Scientific Paper

# *Metabolic utilization of whole sorghum grains with different tannin contents in British steers*

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**ABSTRACT:** The *in vivo* digestibility of starch (IVDS) of the whole sorghum grain, with high and low tannin contents (SGHT and SGLT, respectively), as supplement, was evaluated in growing British males (Red Aberdeen Angus); as well as the losses in feces and the differential effect of these losses, according to the tannin content. Two treatments ($T_1$ and $T_2$) and two repetitions were established. A completely randomized design was used and each animal constituted an experimental unit. The diets were supplied once per day and were composed by different proportions of SGHT and SGLT, sunflower meal pellet and mixed pasture hay. The protein level was 18 and 15 % for $T_1$ and $T_2$, respectively. The dry matter intake (DMI), *in vivo* dry matter digestibility (IVDMD), IVDS and water intake per kilogram of consumed DM, were measured. The DMI was 8,5 and 12,0 kg for $T_1$ and $T_2$, respectively, while the IVDMD was similar (71,64 and 71,66 %). The IVDS was higher in $T_1$ (74,25 *vs*. 66,67 %); while the starch loss in feces was higher in $T_2$ (31,56 *vs*. 27,27 %). The water intake was similar (1,8 L of water/kg DM). It is concluded that there was a differentiated performance in the utilization of the whole sorghum grain, due to the size of the animal and the different tannin contents. The calves utilized 33 % of the grain offer and the steers, 25 %.

***Key words***: starch, digestibility, feces

## INTRODUCTION

In the pastoral systems of recent years –in Argentina and other countries– the supply of cereal grains has increased, in order to raise the production of individual and per-hectare meat production. This last indicator occurs due to the increase of the stocking rate, when the pasture is substituted by grain (Rearte, 2010).

The productive results reached, together with the lower implantation costs and to the plasticity shown by the grain sorghum to be adapted to unfavorable conditions, prove that this crop has great perspectives in livestock production (Cordes, 2008).

Regarding the supply forms of the grain to cattle, there are several alternatives: whole, broken, treated with heat or chemically treated, among others. Although the grain processing improves the digestibility of dry matter and starch, and increases the passage rate along the digestive tract (Santini, 2004), to prevent the sudden accumulation of lactic acid in the rumen and, thus, the excessive decrease of the ruminal pH (acidosis), the supply of unprocessed grains (whole or coarse broken) is recommended, especially when the intake levels exceed 50 % of the diet on dry basis (Fernández Mayer and Tomaso, 2003).

The grain processing could depend on the animal category that is being supplemented. In this sense, Stritzler (2008) showed that there is an inverse relation between grain mastication and the live weight of the animal. However, if the sorghum grain is supplied whole, it can pass intact through the reticulo-omasal orifice and end in the feces, without being digested, in a high proportion, which is due to its small size (Rearte, 2003; Fernández Mayer *et al*., 2012). This is in addition to the fact that the intact pericarp of the whole grain acts as a shield against the attack of rumen microorganisms and it hinders their digestion (Gagliostro and Gaggiotti, 2002).

In addition to the form of supply, the tannin content should be taken into consideration. Condensed tannins (proanthocyanidins) are non-branched polymers of hydroxyflavonols (Reed, 1995), which are found on the grain testa and are responsible for desirable agronomic traits, such as: resistance to environmental deterioration, storage, damage by fungi and, under certain conditions, to the attack by birds (Makkar, 2003; Massigoge *et al*., 2009). Nevertheless, several authors have found a reduction of 10 to 30 % in the digestibility of some proteins (globulins and prolamines), which are little

soluble in the rumen liquor (Giorda, 2008; Giorda and Cordes, 2009).

On the other hand, some advantages of tannins have been reported, such as: partial control of egg laying in gastrointestinal parasites, increase of bypass protein to the duodenum, reconstitution of the intestinal tissue damaged by parasites, among others (Min and Hart, 2003).

Due to the importance of the topic, the objectives of this study were: to evaluate the *in vivo* digestibility of the starch of the whole sorghum grain, with low and high tannin contents (SGHT + SGLT), in calves and steers; as well as to determine the losses in feces of the whole sorghum grains in these animals (with different live weight) and the differential effect of these losses, according to the tannin contents.

## MATERIALS AND METHODS

The study was conducted in the experimental field Cesáreo Naredo (Guaminí), belonging to the INTA Bordenave (Buenos Aires, Argentina), with growing British males (Red Aberdeen Angus). The essay lasted 15 days (12 days of adaptation to the diets and three days of data recording).

