International Journal of Animal Science, Husbandry and Livestock Production ISSN: 2141-5191 Vol. 7(7), pp. 415-422, November, 2021. Available online at www.advancedscholarsjournals.org © Advanced Scholars Journals

Full length Research paper

Effects of gingember meal (*Zingiberofficinalis*) as food additive on the *in vivo* digestibility and feed intake of guinea pig (*Caviaporcellus*L.)

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Accepted 11th January, 2021

Guinea pigs are monogastric herbivores with a particular digestive system essentially based on the gut flora equilibrium. Due to some of their properties, gingember meal in the diet can improve feed intake and the digestibility of diets by stimulating in the caecum the development of fibrolytics bacteria over pathogens bacteria. Thus, the aim of this work carried out at the Faculty of Agronomy and Agricultural Sciences (FAAS) of the University of Dschang farm was to study the effects of ginger powder (Zingiberofficinalis**) as a food additive on the *in vivo* digestibility and intake of nutrients of guinea pigs. The trial was set up according to a factorial design (ration and sex) in four batches of 5 males and 5 females each. Thus, 40 guinea pigs weighing 450 ± 50 g were used. The control ration assigned to animals in batch 1 (TG 0) did not contain ginger meal. The animals of batch 2 (TG 0.5); 3 (TG 0.75) and 4 (TG 1) received respectively 0.5%; 0.75% and 1% ginger meal in their rations. The grass*T. laxum* was served *ad libitum* as base diet. It appears from this study that the ration containing 0% of ginger meal significantly ($p<0.05$) improved the compound food (26.46 DM/d/ animal), the dry matter (DM) (89.52 DM/d/animal), the organic matter (MO) (81.51 DM/d/animal) and the crude protein (PB) (14.15 gDM/d/ animal) intake compared to animals of other diets. The ration containing 0.75% of ginger meal significantly better ($p<0.05$) improved the crude protein digestibility (94.92%) only on males. Regarding Daily weight gain (ADG), males of the control diet have obtained significantly better weight gain (26g/d) than others.**

Key words: feed intake, Guinea pig, *in vivo* digestibility, weight gain, *Zingiberofficinalis*.

INTRODUCTION

Africa suffers from poverty, malnutrition and other related social illnesses, especially in the rural landscape where the lack of capital and the necessary experience precludes intensive production of animal proteins. Faced with this situation, mini-farming, which is too often neglected, must be considered (Ndébiet al., 2015). Caviaculture, which is the breeding of guinea pigs, presents itself as one of the opportunities to be seized to help poor households to emerge from the food insecurity situation to which they are subjected (Noumbissi et al., 2014; Kouakou et al., 2012; Metre, 2012; Ntsafack et al., 2020). The guinea pig is a monogastric herbivore whose major interest lies in its prolificacy, its rapid growth rate, its meat rich in protein and its inexpensive diet (Cicogna, 2000). Indeed, this small monogastric herbivore is widely bred and consumed by populations in many regions of Cameroon (Kenfack et al., 2006). However, its optimal use as a source of protein requires an adequate diet in order to improve its productivity (Zougou et al., 2017).
In this vein, many plants rich in nitrogen like *Tithoniadiversifolia* (Noumbissi et al., 2013),

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Manihotesculanta leaves (Mweugang et al., 2014), *Desmodiumintortum*, *Arachisglabrata, Calliandracalothyrsus* (Miégoué et al., 2016), *Arthropsiraplatensis* (Nguedia et al., 2019), *Ipomeabatatas* leaves and *Stylosanthesguianensis* (Ntsafack et al., 2020) have seen their use increase. Besides these non-conventional protein sources, natural plant extracts have proven to be very effective in animal feed. Recent studies have shown that some spices have a positive impact on the productive performance of domestic animals.

These compounds act indirectly through their antimicrobial, antioxidant and regulator effect on the intestinal flora of animals (Alloui, 2011).

Ginger (*Zingiberofficinalis*) which is a herbaceous plant belonging to the Zinbéraceae family, enters this group of phytobiotics containing all these properties. The studies of Dieumou et al. 2009 revealed that this spice contains many important compounds like gingerol, and gingerdiol, which stimulate digestive enzymes in chickens, and which have a positive impact on microbial activity.

In small ruminants, the *in vitro* digestibility of the forage was significantly improved with the addition of 100 and 200 mg of essential oil of ginger rhizome in the diet, combined with *Pennisetumclandestinum* hay (Mekuiko et al., 2018).

