

COB-2023-2234 EXPERIMENTAL DETERMINATION OF THE MINIMUM FLUIDIZATION VELOCITY OF THE AÇAÍ SEED TO BE USED IN FLUIDIZED BED FURNACES

Amanda Cristina Ferreira Carvalho
Hendrick Maxil Zárate Rocha
Danielle Regina da Silva Guerra
Manoel Fernandes Martins Nogueira
Arthur Vilhena Lima
Paloma Gama da Silva

Universidade Federal do Pará - Belém/Pa
amanda.carvalho@itec.ufpa.br
hendrick@ufpa.br
daguerre@ufpa.br
mfmn@ufpa.br
arthur.lima@itec.ufpa.br
paloma.silva@itec.ufpa.br

Abstract. In Brazil, the state of Pará is the largest producer of açai, with a production of approximately 1,300,000 tons/year. Considering that for each ton of açai processed, 90% of the seeds are obtained, the available annual mass of seeds is around 1,170,000 tons. Most of the waste is either dumped in sanitary landfills in Belém and in the producing municipalities, or is accumulated as open garbage, causing considerable environmental impacts. Currently, the industry uses several processes based on fluidization technologies, due to the fact that fluidized beds have higher heat transfer rates, efficient in addition to a more thermochemical conversion. One of the most important parameters in particle fluidization is the minimum fluidization velocity of the bed, which depends on the size, shape and specific mass of the particles. In the case of açai seed, the existing information about the fluidization characteristics is very limited, the minimum objective of this study is to determine the fluidization speed of the açai seed for its application in fluidization processes. The different properties of the açai seed particles and their influence on the fluidization behavior in a cold fluidized bed were determined by analyzing the pressure drop and the air velocity in the bed.

Keywords: Açai seed; Fluidized bed; minimum fluidization velocity

1. INTRODUCTION

A renewable energy source that can be biodegradable as a renewable chemical energy source and potentially biodegradable to be a non-fossil biodegradable organic matter, through processes such as chemical and biodegradable biomass, through processes such as chemical biomass can be used for fluidization and gasification. In recent years, biomass has come to be considered an alternative for the diversification of world energy and, consequently, a viable way to reduce dependence on fossils, since, even though it is little In this matrix, biomass is one of the sources for the production energy sector with the greatest growth potential in the coming years. In this respect, the world scenario for renewable energy research has received special attention.

The use of different biomasses as fuels in energy generation is a focus of interest in several parts of the world. This change in relationship with the finitude of non-renewable sources, in addition to the energy potential of some biomasses, as is the case of açai (*Euterpe oleracea*), a native palm tree naturally occurring in Central and South America. The largest national producer is the largest national producer with 1,228.8 tons/year of fruits from Pará in the 2015 harvest. De concordasend et al. (200%) about 83% of açai production is solid waste (seeds), thus producing, in the year 2015, in the year 2015, between 1.015 and 1.044489 tons of waste per year.

According to Moreira (2019), fluidized bed is an engineering process characterized by presenting a bed of particulate materials that must behave in a fluidic regime. The great advantage of fluidized beds is that they achieve higher and more efficient heat and mass transfer rates, allowing for greater uniformity of temperature distribution H. Rezaei et al (2017). Due to this efficiency, the fluidization technology is called "clean", as it allows burning fuels considered of lower quality, as is the case of biomass in this case, açai. In this case, a biomass with irregular geometry, in this case the fluidized bed is the most indicated (Shukrie et al., 2016).

The most important parameter in the design of a gas-solid system is the minimum fluidization velocity (V_{min}). This parameter depends on the size, shape and density of the particles, since irregular particles exhibit different fluidization behavior when compared to regular surface particulates (Rezaei et al., 2017). The objective of the present study is to determine the minimum speed of fluidization of açai seeds, in addition to their characteristics such as sphericity, diameter and bulk density.

2. MATERIALS AND METHODS

2.1 Preparation of açai seed

The açai (*Euterpe oleracea*) seeds in natura were obtained from producers located in the district of Belém, state of Pará, they were initially dried at a temperature of 105°C for thirty minutes using a muffle oven of the brand Quimis, model Q318M21. Subsequently, the fibers were removed by agitation, obtaining the product shown in figure 1.