Two treatments were used, with two animals (repetitions) of equal live weight and genetic origin in each one (calves and steers, respectively); the low variability in the metabolic response to tannins was taken into consideration (Fernández –INTA Balcarce–, personal communication) to design the treatments:

- $T_{1:}$ 2 calves of 188,0 ± 0,5 kg LW
- $T_{2:}$ 2 steers of 375,0 ± 0,3 kg LW

The experimental design was completely randomized, with factorial arrangement and two animal categories by two diets. The experimental unit used in this trial was the animal.

The isoenergetic diets (2,79 Mcal of ME/kg DM, table 1) were formulated according to the NRC (2001) and were constituted (table 2) by unprocessed sorghum grain, pellet of sunflower meal (SM) and pasture hay (PH), supplied once per day (10:00 a.m.). The composition on fresh basis was the following:

- 2,5 kg of SGHT /animal/day + 2,5 kg of SGLT / animal/day + 3 kg of SM /animal/day + PH *ad libitum*, for $T_1$
- 4 kg of SGHT /animal/day + 4 kg of SGLT/animal/day + 2,5 kg of SM /animal/day + PH *ad libitum*, for $T_2$

A pen was assigned to each animal, in which it received the daily diet and water at will. The sorghum grain corresponding to each treatment were mixed and supplied whole. At the same moment in which the feedstuff was supplied water was added in each drinking trough.

The bromatological analyses were made in the laboratory of INTA Bordenave, according to the following techniques: DM (AOAC, 1995), crude

Table 1. Nutritional concentration of the treatments.

| Treatment | CP (%) | Metabolizable energy (Mcal/ kg DM) | Calcium (%) | Phosphorus (%) |
|---|---|---|---|---|
| $T_1$ | 18,00 | 2,79 | 2,09 | 5,54 |
| $T_2$ | 15,00 | 2,79 | 1,97 | 4,42 |
| SE (±) | 1,48* | 0,001 | 0,59 | 1,05* |

Unequal values vertically differ at $p < 0,05$ (Duncan, 1955).
*$p < 0,05$

Table 2. Characteristics of the diets (%)

| Diet | DM | DMD | CP | Starch |
|---|---|---|---|---|
| Whole sorghum grain with high tannin content (SGHT) | 89,0 (0,21) | 88,7 (0,11) | 8,0 (0,37) | 56,3 (0,41) |
| Whole sorghum grain with low tannin content (SGLT) | 90,0 (0,28) | 89,1 (0,35) | 8,1 (0,42) | 62,9 (0,25) |
| SE (±) | 1,85 | 1,54 | 1,88 | 0,09 |
| Significance | NS | NS | NS | NS |
| Pellet of sunflower meal (SM) | 91,0 (0,71) | 72,4 (0,54) | 32,0 (0,88) | 0,0 |
| Pasture hay (PH) | 87,0 (0,65) | 58,4 (0,55) | 10,2 (0,41) | 0,0 |

Standard deviation (SD) between parentheses.

protein (total N x 6,25) (AOAC, 1995), DM digestibility (Tilley and Terry, 1963, modified. Method of direct acidification) and starch (AOAC, 1995. Method No. 168. Enzymes: alpha amyloglucosidase. Amylase method).

For the data analysis an ANOVA was applied and the means were compared through Duncan's test (1955) at 5 %, using SAS (2005).

The first day of the trial both treatments received 2 kg of concentrate feed (1 kg of whole sorghum grain, constituted by 0,5 kg of SGHT and 0,5 kg of SGLT + 1 kg of SM) plus PH at will. Until day 12 of the essay, the concentrate feed levels increased progressively up to reaching the final concentration of 8 and 10,5 kg/animal/day for $T_1$ and $T_2$, respectively. During the last three days, the total feces of each animal were collected, two times a day (8:00 a.m. and 6:00 p.m.). Afterwards, they were weighed and kept in the freezer. At the end of the experiment, a representative sample was extracted (1,5 kg/animal/treatment) to be analyzed in the laboratory.

*Measurements*

From the feces pool of each animal, three subsamples of 0,5 kg/animal were separated, before being mixed, to perform the following determinations:

- The IVDMD was determined by means of the difference of dry weight of the consumed feedstuff and the total dried feces (kg/animal/day), at 60ºC in stove, during 48 h.
- The grain IVDS was calculated from the difference between the consumed starch (diet) and the starch detected in the total feces. A sample was analyzed in the laboratory to determine the starch concentration in the feces.
- In the case of the utilization of the sorghum grain, a subsample of feces was filtered and washed through a special mesh fabric, to facilitate the retention and count of the whole and broken grains.

In addition, estimations were made of:

- The DM intake, through the difference between offer and rejected feed.
- The water intake, from the measurement of the quantity added to the troughs, until reaching the previously made mark (measure). Thus, the intake of water liters per kilogram of DM of the consumed feed was calculated, based on the water added daily.

