Apparent digestibility (Da) of feed rations containing different levels of incorporation of germinated off-season sorghum in broilers from start-up to finishing in the town of Maroua in the Far North of Cameroon.

ABSTRACT

With a view to finding solutions to maize in the composition of poultry feed, a study was conducted to evaluate the effect of ~~the~~ substituti~~on~~ng ~~of~~ maize by germinated off-season sorghum on the growth performance and physiological ~~response~~ parameters of broilers at~~-~~ stater phase~~start-up~~. To achieve this, 180 of the 1-day-old chicks ~~of the~~ "Cobb 500" strain with a live weight of 34 ± 3.26, were randomly divided into nine~~9~~ batches corresponding to ~~03~~ three treatments with ~~03~~ three replicates of 20 ~~subjects~~birds. The ~~batches~~ treatments were subjected to one of 03 feed rations~~:~~ of 100% maize (R0), 50% maize and 50% germinated off-season sorghum (R1) and 100% germinated off-season sorghum (R2). To achieve these objectives at 18 and then at 35 days of age, a total of 36 broilers were used, i.e. 18 in the start-up phase at a rate of ~~06~~ six ~~subjects~~ birds per treatment and 18 in the growth/finishing phase at a rate of ~~06~~ six ~~subjects~~ birds per treatment. ~~and~~ T~~t~~he droppings and feed from digestibility trials; measured apparent digestibility (Ad) for energy, protein, fiber, mineral matter and organic matter; histological studies of the small intestine were performed. Energy, organic matter, mineral matter, proteins and fibres were not significantly influenced by the experimental rations used at the 0.05% threshold for digestibility. ~~and~~ T~~t~~he histological sections did not show any structural and morphological alterations. ~~We~~ It can be~~therefore~~ concluded that maize can be substituted at 50% and 100% by germinated off-season sorghum without negatively impacting digestibility in broilers at the start, as well as in the growth/finishing phases.

Keywords: Broilers, off-season sorghum, broiler, digestibility and digestibility cage.

I- Introduction

In developing countries, poultry production is one of the main sources of animal protein supply for the population. The lack of animal proteins in the world is a real problem that several countries ~~have to~~are facing ~~face~~ in the fight against the food deficit. In Africa, about one in four

people remains undernourished (FAO/IFAD and WFP, 2014). The poultry sector, particularly modern poultry farming, has emerged in recent years as an attractive solution to compensate for the ever-increasing demand for animal-based protein (FAO, 2018). This sector occupies a prominent place in the livestock sector in Cameroon because of the short breeding cycle of the species ~~that make it up~~, ~~its~~ low price, the ease of ~~its~~ production, and the ~~its~~ nutritional ~~qualities~~quality. Poultry farming is a source of income for women and households (Issa et al., 2012). The development of the poultry sector has an important role to play in ~~the~~ fighting ~~against~~ food insecurity in Africa in general, and in Cameroon in particular (Mingoas et al., 2017). Poultry farming in Cameroon has evolved over the years, from 37800 tons in 2020 to 52.6% ~~tons~~ in 2021 of the 270000 tons of meat produced during the same year. In 2022, the proportion of poultry in meat production in Cameroon increased by 7% compared to 2021 when poultry meat production was 42369 tons, reflecting a slow increase in poultry production (INS, 2023~~),~~). ~~for the~~In ~~year~~ 2023 poultry meat production was about 107680 tons. However, the development of poultry farming is limited by the availability and quality of feed. In addition, the high cost of feed remains a major obstacle to the profitability of poultry production ~~and~~ represents 60 to 70% of the total cost of feed production (Teguia et al., 2004; Diarra and Devi, 2015). Indeed, feed is the first element involved in the cost price of poultry and is the most effective way to control production costs and meat quality. However, many feed ingredients commonly used in poultry feed are often out of stock due to food competition between humans and animals (Dahouda et al., 2009; Pomalégni et al., 2017; Tadondjou et al., 2022). Maize imports in Cameroon were around 64.4% in 2022, these imports have risen again during the year 2023, reaching 39991.3 tons (INS 2023). ~~and~~ T~~t~~herefore, the inflation of the cost on the market~~,~~ is increasingly slowing down the development of the poultry sector (Amougou et al., 2013; Tchuenga et al., 2017). In addition, the importation of inputs at very high prices leads to broiler production at prices beyond the reach of the population (Beghoul, S. 2015; Kouakou et al., 2019). To reduce the cost of production due to ~~the~~ increases in the cost of conventional raw materials, research is directed towards alternative feed resources that can reduce dependence on corn and main ingredients such as soybean meal, fish meal and other imported materials~~...~~ in poultry feed (Métayer et al., 2019; Akadiri et al., 2022). The Sahelian zone has large quantities of alternative food resources to maize, including off-season sorghum, which is widely used in the feed of poultry in traditional farming. Studies on the use of this variety in broiler feed remain scarce. The objective of this work is ~~therefore~~ to evaluate the digestibility of feed rations