Figure 1. Dry, fiber-free açai seed

2.2 Determination of particle shape

Sphericity is determined by the ratio of an inscribed circle to the circle circumscribed in an irregular polygon (see Equation (1)). The more this polygon obtains a spherical shape, this ratio will tend towards a unit value ($\phi = 1$). To determine the sphericity of the analyzed particles, an imaging technique was used, where the inscribed and circumscribed circles are determined for each analyzed particle (see Figure 2). In all images, a reference scale was used to measure the diameters of the designed drawings.

$$\phi = \frac{d_{inscribed}}{d_{circumscribed}} = \frac{d_i}{d_o} \quad (1)$$

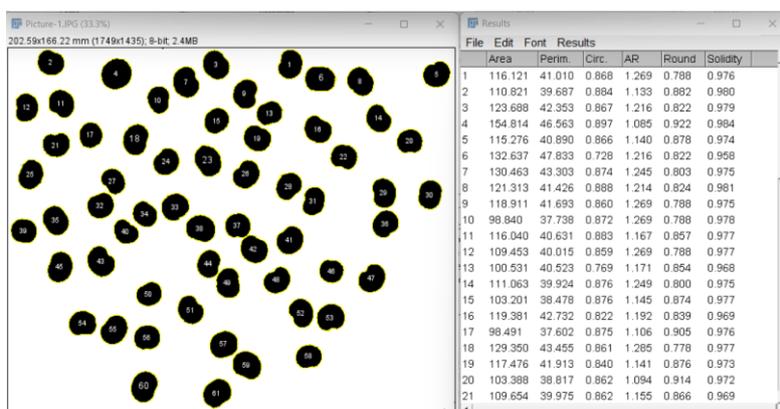
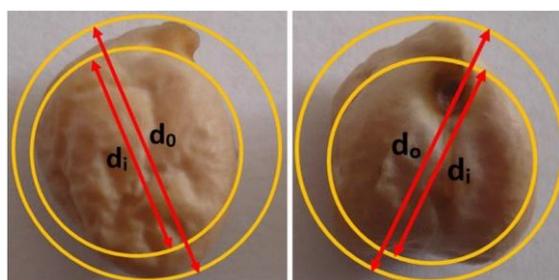


Figure 2. Image analysis to determine the sphericity of açai seed.
 Available from: Own authorship

The calculation of the average diameter and sphericity of the açai seeds was carried out with the aid of free software IMAGEJ developed by the National Institutes of Health (Schindelin et al, 2012), the program is open source in Java and uses digital image processing methods to determine the area of the particles of interest, after previous image processing and software calibration. Figure 3 and Figure 4 show the sequence of image processing and determination of the area occupied by each açai seed. In this step, 221 dry and fiber-free açai seeds were analyzed.

