# DYNAMIC CHANGES IN STRUCTURAL CARBOHYDRATE COMPONENTS DURING THE ENSILING OF SWEET SORGHUM

Sun, Z.[1], Han, S.[1], Xu, R.[1], Zhang, Y.[1], Luo, H.[2], Yu, Z.[1]

[1]College of Grassland Science and Technology, China Agricultural University, Beijing, China
[2]College of Animal Science and Technology, China Agricultural University, Beijing, China

## ABSTRACT

Sweet sorghum can be used to produce a substantial quantity of biofuel due to its high biological yield and high carbohydrate content. In this study, we investigated the dynamic changes in fermentation characteristics, carbohydrate components, and the bacterial community during the ensiling of wilted and unwilted sweet sorghum. The results revealed a rapid fermentation pattern and high-quality fermentation quality in wilted and unwilted sweet sorghum, wherein lactic acid, and acetic acid accumulated and stabilized during the initial 9 days of ensiling, with the pH values less than 4.2, until 60 days of ensiling. We found that the ensiling of sweet sorghum involved the degradation (5%~10%) of neutral detergent fiber (NDF) and hemicellulose and that the degradation of NDF fit a first-order exponential decay model. A shift in dominance from *Lactococcus* to *Lactobacillus* occurred before the first 9 days of ensiling, and the abundance of *Lactobacillus* ($r=-0.68$, $P<0.001$) was negatively correlated with the NDF content. The relative abundances of *Lactobacillus* in wilted and unwilted sweet sorghum after ensiling for 60 days were 76.30% and 93.49%, respectively, and relatively high fermentation quality was obtained. In summary, ensiling is proposed as a biological pretreatment for sweet sorghum for subsequent biofuel production, and unlike other materials, sweet sorghum quickly achieves good fermentation quality and has great potential for bioresource production.

Keywords: sweet sorghum, carbohydrate components, ensiling

## INTRODUCTION

The production of bioresources is under great pressure due to global climate change and the continuous emergence of issues such as urbanization and water scarcity. In general, plants that have more carbohydrates and less lignin generally have the benefit of being able to produce significant amounts of biofuel (Mathur *et al.*, 2017). Sweet sorghum (*Sorghum bicolor* L. Moench) is a C4 herbaceous annual grass that has high photosynthetic efficiency. Moreover, sweet sorghum has comparatively high energy and carbohydrate contents. After the required processing, the accessible holocellulose in the biomass may be readily used to produce biofuel (Velmurugan *et al.*, 2020). However, owing to its short harvest periods and seasonality, sweet sorghum requires appropriate preservation after widespread harvest to guarantee a steady supply throughout the year for subsequent biofuel production. Thus, in this study, we investigated the dynamic changes in carbohydrate components of wilted and unwilted sweet sorghum during ensiling pretreatment, as well as the impact of ensiling processes on the fiber degradation kinetics of sweet sorghum.

## MATERIALS AND METHODS

Sweet sorghum plants were harvested at the heading stage in Wuzhong, Ningxia Hui Autonomous Region, China (N 37°43′, E 106°04′, elevation 1240 m). A portion of the test materials was collected immediately after harvest, and additional materials were obtained after 48 h of wilting in the field. The wilted and unwilted materials were shredded into approximately 2 cm pieces using a small plant chopper. The 42 bags (2 treatments × 7 days × 3 replicates) were vacuum-sealed and kept in a room at approximately 20°C. Three bags per treatment were opened after the initial (3d, 6d, 9d), intermediate (14d, 21d, 30d) and late (60d) fermentations. Then the carbohydrate components of silage samples was examined. The contents of neutral detergent fiber (NDF) and acid detergent fiber (ADF) were analyzed using an automatic fiber analyzer (Ankom 2000i full; Ankom Tech Co., Macedon, NY, USA) in accordance with the procedures outlined by Van Soest *et al.* (1991). The hemicellulose (HC) and cellulose (CL) contents were calculated according to the NDF, ADF and acid detergent lignin contents. The NDF, ADF, HC, and CL data were fitted to the following exponential decay model (Eq. (1)) to characterize the fiber degradation properties (Zhao, *et al.*, 2018):

$$y = y_0 + a * \exp(-bt) \tag{1}$$

Among these are: y, the total amount of undegraded material at time t; y0, the undegraded portion fraction after 60 days of ensiling; a, the degradable fraction; b, the percentage disappearance rate ($day^{-1}$) of a; t, the number of ensiling days; and e, 2.7183.

## RESULTS AND DISCUSSION

The dynamic changes in the (a) NDF, (b) ADF, (c) HC and (d) CL contents in wilted and unwilted sweet sorghum during the ensiling are shown in Fig. 1(a-d). With increasing ensiling time, the NDF and HC contents in the wilted and unwilted sweet sorghum silages decreased to varying degrees, the ADF and CL

**Tab. 1:** Degradation kinetic parameters of fiber during the ensiling of sweet sorghum and fitted to a first-order exponential decay model (y = y0 + a * exp (-bt))

| Item1 | $y_0$ | a | b | $R^2$ |
|---|---|---|---|---|
| NDF | 94.81 | 5.26 | 0.25 | 0.957 |
| ADF | 95.55 | 4.54 | 0.04 | 0.821 |
| HC | 91.57 | 8.43 | 0.55 | 0.882 |
| CL | 96.37 | 3.67 | 0.25 | 0.868 |

