



Heat Treated Rosella Seeds in Floury and Granulated Diets for Broilers

Ayssiwede et al.

## Effects of Heat Treatments of Rosella Seeds (*Hibiscus Sabdariffa*, Linn) and the Presentation of Diets containing them on Growth and Economic Performances of Broilers in Dakar Region (Senegal)

S. B. Ayssiwede\*, K.E. Abodi, S. Atchiwassa, M. C. Bonou and A. Missohou

<sup>1</sup>Laboratoire d'Alimentation et de Nutrition Animales (LANA)/Service de Zootechnie-Alimentation, Ecole Inter-états des Sciences et Médecine Vétérinaires (EISMV) de Dakar ; BP: 5077 Dakar-Fann (Sénégal)

\*Correspondence: s.ayssiwede@gmail.com

### ABSTRACT

This study carried out to assess the effects of heat treatments of rosella seeds and the presentation of diets containing them on growth performance and economic margins of broilers. It involved 400 unsexed Coob500 strain chicks of two-weeks-old, randomly distributed into 8 groups of 50 birds each, corresponding to 8 iso-protein and iso-energetic experimental diets consisting of 4 floury (HSF<sub>0</sub>, HSCF<sub>15</sub>, HSTF<sub>15</sub>, HSBF<sub>15</sub>) and 4 granulated (HSG<sub>0</sub>, HSCG<sub>15</sub>, HSTG<sub>15</sub>, HSBG<sub>15</sub>) containing respectively 0% (control), 15% of raw, roasted and boiled rosella seeds in partial substitution of groundnut cake. At 6 weeks of age, data obtained per dietary treatment, were subjected to one-way ANOVA, completed by Duncan's Multiple Range Test at 5% error risk level. The results showed that the live body weight, daily feed intake and carcass weight of broilers fed granulated diets (HSG) were higher ( $P < 0.05$ ) respectively than those of birds from floury diets (HSF). It was the same trend with the average daily weight gain and dressing carcass, except for roasted seed diets (HST<sub>15</sub>) where these last were similar. The feed conversion ratio of birds fed HSG were better ( $P < 0.05$ ) than those of subjects from HSF. Whether floury or granulated, HSB-diets have improved ( $P < 0.05$ ) these parameters compared to those of birds fed roasted and raw seed diets. The feed costs (per bird or kg carcass) obtained from HSC<sub>15</sub>, HST<sub>15</sub>, HSB<sub>15</sub> were higher ( $P < 0.05$ ) than those of the HS<sub>0</sub> unlike the gross margins realized. But, compared to HSC<sub>15</sub> and HST<sub>15</sub>, these gross margins were higher ( $P < 0.05$ ) in HSB<sub>15</sub> diets, with granulated in the lead. It was concluded that boiling rosella seeds, accompanied with pelletizing of diet containing them, significantly improved the growth performances and profit margin of broilers compared to roasted and raw rosella seeds diets.

**KEY WORDS:** Broilers, Diets, Growth, Heat treatments, *Hibiscus sabdariffa* seeds, Profit

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### INTRODUCTION

The evaluation of unconventional or alternative local feed resources constitutes now-a-days a promising niche to alleviate feeding difficulties in poultry or animal production even though anti-nutritional factors remains a limiting factor for their large-scale use (Diarra et al., 2011). To this end, works of several authors (Mukhtar, 2007; Cissé et al., 2009; Ayssiwede et al., 2015 and Ouédraogo et al., 2015) on rosella (*Hibiscus sabdariffa*) seeds, alternative locally available feed resource rich in energy, protein and various nutrients, revealed a decrease in growth performance of birds as soon as these seeds were incorporated up to 10-20% in their

diets. According to some authors this performance decreasing in birds is due to the acidic taste and the presence of anti-nutritional factors such as tannins (0.25-0.53%), phytic acid (0.21- 0.89%) and total phenols (0.72-0.88%) in these seeds (Yagoub et al., 2004; Marcel et al., 2006; Abu El Gassim et al., 2008; Kwari et al., 2010). Thus, Yagoub et al. (2008), Kwari et al. (2011), Ari et al. (2014) and Ayssiwede et al. (2022) have used various seed treatment processes (boiling, fermentation, roasting, soaking, germination) aimed at reducing these toxic factors content, but with the obtaining of varied and sometimes relatively unsatisfactory results compared to expectations. However, in addition to the possible residues of anti-nutritional factors, one of the probable reasons for

these mitigated results remains the fact that the experimental diets used by these different authors are floury. Consequently, the likelihood that rosella seed meal (raw or processed although richer in energy and protein) incorporated into these diets would be found in high quantity in the refusals during the feeding remains high, as birds prefer grains or granulated diets much more (Calvé et al., 2011; Ayssiwede et al., 2022). In order to compensate for this, it is often desirable to present the broiler diet in granulated form. Thus, this study was undertaken to evaluate the effects of rations containing raw, boiled and roasted rosella seeds and presented in mealy and granulated forms, on growth performance and economic margins in broilers chicken in Senegal.

## MATERIALS AND METHODS

The experiment was conducted in a farm located next to that of the Interstate School of Sciences and Veterinary Medicine (EISMV) at Sangalkam, about 30 km from Dakar. It was undertaken in the full respect of ethic and animal care according to all procedures approved by the Ethics and Animal Welfare Committees of EISMV of Dakar.