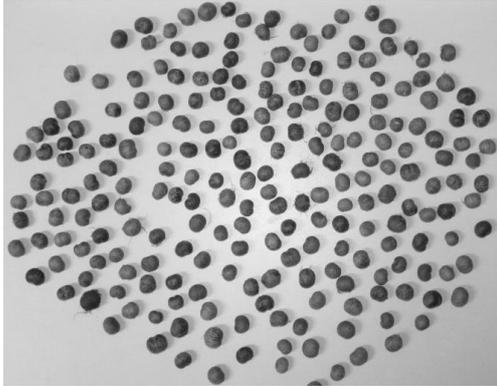


Figure 3. Recognition of pit surfaces
Available from: Own authorship

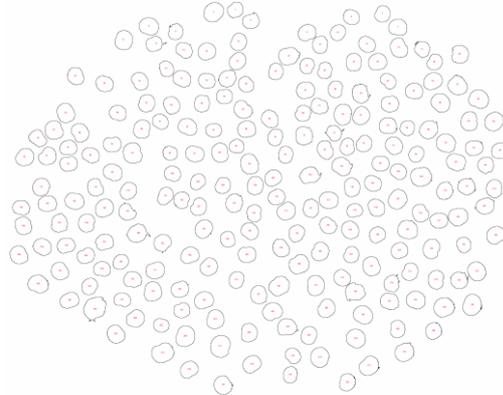


Figure 4. Recognition of pit surfaces
Available from: Own authorship

2.3 Determination of the bulk specific mass of açai seeds

The bulk density of açai seeds was initially determined by designing a wooden box measuring 25.2 x 28.8 x 9.0 cm representing a volume of 0.006532 m³, figure 5 and figure 6. This box was weighed empty and then filled with açai, with and without hair. The core limiting element was the closing of the box by sliding the lid. During sliding, excess pit was removed from the box. 10 measurements were performed for pits with fur and 10 for without fur. Bulk density was determined by equation 2.

$$\rho = \frac{m_{full} - m_{empty}}{V_{box}} \quad (2)$$



Figure 5. Acai kernel inside the reference box
– internal view
Available from: Own authorship



Figure 6. Acai kernel inside the reference box
– external view
Available from: Own authorship

2.4 Determination of the minimum fluidization speed

The minimum speed of fluidization of açai seeds was determined from an experimental fluidized bed bench designed in the engine laboratory of the faculty of mechanical engineering of the Federal University of Pará (UFPA), using a glass tube with an internal diameter of 68.3 mm. , 3.6 mm thick and 1 m long. On the bench, the air was induced by a radial blower with a power of 6.25 hp (JKW brand and JKW004 model) the blower rotation was controlled by a frequency inverter (WEG brand and CFW08 model) that allowed controlling the blower speed by varying the electrical frequency of the inverter from 0 to 60hz. The schematic diagram of the experimental bench is shown in figure 7.

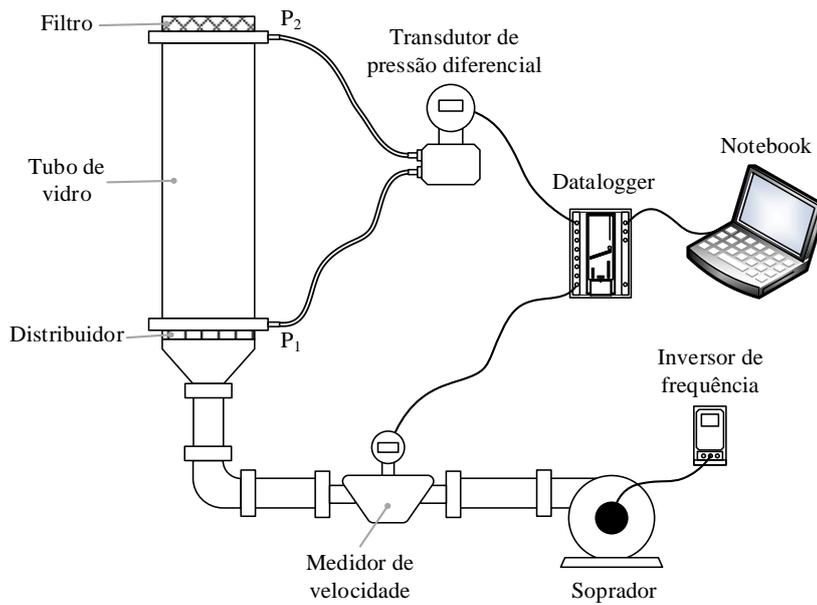


Figure 7. Schematic diagram of the experimental bench
Available from: Own authorship

The air flow is conducted from the blower to the bed through PVC tubes with a diameter of 60 mm, reaching a speed meter. Then the air flow reaches an air distributor with 3 mm holes (see figure 8). Right above the distributor, the first static pressure tap of the bed is located (see figure 9 and figure 10). At the top of the glass column is the second static pressure tap, both connected to a differential pressure transducer (Yokogawa brand, model EJ0110A) responsible for reading the pressure difference. The signals measured by the equipment were sent to a Datalogger data collection system (Contemp brand, model A202). Subsequently, the data were recorded in real time on the computer (see figure 7).