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containing germinated off-season sorghum used as an energy source in broilers in the starter ~~-up phase~~ and then in the growth/finishing phases.

II- Materials and methods

II. 1. Study Area

The experiment was carried out from June to August 2022 in the city of Maroua, located at 10°35'N latitude, 14°19'N longitude and 384m altitude in the Far North region of Cameroon. The experiment was carried out from June to August 2022 in the city of Maroua, located at 10°35'N latitude, 14°19'N longitude and 384m altitude in the Far North region of Cameroon. The climate is tropical of the Sahelian type and includes two main seasons: a dry season and a rainy season. The climate is tropical of the Sahelian type and includes two main seasons: a dry season and a rainy season. The rainy season lasts three months (June-September) with an average rainfall of 700 millimeters per year. The rainy season lasts three months (June-September) with an average rainfall of 700 millimeters per year. The dry season lasts nine months (October-May) and includes a relatively cool period (October-January) and a hot period (February-May) with variable temperatures. They average around 25°C in the cool season, 30°C in the rainy season and peak at 45°C in hot periods (Banga et al., 2019).

II. 2. Animal material

A total sample of ~~180-day-old~~180-day-old chicks ~~(of~~ Cobb 500 strain~~),~~ obtained from the AGROCAM hatchery in Ngaoundere with an average weight of 35g, was used. On arrival, the chicks were subjected to a routine check, including the condition of the legs, beak and liveliness. They were each given glucose water enriched with lemon and then they received an anti-stress to prevent possible effects related to transport stress. The ~~animals~~ chicks were raised in the same building on wood chip bedding on the floor; in compartments with a density of 8/m2 under the same environmental conditions. They ~~animals~~ were given water and feed *ad libitum* in accordance with the recommendations of the ethics committee.

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II. 3. Experimental design

The chicks were randomly assigned without sexing into three ~~batches~~ treatments of 60 chickens each. Each treatment~~batch~~ was randomized into three repeats of 20 ~~subjects~~ chicks each. ~~Batch~~ Treatment 1 ~~or~~ (R0) ~~treatment consisted of~~ birds were fed only on a ration where ~~the~~ maize substitution rate was 0%. Treatment ~~; batch~~ 2 (~~or~~ R1) ~~treatment~~ consisted of birds were fed only on a ration where the rate of substitution of maize by sprouted sorghum was 50% and ~~in the end~~ treatment~~batch~~ 3 (~~or~~ R2) birds were~~treatment consisted of birds~~ fed only on a ration where the rate of substitution of maize by sprouted sorghum was 100%. For digestibility, the chickens in the start~~up~~er phase as well as those in the finishing phase were installed in an experimental random block device consisting of 05 metabolic cells at the rate of one chicken per experimental unit. A total of 36 Cobb 500 broilers chicks were used, 18 in the start ~~up~~ er phase at a rate of ~~06~~ six ~~subjects~~ chicks per treatment and 18 in the growth/finishing phase at a rate of ~~06 subjects~~six chicks per treatment were used. Each experimental ~~subject~~ birds was individually housed in a metal cage measuring 45 cm x 30 cm x 45 cm which ~~, thanks to its grids,~~ allows a good ~~collection and a~~ collection of total droppings without contamination. This experimental device is also equipped with a feeder and a drinking trough. The ~~subjects~~ chicks of the ~~different~~ three ~~batches~~ treatments received one of the three experimental ~~rations,~~rations; the water was served *ad libitum*. The quantities of feed fed according to needs, age and leftovers were weighed per chicken. Droppings were collected by chicken during the stay in the metabolic case. The use of sterile aluminum foil sheets made it possible to take samples under conditions that limited the risk of contamination of the samples. The samples of manure collected were kept in the refrigerator to carry out chemical analyses.

