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Effects of Defatting Combined or not to Heating of *Jatropha curcas* Kernel Meal on Feed Intake and Growth Performance in Broiler Chickens and Chicks in Senegal

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Keywords: Broiler chickens- Broiler chicks- *Jatropha curcas*- Ingestion- Growth performance- Senegal

Summary

Jatropha curcas *is a tropical plant belonging to the* Euphorbiaceae *family whose cultivation has been largely promoted in recent years for the production of biofuels. The kernel of the seed contains approximately 55% lipid in dry matter and the meal obtained could be an exceptional source of protein for family poultry farming, after treatments to remove toxic and anti-nutritional compounds. The ingestion and the growth performance of* J. curcas *kernel meal (JKM), obtained after partial physico-chemical de-oiling combined or not with heating was evaluated in broiler chickens and chicks. Sixty unsexed broiler chickens, 30 day-old, divided into three groups as well as twenty broiler chicks, 1 day-old, divided into two groups were used in two experiments. In experiment 1, jatropha kernel was de-oiled and incorporated into a control fattening (0JKM$_1$) feed at 40 and 80 g/kg (diets 4JKM$_1$ and 8JKM$_1$). In experiment 2, jatropha kernel meal obtained in experiment 1 was heat treated and incorporated into a growing diet at 80 g/kg (diet 8JKM$_2$). Daily dietary intakes as well as weight gain of the animals were affected by the incorporation of jatropha kernel meal in the ration. In experiment 1, Average Daily Feed Intake (ADFI$_1$) of 139.2, 55.2 and 23.4 g/day/animal and also average daily weight gain (ADWG$_1$) of 61.9, 18.5 and -7.7 g/animal were obtained respectively for the groups fed with diets 0JKM$_1$, 4JKM$_1$ and 8JKM$_1$. In experiment 2, Average Daily Feed Intake (ADFI$_2$) of 18.7 and 3.1 g/day/animal and also Average Daily Weight Gain (ADWG$_2$) of 7.1 and 1.9 g/animal were obtained respectively for the groups fed with diets 0JKM$_2$ and 8JKM$_2$. In both experiment, feed conversion ratio (FCR) was also affected by the dietary treatments and the overall mortality rate showed an increase according to levels of jatropha kernel meal in diet.*

Résumé

Effets d'une délipidation combinée ou non au chauffage d'un tourteau d'amande de *Jatropha curcas* sur l'ingestion alimentaire et les performances de croissance de poulets et poussins de chair au Sénégal

Jatropha curcas *est une plante appartenant à la famille des* Euphorbiaceae *dont la culture a été largement promue au cours des dernières années pour la production de biocarburants. Sa graine referme une amande qui contient environ 55% de matière grasse par rapport à la matière sèche et le tourteau obtenu après l'extraction de l'huile pourrait être une source exceptionnelle de protéines notamment en aviculture familiale, après des traitements destinés à supprimer les composés toxiques et antinutritionnels. L'ingestion et les performances de croissance du tourteau de l'amande de* J. curcas*, obtenu après déshuilage physico-chimique partiel et traitement à la chaleur, ont été évaluées sur des poulets en croissance et des poussins de chair. Soixante poulets de chair, âgés de 30 jours, divisés en trois groupes ainsi que 20 poussins de chair, âgés d'un jour, divisés en deux groupes ont été utilisés dans deux expériences. Dans l'expérience 1, de l'amande de jatropha a été déshuilée et incorporée à un aliment témoin (0JKM$_1$) à raison de 40 et 80 g/kg (rations 4JKM$_1$ et 8JKM$_1$). Dans l'expérience 2, le produit déshuilé obtenu dans l'expérience 1 a subi un traitement thermique puis a été incorporé dans un aliment de démarrage à raison de 80 g/kg (ration 8JKM$_2$). L'ingestion moyenne quotidienne ainsi que la croissance pondérale ont été affectées par l'incorporation du tourteau d'amande de jatropha dans la ration. Les animaux de la 1ère expérience ont présenté des ingestions moyennes de 139,2; 55,2 et 23,4 g/jour/animal ainsi que des gains*