### Feed resources used

The feed ingredients used in the experimental diets consisted of rosella (*Hibiscus sabdariffa*) seeds, maize, wheat bran, groundnut cake, fish meal, lysine, methionine, oyster shell meal and mineral and vitamin supplement (MVS). Most of these raw materials were purchased from a local feed factory, while the rosella seeds were paid at the Thiaroye market in Dakar. Before being subjected to detoxification treatments (boiling, roasting), these rosella seeds were first winnowed to remove the debris and stones that were present, and then divided into three equal parts of 50 kg each. The first, consisting of raw seeds, was simply dried in the sun for about 12 hours. The second part underwent a wet heat treatment (boiling). So, the raw rosella seeds were then poured into a pot containing boiling water at 100°C taken with a boiling thermometer. They were maintained at this temperature for 30 minutes at the end of which they were then recovered for sun drying for approximately 12 hours. The roasting concerned the

last part of rosella seeds and was carried out in a dry preheated pot in which the raw seeds were introduced at 150°C taken with the previous thermometer, during 15 minutes. The continuous stirring of the roasting seeds in the pot was ensured by using a spatula and the temperature was recorded progressively in order to adapt the gas flow during treatment to avoid the carbonization of the seeds. At the end of these operations, the three types of rosella seeds underwent a grinding in the mill, which allowed to obtain respectively raw, boiled and roasted seed flours.

### Proximate analyses and formulation of diets

Samples of some feed resources (rosella seeds, fish meal, groundnut cake) and experimental diets were analyzed at the Laboratory of feed analyses and animal nutrition (LANA) of EISMV at Dakar. Chemical analyses were focused on the determination of dry matter (DM), crude mineral matter or ash (MM), crude protein (CP), ether extract (EE) and crude fiber (CF). The DM and MM contents of the different samples were obtained respectively according to the standard methods of the French Association for Standardization (AFNOR, 1977) while those of CP and EE were made according to the same standard based respectively, on the Kjeldhal method (N x 6,25) and on reflux extraction method under diethyl ether by using the Soxhlet apparatus. The CF content, was determined according to AFNOR (1993) based on the Wende's method. The metabolizable energy (ME) of the diets analyzed was calculated using the regression equation of Sibbald et al. (1980) cited by Leclercq et al. (1984);  $ME \text{ (kcal/kg DM)} = 3951 + (54.4 \times EE) - (40.8 \times MM) - (88.7 \times CF)$ .

Based on the chemical analyses results (of rosella seeds, groundnut cake and fish meal) and the nutrient values of the other feed resources reported by Ayssiwede et al. (2010), four (4) iso-energetic and iso-protein experimental diets of growth-finishing type for broilers presented each in floury (F) and (4) in granulated (G) forms, were formulated and manufactured making a total of eight (8) dietary treatments. These floury (HSF<sub>0</sub>, HSCF<sub>15</sub>, HSTF<sub>15</sub>,

HSBF<sub>15</sub>) and granulated (HSG0, HSCG15, HSTG15, HSBG15) diets contained respectively 0% (control), 15% of raw (C), roasted (T) and boiled (B) *Hibiscus sabdariffa* seeds meal, incorporated in partial substitution of groundnut cake, the main protein source of these diets (Table 1). The floury diets production consisted of manually mixing the quantities of the different raw materials constituting them, starting with small quantities to obtain a premix. To this last, were added the ingredients in relatively medium and large quantities in order to have good

homogeneous floury diets. Each floury diet obtained was divided into two equal quantities, the first kept in floury form, and the second presented in granulated form using a pelletizing machine of a local company of livestock feed production, by continuous hot steam pressure (75-85°C) of the mealy feed (between the pelletizing mesh and the press hammer) which came out well granulated. These two forms of experimental diets thus obtained are packaged and stored in adapted bags for their use during the experimental period.

Table 1. Ingredient composition and cost price of the floury (F) and granulated (G) rosella seeds based experimental diets

Feed resources or ingredients used	Unit Price (FCFA <sup>1</sup> /kg)	Expérimental dietary treatments*							
		HS <sub>0</sub>		HSC <sub>15</sub>		HST <sub>15</sub>		HSB <sub>15</sub>	
		F	G	F	G	F	G	F	G
Yellow maize (%)	195	54.3		53.0		53.0		53.0	
Wheat bran (%)	160	11.9		9.20		9.20		9.20	
Groundnut cake (%)	200	25.8		16.0		16.0		16.0	
Raw <i>H. sabdariffa</i> seeds meal (%)	150	0.00		15.0		-		-	
Roasted <i>H. sabdariffa</i> seeds meal (%)	-	-		-		15.0		-	
Boiled <i>H. sabdariffa</i> seeds meal (%)	-	-		-		-		15.0	
Fish meal (%)	560	5.80		5.10		5.10		5.10	
L-Lysine, 99% (%)	2200	0.20		0.05		0.05		0.05	
DL-Methionine, 99% (%)	3600	0.05		0.00		0.00		0.00	
Oyster shell meal (%)	120	0.65		0.75		0.75		0.75	
Dicalcium phosphate (%)	680	1.00		0.60		0.60		0.60	
Macrovitamix, MVS-broilers (%)	2200	0.30		0.30		0.30		0.30	
Total				100		100		100	
Diet theoretical price (FCFA/kg)				230		215		215	
Diet manufacturing cost (FCFA/kg)				12	27	32	47	52	67
Diet cost price (FCFA/kg)				242	257	247	262	267	282

FCFA: local money of french community of Africa (1€ = 655.957 FCFA).