## RESULTS AND DISCUSSION

The average DM intake of the three days of data recording for the two evaluated treatments is shown in table 3.

In both treatments the DM intake (4,05 and 2,86 % of live weight for $T_1$ and $T_2$, respectively) was adequate and consistent with that of other experimental works (Rearte, 2010; Fernández Mayer *et al*., 2012). In the case of the sunflower pellet, it was totally consumed by the animals, for which the sorghum grain intake was 4,5 kg for $T_1$ and 7,5 kg for $T_2$.

Table 4 shows the DM concentration of the feces, which allowed the calculation of the IVDMD of both treatments (table 5).

No differences were detected in the *in vivo* digestibility of DM between the treatments. In spite of the differences obtained in the live weight, the diet was very similarly utilized by both groups of animals, due to the scarce genetic variability existing between them (Mezzadra *et al*., 2003).

Significant differences ($p < 0,05$) were found in the starch concentration in the feces, with values of 287 (28,7 %) and 439 (43,9 %) grams of starch per kilogram of DM of feces for $T_1$ and $T_2$, respectively. From these data the total starch content was calculated in the feces (table 6) and the IVDS (table 7).

A higher *in vivo* digestibility of starch was observed in $T_1$ with regards to $T_2$ ($p < 0,05$). In this

Table 3. Diet intake by the calves ($T_1$) and steers ($T_2$).

| Diet | $T_1$ | | | $T_2$ | | |
|---|---|---|---|---|---|---|
| | Offer | Rejected feed | Intake | Offer | Rejected feed | Intake |
| Concentrate feed (SG and SM) (kg/animal/day) | 8 | 0,5 | 7,5 | 10,5 | 0,5 | 10 |
| PH (kg/animal/day) | 1 | 0 | 1 | 2 | 0 | 2 |
| Total intake on fresh basis (kg/animal/day) | | | 8,5 | | | 12 |
| Total DM intake (kg DM/animal/day) | | | 7,62 | | | 10,74 |

Table 4. DM concentration of the feces

| Treatment | Fresh weight of the feces (kg/animal/day) | DM (%) of the feces | Dry weight of the feces (kg/animal/day)* |
|---|---|---|---|
| $T_1$ | 6,9 (0,10) | 34,92 (0,15) | 2,41 (0,09) |
| $T_2$ | 10,96 (012) | 31,02 (0,07) | 3,4 (0,21) |
| SE (±) | 2,05* | 1,97* | 0,47* |

Different values vertically differ at $p < 0,05$ (Duncan, 1955) *$p < 0,05$.
SD between parentheses.

Table 5. *In vivo* digestibility of DM.

| Treatment | DM intake (kg/animal/day) | Feces (kg DM/animal/day) | IVDMD (%) |
|---|---|---|---|
| $T_1$ | 7,62 (0,88) | 2,41 (0,42) | 68,37 (0,55) |
| $T_2$ | 10,74 (0,58) | 3,4 (0,47) | 68,34 (0,61) |
| SE (±) | 2,49* | 0,47* | 0,98 |

Unequal values vertically differ at $p < 0,05$ (Duncan, 1955) *$p < 0,05$
SD between parentheses.
% IVDMD = DM intake – dry weight of the feces/ DM intake (*100)

Table 6. Starch content in the feces.

| Treatment | Feces (kg DM/animal/day) | Starch concentration in the feces (%) | Starch in feces (kg DM/animal/day) |
|---|---|---|---|
| $T_1$ | 2,41 (0,88) | 28,7 | 0,69 (0,21) |
| $T_2$ | 3,4 (0,51) | 43,9 | 1,49 (0,77) |
| SE (±) | 0,47* | - | 0,47* |

Unequal values vertically differ at $p < 0,05$ (Duncan, 1955) *$p < 0,05$.
SD between parentheses.
Starch in feces = kg DM of feces/animal/day * % of starch.