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de poids moyens quotidiens de 61,9; 18,5 et -7,7 g/animal avec, respectivement, les rations 0JKM$_1$, 4JKM$_1$ et 8JKM$_1$. Dans l'expérience 2, des ingestions moyennes quotidiennes de 18,7 et de 3,1 g/jour/animal tandis que des gains de poids moyens quotidiens de 5,9 et 1,7 g/animal ont été obtenus respectivement pour les groupes nourris avec des régimes 0JKM$_2$ et 8JKM$_2$. Dans les deux expériences, l'indice de consommation a aussi été affecté par le niveau d'incorporation du jatropha et il en est de même pour le taux de mortalité total enregistré.

Introduction

To meet the population demand for animal proteins and lower the cost production, including those of poultry, expenses related to feed must be reduced. In Senegal, many raw materials and agricultural by-products used in the manufacture of feed are available (12). However, oilseeds meal used in poultry feed are mainly those of peanut and cotton. This is due to low domestic soybean meal production and high cost of imports thereof. A challenge is to find out alternatives valuing plant resources that abound in the country. Some by-products of these resources contain anti-nutritional or toxic natural substances that limit their use. Potentially usable byproduct is cake of *Jatropha curcas* seed. The plant, known as physic nut, or *tabanani* in Senegal, is a wild drought-resistant shrub belonging to the *Euphorbiaceae* family, which can grow in marginal wastelands and planted as a fence to protect fields because it is not consumed by animals (25). The oil content of the seed is about 22 to 48% (9), can be converted into bio-diesel (14). The kernel meal, obtained after shelling the seed and oil extraction, contains about half protein (4). It is nitrogen-rich and a very good soil fertilizer (19), but its use in animal feed remains limited. The seed was found to be toxic for several species types such as rat and rabbit (16), chicks (13) and also fish (8).

Jatropha toxicity is due to diterpene derivatives classified as phorbol esters (29). They activate protein kinase C, an enzyme which plays an essential role, regulating cell growth and differentiation (11). In addition, the nut by-products contain curcin, a lectin which has an effect on the protein synthesis (26) and anti-nutritional factors such as trypsin inhibitors, saponins and phytate which interfere with digestive process in animals (4).

Particularly in chickens, toxicity manifested as growth depression was observed with unprocessed meal (35). The cake should be detoxified before being use as feed. Common detoxification methods are essentially chemical (8, 10), e.g., de-oiling. Heating can give additional interest.

The objective of this study was to evaluate in Senegal, the impact of the introduction in a diet of *J. curcas* kernel meal physico-chemically de-oiled or de-oiled and heated, on ingestion and growth performance of broiler chickens.

Materials and methods

Location of the experiment

Experiments were conducted in *Ecole Nationale Supérieure d'Agriculture* (ENSA), University of Thies (Senegal) in two stages. The first part (experiment 1) was planned during the dry season (April) with a temperature ranging from 21.9 to 34.7 °C, a relative humidity ranging from 22.4 to 53.4% and the second part (experiment 2) just after the rainy season (October) with a temperature ranging from 24.8 to 34.7 °C and a relative humidity ranging from 59.3 to 96.5%.

Preparation of the jatropha kernel meal and diet formulation

Thirty kg mature and dry seeds of *J. curcas* were collected from Dialacoto, Senegal. The seeds were cracked and unshelled manually to obtain kernels, which were grinded to get a Jatropha Kernel Paste (JKP). A residual level of Ether Extract (EE) lower than 100 grams per kilo gram (g/kg) Dry Matter (DM) was judged to be adequate to perform the trial. Oil extraction with petroleum ether (boiling range 60-80 °C) was assessed diluting 3 vol ether in 1 vol JKP, assuming a homogeneous distribution of the solvent in the mass.

The JKP was introduced into a barrel and dipped in petroleum ether (1:3 vol.) for 7 consecutive days. Meanwhile, the drum was regularly shaken to allow the kernel impregnation with ether. At the end of the soaking process, the kernel was recovered by filtering oil and ether and drying in the sun. Defatted Jatropha Kernel Meal (JKM) was obtained.