(\*) HS<sub>0</sub>: Control diets containing 0% of *Hibiscus sabdariffa* seeds meal; HSC<sub>15</sub>: Diets containing 15% of raw *H. sabdariffa* seeds meal; HSB<sub>15</sub>: Diets containing 15% of boiled *H. sabdariffa* seeds meal; HST<sub>15</sub>: Diets containing 15% of roasted *H. sabdariffa* seeds meal; MVS: mineral and vitamin supplement

### Animals and experimental design

The experiment was conducted in a farm located next to that of EISMV in Keur Ndiaye LO, Sangalkam (Dakar region) during the period from March to April 2019. It lasted six (6) weeks and involved 400 chicks of Coob<sub>500</sub> strain raised in a semi-open hen house, with a double slope roof and made of zinc sheets. The cleaning, the disinfection and the sanitary vacuum of this building stained at the end with quicklime, were carried out with bleach as well as the breeding material (feeders, drinkers) and the wire frames which were used for the constitution of the brooder and the batches. On the eve of reception of the chicks, the brooding room is set up and delimited by wire frames and covered with a thick layer of wood shavings. A radiant heater suspended at about 1 m from the ground allowed to heat the living area to an ideal temperature (32-33°C) measured by the thermometer installed for this purpose. In addition to the footbath filled with cresyl solution installed at the entrance of the building, control equipment, monitoring and data collection sheets were also used.

The chicks on arrival were checked for number, live weight, homogeneity, umbilicus condition, legs and vivacity before being installed in the equipped chick house. Thus, after a collective start in this nursery, they were divided at 12 days old according to a completely randomized system in eight batches of 50 subjects each corresponding to the eight previous growth-finishing dietary treatments constituted by 4 floury (HSF<sub>0</sub>, HSCF<sub>15</sub>, HSTF<sub>15</sub>, HSBF<sub>15</sub>) and 4 pelleted (HSG<sub>0</sub>, HSCG<sub>15</sub>, HSTG<sub>15</sub>, HSBG<sub>15</sub>). Each batch of chicks was subdivided into two replicates of 25 chicks by using wire frames based on a density of 10 birds/m<sup>2</sup> at the end of the trial. They were fed a commercial crumb starter diet for the first 10 days and then, after a 4 days linear feed transition period, were submitted to the experimental diets from 15<sup>th</sup> day of age until the end of the trial (42 days of age). Experimental diets and tap water (from the SDE) were served *ad libitum*. Throughout the trial, birds were vaccinated against Newcastle and Gumboro diseases, and received

vitamin therapy and preventive treatment against avian coccidiosis according to the local medical prophylaxis program in Senegal. The lighting was permanent and provided by natural light during the day, completed by night lighting with electric lamps.

### Zootechnical and economic parameters

The main data collected during the trial were ambient temperature in the poultry house (regularly measured and recorded with a mini-maxi thermometer), mortalities, live weights, feed intake, carcass and organ weights and economic data, i.e. ingredients prices, transport costs, feed production costs, selling revenues. Then, birds were weighed weekly using an SF-400 electronic scale, while feed intake and mortalities were monitored daily. At the end of the trial, 48 birds (6 birds/batch) were randomly selected, weighed and slaughtered by severing the jugular vein of the neck in order to better assess birds' carcass and organs characteristics. Chickens slaughtered per dietary treatment were dipped in hot water, defeathered, eviscerated and their carcasses, whole and some organs (especially liver and gizzard) dissected, were individually weighed. The various data were entered and recorded in the Microsoft Excel spreadsheet which was used to calculate per dietary treatment the different zootechnical parameters including average live weight (ALW), average daily weight gain (ADG), average daily feed intake (DFI), feed conversion ratio (FCR), average carcass weight (CW), dressing carcass (DC) and organ (DO) according to the following formulas:

$$\text{ADG (g/d)} = \frac{\text{Live weight gain of the period (g)}}{\text{Length of the period (days)}}$$

$$\text{DFI (g/bird/d)} = \frac{[(\text{Quantity of feed offered} - \text{Quantity of feed refused})/\text{day}]}{\text{Number of birds}}$$

$$\text{FCR} = \frac{\text{Feed intake during a period (g)}}{\text{Weight Gain of the period (g)}}$$

$$\text{MR (\%)} = \frac{[(\text{Initial number of birds} - \text{Final number of birds})]}{\text{Initial number of birds}} * 100$$

$$\text{DC (\%)} = \frac{(\text{Carcass weight of the bird} \div \text{Live body weight of the bird}) * 100}$$

DO (%) = (Total organ weight in bird ÷ Live body weight of the bird) \* 100

From these technical results, an economic evaluation was made based on feed costs and gross incomes from broilers selling (1700 FCFA/kg carcass). The other expenses included in the production cost being the same for the different dietary treatments, the feed expenses were determined from the feed intake and the prices of the starter (295 FCFA/kg) and experimental diets. Those for these last were evaluated by taking into account the prices of the feed resources used, the additional costs of heat treatment of rosella seeds, and the labor costs for feeds manufacturing as showing in Table 1. Thus, the economic parameters were similarly calculated and recorded per dietary treatment according to the formulas below:

Feed Cost/bird (FCFA) = [Starter diet cost + FCR \* Feed price/kg \* LW gain (kg) in 3-6 weeks]

Feed Cost/kg carcass (FCFA) = [(Feed Cost/bird) ÷ Carcass weight of bird (kg)]

Gross selling revenue (GSR)/bird (FCFA) = Bird carcass weight (kg) \* Selling price/kg carcass

Gross margin feed (GMF)/bird (FCFA) = (GSR/bird carcass) - (Feed Cost/bird)

GMF/kg carcass (FCFA) = (Selling price/kg carcass) - (Feed Cost/kg carcass)

### Statistical analysis

The various data collected and treated with Microsoft Excel v.2013 table on growth and economic performances of broilers per dietary treatment, were subjected to one-way factor ANOVA at 5% error risk level ( $p < 0.05$ ) using the Statistical Package for Social Science software

(SPSS-v.23). It was completed by Duncan's Multiple Range Test to completely separate the means using this same statistical software when showing significant dietary treatment effect between the results.