Table 7. *In vivo* digestibility of starch.

| Treatment | Starch intake (kg/animal/day)[1,2] | Starch in feces (kg DM/animal/day) | *In vivo* digestibility of starch (%)[3] |
|---|---|---|---|
| $T_1$ | 2,66 (0,31) | 0,69 (0,21) | 74,06 (0,33) |
| $T_2$ | 4,46 (0,25) | 1,49 (0,77) | 66,59 (0,58) |
| SE (±) | 1,88* | 0,56* | 6,18* |

Unequal values vertically differ at $p < 0,05$ (Duncan, 1955) *$p < 0,05$.
SD between parentheses.
Starch intake in $T_1$ = intake of SGHT (kg DM/animal/day) x 56,3 % of starch/kg DM of SGHT
Starch intake in $T_2$ = intake of SGLT (kg DM/animal/day) x 62,9 % of starch/kg DM of SGLT
IVDS= (Starch intake-starch content in feces)/Starch intake *100.

sense, the young animals have a smaller reticulo-omasal orifice; thus, it is more difficult for the whole grain to pass, which increases the mastication time (rumination). This causes higher salivation and also provides the starch with more possibilities of being in contact with the gastric juices and of being digested (Pordomingo *et al*., 2003, 2007). This effect is not observed in larger animals whose reticulo-omasal orifice is bigger.

Several authors found that the digestion of starch in the duodenum is limited to 600-650 g/day (Russell *et al*., 1981). The incomplete digestion of starch in the small intestine in ruminants is due, among other reasons, to the inadequate production of enzymes and the presence of a protein matrix around the granules of starch, as well as to a sub-optimal intestinal pH for the amylase activity (Owens *et al*., 1986; Montiel *et al*., 2002).

Another factor that hinders the utilization of starches is related to the fact that the tannins of the sorghum grain form a coat that reduces the attack of rumen microorganisms. Under these conditions the digestion of the starch of grains with high tannin content can decrease, compared with the low-tannin grains, in this chemical indicator (Pordomingo *et al*., 2007a). This would explain the lower digestibility of starch in $T_2$ with regards to $T_1$, because in the latter the animals had a higher ingestion of grain with high tannin content.

Table 8 shows the grain loss (SGHT + SGLT) in the feces, which was measured from the quantity of starch detected in the feces in each treatment, transformed into its equivalent in grain, divided by the concentration of this chemical indicator in the grains. These results coincide with reports made by Pordomingo *et al*. (2002) and Zamora *et al*. (2009), who found higher losses of starch in the feces of steers, when comparing them to calves. These losses are turned into a higher concentration of starch in the feces as the live weight of the animals increases (Aello and Dimarco, 2004).

There was higher utilization ($p < 0,05$) of the SGLT with regards to the SGHT, in $T_1$ and $T_2$. In addition, the proportion of utilization of each one was similar in both treatments (table 9). In this sense, it is known that the proteins in cereal grains are distributed in the pericarp (shell); while the starch granules of corn grain are surrounded by zein (highly degradable protein in rumen) and those of sorghum grain are surrounded by glutelins and prolamines, which have a very low ruminal degradability (Fernández Mayer, 2006). The presence of tannins and these two proteins –which are abundant in tannin-rich grains– restricts the entrance of water and digestive juices (enzymes) through the integument of the whole grain. Thus, the starch digestion is limited and, with it, the digestibility of all the grain, especially of the whole grain (Montiel *et al*; Pordomingo *et al*., 2003).

Regarding water, the intake was similar (around 1,8 L/kg of consumed DM) in both treatments, and lower than the one found by other authors (3 L/kg DM) in similar breed and genetic type (Colacelli, 1997); although these differences can be due to the fact that the studied diet had a higher energy concentration (2,79 Mcal of ME/kg DM) compared to the mean of other studies (Gagliostro and Gaggiotti, 2002).

It is concluded that the *in vivo* digestibility (utilization) of the whole sorghum grain was higher in the young animals, compared to the steers (of higher live weight), and that the sorghum grain supplied whole, with low tannin content, had a higher utilization. The utilization with young animals was equivalent to one per every 3 kg of whole grain (± 33 %); while with larger animals, it was one per every 4 kg of consumed grain (± 25 %).

Table 8. Starch concentration and grain percentage lost in the feces.

| Treatment | Concentration of starch per kg of DM of the feces (%) | Lost grain (%) |
|---|---|---|
| $T_1$ | 28,7 | 27,27 |
| $T_2$ | 43,9 | 31,56 |
| SE (±) | 7,66* | 2,45 |

Unequal values vertically differ at $p < 0,05$ (Duncan, 1955) *$p < 0,05$.
SD between parentheses
Lost grain - Proportion of starch (grain) in the feces with regards to the consumed starch (grain) (%)
= (kg of starch (grain) in feces x 100)/kg of consumed starch (grain)

Table 9. Percentage of grains, with and w ıt tannins, recovered in the feces.

| Treatment | SGHT in feces (%) | SGLT in feces (%) | SE (±) |
|---|---|---|---|
| $T_1$ | 53,62 | 46,38 | 2,88* |
| $T_2$ | 53,02 | 46,98 | 2,47* |

Unequal values horizontally differ at $p < 0,05$ (Duncan, 1955)
*$p < 0,05$.
SD between parentheses.

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