Experiment 1: JKM was incorporated as such in a commercial feed (SEDIMA) at levels of 40 and 80g/kg (diets $4JKM_1$ and $8JKM_1$) (Table 1). This commercial feed, constituting the control diet ($0JKM_1$), was mainly composed of maize, cereals issues, soybean meal, peanut meal, fish meal, calcium carbonate and vitamin-mineral complex. Extra-maize warranted iso-nitrogenous and iso-caloric traits of the diets.

Experiment 2: JKM was placed in a drying oven (105 °C for 2 hours), cooled and then incorporated in an experimental diet ($0JKM_2$) at 80g/kg (diet $8JKM_2$), in substitution of groundnut cake (Table 2), allowing iso-nitrogenous and iso-caloric properties of the diets.

Table 1
Composition of diets incorporating the *J. curcas* kernel meal in experiment 1.

Raw materials	$4JKM_1$	$8JKM_2$
	%	%
Control diet ($0JKM_1$)	76.6	67.0
JKM	4.0	8.0
Maïze	19.4	25.0
Total	100.0	100.0

$4JKM_1$ and $8JKM_1$=control diet (maize, cereals issues, soybean meal, peanut meal, fish meal, calcium carbonate and vitamin-mineral complex) incorporated with 4 and 8% jatropha kernel meal and maize.

Table 2
Gross composition of experimental diets for broiler chicks starters in experiment 2.

Ingredients (%)	$0JKM_2$	$8JKM_2$
Maize	40.0	40.0
Millet	17.0	17.0
Groundnut cake	23.0	15.0
JKM	0.0	8.0
Fishmeal	10.0	10.0
Chalk	0.5	0.5
TCP	0.3	0.3
Peanut oil	4.5	4.5
Synthetic lysine	0.2	0.2
Synthetic methionine	0.1	0.1
Vitamin-mineral Premix	4.5	4.5
Total	100.0	100.0
Calculated values		
Crude protein (%)	23.1	23.5
ME (kcal/kg)	3130.6	3181.2

JKM=*Jatropha curcas* meal, TCP= Tricalcium phosphate, ME= metabolic energy, $OJKM_2$= control diet, $8JKM_2$=diet incorporating 8% of JKM.

Animals and housing
Experiment 1: sixty unsexed broiler chickens, 30 day-old, local strain White Ross, were obtained, divided into three groups of twenty subjects corresponding to the three dietary treatments ($0JKM_1$, $4JKM_1$ and $8JKM_1$) and maintained during their final growth phase. The experiment was carried out for 15 days from the day 30.

Experiment 2: twenty unsexed one-day old chicks, local strain White Ross, were obtained, divided into two groups of ten subjects corresponding to the two dietary ($0JKM_2$ and $8JKM_2$) treatments and maintained during their growing phase. The experiment was carried out for 15 days from the day 1.
Animals were kept in a well-ventilated broiler chickens barn in which three areas, separated by fences of 0.75 m in height, were installed. Each area, which was 4.5 m² (3x1.5 m) and was provided with troughs suitable for the distribution of feed and water. During the test, water was available *ad libitum*. Feed was weighed early in the morning and provided once a day. Refusals of food were collected and weighed the day after the distribution. Animals were kept on a concrete floor that was previously disinfected.

Feed consumption and growth performance
Every day, the amounts of feed distributed and the rejected quantities of the previous day were recorded to determine the feed intake by animal.
The daily group amounts of feed intake= feed supplies - feed rejected, were recorded.
It was deduced the Average Daily Feed Intake (ADFI).
The Feed Conversion Ratio (FCR) was determined as the feed intake per unit weight gain.
During experiments, birds in each replicate were individually weighed at the beginning of the experiment and weekly thereafter to monitor the growth.
Weight gain was determined as the difference in weights between two successive weeks. It was deduced the Average Daily Weight Gain (ADWG).
Mortality in each replicate was calculated as the percentage of the total number of birds in the replicate at the beginning of the experiment.