## RESULTS AND DISCUSSION

### Nutrient composition of diets

The nutrient composition of raw, boiled and roasted rosella seeds and the flourey and granulated experimental diets is reported in Table 2. This last shows that the roasting and boiling treatments induced a decrease in crude protein (CP) content of the seeds and corresponding diets compared to the control and raw seed based diets, while the pelletizing process of the diets at 80-85°C seemed to improve their metabolizable energy (ME) content. This reduction of CP in boiled and roasted rosella seeds and corresponding diets is believed to be due to slight denaturation of protein by the thermal process during seed detoxification treatments. Indeed, Kwari et al. (2011) had noted that processes such as boiling, germination, soaking and fermentation of rosella seeds reduce their CP content by 37.4%; 37.8%; 38.2% and 38.6% respectively compared to raw seeds. Admittedly, Yagoub et al. (2008) had, themselves noted that boiling of these seeds little affected their CP content, while Ari et al. (2014) reported an its improvement with this same process and fermentation.

The flourey and granulated diets remained globally iso-energetic, even if this second had a slightly higher ME content than the flourey ones (3.21 vs. 3.17 kcal ME/g), while the control and raw rosella seed diets were globally iso-protein, with an average CP content (23.5%) slightly higher than that (22%) of the iso-protein diets containing roasted and boiled seeds.

Table 2. Nutrient composition of rosella (*Hibiscus sabdariffa*) seeds and experimental diets (flourey and granulated) used in broilers

Nutrient composition (%)	Experimental dietary treatments										
	<i>Hibiscus sabdariffa</i> seeds meal				Experimental dietary treatments						
	Raw (C)	Boiled (B)	Roasted (T)	HSF <sub>0</sub>	HSG <sub>0</sub>	HSCF <sub>15</sub>	HSCG <sub>15</sub>	HSBF <sub>15</sub>	HSBG <sub>15</sub>	HSTF <sub>15</sub>	HSTG <sub>15</sub>
Dry matter	91.4	87.5	94.8	89.6	90.5	89.0	90.5	89.0	90.5	89.7	90.6
Crude protein	27.5	26.2	25.7	23.7	23.5	23.37	23.5	21.9	22.0	21.8	21.8
Ether extract	17.8	17.7	20.4	4.95	5.20	5.37	5.35	5.30	5.47	5.31	6.17
Crude fiber	18.1	16.3	19.1	4.71	4.82	4.95	4.90	4.80	4.78	4.95	5.86
Ash	5.26	4.95	5.20	5.17	5.12	5.10	5.23	5.13	5.27	5.81	5.76
Metabolizable Energy (kcal/g)	2.76	2.77	2.94	3.18	3.22	3.16	3.21	3.17	3.23	3.15	3.16
[ME/CP] (kcal/g)	10.0	10.5	11.4	13.4	13.6	13.5	13.6	14.4	14.6	14.4	14.4

HSF<sub>0</sub> and HSG<sub>0</sub>: Flourey and granulated control diets containing 0% *Hibiscus sabdariffa* seeds meal; HSCF<sub>15</sub> and HSCG<sub>15</sub>: Flourey and granulated diets containing 15% of raw *H. sabdariffa* seeds meal; HSBF<sub>15</sub> and HSBG<sub>15</sub>: Flourey and granulated diets containing 15% of boiled *H. sabdariffa* seeds meal; HSTF<sub>15</sub> and HSTG<sub>15</sub>: Flourey and granulated diets containing 15% of roasted *H. sabdariffa* seeds meal; ME: metabolizable energy; CP: crude protein.

As a result, the [ME/CP] ratio is relatively lower by about 1 point for the raw seed diets than that (14.5) containing the roasted and boiled seeds, but well within the range [13-16] recommended by INRA (1984) for broiler feeds during grower and finishing. The slight high ME content of granulated diets, could be explained by the likely improvement in digestibility of their starch subjected to heat during pelletizing. This is in agreement with the results of Kaysi and Melcion (1992) who noted that the cooking-extrusion of faba bean seeds resulted in an increase of ME content in broiler diets by 8 to 11%.

### Ambient temperature and mortality in broilers

The average ambient temperature recorded in the poultry barn during the trial ranged from 19.5 to 29.2°C, with the lowest obtained during the 5<sup>th</sup> week, and highest in the 6<sup>th</sup> week of age. These relatively low ambient temperatures are in line with the standard (19-27°C) recommended by ITAVI (2003), but are still lower than those (22.7 - 35°C) recorded by Ayssiwede et al. (2015) during September-October period in this same region. These variations would be due to the fact that unlike to this last authors, our trial was conducted during March-April, being a part of the cool period in Senegal. For the whole trial period, no cases of disease were noted. Only two (2) mortalities were recorded, one in each of HSG<sub>0</sub> (2%) and HSCF<sub>15</sub> (2%) dietary treatments, which represents an overall mortality rate of 0.5% of chickens reared. This result highlighted that the heat treatment process or not of rosella seeds and diet presentation, did not adversely affect the broilers health status as reported by Wafar (2013) in Nigeria by incorporating these roasted rosella seeds up to 20% in their diet. Also, autopsies performed on dead birds (which previously had locomotion problem), did not reveal any pathognomonic lesions of a disease, confirming that broilers death would rather be due to starvation as they had difficulty feeding and drinking due to mobility reduction.