Figure 8. Air distributor
Available from: Own authorship

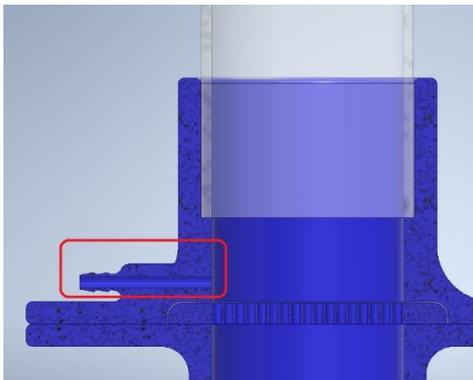


Figure 9. Internal view of the pressure taps
Available from: Own authorship



Figure 10. External view of the pressure taps
Available from: Own authorship

To determine the minimum fluidization velocity (V_{min}) of açai, the differential pressure of the bed was analyzed as a function of the air velocity. In the period prior to the beginning of fluidization, the bed resistance increases with the gradual increase in air velocity, where the transition point when this increase ceases or almost ceases defines the minimum fluidization velocity.

Observing Figure 11, we initially notice an increasing curve, after this almost linear curve, we have the minimum fluidization velocity, which can be identified in the region where the bed pressure decreases abruptly or when the pressure drop begins and remains constant as the fluidization velocity progresses, according to H. Rezaei et al (2017).

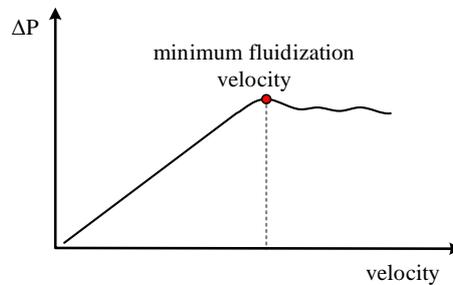


Figure 11. Representation of the minimum fluidization velocity

3. RESULTS AND DISCUSSION

3.1 Medium diameter and sphericity of açai seeds

The mean diameter obtained from the 221 samples of açai seeds without fiber was approximately 11.5 ± 0.9 mm. This parameter directly influences the values of minimum fluidization velocity, in addition, Shukrie et al (2016) in his studies on the average diameter of biomass particles found average values lower than those found in this study. In addition, very large particles provide a lower pressure drop.

Figures 12 and 13 show, respectively, the distribution of particle diameters and the sphericity of the açai seeds. It was observed that the particles have a shape close to a sphere, where the average sphericity value found was approximately $\phi=0.86 \pm 0.03$, close to 1. In a recent study Rezaei et al (2017) analyzing biomass particles, showed that particles with a sphericity close to 1 have a lower minimum fluidization velocity when compared to particles whose sphericity exceeds the value 1.

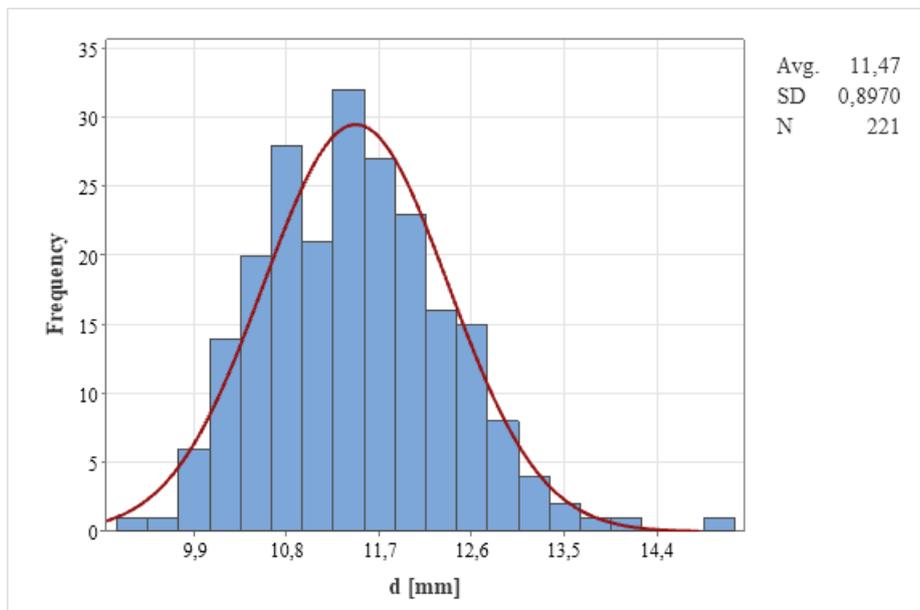


Figure 12. Histogram of the average diameters of dry and fiber-free açai seeds
Available from: Own authorship