Although favorable results have been obtained in poultry and small ruminants, very few studies on the intake and digestibility of diet associated with ginger powder as a feed additive have been carried out in guinea pigs. It is in this logic that the present work was done with the main objective to evaluate the effects of the inclusion of ginger meal as a food additive in the diet, on ingestion and digestibility in guinea pig.

MATERIAL AND METHODS

Study site

This study was carried out at the Animal Production and Nutrition Research Unit (URPRONAN) of the Faculty of Agronomy and Agricultural Sciences (FAAS) of the University of Dschang. The city of Dschang is located at the 15th degree of the East meridian, at latitude 5° 36'- 5° 44 'North and longitude 09° 85'-10° 06' East.

The climate of the region is equatorial of Cameroonian type modified by altitude. In the locality, rainfall varies between 1,500 and 2,000 mm per year. The annual average temperature is around 20°C, the total annual insolation at 1800 hours and an average relative humidity varying between 40 and 90%.

Animal equipment and housing

Forty (40) local breed guinea pigs (20 males and 20 females) of average weight 450 ± 50g were used for the evaluation of the effect of ginger meal on the intake and digestibility of the diet. They were placed in individual wire cages (40) of size: 80 cm in length, 50 cm in width and 30 cm in height. Each of the cages was equipped with a device for collecting feces, and also had a feeding trough and water through with a capacity of 0.5 l.

Plant material

The plant material consisted of the rhizomes of ginger collected in the town of Santchou (West Cameroon) and *Trypsacumlaxum*, harvested in the fodder field of the farm the day before, kept in one of the dwellings of the livestock building and pre-dried before to be served *ad libitum* the next day to the animals.

Manufacture of compound feed

The proportions of the various byproducts purchased from feed reseller in the city of Dschang used to manufacture the compound feed as well as their nutritional value are presented in Table 1. The feed formula was established from diet containing no ginger meal (TG0).

The animals of batch 2 (TG0.5); 3 (TG0.75) and 4 (TG1) received respectively 0.5%; 0.75% and 1% ginger powder in their rations. *T. laxum* grass was served ad libitum for each batch

Trial on feed intake and *in vivo* digestibility of diet.

Digestibility was determined following the modify guidelines of the European Reference Method for the measurement of in vivo Digestibility Established for the Rabbit (Tatsinkou et al., 2020, Miégoué et al., 2018).

According to this method, the measurement of digestibility in rabbits requires at least 8 rabbits per diet and the fecal collection period, which lasts at least 4 days, must be preceded by an adaptation period of at least 7 days.

The animals were distributed according to afactorial design (ration and sex) into four groups then placed in individual cages.

The feed was distributed over a period of 15 days, divided into 2 periods: a period of adaptation to the digestibility cage and to the diet of 10-day during which each animal received ad libitum vitaminized water and the corresponding experimental diet for its batch.

This period was followed by a second called "digestibility" of 5 days, corresponding to the data collection phase.

During these 5 days, each animal also received *ad libitum* vitaminized water and the experimental ration corresponding to its batch. Each morning, each ration was weighed before being served.

At the start and end of the test, animals were

Table 1: Percentage and chemical composition of the compound feed

Ingredients	**Quantities(kg)**
Qu antities(kg)	
Corn	26
Wheat bran	48
Soybeanmeal	06
Cottonmeal	03
Palmkernelmeal	07
Fishmeal	06
Bonemeal	02
Cookingsalt	01
Premix	01
Total	**100**
Chemical composition	
Dry matter (%)	92,03
Organic matter (% DM)	86,71
Crude protein (% DM)	19,92
Fat (% DM)	2,92
Crude fiber (% DM)	9,74
Ash (% DM)	13,29
ME (kcal/kg DM)	2703,68

DM: Dry Matte;r M E: Metabolisable energy

weighed on an empty stomach for weight gain determination in order to calculate the mean daily weight gain (ADG) during the digestibility period.

During the 5 days of data collection, every morning, before any new service, the leftovers or refusals were collected and weighed, which made it possible to assess the daily food intake in each experimental unit (Food intake = Daily quantity of food served - Quantity not consumed (refusal)).

Then the feces of each animal were collected and weighed. A 100g sample of these feces was taken and dried at 60°C to constant weight in a ventilated oven.

Then, it was crushed and stored in plastic bags for determination of its chemical composition (dry matter, organic matter, crude protein and crude fiber) as recommended by the A.O.A.C. (2000).