### Growth performance of broilers

The different growth parameters obtained in broilers per dietary treatment are reported in Table 3. It can be noted from this that the average live

body weights (ALW) of broilers changed similarly with age, but remained significantly different ( $P<0.05$ ) between dietary treatments throughout the trial. From the 3<sup>rd</sup> to 6<sup>th</sup> week of age, the ALW of broilers fed granulated diets were significantly higher of 48%, 18%, 20% and 23% than those of their counterparts fed floury-diets respectively, led by the granulated control (HSG<sub>0</sub>), followed by the boiled (HSBG<sub>15</sub>), roasted (HSTG<sub>15</sub>), raw (HSCG<sub>15</sub>) seed based granulated diets, then the floury boiled (HSBF<sub>15</sub>), the control (HSF<sub>0</sub>) and finally the roasted (HSTF<sub>15</sub>) and raw (HSCF<sub>15</sub>) seed diets. Consequently, the same trends were noted with the average daily gains (ADGs) of the subjects which, regardless of the diet presentation, remained significantly higher with the boiled seed diets compared to those of the birds fed the roasted and raw rosella seed diets. Overall, the ADGs of broilers in granulated (HSG<sub>0</sub>, HSBG<sub>15</sub>, HSTG<sub>15</sub> and HSCG<sub>15</sub>) dietary treatments were significantly improved by 64%, 23%, 27% and 31%, respectively, compared to those fed the same diets floury presented. The daily feed intakes (DFI) of chickens, regardless of seed treatment process, were significantly ( $P<0.05$ ) higher in subjects fed respectively these granulated diets by 14.6%; 6%; 8.4% and 10.6% compared to their counterparts fed mealy diets. Furthermore, the DFI of chickens fed the boiled seed diets (HSBF<sub>15</sub> and HSBG<sub>15</sub>) was significantly higher than that of the other corresponding dietary treatments, except for the control HSG<sub>0</sub>.

Table 3. Growth parameters obtained in broilers chicken fed rosella (*Hibiscus sabdariffa*) seeds based diets

Zootechnical parameters	Age (weeks)	Experimental dietary treatments										P Value
		HSF <sub>0</sub>	HSG <sub>0</sub>	HSCF <sub>15</sub>	HSCG <sub>15</sub>	HSTF <sub>15</sub>	HSTG <sub>15</sub>	HSBF <sub>15</sub>	HSBG <sub>15</sub>			
Average live body weight (g)	2	412±2.4 <sup>b</sup>	410±2.0 <sup>b</sup>	413±2.7 <sup>a</sup>	410±2.7 <sup>d</sup>	405±3.1 <sup>a</sup>	413±5.3 <sup>d</sup>	412±3.1 <sup>a</sup>	414±3.5 <sup>d</sup>			*
	4	906±9.3 <sup>b</sup>	1339±7.9 <sup>g</sup>	880±2.8 <sup>a</sup>	1027±4.9 <sup>d</sup>	889±4.7 <sup>ab</sup>	1079±2.6 <sup>e</sup>	971±38 <sup>e</sup>	1165±5.2 <sup>f</sup>			***
	6	1638±4.5 <sup>b</sup>	2427±46 <sup>f</sup>	1529±20 <sup>a</sup>	1881±5.5 <sup>d</sup>	1549±17 <sup>a</sup>	1860±49 <sup>d</sup>	1727±5.2 <sup>c</sup>	2034±43.5 <sup>e</sup>			***
Average daily weight gain (g)	3-4	35.3±0.5 <sup>b</sup>	66.3±0.4 <sup>g</sup>	33.3±0.04 <sup>a</sup>	44.1±0.2 <sup>d</sup>	34.6±0.3 <sup>ab</sup>	47.5±1.9 <sup>e</sup>	39.9±2.2 <sup>c</sup>	53.6±0.3 <sup>f</sup>			***
	5-6	52.2±0.7 <sup>b</sup>	77.7±2.8 <sup>e</sup>	46.3±1.6 <sup>a</sup>	61.0±0.7 <sup>d</sup>	47.1±1.2 <sup>a</sup>	55.7±2.0 <sup>e</sup>	53.9±1.9 <sup>b</sup>	62.0±2.8 <sup>d</sup>			***
	3-6	43.8±0.2 <sup>b</sup>	72.0±1.6 <sup>f</sup>	39.8±0.8 <sup>a</sup>	52.5±0.2 <sup>d</sup>	40.9±0.7 <sup>a</sup>	51.6±1.9 <sup>d</sup>	47.0±0.1 <sup>c</sup>	57.8±1.5 <sup>e</sup>			***
Daily feed intake (g/d)	3-4	94.8±1.7 <sup>a</sup>	108±0.9 <sup>d</sup>	99.9±1.6 <sup>b</sup>	102±0.5 <sup>c</sup>	95.2±0.7 <sup>a</sup>	103±3.2 <sup>c</sup>	101±0.8 <sup>bc</sup>	107±1.9 <sup>d</sup>			***
	5-6	127±1.4 <sup>a</sup>	146±3.2 <sup>f</sup>	138±0.9 <sup>c</sup>	141±0.8 <sup>de</sup>	128±0.5 <sup>a</sup>	139±2.0 <sup>ad</sup>	134±0.3 <sup>b</sup>	142±2.7 <sup>e</sup>			***
	3-6	111±0.7 <sup>a</sup>	127±1.4 <sup>c</sup>	119±1 <sup>b</sup>	122±0.5 <sup>c</sup>	111±0.5 <sup>a</sup>	121±2.5 <sup>c</sup>	117±0.5 <sup>b</sup>	125±2.3 <sup>d</sup>			***
Feed conversion ratio	3-4	2.68±0.14 <sup>f</sup>	1.64±0.02 <sup>a</sup>	2.99±0.05 <sup>g</sup>	2.30±0.02 <sup>d</sup>	2.75±0.40 <sup>f</sup>	2.17±0.02 <sup>c</sup>	2.54±0.15 <sup>e</sup>	2.00±0.04 <sup>b</sup>			***
	5-6	2.44±0.02 <sup>c</sup>	1.88±0.05 <sup>a</sup>	2.99±0.09 <sup>c</sup>	2.32±0.03 <sup>b</sup>	2.70±0.07 <sup>d</sup>	2.50±0.06 <sup>c</sup>	2.50±0.09 <sup>c</sup>	2.31±0.10 <sup>b</sup>			***
	3-6	2.54±0.02 <sup>d</sup>	1.77±0.03 <sup>a</sup>	2.99±0.05 <sup>f</sup>	2.32±0.01 <sup>c</sup>	2.74±0.06 <sup>e</sup>	2.35±0.04 <sup>c</sup>	2.51±0.02 <sup>d</sup>	2.16±0.06 <sup>b</sup>			***