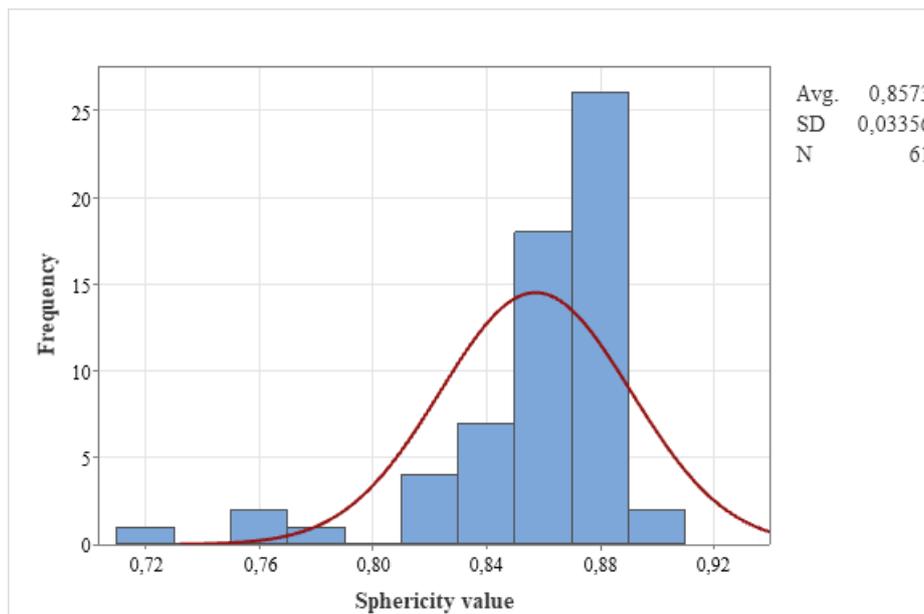


Figure 13. Histogram of the sphericity of açai seeds
 Available from: Own authorship

3.2 Apparent specific mass.

The apparent specific mass of açai seed in-natura and with determined fiber was $r = 425.3 \pm 0.5 \text{ kg/m}^3$ and of dry açai seed and without fiber was $r = 737.2 \pm 0.7 \text{ kg/m}^3$. In this aspect, the presence of fibers in açai seeds interfere na quantidade de massa armazenada em um mesmo volume. Portanto, há vantagens logísticas e de transporte na remoção das fibras das sementes de açai.

3.3 Minimum fluidization speed

To validate the results of the measurement of the minimum fluidization velocity, 34 experimental tests were carried out testing four bed heights: 90, 100, 110 and 120 mm of açai seed. The average result obtained was $4.4 \pm 0.2 \text{ m/s}$. Studies with biomass with a diameter of less than 1 mm found a minimum fluidization velocity lower than those defined in this study, so it was possible to verify the correlation described by Abdullah et al (2016) and Rezaei et al. (2017) which shows the influence of the average diameter and sphericity of the particles on the minimum fluidization velocity

Figure 14 shows the histogram of frequencies, the mean and the standard deviation of the tests performed. The minimum speed found in this study was similar to the speeds found in (Shukrie et al., 2003).