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II. 4. Analysis of droppings and rations

The samples of lyophilized droppings and the ~~3~~ three experimental rations were all scanned on the same spectrometer in reflectance mode, on the powdered samples (grinding = 1 mm) presented in cups. Each sample was passed twice and spectra were averaged. The wavelengths used in the analysis range from 800 to 2500 nm with a step of ~~2~~ two nm. The visible wavelengths (400-800 nm) did not contribute anything to the models and were therefore discarded. The spectra were then subjected to mathematical pre-processing (second derivative, normalization, smoothing and baseline correction). The same pretreatment was applied to all spectra. For each manure spectrum, the spectrum of the corresponding food was associated, resulting in a concatenated spectrum with the two signals one after the other. (Bourdillon et al., 1990; Métayer et al., 2015). Apparent

digestibility (Da) corresponds to the share of nutrients that disappear in the intestine, it is calculated using the following formula :

$$Ad\ (\%)\ = \frac{quantity\ of\ nutrient\ ingested\ -\ quantity\ of\ nutrient\ excreted}{quantity\ of\ nutrient\ ingested}$$

II. 5- Experimental rations

The rations were formulated from different ingredients purchased from the city's feed mills. Some ingredients such as concentrate, lysine and methionine ~~have been~~ used based on the nutritional characteristics indicated on the labels. Other ingredients such as off-season sorghum, maize, groundnut meal and maize bran were analysed. A 100 g packet of each of these ingredients was sent for bromatological analysis to the Animal Nutrition and Feed Laboratory of the Faculty of Agronomy and Agricultural Sciences of the University of Dschang (FASA).

Table 1: Chemical composition of off-season sorghum, maize, groundnut meal and maize bran.

Samples	Dry matter (%)	Organic matter (% MS)	Crude protein (% MS)	Raw cellulose (% MS)	Fat (% MS)	Gross energy (Kcal/kg MS)	Metabolizable energy (Kcal/kg MS)
Corn bran	90.90	92.38	1.20	7.80	4.30	4220	2460
Groundnut cake	95.62	93.52	37.68	11.15	13.32	5201.18	3422.45
Corn	95.05	98.49	7.98	3.41	3.68	4400.15	3787.72
Sprouted sorghum	95.67	98.49	6.99	3.22	3.06	4359.94	3770.41

MS : ; Kcal/kg MS : .

Three iso-energetic and iso-protein starter rations were formulated (Table 2). The centesimal values of the ration ingredients are reported in Table 2

Table 2: Centesimal and nutritional composition of experimental rations for broilers in the start-up phase.

Ingredients	Corn-based feed Ration R_0 (%)	Corn and sorghum sprout feed Ration R_1 (%)	Sprouted sorghum feed Ration R_2 (%)
Corn	40	20	00
Sound	15	15	14.50
Sprouted sorghum	00	20	40.50
Groundnut cake	37.50	37.50	37.50
5 % concentrate	5	5	5
Bone powder	1	1	1
Shell	1	1	1
Kitchen salt	0.20	0.20	0.20
Lysine	0.15	0.15	0.15
Methionine	0.15	0.15	0.15
Total	100	100	100
	Calculated nutritional values		
Crude protein	20.77	20.87	20.87
Metabolizable energy (Kcal/kg DM)	3253.74	3250.38	3254.54
Energy / Protein	156.28	155.76	155.92

% : percent.

Table 3: Centesimal and nutritional composition of experimental rations of broilers in the growth/finishing phase.