Chemical analyses
At the beginning of the experiment, samples of the raw materials but also of the diets were collected for analysis.
Chemical analyses were performed according to the procedures of AOAC (6). Crude Protein (CP) was determined by the Kjeldahl method (N x 6.25), Ether Extract (EE) by the Soxhlet method and Crude Fiber (CF) by the method of Weende.

The following values were calculated from those measured:
Organic Matter (MO)= 100 - Ash
Non-nitrogen Extract (NNE)= MO- EE- CP- CF
The true metabolic energy of each diet is given by the following formula: ME (kcal/kg D= 3951 + (54.4xEE) - (88.7xCF) - (40.8 x Ash) (36).

Statistical analysis

All data generated were subjected to analysis of Variance in a Complete Randomized Design of Statistix 8.1 software package. Significant means were separated using Tukey HSD all-pairwise comparisons test of the same package. Mortalities data were compared according to Fischer's Exact test.

Results

Chemical composition of feed

Effect of various processing methods on proximate and energy composition of *Jatropha curcas* Kernel (JK), *J. curcas* Kernel Meal (JKM) and experimental diets are shown in table 3.
Kernel contained 560 g EE/kg dry matter (DM) and about 260 g CP/kg DM, while Ash remained close to 50 g/kg DM. Crude Fiber and Nitrogen Free Extract (NFE) reached values, respectively of 120 and 24 g/kg DM. The residual level of EE in jatropha kernel meal almost reached the objective of 100 g/kg DM. As a consequence, CP represented about half of material. NFE represented about a quarter of DM, while CF and ash remained close to 100 g/kg DM.

For experiment 1, the control feed, which was the carrier of the diets, gave a crude protein level of 220 g/kg DM. Ether extract and CF remained below 100 g/kg DM, while ash were 180 g/kg DM. The NFE constituted about half of the dry matter. Diets ($4JKM_1$ and $8JKM_1$) that were used for this experiment were developed so as to provide protein and energy levels approximately similar. Moreover, the other nutrients remained in the same values for all diets. The value of the real metabolic energy was calculated to be about 3200 kcal/kg DM for the control diet. Concerning diets 4JM and 8JM, this value was calculated, respectively, to about 3300 and 3200 kcal/kg DM.

For experiment 2, diets ($0JKM_2$ and $8JKM_2$), showed almost similar values with regard to the DM, CP, ash and Metabolic Energy (ME) which were respectively 900 g/kg, 20 g/kg DM, 11 g/kg DM and 3500 kcal/kg DM. Only the EE and CF were slightly different (respectively 120 vs. 104 g/kg DM and 66 vs. 58 g/kg DM).
Analytical results showed that diets were iso-protein and iso-energetic.

Feed consumption

Table 4 shows the daily individual feed intake by animals during the experiments. It was inversely proportional to the incorporation of jatropha kernel meal and significantly different ($P<0.05$) in the first and in the second experiment.
In experiment 1, for animals fed with $0JKM_1$, the $ADFI_1$ was 139.2±13.3 g/d/an (gram per day per animal) while it was 55.2±27.5 and 23.4±24 g/d/an, respectively, for $4JKM_1$ and $8JKM_1$.
In experiment 2, the $ADFI_2$ of animals fed with $0JKM_2$ was 18.7±4.9 g/d/animal when it was 3.1±2.5 g/d/animal for $8JKM_2$.
The FCR presented mean values that varied from 2.3 for $0JKM_1$, to 17.4 for $4JKM_1$ and -0.5 for $8JKM_1$, and values that varied between 3.1 and 1.9, respectively for $0JKM_2$ and $8JKM_2$, without significant difference ($P>0.05$).

Table 3
Proximate composition of raw materials and feed used in experiments 1 and 2.

