Analysis of the Performance of an L-Valve Feeding Spent Coffee Ground Powders into a Circulating Fluidized Bed

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- Feeding powders continuously and with stable mass flowrate is challenging;
- Feeding residue-based powders is more difficult: size-distribution, shape, moisture content...

Soluble Coffee Industries → **Spent Coffee Grounds (SCGs)** → ***Renewable energy***

Around 2.5 million ton/year
High heat value (~25 kJ/kg)

Feeding of unit operations, and reactors

↓

Silos, Rotary valve, Screw feeder etc…

→ ***Non-mechanical feeding devices*** → ***L-valve***

Objectives

● Could non-mechanical L-valves be used to feed SCGs to Circulating Fluidized Beds (CFBs)? (Biomass residue/Geldart B powders with low particle density).

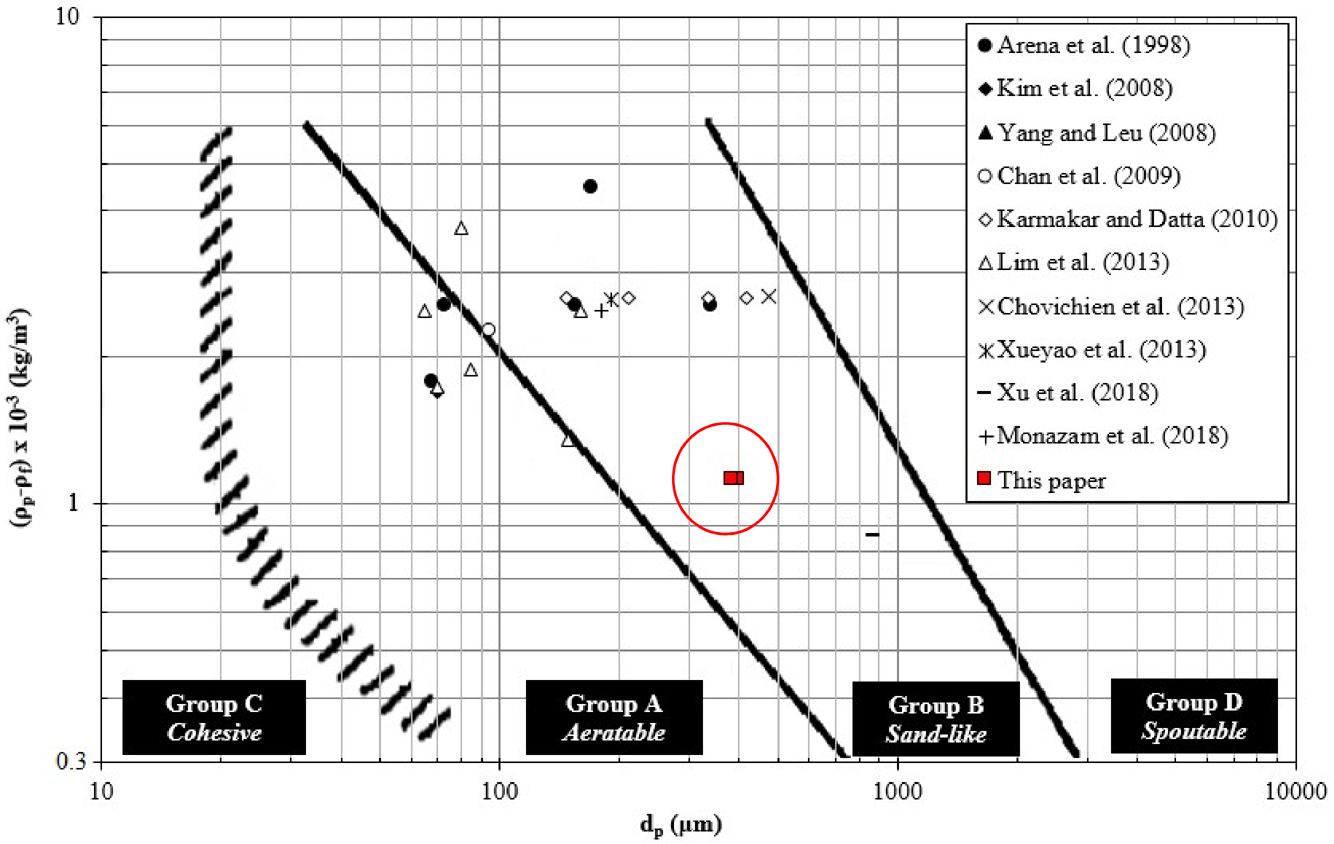


Fig 1. Geldart classification of the powders that have already been fed to CFBs using L-valves in the literature, and region for the dry powders used in this study.