Ingredients	Corn-based feed	Corn and sorghum sprout feed	Sprouted sorghum feed
	Ration R_0	Ration R_1	Ration R_2
	(%)	(%)	(%)
Corn	42.5	21.25	00
Sound	15	14.75	14.50
Sprouted sorghum	00	21.25	43
Groundnut cake	35	35	35
5 % concentrate	5	5	5
Bone powder	1	1	1
Shell	1	1	1
Kitchen salt	0.20	0.2	0.20
Lysine	0.15	0.15	0.15
Methionine	0.15	0.15	0.15
Total	100	100	100
Corn ???		**Calculated nutritional values**	
Sound	18.85	19.05	18.95
Sprouted sorghum	3150.4565	3180.3301	3158.65
Groundnut cake	167.13	166.94	166.68

% : percent.

II . 6. Statistical analysis of the data

Concerning the digestibility test, the ANOVA was carried out on Apparent Digestivity (Ad) Proteins, Organic Matter (OM), Mineral Matter (MM), Fibres and Energy. The sources of variation considered were rations containing germinated off-season sorghum and maize; these were presented as a mean ± standard deviation. Analysis of variance using Graphpad Sprint 5 software was used to test the effect of different rations on digestibility. The comparison of the means was made using the Tukey test at the 5% threshold.

III. Results

III.1. Effects of rations at different levels of incorporation of germinated off-season sorghum on apparent digestibility at start-up.

Table 4 presents the values of apparent digestibility (Ad) in broilers subjected to the three rations in the start-uper phase. It appears that energy, organic matter, mineral matter, proteins and fibers were not significantly influenced by the experimental rations used at the 0.05% threshold.

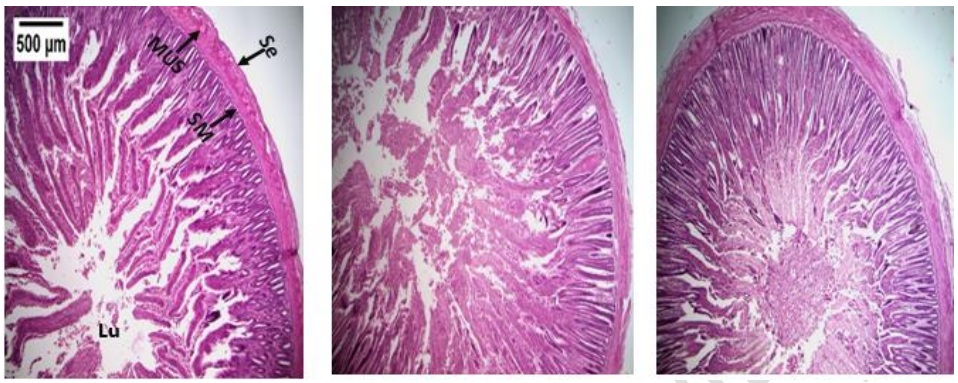
Table 4: Apparent digestibility in broilers fed rations at different levels of incorporation of germinated off-season sorghum

	Apparent digestibility at startup								
	R0 100% Maize			**R1 50%**			**R2 100%** Sorghum		
	Feed	**Droppings**	**Ad**	**Feed**	**Droppings**	**Ad**	**Feed**	**Droppings**	**Ad**
Proteins (%)	23.53± 0,33	18.34± 0,43^{b}	0,27± 0,12^{b}	22.97± 0,59	17.87± 0,09^{b}	0,28± 0,22^{b}	22.75± 0,13	17.37± 0,13^{b}	0,30± 0,21^{b}
OM (%)	54.36± 0,53	33.16± 0,63^{b}	0,63± 0,36^{b}	56.18± 0,32	36.08± 0,12^{b}	0,55± 0,41^{b}	52.62± 0,29	32.32± 0,52^{b}	0,62± 0,37^{b}
MM (%)	33.79± 0,54	30.94± 0,15^{a}	0,08± 0,19^{a}	32.51± 0,67	30.65± 0,49^{a}	0,06± 0,23^{a}	36.89± 0,26	34.38± 0,72^{a}	0,073± 0,1^{a}
Fibers (%)	33.21± 0,82	31.32± 0,64^{a}	0,06± 0,67^{a}	32.79± 0,86	31.17± 0,54^{a}	0,05± 0,72^{a}	31.68± 0,73	30.27± 0,44^{a}	0,046± 0,51^{a}
Energy (kcal/kg)	3287.37± 0,65	3015.43± 0,51^{a}	0,095± 0,48^{a}	3300.01± 0,72	3002,01± 0,27^{a}	0,099± 0,32^{a}	3291.92± 0,82	3024.41± 0,65^{a}	0,088± 0,36^{a}

