RT: commercial control ration, R4: 10% cashew apple, 10% mango peel and 10% cottonseed meal ; R5: 10% cashew apple, 10% mango almond and 10% cottonseed meal; R6: 10% mango peel, 10% mango almond and 10% cottonseed meal; R7: 6% cashew apple, 7% mango peel, 7% mango almond and 10% cottonseed meal.

Average weight and Average daily gain

As shown in Table 4, the weights of the animals in the different treatments were approximately equal at the start of the experiment, at D19. During the experiment, all batches showed a progressive increase in weight. This trend became more pronounced in the fifth week at D35, with batch R5 (1646.33g) in the lead. At the end of the experiment (D45), there was a significant difference between the average weight of the subjects in batch RT (2360.11g) and that of the subjects in the other batches. The average weights of the subjects in the batches consuming the by-products ranged from 1983.50g to 2268.74g. The highest average weight was obtained with chickens from batch R5 and the lowest with chickens from batch R6. There was no significant difference between the average weight of chickens in batches R7 (2018.34g) and R6 (1983.50g).

On average from D19 to D45 (Table 5), the RT treatment recorded the highest average daily gain (65.01 g/d). The average daily gain of subjects consuming rations containing by-products ranged from 51.03 g to 61.59 g/d. The subjects in batches R5 recorded the highest ADG, while those in batches R6 recorded the lowest. However, there is no significant difference between the ADG of the subjects in lots R4 and R5 which are very close to that of the control as well as those in lots R6 (51.03g) and R7 (52.31g).

Chickens fed RT feed obtained the best average weight. Indeed, they recorded the highest AWG availability and nutritional balance of these rations.

Average Weigh gains of R4, R5, R6 and R7 rations, ranging from 51.03 to 61.59 g, are higher than those obtained by [24] in Côte d'Ivoire (AWG ranging from 30 to 50 g/d in their test on the effect of substitution of soybean meal by cashew meal in the feed of broiler chicken COOB 500. These values are also higher than those obtained by [25] for 56-day broiler chickens fed rations containing 5, 10.15, 20 and 25% boiled pigeon pea (35.76 to 36.02 g/d). The average weights of experimental rations, ranging from 1,983.50 to 2,268.74 g, are much higher than those obtained by [26] with values between 1243.24 and 2416.67g for 52-day broilers fed 20-day rations. 40, 60 % of pigeon pea.

Also, the values obtained by [23] ranging from 1179.6 g to 1664.6 g for 48-day broilers fed with rations containing mango feed are much lower than ours (1 983.50 to 2 268.74 g).

The reason for the higher R5 weight gain could be due to the higher DM and nutrient intake in this ration over all experimental periods. In contrast, the lowest weight gain (P<0.001) of birds in R6 is probably due to a high content of tannins in mango waste, which gradually leads to less effective use of food and reduces body weight gain when included as a major component [23].

However, the combination of cashew apple with mango almond (R5) or mango skin (R4) at 10% corn substitution each gives better results than the combination of mango skin with almond (R6 and R7). This may be due to the low tannin content of the cashew apple compared to the mango peel or almond.

Table 4. *Average weight in g of the different batches of broilers*

		Age		
Treatments	**J19**	**J28**	**J35**	**J45**
RT	604.77± 1.01[a]	1219.67±81,36[a]	1637.33±97.32[a]	2360.11±158.43[a]
R4	606.13±1,11[a]	1167.67±51,59[b]	1606.50±76.93[a]	2222.89± 122.31[b]
R5	605.77± 0,68[a]	1148.97± 45,64[b]	1646.33± 91,81[a]	2268.74±129.68[c]
R6	605.63±0,76[a]	1074.53± 75,31[c]	1402.20±118,61[b]	1983.50±12724[d]
R7	605.87±0.86[a]	102267± 63.19[d]	1411.33±102.19[b]	2018.34±148.52[d]
P	<0.001	<0.001	<0.001	<0.001

In each column, the means assigned a common letter are not significantly different from each other at p < 0.05. RT: commercial control ration, R4: 10% cashew apple, 10% mango peel and 10% cottonseed meal ; R5: 10% cashew apple, 10% mango almond and 10% cottonseed meal; R6: 10% mango peel, 10% mango almond and 10% cottonseed meal; R7: 6% cashew apple, 7% mango peel, 7% mango almond and 10% cottonseed meal.