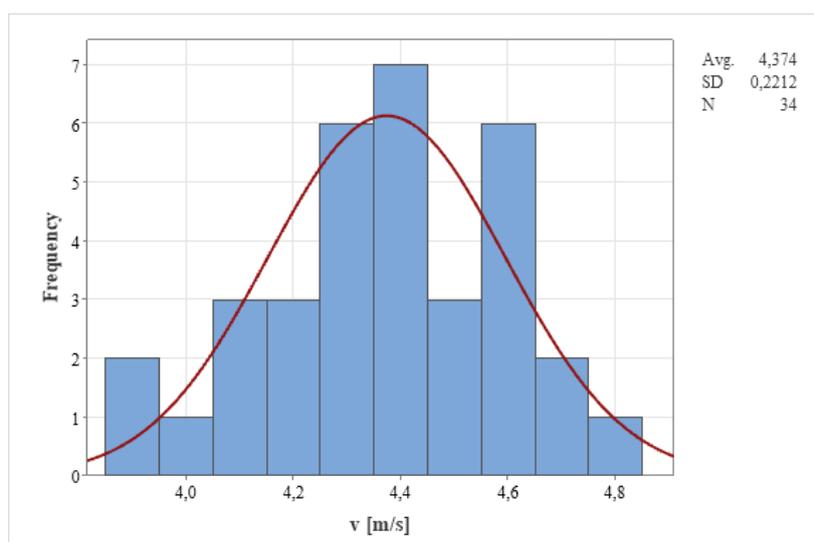


Figure 14. Histogram of the minimum fluidization velocity
 Available from: Own authorship

Figures 15, 16, 17 and 18 show the results of the pressure drop, and the minimum fluidization velocity found for the four analyzed bed heights, in which it is possible to observe the phenomenon of a sudden pressure drop followed by its oscillation, as described by H. Rezaei et al (2017).