(<sup>a, b, c, d, e, f, g</sup>): different letter exponents assigned to means within the same line indicate significant differences between groups at the 5% level ( $p<0.05$ ).

HSF<sub>0</sub> and HSG<sub>0</sub>: Flourey and granulated control diets containing 0% of *Hibiscus sabdariffa* seeds meal; HSCF<sub>15</sub> and HSCG<sub>15</sub>: Flourey and granulated diets containing 15% of raw *H. sabdariffa* seeds meal; HSBF<sub>15</sub> and HSBG<sub>15</sub>: Flourey and granulated diets containing 15% of boiled *H. sabdariffa* seeds meal; HSTF<sub>15</sub> and HSTG<sub>15</sub>: Flourey and granulated diets containing 15% of roasted *H. sabdariffa* seeds meal. (\*, \*\* and \*\*\*): means that  $P<0.05$ ,  $P<0.01$  and  $P<0.001$  respectively.

These results corroborate those of Kwari et al. (2011) who showed that boiling, germination and fermentation or soaking of rosella seeds improved DFI by reducing their tannin and phenol content of 34%, 21.9% and 21.3% respectively compared to raw seeds. They are also in line with those reported by Duwa et al. (2012), Ari et al. (2014) and Ayssiwede et al. (2022), who had noted an improvement in ALW, ADG, DFI and feed conversion ratio (FCR) in broilers fed boiled (4-17%), boiled-fermented (23%) seed rations compared to those containing roasted or raw rosella seeds. Similar results were reported by Traoré et al. (2018) with *Cajanus cajan* seeds, Udensi et al. (2007) with chickpea, and Egounlety and Aworh (2003) with soybean, cowpea and faba bean seeds, on anti-trypsin factors reduction by steaming and roasting, with the better growth noted in birds fed cooked or roasted seed diets compared to those in raw seed diets.

The FCRs of broilers fed the pelleted diets were significantly lower than those of their counterparts fed the floury rations. Overall, the FCR of birds in boiled seed diets were significantly improved ( $P < 0.05$ ) compared to those of the roasted and raw seed diets, with the granulated leading. However, the FCR for this HSBG<sub>15</sub> diet was significantly higher than that of the corresponding granulated control (HSG<sub>0</sub>), while those of the same two diets floury presented (HSBF<sub>15</sub> and HSF<sub>0</sub>) remained similar. Then, it has been noted that boiling rosella seeds, along with pelletizing the diet containing them, significantly improved live body weight (LW), ADG, DFI and FCR in broiler chickens compared to their counterparts fed the same types of diets based on raw and roasted seeds meal.

The better growth performances obtained in broilers fed granulated diets compared to those fed floury diets regardless of the seed treatment process, is in agreement with the results of Maliboungou et al. (1999), Chagneau et al. (2009) and Calvé et al. (2011) who noted that growth and DFI of chickens fed a pelleted diet were higher of 10-25%, 18% and 7% than those fed a floury one, which also had a

significant deterioration of 2.4% in FCR. This growth parameters improvement would be due to the fact that diets pelletizing allowed better homogeneity, increased feed nutritional value and feed consumption by reducing the sorting of feed by the birds. The leading noted with broilers performance in boiled seed diets (HSB) compared to roasted (HST) and raw (HSC) seed diets allow to say that boiling remains the most favorable detoxification process for an optimal reduction of anti-nutritional factors in rosella seeds, thus improving the birds' palatability for the corresponding diets. Indeed, boiling the seeds, apart from neutralizing acidity and heat-sensitive anti-nutritional factors, has the additional advantage of also removing those water-soluble, which would have improved feed intake compared to roasting, which has almost no effect on the latter (Ayssiwede et al., 2022). In Nigeria, Wafar (2013) by incorporating 15-20% of roasted rosella seeds in the diet had also noted, compared to the control, a significant decrease in ALW, ADG and DFI in chickens. However, the high performance noted with birds in HSG<sub>0</sub> diet compared to the HSBG<sub>15</sub> diet, is due to the fact that this later already lower in protein content, was still consumed significantly less by the chickens than this granulated control diet (HSG<sub>0</sub>). The FCR deterioration in chickens fed roasted and raw seed diets (with floury the lead) compared to those fed boiled seed and control diets, shows that these latter diets were better valorized by the birds as observed by Ari et al. (2014) with boiled-fermented seeds and Duwa et al. (2012) with boiled rosella seeds by respectively incorporating them at 23% and 17% in their ration. It is the same for Ouedraogo et al. (2015) and Traoré et al. (2018) who noted a deterioration of FCR in chickens fed diets containing respectively dried raw rosella and *Cajanus cajan* seeds compared to birds fed steamed or roasted *C. cajan* seed diets, but contrary to the results of Wafar (2013) who obtained an improvement in FCR in these birds when fed diets containing 15-20% roasted rosella seeds.