The apparent digestibility utilization coefficients of Dry Matter (ADUCsDM), Organic Matter (ADUCsOM), Crude Protein (ADUCsCP), and Crude Cellulose (ADUCsCF) were calculated according to the formula adapted by Miégoué et al. (2018)

Statistical analyzes

Data on food intake and in vivo digestibility were subjected to 2-way analysis of variance (ANOVA) (Diet type and sex of animal) according to the General Linear Model (MLG).

Significantly different mean values between rations were separated by the Waller Duncan test at the 5% significance level (Steel and Torrie,1980). SPSS 21.0 analysis software was used.

RESULTS

Effects of inclusion level of ginger powder in the ration on the intake of food rations

Food ingestion shows that for all sexes combined, the animals subjected to the diet containing 0% (TG0) of ginger meal significantly ($p < 0.05$) ingested the compound food, the dry matter (DM), organic matter (OM) and crude protein (PB) compared to those subjected to diet containing 0.5% (TG0.5) and 0.75% (TG0.75) of ginger meal (Table2).

Similarly, the females subjected to the diet containing 0% of ginger meal, recorded an ingestion of dry matter (DM), organic matter (OM) and crude protein (CP) in a significantly higher proportion than that of the females in the diet containing 0.75% of ginger meal, and on the other hand comparable ($p > 0.05$) to that of female fed with diet containing 0.5% and 1% ginger meal. However, regardless of sex, intake remained comparable between animals fed with diet containing 0% and 1% ginger meal, respectively.

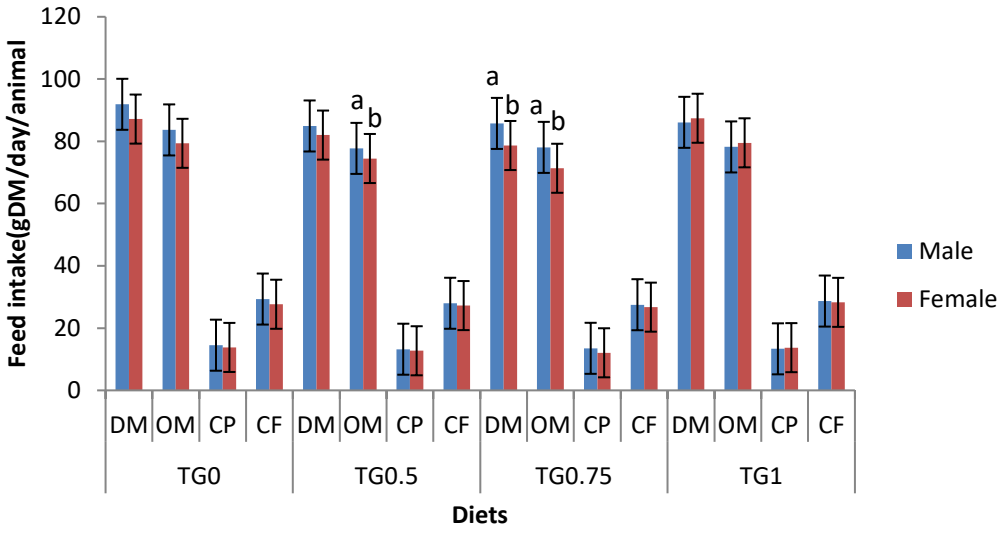
Table 2. Food intake according to diet and sex

Intake (gDM/Day/Animal)		Diets					
		TG0	**TG0.5**	**TG0.75**	**TG1**	**SEM**	**p**
Experimental feed							
T. laxum	♂	67 .35^{a}	65.12^{a}	63.31^{a}	67.08^{a}	1.55	0.26
	♀	63.35^{a}	63.62^{a}	69.97^{a}	65.27^{a}	2.04	0.86
	♂♀	65.35^{a}	64.37^{a}	63.14^{a}	66.18^{a}	1.39	0.47
Compound food	♂	24.54^{a}	19.80^{a}	22.44^{a}	19.01^{a}	1.79	0.16
	♀	24.39^{a}	18.36^{bc}	15.67^{c}	22.13^{ab}	1.88	0.02
	♂♀	24.46^{a}	19.08^{b}	19.05^{b}	20.57^{ab}	1.30	0.03
Nutrients							
Dry matter	♂	91.89^{a}	84.93^{a}	85.75^{a}	86.10^{a}	2.08	0.11
	♀	87.14^{a}	82.00^{ab}	78.65^{b}	87.41^{a}	2.43	0.05
	♂♀	89.52^{a}	83.46^{b}	82.20^{b}	86.76^{ab}	1.75	0.04
Organicmatter	♂	83.66^{a}	77.73^{a}	78.05^{a}	78.20^{a}	1.97	0.15
	♀	79.36^{a}	74.48^{ab}	71.34^{b}	79.52^{a}	2.24	0.05
	♂♀	81.51^{a}	76.11^{b}	74.69^{b}	78.86^{ab}	1.64	0.04
Crude protein	♂	14.51^{a}	13.22^{a}	13.51^{a}	13.34^{a}	0.38	0.11
	♀	13.79^{a}	12.72^{ab}	12.07^{b}	13.72^{a}	0.43	0.03
	♂♀	14.15^{a}	12.97^{b}	12.79^{b}	13.53^{ab}	0.30	0.03
Crude fiber	♂	29.33^{a}	27.98^{a}	27.51^{a}	28.69^{a}	0.60	0.20
	♀	27.66^{a}	27.24^{a}	26.73^{a}	28.27^{a}	0.79	0.58
	♂♀	24.49^{a}	27.61^{a}	27.12^{a}	28.48^{a}	0.55	0.26