Values with the same letter on the same line are not significantly different at the 5% threshold. OM (organic matter); MM (mineral matter); Da (apparent digestibility).

III.2. Effects of rations at different levels of incorporation of germinated off-season sorghum on the intestines of broilers.

Figure 1 shows the effects of the different rations on the architecture of the small intestine of broiler chickens in the start-uper phase. Indeed, Ceompared to the R0 control, the histological sections did not show any structural and morphological alterations in R1



R0 **R1** **R2**

Lu = Intestinal lumen; SM = Submucosa; Mus = Muscularis; Se = Serosa.

Figure 1: Histological sections of the small intestine of chickens in the starter phase

III. 3. Effects of rations at different levels of incorporation of sprouted off-season sorghum on apparent digestibility during growth/finishing.

Table 5 shows the apparent digestibility (Ad) values for broilers fed the three rations during the growth/finishing phase. It can be seen that energy, organic matter, mineral matter, protein and cellulose were not significantly influenced by the experimental rations used at the 0.05% threshold.

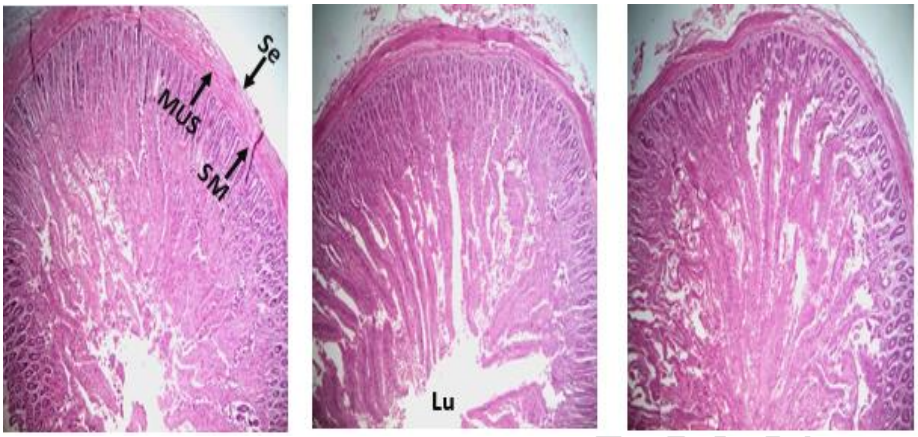
Table 5: Apparent digestibility of broilers fed rations with different levels of sprouted off-season sorghum incorporation

Apparent digestibility in growth/finishing									
	R0 100% Maize			R1 50%			R2 100% sorghum		
	Feed	Droppings	Ad	Feed	Droppings	Ad	Feed	Droppings	Ad
Protein (%)	20.05± 0,23	15.67± 0,39	0,279±0,21	20.69± 0,69	16.08± 0,58	0,286± 0,33	19.95± 0,09	15.49± 0,29	0,287 ±0,29
OM (%)	31.84± 0,10	27.45± 0,27	0,159± 0,22	29.31± 0,45	24.94± 0,38	0,175± 0,19	35.19± 0,17	30.06± 0,44	0,170 ±0,32
MM (%)	23.75± 0,14	21.91± 0,21	0,083±0,34	22.49± 0,85	20.74± 0,36	0,084± 0,44	24.38± 0,24	22.42± 0,33	0,087 ±0,29
Fibers (%)	21.86± 0,78	19.35± 0,27	0,129±0,14	22.63± 0,23	19.92± 0,18	0,136± 0,21	21.67± 0,39	19.01± 0,25	0,139 ±0,27
Energy (kcal/kg)	3198.48 ± 0,31	2857.35± 0,45	0,11 ±54	3189.86± 0,52	2874.54± 0,41	0,10,96 ±0,41	3195.84± 0,33	2862.84± 0,44	0,116 ±0,39

Values with the same letter on the same line are not significantly different at the 5% threshold. OM (organic matter); MM (mineral matter) Da (apparent digestibility).