Raw materials and diets	DM (%)	Chemical composition (% in DM)						ME
		OM	CP	EE	CF	Ash	NFE	kcal/kg DM)
JK	96.1	95.2	25.9	55.5	11.6	4.8	2.4	5747.2
JKM	95.0	90.7	48.6	10.0	6.5	9.4	25.6	3537.0
$0JKM_1$	90.7	81.8	22.0	7.5	5.1	18.2	47.2	3160.7
$4JKM_1$	89.2	84.6	20.5	8.6	5.2	15.4	50.3	3328.0
$8JKM_1$	89.3	84.7	20.7	7.4	5.5	15.4	51.1	3243.1
$0JKM_2$	90.0	88.8	20.3	12.3	6.6	11.2	49.6	3577.8
$8JKM_2$	89.9	88.7	20.7	10.4	5.8	11.3	51.8	3440.9

JK= *J. curcas* kernel, JKM=*Jatropha curcas* Kernel Meal, $0JKM_{1-2}$= control diets, $4JKM_1$ and $8JKM_{1-2}$= diets with 4% and 8% jatropha kernel meal in control diet, DM= Dry Matter, MO= Organic Matter, CP= Crude Protein, EE= Ether Extract, CF= Crude Fiber, NFE= Nitrogen Free Extract, ME=metabolic energy

Table 4
Growth performance characteristics of broiler chickens and chicks during the experiments.

	0JKM	4JKM	8JKM	P>F	SEM
Initial w eight (g)	1153.5	1132.1	1200.6	0.5	42.0
Final w eight (g)	2078.1[a]	1407.5[b]	1089.6[c]	0.000	55.4
ADFI$_1$ (g/d/animal)	139.2[a]	55.2[b]	23.4[c]	0.000	5.8
ADWG$_1$ (g/d/animal)	61.9[a]	18.5[b]	-7.7[b]	0.001	6.6
FCR$_1$	2.3	17.4	-0.5	0.3	8.3
Initial w eight (g)	45.7		46.1	0.7	0.8
Final w eight (g)	135.5[a]		70.9[b]	0.000	7.4
ADFI$_2$ (g/d/animal)	18.7[a]	-	3.1[b]	0.000	1.1
ADWG$_2$ (g/d/animal)	7.1	-	1.9	0.17	1.2
FCR$_2$	3.1	-	1.9	0.48	1.0

SEM= Standard Error of the Mean.
a, b, c= means with different superscripts on the same row differ significantly (P<0.05). In both experiments (1 and 2), ADFI= Average Daily Feed Intake, ADWG= Average Daily Weight Gain, FCR= Feed Conversion Ratio.

Growth performance

During the two weeks, it was found that the control group showed a linear weight growth, evolving from 1153.5± 48.7 g on day 30 (d30) to 2078.1±360.1 g on day 44 (d44). For the same periods, animals that received the 4JKM$_1$ diet showed lower performance, from 1132.1±267.8g to 1407.5±211.1 g. Finally, the animals that received the 8JKM$_1$ diet, in turn, presented a decreasing weight change over the weights from 1200.6±110.1 g to 1089.6±124.4 g. Thus, Average Daily Weight Gain (ADWG) per animal significant (P<0.05) evolved inversely to the incorporation of jatropha kernel meal, ranging from 61.9 g/d/animal for the control group to 18.5 g/d/animal for the 4JKM$_1$ group and -7.7 g/d/animal for the 8JKM$_1$ group (Table 4).

The total mortalities recorded during experiment 1 showed an increase without significant difference (P>0.05) according the incorporation of jatropha kernel meal in diets, from 0% for the control group to 5 and 20% for respectively the 4JKM$_1$ and 8JKM$_1$ groups.

In experiment 2, it was found that the control group showed a linear weight increase, evolving from 45.7±2.2 g on day 1 (d1) to 135.5±29.8 g on day 15 (d15). For the same periods, animals that received the 8JKM$_2$ diet showed lower weight, from 46.1±2.9 g to 70.9±24.2 g. Thus, Average Daily Weight Gain (ADWG) per animal had evolved inversely to the incorporation of jatropha kernel meal, and without significant (P>0.05), ranging from 7.1 g/d/animal for the control group to 1.9 g/d/animal for 8JKM$_2$ group. During experiment 2, the total mortalities recorded showed a significant difference (P<0.05) according incorporation of the jatropha kernel meal in diets, from 0% for the control group to 60% for the 8JKM$_2$ group.

