How does milling impact the aspect ratio of miscanthus stem particles ?

Claire Mayer-Laigle, Boubker Chilah, Cécile Barron

How does milling impact the aspect ratio of miscanthus stem particles ?

Claire Mayer-Laigle, Boubker Chilah and Cécile Barron*

[1] *UMR IATE, Univ Montpellier, INRAE, Institut Agro, Montpellier, France.*
**Corresponding author*: cecile.barron@inrae.fr

Keywords: particle, elongation, grinding, lignocellulose

The increasing demand for recyclable and biodegradable materials has led to a growing interest in the use of natural fibers in technical composite applications. Natural fibers have been known to decrease the environmental impact of composite materials and to lightweight them strengthening their interest for automotive, building and construction sectors. However, the word "fiber" can take many different meaning and many plant organs have been studied: from pure bast fibers extracted from fiber plants (e.g. flax, hemp, or ramie) to particles from whole plant (e.g. miscanthus, cereal stems) or leaves (e.g. sisal, curauá, coir fibers), leading to a large range of plant-based composites performances. Among lignocellulosic crops, miscanthus seems to be a good candidate considering the high agronomic yield of the main cultivated species (Miscanthus gigantheus), its good water use efficiency and low intrant requirements [1]. However, miscanthus reinforced biocomposite materials exhibits lower mechanical properties than other plant fiber-composites (as flax or hemp fiber composite). The decrease in mechanical properties could be attributed to the fact that particles are more lignified, exhibits a lower aspect ratio, and has an important proportion of dust [2-4]. The production of tailor-made fibers (length and size) from miscanthus is thus a priority to improve the mechanical performances of such composite materials.

In this study, miscanthus fibers were obtained by grinding the whole plant then sieving the powder in order to select the most suitable fraction for further compounding process. The objective of this work was to establish a relationship between the comminution process and the aspect ratio of the miscanthus particles. In particular, the impact of the dominant mechanical stress and the mechanical work intensity in the grinder were studied**.**

Material and Methods.

<u>Material.</u> Whole miscanthus gigantheus stems were harvested after senescence (Novabiom, France). Leaves were discarded and internode were manually isolated.
<u>Milling technologies</u>. Different milling technologies have been used: knife mill SM100 (Retsch), impact mill (Hozokawa alpin^{TM} UPZ100) and centrifugal mill ZM200 (Retsch) using different screen size selectors (6, 4, 2 and 1mm) to generate different mechanical work intensity.
<u>Particle characterization</u>. The particle size distributions were obtained through mechanical sieving using adapted mesh sizes. The particle morphology was obtained by image analysis using a QicPic (Sympatec) with Gradis dispersion unit. The fibre length (Lefi) and diameter (Difi), and elongation factor (defined as the ratio of Difi to Lefi value) and their distributions were determined using Paqxos software.

Results.

Miscanthus was ground with knife mill, impact mill and centrifugal mill generating different main mechanical forces : shear and cut (knife mill) , impact (impact mill), and a combination of both impact+shear (centrifugal mill) [5]. Different experiments were conducted with screen size selectors set at 1mm, 2mm and 4mm (Figure 1) to generate different mechanical work intensity.

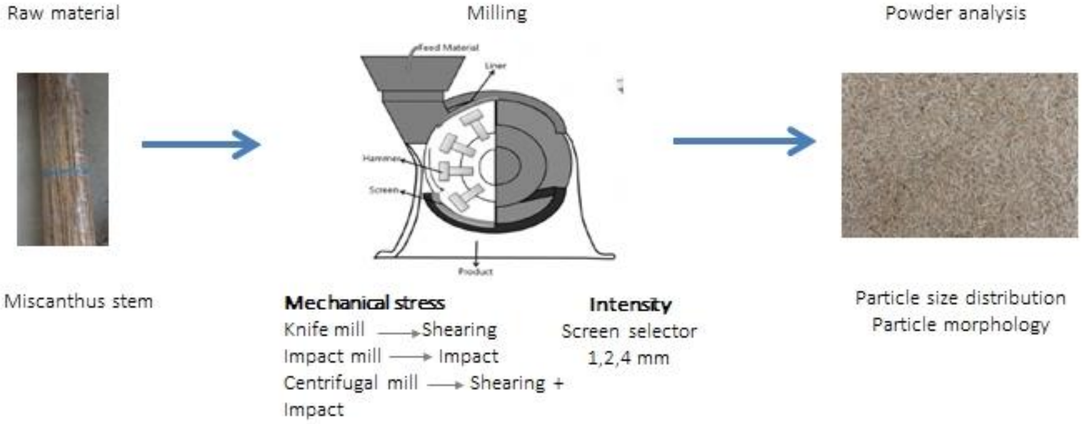

Figure 1. Experimental design

According to screen size selectors used, significant differences in particle size distribution were observed between the milling technologies. Knife mill tended to produce slightly smaller particle sizes and a larger amount of dust (<200µm) than impact mill.
Subsequently, more attention was paid to a sub-fraction, obtained between the 200µm and 500µm sieves, which appeared to be the most suitable for composite polymer applications. As expected the yield of this fine fraction increased as the screen size selector decreased for each type of grinder and reach values above ~40% for screen selector size equal to 2mm or below. The particle morphology of this fraction was studied using image analysis. Whatever the technologies considered, the coarser particles were more elongated. The particle length (Lefi) was more related on the selector screen size (mechanical work intensity) than on the mechanical stress generated by the milling technology. Indeed, even though collected on the same sieve ([200µm; 500µm[) the median particles length and elongation differ according to the screen size selector used. Smaller screen size selectors lead to shorter fiber length and less elongated particles. Thus, milling mainly affect the particle length rather than their diameter. The impact of the mechanical stress was most pronounced with the finest screen size selector (1mm). A medium elongation factor of 0.05 (=aspect ratio of 20) could be obtained for some fractions. The more elongated particles were obtained in the centrifugal mill (combination of shear and impact stress) compared to impact mill (mainly impact) and then knife mill (mainly shear and cut). This could be explained by the anisotropy of the miscanthus stem and the direction of the application of the constraint. In a knife mill, shearing is applied both parallel and orthogonal to the direction of the fiber, resulting in shearing but also in cutting of the fiber length. In the centrifugal mill, the centrifuge force drives the particle tangentially to the selector favoriting shearing in the lengthwise of the fiber.

To conclude, our study shows that the aspect ratio of miscanthus particles can be improved using tailored fractionation diagram while keeping acceptable yield of production. Multi scale milling has been shown to be potentially interesting to preserve the initial particle shape and maximize the particle aspect ratio.

[1] van der Weijde, Kiesel, Iqbal, Muylle, Dolstra, Visser et al. *GCB Bioenergy* **2017**, 9, 176-90.
[2] Bourmaud, Beaugrand, Shah, Placet, Baley. *Progress Materials Sci.* **2018**, 97, 347-408.
[3] Bourmaud, A; Pimbert, S. *Comp. Part A: Applied Sci. Manufacturing* **2008**, 39, 1444-54.
[4] Girones, Vo, Arnoult, Brancourt-Hulmel, Navard, P. *Polymer Testing* **2016**, 55, 166-72.
[5] Mayer-Laigle, Rajaonarivony, Blanc, Rouau. *Bioengineering* **2018**, 5