1 NDF, neutral detergent fiber; ADF, acid detergent fiber; HC, hemicellulose; CL cellulose.

https://doi.org/10.11118/978-80-7701-093-1-0120

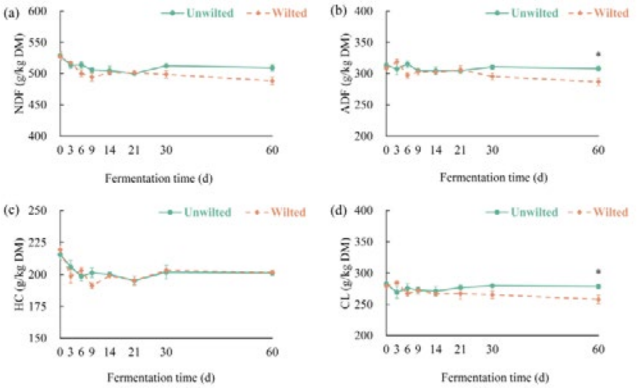


**Fig. 1:** The dynamic changes in (a) neutral detergent fiber (NDF), (b) acid detergent fiber (ADF), (c) hemicellulose (HC) and (d) cellulose (CL) contents in wilted and unwilted sweet sorghum after 3, 6, 9, 14, 21, 30 and 60 days of ensiling. DM, dry matter. Asterisks indicate significant differences between different treatments on the same days of ensiling (*, significant at P<0.05)

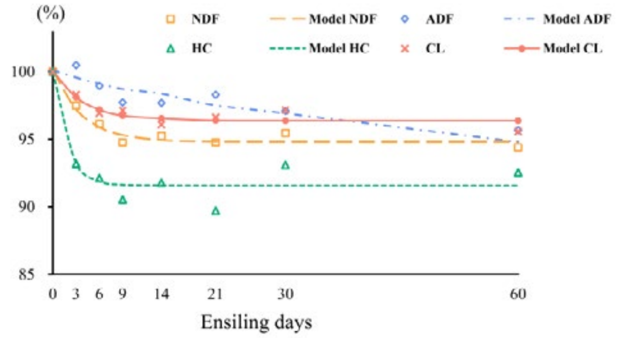


**Fig. 2:** Degradation kinetic parameters of fiber during the ensiling of sweet sorghum and fitted to a first-order exponential decay model (y = y0 + a * exp (-bt)).

contents in the unwilted sweet sorghum silage remained basically unchanged, and the ADF and CL contents in the wilted sweet sorghum silage tended to decrease during the later stage of ensiling. The degradation mechanism of structural carbohydrates observed in the study could be explained by enzymatic action, acidolysis and microbial activity (Dewar *et al*., 1963). Unlike other materials, sweet sorghum has a higher content of WSCs and a lower buffering capacity. After the formation of an anaerobic environment, the microbial fermentation process intensifies, and the acid production ability of the microbial mixture becomes stronger, which may lead to a certain degree of degradation of structural carbohydrates.

The measured structural carbohydrate contents were fitted using a first-order exponential decay model, and the kinetic parameters and related fit curves are shown in Table 1 and Fig. 2, respectively. We found that the correlation coefficient ($R^2$ value) of the NDF degradation curve was 0.957, which indicates that the degree of NDF degradation in sweet sorghum silage can be well predicted using a first-order exponential decay model. Degradation of NDF occurred mainly during the initial 14 days of ensiling, suggesting that structural carbohydrates are more readily degraded during the early phases of ensiling. Similar results were also found in a previous study, in which the combination of *Lactobacillus plantarum* and cellulase increased the breakdown of structural carbohydrates in forage silage. ADF showed slight degradation, and the degradation rate was 0.04, which could be attributed to continued acidolysis. The large reduction in NDF was attributed to the high breakdown of HC, which is consistent with the finding that HC is readily hydrolyzed (McDonald *et al*., 1991).

## CONCLUSION

The ensiling of sweet sorghum involved the degradation (5%~10%) of NDF, and the degradation of NDF fit a first-order exponential decay model. However, in our study, there was no change in the ADL content in wilted or unwilted sweet sorghum silage with increasing ensiling time.

## REFERENCES

Dewar, W. A., Whittenbury, R., Mcdonald, P. 1963. The hydrolysis of grass hemicelluloses during ensilage. *J. Sci. Food Agric*. 14(6), 411–417.

Mathur, S., Umakanth, A. V., Tonapi, V. A., Sharma, R., Sharma, M. K. 2017. Sweet sorghum as biofuel feedstock: recent advances and available resources. Biotechnol. *Biofuels*. 10, 146.

McDonald, P., Henderson, A. R., Heron, S. J. E. 1991. *The biochemistry of silage*. Chalcombe Publications, Marlow, UK.

Van soest, P. J., Robertson, J. B., Lewis, B. A. 1991. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. *J. Dairy Sci*. 74(10), 3583-3597.

Velmurugan, B., Narra, M., Rudakiya, D. M., and Madamwar, D. 2020. Sweet sorghum: a potential resource for bioenergy production. In: Kumar, R. P., Gnansounou, E., Raman, J. K., Baskar, G. (Eds.). *Refining biomass residues for sustainable energy and bioproducts*. New York, NY: Academic Press, pp. 215–242.

## Contact Information

Zhiqiang Sun: e-mail: sunzhiqiang@cau.edu.cn
Zhu Yu: e-mail: yuzhu33150@sina.com