Discussion

The extract of vegetable oil from seeds is mainly based on two processes which are mechanical pressing and solvent extraction. Mechanical screw press is a mean of oilseed crushing to small and medium scale (40).

To avoid the presence of low digestible shells in monogastrics (20), and thus to study the specific effects of kernels on poultry, seeds were shelled manually. After shell removing, the kernels contained between approximately 550 g/kg in DM of EE. These values confirm those obtained by Aderibigbe *et al.* (4), Kumar *et al.* (24), Makkar *et al.* (27), and Martinez-Herrera *et al.* (30).

Use of mechanical press for de-oiling the kernel after shelling did not allow a satisfactory extraction of oil and just helped to reduce it into a paste. To overcome this difficulty, petroleum ether was used to allow oil extraction from the paste. The solvent is a special gasoline G type, colorless liquid, of low viscosity and very good solvent of greases. It allows direct extraction by exhaustion. However, its flammability, toxicity and price indexed to oil prices are major disadvantages of its use (22).

The de-oiling process used yielded about 10% residual fat in the dry matter of jatropha kernel meal. These values matched those obtained by Aderibigbe *et al.* (4) with a partial de-oiling with a screw press, but higher than those obtained by the same authors and (27) with a totally defatted meal. These differences in results compared to the method used, can be explained by the process of de-oiling. Indeed, the last authors implemented a soxhlet de-oiling which eliminates all the fat of the matter.

Soaking method used presently, more compatible with a field experiment, left a significant amount of fat. Concerning the procedure that was used, the kernel paste was dipping in petroleum ether (1:3 vol.) inside a barrel where it was maintained for 7 successive days and then was recovered by draining residual ether and drying in the sun to allow the ether evaporation.

For experiment 2, following the de-oiling process, the JKM powder obtained in the first experiment was treated by passage in a drying oven (105 °C for 2 hours). The aim of this stage was to inactivate toxic and anti-nutritional compounds. Indeed, Martinez-Herrera *et al.* (31), by heat treatment in an autoclave (121 °C for 20 mn), significantly inactivated trypsin inhibitor activities which are anti-nutritional factors but also lectin activity which is considered to be another toxic factor in *J. curcas* seeds. In the same way, Abo El-Fadel *et al.* (2) decreased the concentration of trypsin inhibitor and lectin by about 75 and 83% respectively. These results were in agreement with Haas and Mittlebach (18) who reported also that heat treatment has a positive effect on reducing trypsine inhibitor and lectine concentration in *J. curcas* meal.

Chemical analyzes made on JKM showed that it mainly consist of crude protein and nitrogen free extract (723 g/kg in DM). The levels of crude protein and ash were similar with those obtained by Aderibigbe *et al.* (4) for partially de-oiled cake, but the values in EE and especially in crude fiber were higher.

Jatropha meal showed good nutritional potential with a level of crude protein noted higher than that of soybean meal (27), confirming the protein concentrate nature of this product for poultry feed. Diets offered during the experimentation showed a crude protein content of 21% DM. These values corresponded to the recommended ones for broiler chickens production (21).

In our study, the daily intake per broiler chickens and chicks was inversely dependent on the incorporation of the JKM, resulting in lower weight gain, especially for animals that received the 8 JKM diet.

The decrease feed intake recorded during experimental sequence, which was reflected in weight gain, was probably related to the incorporation of the jatropha kernel meal in diet. Feed intake was influenced by a variety of factors, such as taste, smell and texture of the diet (38). The decline was probably related of palatability as animals systematically reduced their consumption whenever they were exposed to jatropha. The daily feed intake and body weight change during the test sequence were significantly lower in jatropha kernel groups in comparison with control group. These results confirmed those obtained by Sumiati *et al.* (37) which incorporated *J. curcas* meal at the level of 5% in the diets of broiler chickens and observed reduced feed intake.