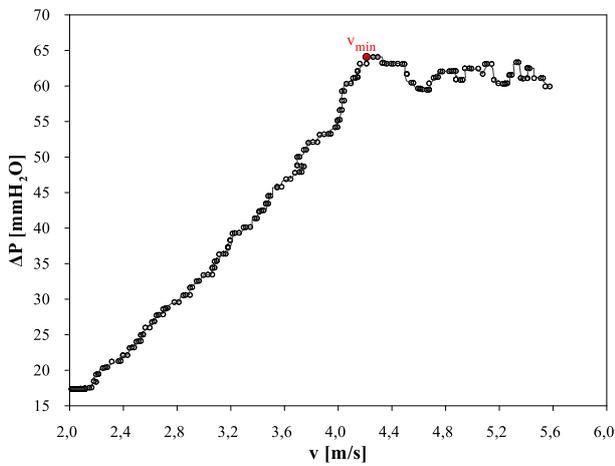


Figure 15. Test with a bed height of 90 mm
Available from: Own authorship

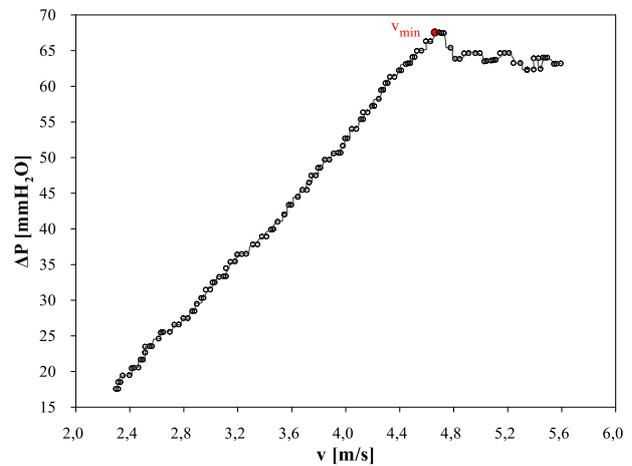


Figure 16. Test with a bed height of 100 mm
Available from: Own authorship

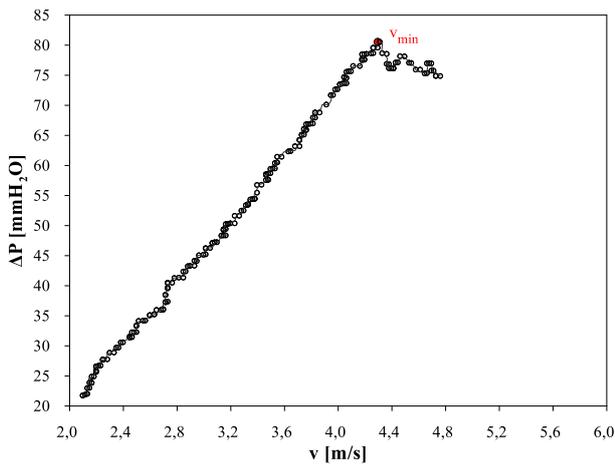


Figure 17. Test with a bed height of 110 mm
Available from: Own authorship

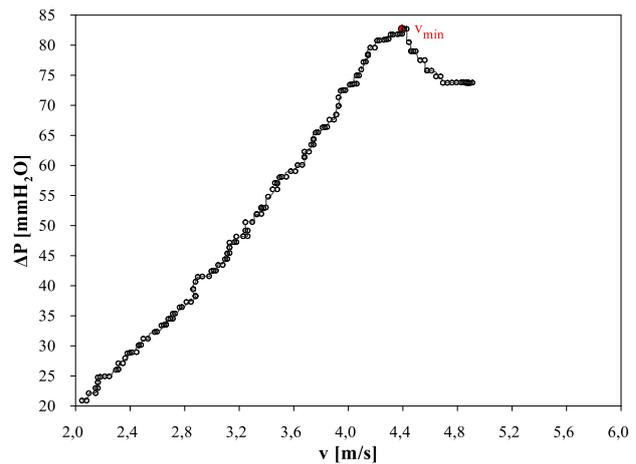


Figure 18 - Test with a bed height of 120 mm
Available from: Own authorship

The pneumatic transport speed was not measured, because the internal diameter of the reactor in relation to the average diameter of the açai seeds is very small (60 mm), favoring the accumulation of particles that move together, as shown in Figure 19. In the future, a new reactor will be built with a greater number of pressures taps and a larger internal diameter, which will allow the measurement of the pneumatic transport speed.



Figure 19. Displacement of the açai bed
Available from: Own authorship

It is worth mentioning that no studies published in Brazilian and international databases were found for data on the minimum fluidization velocity of açai seed in a fluidized reactor.

4. CONCLUSÃO

The results showed that dry and fiber-free açai seeds have good fluidizing behavior, and that seeds with fibers tend to aggregate, reducing the porosity of the bed and thus making fluidization difficult. It was also found that the geometry of the particles is almost spherical, so it is easier to start the fluidizing process. However, further studies are still needed on the influence of the presence or absence of fibers in açai seeds as well as to analyze the influence of seed geometry on pressure drop.

5. REFERENCES

- Abdullah, M.Z., Husain, Z., Yin Pong, S.L.,2003."Analysis of cold flow fluidization test results for various biomass fuels". *Biomass and Bioenergy*, Vol.24, pp. 487–494.
- Shukrie, A., Anuar, S., Oumer, A.N.,2016 "Improvement on particulate mixing through inclined slotted swirling distributor in a fluidized bed: An experimental study". *Advanced Powder Technology*, Vol. 27, pp. 2102 –2111.
- Rezaei, H., Sokhansanja,S., Jim Lim, C.,2017."Minimum fluidization velocity of ground chip and ground pellet particles of woody biomass". *Chemical Engineering & Processing: Process Intensification*, Vol.124, pp.222-234.
- Claudio Ramalho Townsend; Newton de Lucena Costa; Ricardo Gomes de Araújo Pereira; Clóvis C. Diesel Senger. Características químico-bromatológica do caroço de açai. COMUNICADO TÉCNICO N° 193 (CT/193), EMBRAPA-CPAF Rondônia, ago./01, 1-5. ISSN 0103-9458, <https://ainfo.cnptia.embrapa.br/digital/bitstream/item/100242/1/Cot193-acai.pdf>
- Schindelin, J., Arganda-Carreras, I., Frise, E., Kaynig, V., Longair, M., Pietzsch, T., ... Cardona, A. (2012). Fiji: an open-source platform for biological-image analysis. *Nature Methods*, 9(7), 676–682. doi:10.1038/nmeth.2019.
- Moreira, N.A.R., 2019. *Caracterização da combustão de carvões vegetais em leito fluidizado*. Ph.D. thesis, Universidade do Porto, Cidade do Porto, Portugal.

RESPONSIBILITY NOTICE

The authors are the only responsible for the printed material included in this paper.