## Carcass characteristics and economic results

As for the carcass characteristics and profit margin obtained per dietary treatment, the results are reported in the table 4. This latter, showed that the carcass and organ weights (especially liver) of broilers fed granulated diets were significantly higher than those fed the same diets respectively floury presented. The same is true for dressing carcass, except for the HSTF and HSTG treatments, where they were similar. Overall, only the floury raw seed diet (HSCF<sub>15</sub>) had significantly lower carcass weights and dressing carcass (85.3%) compared to the control, while higher dressings carcass (89.5%) were obtained with the HSG<sub>0</sub> and HSBG<sub>15</sub> diets. However, dressing organ of chickens fed floury diets were significantly higher than those of birds fed granulated rations, except for the boiled seed dietary treatments where the opposite effect was noted. Our results are in line with Duwa et al. (2012) who had obtained an increase of carcass weights (1385-1638 g) of birds fed diets containing 4-17% of boiled rosella seeds compared to the control (1273 g), and Wafar (2013) who noted that increasing of roasted rosella seeds incorporation 5-20% in the diets, significantly decreased bird carcass weights compared to the control subjects. Although carcass and liver weights and dressing carcass of broilers fed rosella seed diets were overall significantly lower than those of the control birds regardless of diet presentation, the lower performance in birds fed floury raw seed diet compared to the other dietary treatments should be mainly due to the anti-nutritional factors in these seeds (Diarra et al., 2011; Ayssiwede et al., 2022).

Table 4. Carcass characteristics and economic results obtained in broilers chicken fed rosella (*Hibiscus sabdariffa*) seeds based diets

Carcass characteristics	Experimental dietary treatments										P Value
	HSF <sub>0</sub>	HSG <sub>0</sub>	HSCF <sub>15</sub>	HSCG <sub>15</sub>	HSTF <sub>15</sub>	HSTG <sub>15</sub>	HSBF <sub>15</sub>	HSBG <sub>15</sub>			
Carcass weight, CW (g)	1417 ±4.0 <sup>c</sup>	2169 ± 41 <sup>e</sup>	1305±4.4 <sup>a</sup>	1618±4.3 <sup>e</sup>	1374±19 <sup>b</sup>	1647± 43 <sup>e</sup>	1507±4.0 <sup>d</sup>	1818±44 <sup>f</sup>	***		
Dressing carcass, DC (%)	86.7±0.5 <sup>bc</sup>	89.6±0.1 <sup>e</sup>	85.3±1.2 <sup>a</sup>	86.1±1.1 <sup>ab</sup>	88.8±0.7 <sup>de</sup>	88.5±0.2 <sup>cd</sup>	87.8 ±5 <sup>cd</sup>	89.4± 0.5 <sup>de</sup>	***		
Liver weight (g)	45.7±0.6 <sup>b</sup>	55.7±0.5 <sup>d</sup>	41.0±0.8 <sup>a</sup>	48.0±1.6 <sup>c</sup>	41.0 ±0.8 <sup>a</sup>	46.0±0.8 <sup>b</sup>	42.0 ±1.6 <sup>a</sup>	64.6± 0.5 <sup>e</sup>	***		
Gizzard weight (g)	65.9±0.7 <sup>bc</sup>	61.5 ± 1.0 <sup>ab</sup>	66.9±1.7 <sup>c</sup>	75.3± 6.3 <sup>d</sup>	61.2±6.6 <sup>ab</sup>	57.8±1.5 <sup>a</sup>	61.5±1.5 <sup>ab</sup>	70.8 ± 4.7 <sup>cd</sup>	***		
L-G-Spleen-Heart weight (g)	122±1.0 <sup>c</sup>	128 ±1.5 <sup>d</sup>	118±1.0 <sup>bc</sup>	134±7.2 <sup>e</sup>	113±7.1 <sup>a</sup>	114 ±1.0 <sup>ab</sup>	114±1.5 <sup>ab</sup>	146± 5.1 <sup>f</sup>	***		
Dressing organ, DO (%)	7.5±0.1 <sup>de</sup>	5.3±0.1 <sup>a</sup>	7.8±0.1 <sup>e</sup>	7.1±0.4 <sup>d</sup>	7.3±0.5 <sup>d</sup>	6.2±0.1 <sup>b</sup>	6.6±0.1 <sup>e</sup>	7.2±0.2 <sup>d</sup>	**		
Economic results											
Used diets prices (FCFA/kg)	242	257	247	262	267	282	267	282	-		
Feed cost/broiler (FCFA)	891±5 <sup>a</sup>	1055±10 <sup>d</sup>	965±8 <sup>b</sup>	1035±4 <sup>c</sup>	976±4 <sup>b</sup>	1098±20 <sup>e</sup>	1021±4 <sup>c</sup>	1127±18 <sup>f</sup>	***		
Feed cost/kg carcass (FCFA)	629±3 <sup>b</sup>	486±7 <sup>a</sup>	740±7 <sup>e</sup>	640±3 <sup>c</sup>	711±12 <sup>f</sup>	667±5 <sup>d</sup>	678±4 <sup>e</sup>	620±14 <sup>b</sup>	***		
Gross revenues/bird (FCFA)	2409±7 <sup>e</sup>	3688±70 <sup>e</sup>	2218±7 <sup>a</sup>	2750±7 <sup>e</sup>	2336±32 <sup>b</sup>	2780±73 <sup>e</sup>	2563±7 <sup>d</sup>	3090±75 <sup>f</sup>	***		
Gross Margin Feed/bird (FCFA)	1518±7 <sup>e</sup>	2633±65 <sup>f</sup>	1253±14 <sup>a</sup>	1715±9 <sup>d</sup>	1359±35 <sup>b</sup>	1701±53 <sup>d</sup>	1541±9 <sup>c</sup>	1963±69 <sup>e</sup>	***		
GME/kg carcass (FCFA)	1071±3 <sup>f</sup>	1214±7 <sup>a</sup>	960±7 <sup>a</sup>	1060±3 <sup>e</sup>	989±12 <sup>b</sup>	1033±5 <sup>d</sup>	1022±4 <sup>c</sup>	1080±14 <sup>f</sup>	***		