a, b: The means bearing the same letters on the same line are not significantly different at the 5% level; SEM: Standard error on the mean; p:Probability; TG0; TG0,5; TG0,75; TG1: inclusion level of gingember meal

Comparative nutrient intake between males and females depending on the inclusion level of ginger meal in the diet.

Figure 1 compares the effects of the level of ginger meal in the diet on nutrient intake in males and females guinea pigs. It emerges from this table that the ingestion of MS, OM, PB and CF was comparable ($p>0.05$) between the TG0 and TG1 diet. On the other hand, the ingestion of OM from the TG0.5 diet and the DM and OM of the TG0.75 diet on the other hand were significantly ($P <0.05$) higher in males.



a, b: the means bearing the same letter for the same ration are not significantly different at the 5% level.
TG0; TG0,5; TG0,75; TG1: inclusion level of gingember meal**; DM: Dry Matter; OM: Organic Matter; CP: Crude Protein; CF: Crude Fibre**

Figure 1. Comparative ingestion of MS, OM, PB and CF between males and females according to diet.

Apparent digestive utilization coefficients (ADUCs) of nutrients in guinea pigs depending on the inclusion level of ginger powder in the diet.

Apparent Digestive Utilization Coefficients (ADUCs) of dry matter (ADUCsMS), organic matter (ADUCsMO), crude protein (ADUCsPB) and crude fiber (CUDsCF) as according to ginger powder levels in the diet and sex reveal that, the males fed with the diet containing 0.75% (TG0.75) of ginger powder significantly ($p<0.05$) digested the crude protein better compared to the males of the diet containing 0% (TG0) and 1% (TG1) of ginger powder. However, the digestive use of crude protein remained comparable ($p>0.05$) between male fed with diets containing 0.75% and 0.5% ginger powder.

In contrast, in females and regardless of sex, the inclusion of ginger powder in the diet had no significant effect ($P>0.05$) on the digestive use of crude protein. Likewise, whatever the sex and for all sex combined, the inclusion of ginger powder in the diet did not significantly ($p>0.05$) influence the digestive use of dry matter, organic matter and crude fiber.

Tableau 3. Apparent digestive utilization coefficients (ADUCs) of nutrients in guinea pigs according to the level of ginger powder in the diet.

ADUCs (%)	Diets	TG0	TG0.5	TG0.75	TG1	SEM	p
ADUCsDM	♂	85.82^{a}	89.46^{a}	90.69^{a}	86.68^{a}	0.82	0.16
	♀	86.13^{a}	85.66^{a}	85.34^{a}	87.43^{a}	0.73	0.76
	♂♀	85.97^{a}	87.56^{a}	88.02^{a}	87.05^{a}	0.51	0.55
ADUCsOM	♂	86.37^{a}	90.70^{a}	91.32^{a}	86.96^{a}	0.77	0.08
	♀	87.06^{a}	86.61^{a}	86.00^{a}	87.91^{a}	0.69	0.80
	♂♀	86.71^{a}	88.66^{a}	88.66^{a}	87.44^{a}	0.48	0.42
ADUCsPB	♂	89.21^{b}	93.03^{ab}	94.92^{a}	89.64^{b}	0.62	0.01
	♀	89.73^{a}	89.65^{a}	89.71^{a}	90.66^{a}	0.69	0.95
	♂♀	89.47^{a}	91.34^{a}	92.31^{a}	90.15^{a}	0.45	0.16
ADUCsCF	♂	85.71^{a}	83.81^{a}	88.10^{a}	89.84^{a}	1.39	0.46
	♀	84.08^{a}	86.61^{a}	87.32^{a}	87.50^{a}	1.09	0.67
	♂♀	84.90^{a}	85.21^{a}	87.71^{a}	88.67^{a}	0.84	0.33

a, b: The means bearing the same letters on the same line are not significantly different at the 5% level; ESM: standard error of the mean; Prob:Probability.TG0; TG0,5; TG0,75; TG1: inclusion level of gingember meal**; ADUCs: apparent digestibility coefficient of DM: Dry Matter; OM: Organic Matter; CP: Crude Protein; CF: Crude Fiber**