III.4. Effects of rations at different levels of incorporation of sprouted off-season sorghum on the gut of broilers.

Figure 2 shows the effects of the different rations on the structure and morphology of the small intestine of broilers in the growth/finishing phase. Compared with the R0 control, the histological sections showed no structural or morphological alterations.



R0 **R1** **R2**

Lu = Intestinal lumen; SM = Submucosa; Mus = Muscularis; Se = Serosa.

Figure 2: Histological sections of small intestine of chicken in growth/finishing phase

IV. Discussion

IV.1. Digestibility

Energy, organic matter, mineral matter, proteins and fibre were not significantly influenced by the experimental rations used at the 0.05% threshold for digestibility. These results would be due to malting which would have hydrolyzed the starch and antinutrients of the sorghum. These results do not corroborate those of Selle et al. (2017) who demonstrated that the digestibility of sorghum is lower than that of maize; because of the intrinsic factors of sorghum including kafirin, phenolic compounds and phytate which can compromise the use of starch by broilers subjected to a sorghum-based diet. These results are confirmed by the in vitro and in vivo experiments of Vilariño et al. (2016). In addition, the results of Métayer et al. (2015) on starch digestibility confirm the hypothesis of starch degradation, more or less important depending on the cereal, with the age of the subjects. The lack of significance with regard to the experimental rations would be justified by the good fibre content; because the presence of high amounts of fiber can impact the intestinal wall and reduce nutrient absorption (Qaisrani et al., 2014). These results can also be explained by the use of dry droppings because the quality of the predicted measurements is lower than that

obtained on dried droppings, which leads to better results (Bouvarel et al., 2014). Decreases in digestibility in birds fed diets containing high tannin sorghum have been observed (Kumar et al. 2007). As well as a significant reduction in nitrogen retention was found in broilers fed red sorghum as the only source of cereals in the diet (Sannamani, 2002),

IV.2. Histological sections of the intestines

The histological sections showed no structural or morphological alterations. This testifies to the non-toxicity of the various experimental rations, as well as the absence of pathogenic elements. The height of the villi and the depth of the crypts can be used as indicators of the health of the intestine and are therefore associated with the condition of the animals and the quality of the feed (Li et al., 2016). A thicker mucosa would consist of larger intestinal villi (length, width) to optimise absorption of digested nutrients Carré et al. (2008). large (length, width) to optimise absorption of digested nutrients Carré et al. (2008). A thicker muscularis could indicate the need for greater muscular work to promote the transit of a greater volume of digesta towards the distal parts of the small intestine. These results are consistent with those of Mathlouthi et al. (2002) who demonstrated that the association of bacteria with the intestinal mucosa and the production of different metabolites lead to anatomical and physiological changes in intestinal wall cells and smooth muscle. The poor quality of the food can be responsible for the alteration and inflammation of the mucosa (Gabriel et al., 2009; Irène et al., 2020). The type of cereal often has a direct influence on intestinal transit Amerah et al. (2008). Weurding et al. (2001), compared small intestine retention times for several types of cereals, including maize, wheat, sorghum, and other types of cereals.

V. Conclusion

The aim of this study was to assess the digestibility of feed rations containing sprouted off-season sorghum used as an energy source in broilers in the start ~~-upe~~r ~~-phase~~ and ~~then in -~~the growth/finishing phase~~s~~. The results showed that broilers fed the three experimental rations showed no significant difference in the apparent digestibility of protein, fibre, organic matter, mineral matter and energy. Histological sections of the small intestine showed no structural or morphological alterations. Sprouted off-season sorghum can be used as a total replacement for maize in broiler diets without affecting morphology, small intestine function or digestibility.

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