Table 4. *Average weight in g of the different batches of broilers*

	Treatments					P-value
Parameters	**RT**	**R4**	**R5**	**R6**	**R7**	
J19-J28	61.49 ±8 [a]	56.15±4.97 [b]	54.32±443 [b]	46.89±7.34[c]	41.68± 6,23[d]	<0,0001
J29-J35	59.67±4.91[a]	62.69±3,82 [a]	71.05± 7,28[b]	46.81±7.43[c]	55.52± 6.60[d]	<0,0001
J36-J45	72.28±6.97[a]	61.64±5,16 [b]	62.24±5,36 [b]	58.13±3,04 [c]	60.70± 5.36[b]	<0,0001
J19-J45	65.01± 5.87[a]	59.88±4,49 [b]	61.59±4,78[b]	51.03±4.69[c]	52.31± 5.50[c]	<0,0001

In each column, the means assigned a common letter are not significantly different from each other at $p < 0.05$. RT: commercial control ration, R4: 10% cashew apple, 10% mango peel and 10% cottonseed meal; R5: 10% cashew apple, 10% mango almond and 10% cottonseed meal; R6: 10% mango peel, 10% mango almond and 10% cottonseed meal; R7: 6% cashew apple, 7% mango peel, 7% mango almond and 10% cottonseed meal.

Feed conversion ratio

At the end of the experiment, subjects in batch RT recorded a significantly lower feed conversion ratio RT (2.12). The consumption indices of the subjects in the experimental batches ranged from 2.33 to 2.57. Subjects in batch R5 had the lowest feed conversion ratio and those in batch R6 the highest. However, there was no significant difference between the feed conversion ratios of subjects in batches R4 and R5 or between those in batches R6 and R7.

The introduction of our by-products into rations increases the consumption index. However, the feed consumption ratio of chickens in R5, R4, R6 and R7 rations between 2.33 and 2.57 are consistent with those of [27], which obtained consumption indices ranging from 2,12 to 2.86 in tests with animal meal in broiler rations. Our results are lower than those obtained by [26] with CI ranging from 1.18 to 3.87 in broiler chickens fed pigeon pea grain meal rations, and those of S.A. [28] with values between 3,35 and 5.22 for broilers fed with rations whose maize had been partially substituted with dried artisanal grain.

The combination of cashew apple and mango almond gives more satisfactory results. This result could be explained by the richness of the cashew apple and mango almond in nutrients, especially in proteins essential for the growth of broilers. [29] had pointed out that the improvement in performance of duckling fed with the ration containing dried cashew apple would be linked to the supply of sufficient quantities of trace elements, essential amino acids, energy through its high glucose content and the elements facilitating digestion such as cellulose. Also, the protein content of dried mango almond is comparable to that of corn and has a good profile in essential amino acids including lysine and methionine [30]. The soaking and boiling of mango almond would have reduced the content of anti-nutritional factors [31] especially tannins [32].

Table 6. *Feed conversion ratio (FCR) of different batches of broilers*

	Treatments					P-value
Parameters	**RT**	**R4**	**R5**	**R6**	**R7**	
J19-J28	1.92 ± 0,22[a]	2.18± 0.19[b]	1.90± 0.17[a]	2.42± 0.37[c]	2.55±0.35[c]	<0,0001
J29-J35	2.40±0,20[a]	2.40± 0.14[a]	2.17±0.22[b]	2.86±0.36[c]	2.47± 0.27[a]	<0,0001
J36-J45	2.07±0.17[a]	2.50±0.20[b]	2.50±0.20[b]	2.49±0.13[b]	2.39±0.19[b]	<0,0001
J19-J45	2.12±0.15[a]	2.36±0.17[b]	2.33±0.17[b]	2.57±0.21[c]	2.49±0.22 [c]	<0,0001

In each line, the means assigned to a common letter are not significantly different from each other at $p < 0.05$. RT: commercial control ration, R4: 10% cashew apple, 10% mango peel and 10% cottonseed meal ; R5: 10% cashew apple, 10% mango almond and 10% cottonseed meal; R6: 10% mango peel, 10% mango almond and 10% cottonseed meal; R7: 6% cashew apple, 7% mango peel, 7% mango almond and 10% cottonseed meal.