Tableau 4. Average daily gains (ADG) in guinea pigs during the in vivo digestibility test

		Diets					
	Sexe	**TG 0**	**TG 0.5**	**TG0.75**	**TG1**	**ESM**	**Prob**
ADG (g/d)	♂	26.00[a]	10.40[b]	9.00[b]	8.80[b]	0.88	0.04
	♀	28.60[a]	20.20[a]	14.80[a]	24.60[a]	1.77	0.72
	♂♀	27.30[a]	15.30[a]	11.90[a]	16.70[a]	1.01	0.20

a, b: The means bearing the same letters on the same line are not significantly different at the 5% level; ESM: standard error of the mean; Prob: Probability.

Effects of inclusion level of ginger meal in the diet on the mean daily weight gain (DWG) in guinea pigs during the in vivo digestibility test.

The effects of the level of inclusion of ginger powder in the ration on the average daily gains (ADG) in guinea pigs shows that, males subjected to the diet containing 0% ginger powder recorded significant ADGs ($p < 0.05$) higher than those of males subjected to diet containing 0.5%; 0.75 and 1% ginger powder (Table 4). However, in females and for all sexes combined, digestive use remained comparable ($p > 0.05$) regardless of the diet used.

DISCUSSION

Overall, food intake was better in animals fed the diet containing 0% ginger powder. This result joins those obtained by Barazesh et al. (2013) and Tariq (2017), who noted that the increasing addition of ginger powder to the diet decreased feed intake in chickens. However, the results obtained during this study confirm those reported by Ademola et al. (2009) and Doley et al. (2009), who found no significant difference between feed intakes in chickens fed ginger powder in their diet, and those in the control group. Using aqueous extracts of avocado seeds as feed additives, Tatsinkou et al. (2020) obtain similar result.

The comparative intake of nutrients between males and females according to the inclusion level of ginger powder in the diet revealed that, the males subjected to the TG 0.5 diet significantly better ingested OM on one hand, while those in the TG 0.75 diet ingested OM and DM significantly better.

This could be explained, among other things, by the fact that in general in adulthood, males have a higher weight than that of females and are therefore more vigorous, which would therefore encourage them to ingest better. Also, food intake is correlated with the weight of the animal. Indeed, some works show that males ingest more than females (Miégoué et al., 2016; Miégoué et al., 2018)

The digestive use of crude protein was significantly better (94.92%) with males fed with diet containing 0.75% (TG 0.75) ginger powder. This result can be explained by the good energy value of ginger powder. Indeed, according to Gigon (2012), the nutritional energy value per 100g of ginger amounts to 20 kcal. The TG 0.75 diet would therefore have provided energy to the microorganisms in the digestive tract, thus promoting their proliferation and hence their production of digestible proteins in the intestine (cecum) (Wambui et al., 2006).

Indeed, the guinea pig through the phenomenon of caecotrophy captures these digestible proteins, which allow it to optimize the digestive use of ingested proteins (Bindelle et al., 2007).

Incorporating 0% ginger powder into the ration allowed males to achieve significantly higher ADGs (26g/d) than females from other rations. This result is in contradiction with those obtained by Barazesh et al. (2013), who noted a significant increase in body weight in chickens fed with diet supplemented with 1.5% ginger powder.

This could be explained by the feeding behavior of the guinea pig; indeed, the guinea pig is preferential to coarse foods such as green or preserved fodder (grasses and legumes) but also compound foods such ascereals, vegetables, fruits, non-moldy germinated seeds (Lhoste et al., 1993; Foyart, 2005).

In addition, the low proportion of ginger powder in dietary fiber and vitamin C could explain the low valorization by animals of diets containing the powder.

CONCLUSION

It emerges from this study that:

Except in males, the nutrients intake was generally, significantly higher in animals receiving the TG0 diet (0% ginger powder).

The inclusion of 0.75% ginger powder as a food additive

in the diet allowed significant digestion of crude protein by males.

Ginger powder had no significant effect on the ADG of animals during this study.

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