(<sup>a,b,c,d,e,f,g</sup>): different letter exponents assigned to means within the same line indicate significant differences between groups at the 5% level (p<0.05).

HSF<sub>0</sub> and HSG<sub>0</sub>: Flourey and granulated control diets containing 0% of *Hibiscus sabdariffa* seeds meal; HSCF<sub>15</sub> and HSCG<sub>15</sub>: Flourey and granulated diets containing 15% of raw *H. sabdariffa* seeds meal; HSBF<sub>15</sub> and HSBG<sub>15</sub>: Flourey and granulated diets containing 15% of boiled *H. sabdariffa* seeds meal; HSTF<sub>15</sub> and HSTG<sub>15</sub>: Flourey and granulated diets containing 15% of roasted *H. sabdariffa* seeds meal. GMF: Gross Margin Feed; FCFA: local money of French community of Africa (1€ = 655.957 FCFA). (\*, \*\*, \*\* and \*\*\*): means that P<0.05, P<0.01 and P<0.001 respectively

Admittedly, the dressings carcass recorded in broilers in our study remain similar to those (85-87%) obtained by Ayssiwede et al. (2015 and 2022) with the same strain of broilers.

Economically, the granulated diets were overall more expensive (+15 FCFA/kg) than the flour diets. Regardless of the type of heat process treatment, the cost price per kg of HSB and HST diets was higher than that of diets containing raw seeds, which in turn was higher than that of the controls, HS<sub>0</sub>. This is in line with the results of Ayssiwede et al. (2022), but in contrast to those of Kwari et al. (2011), Duwa et al. (2012), Wafar (2013) and Ayssiwede et al. (2015) who had noted a decrease in the feed prices involved by incorporating these raw, boiled and roasted seeds in the ration of these birds compared to the control. This difference can be explained by the fact that unlike these authors, the additional costs related to the seeds detoxification and grinding processes, production and pelletizing of the diets, were taken into account in our study. As a result, regardless of presentation, feed costs were significantly higher with subjects on both raw and heat treated rosella seed diets than with the controls, in contrast to the results of Wafar (2013). These variations can be explained not only by the high prices of the rosella seed diets, but also by the significantly high FCR obtained in chickens fed these dietary treatments. However, regardless of the seed treatment process, gross revenues and gross margins feed (GMF) obtained in broilers fed the granulated diets, remained significantly higher than those for the same diets fed as flour and can be explained by their higher carcass weights selling at high price. The higher gross revenue per chicken obtained with the boiled seed dietary treatments (HSB) compared to the roasted and raw seed treatments, would be due to the fact that the broilers in these HSB diets had also higher carcass weights than those in the others, except the granulated control (HSG<sub>0</sub>). But, although the control dietary treatments allowed the highest GMF, it should be noted that those obtained with HSB diets, were in turn, significantly higher than

the GMF generated by the dietary treatments based on raw and roasted rosella seeds. This significantly improved GMF obtained with HSB diets compared to their counterparts HSC and HST regardless of diet presentation, would be due to the fact that these boiled treatments resulted in higher selling revenues per bird and lower feed costs per kg carcass compared to the raw and roasted rosella seeds based diets. Excepted the granulated control (HSG<sub>0</sub>) diet, the boiled seed diets HSB<sub>15</sub>, whether floury or pelleted, significantly improved the growth performance and economic margins of the broilers compared to those fed the roasted (HST<sub>15</sub>), raw (HSC<sub>15</sub>) seed or control (HSF<sub>0</sub>) diets.

## CONCLUSION

Boiling rosella seeds, together with the pelletizing of the diet containing them, significantly improved growth performance and profit margin in broilers compared to roasted and raw seed diets. The incorporation of rosella seeds into the diet after boiling, is necessary to considerably reduce their anti-nutritional factors, diversify feed resources and improve poultry performances in the current context of scarcity and high cost of conventional raw materials in Senegal. But for better optimization of birds' performances, it would be more judicious that the diets containing them are granulated especially in broilers, even if the floury diets based on these boiled rosella seeds are still feasible in laying hens.

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## CONFLICT OF INTEREST

The authors declare that there is no conflict of interest. There have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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