Chicken mortality rates during the trial period

During the trial, a mortality rate of 1.33% was recorded for all batches (see Table 7). All batches showed a low mortality rate. Lot R5 recorded a mortality rate of 2.22%, while lot R4 recorded a rate of 4.44%. Batches RT, R6 and R7 showed no mortality.

Chickens fed with feed containing mango waste as dominant by-product (R6 and R7) did not show mortality during the experimental period, unlike those fed with the ration containing the combination of apple cashew and mango waste (R4 and R5). These rations would better protect chickens from disease. Indeed, the presence of some important antioxidant vitamins in mango residues would help reduce the risk of disease [33].

Table 7. *Mortality rates (%) for different batches of broilers*

Treatments	**RT**	**R4**	**R5**	**R6**	**R7**	**Total**
Initial effectif	45	45	45	45	45	225
J19-J28	0	0	0	0	0	0
J29-J35	0	0	1	0	0	1
J36-J45	0	2	0	0	0	2
Total	0	2	1	0	0	3
Mortality rate	0	4,44	2,22	0	0	1.33%

RT: commercial control ration, R4: 10% cashew apple, 10% mango peel and 10% cottonseed meal; R5: 10% cashew apple, 10% mango almond and 10% cottonseed meal; R6: 10% mango peel, 10% mango almond and 10% cottonseed meal; R7: 6% cashew apple, 7% mango peel, 7% mango almond and 10% cottonseed meal.

Economic analysis

The prices per kg of experimental food rations, based on local market prices for the various raw materials used, are shown in table 10. The price of cashew apple, mango peel and mango almond were estimated to be based on transport, labour and collection difficulties respectively at 75, 100 and 75 F CFA per kg. It is clear from this table that the prices per kg of experimental rations were lower than those of the commercial ration RT (395 FCFA). Prices of experimental rations range from 276.87 to 280.87 FCFA. All gross margins are positive. The experimental rations R5 (1216.64 FCFA) and R4 (1179.81 F CFA) had got higher gross margins, followed by those of R7 (978.49 F CFA), RT (972.23 FCFA) and R6 (933.56 F CFA). The incorporation of by-products into the broiler chicken ration has reduced the cost of producing a kilogram of feed, due to the low cost of these by-products compared to corn and soybeans. Our results are consistent with those of [34] who used Moringa leaves. All rations generated a gross profit margin. However, the gross margins of R5 and R4 rations are better than that of the RT control ration.

Table 8. *Economic assessment of the five (5) batches according to the rations*

Parameters	Batches or food rations				
	RT	R4	R5	R6	R7
(A): Ingestion/chicken (kg)	3.649	3.768	3.823	3.471	3.431
(B): Feed price/kg (XOF)	395	276,87	279,87	276,87	280,87
(C): Feed cost = A*B (XOF)	1441.36	1043.24	1069.94	961.01	963.66
(D): Final weight (kg)	2360.11	2222.89	2268.74	1983.50	2018.34
(E): Initial weight	604.77	606.13	605.77	605.63	605.87
(F)Weight gain=D-E	1755.34	1616.76	1662.97	1377.87	1412.47
(G): Chicken price/kg (XOF)	1375	1375	1375	1375	1375
(H): Chicken cost =F*G/1000(XOF)	2413.59	2223.05	2286.58	1894.57	1942.15
Gross margin per chicken = H-C (XOF)	972.23	1179,81	1216,64	933,56	978,49

RT: commercial control ration, R4: 10% cashew apple, 10% mango peel and 10% cottonseed meal; R5: 10% cashew apple, 10% mango almond and 10% cottonseed meal; R6: 10% mango peel, 10% mango almond and 10% cottonseed meal; R7: 6% cashew apple, 7% mango peel, 7% mango almond and 10% cottonseed meal.

Conclusion

The introduction of combinations of by-products into the ration had no negative effect on the zootechnical parameters of the chicken compared with the control. The best combinations were cashew apple with skin (R4) or mango kernel (R5), which produced parameters very close to those of the control. Using these by-products also reduced production costs and increased profit margins compared with the control. The use of these by-products is an advantage for farmers. These by-products, which were previously unprofitable financially, are now being put to good use in poultry farming. They thus become a source of income for producers. This is also an advantage for poultry farmers, whose production costs will be reduced and whose profit margins will be improved.

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