This shows the negative effect on feed palatability of the jatropha meal. To some extent, this could be surprising since investigators did not perceived abnormal taste of the JK. It is possible that discomfort could be perceived by the animal once the product is ingested.

Phorbol esters, the main toxic compounds in *J. curcas* seeds (29), were reported to possess a diterpene named 12-deoxy-16-hydroxyphorbol (17). They were found to be responsible of an irritant effect after topical application, but also caused diarrhea and mortality in the animals (16). These compounds are thermo stable and isolated from the oil of jatropha (7). Chemical de-oiling of jatropha kernel, followed by a physicochemical detoxification treatment does not cause a complete removal of toxic factors including phorbol esters (24). Its inclusion in diets thus gives rise to a decrease in feed intake and a weight gain reduction on monogastrics and the presence of phorbol esters in feed has significant effects on its' acceptance (7). In spite of chemical treatments (sodium chloride and calcium hydroxide) that decreased phorbol esters and haemagglutination activity, Katole *et al.* (23) observed a reduced nutrient intake. Also, Annongu *et al.* (5) showed a tolerance in diets containing physico chemically treated jatropha kernel meal up to 15%. In addition, mortalities were mainly recorded in experimental group. Monogastrics show great sensibility to this compound in feed (8). They show intestinal irritation and thus feed rejection due to the residual effects of the toxins.

The low animal weight performance observed for group receiving jatropha kernel meal during experiments was probably due to both reduced intake but also poor protein utilization (32). In this respect, trypsin inhibitors and curcin are known to decrease the weight gain performance of animals (15) and were probably related to the level of jatropha kernel in the diet. Tryspin inhibitors are anti-nutritional factors which interfere with the physiological process of digestion in non-ruminants, leading to severe growth depression (39). A similar growth depression due to residual anti-nutritional factors with JKM roasted was observed (34). Furthermore, Other Studies however showed that the feed intake and mortality of animals were not affected by inclusion of jatropha kermel meal fermented with *Aspergillus* niger in their diet, despite a poor feed conversion and a low weight gain (33). For defatted and untreated jatropha kernel meal, Aderibigbe *et al.* (4) measured a trypsin inhibitor activity to about 20 mg/g of sample. Heat treatments reduced this activity to 0.2 mg/g of sample, showing the thermo labile character of the toxin. The effect of heat treatment was confirmed by Abou-Arab A.A. and Abu-Salem (1).

In experiment 1, the kernel of jatropha was de-oiled without heat treatment. Trypsin inhibitors remained present and probably contributed to interference with the physiological digestive process in poultry.

These observations are in agreement with those made by Kumar *et al.* (24), Makkar *et al.* (27) and Makkar and Becker (28) who showed adverse physiological effects in monogastric and therefore a decrease in voluntary intake and reduced weight gain for animals subjected to diets with unheated jatropha kernel meal. Finally, these observations confirm those of our previous studies (32).

The growth depression and the poor feed conversion ratio observed for diets incorporating JKM can be attributed to residual anti-nutritional factors like phorbol esters, curcin and trypsin inhibitors that have been reported to be present in jatropha seed. In experiment 2, the JKM was heat treated. Curcin and Trypsin inhibitors were presumed to be removed eliminated but this did not improve feed intake of animals and thus weight gain. This confirms observations of Pasaribu *et al.* (35) which showed that chemical followed by heat treatments allowed the removal of curcin and some anti-nutritionnal factors such as trypsin inhibitors. However, the reactions of animals that consumed the tested feed let thinking that there was still a toxic compound in the JKM. This was probably a significant fraction of phorbol esters which was not eliminated.

This study was the first field experiment on evaluation of jatropha kernel seed in broiler chickens and chicks production in Senegal.

The results showed that, despite total dehulling, chemical de-oiling using petroleum ether and heat treatment, jatropha kernel meal still conserve a strong negative effect on feed intake and then on growth performance despite the short period of incorporation. Further studies must be performed in order to assess combined effects of thermal, chemical and biological detoxification processes on jatropha seeds.

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