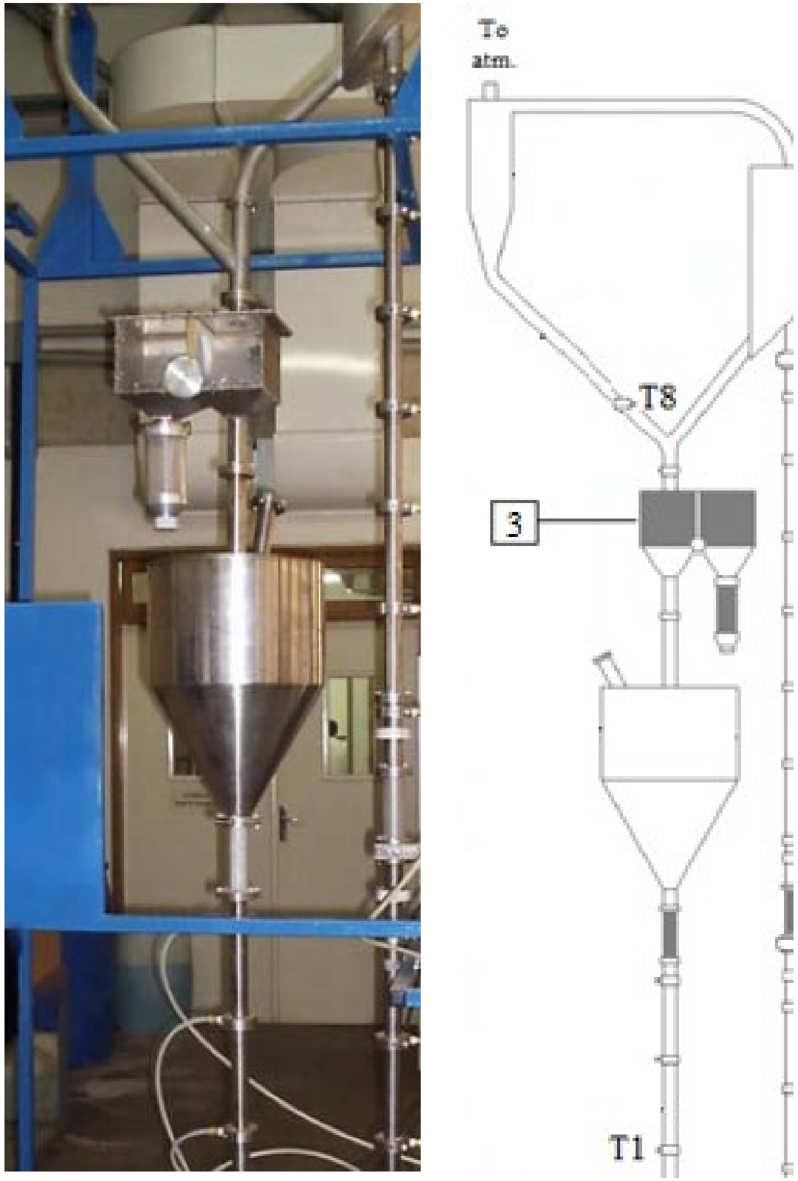
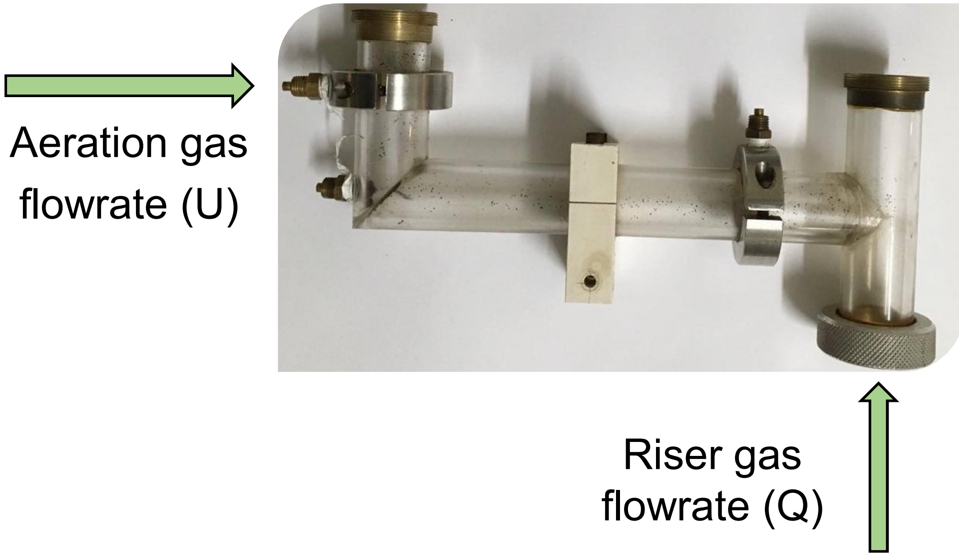


Fig 2. Experimental setup.

Fig 3. L-valve and its operation variables.



- <u>SCG samples</u>:

B_{100}: d_{sv}=400 μm (sieve range: 500-300 μm)

$B_{90}C_{10}$: 10% of fine particles (300-100 μm)
90% of sample B_{100}

B_{100wet}: 30% *wet basis* samples with d_{sv}=400 μm.

Methodology

- **SCG samples:**
  B_{100}, $B_{90}C_{10}$ and B_{100wet}

- **Aeration gas flowrate (U):**
  7, 14, 21 and 28 L/min

- **Riser gas flowrate (Q):**
  220, 250, and 280 L/min

- **Monitored variables/outputs:**
  Pressure in the CFB loop (T1-T8)
  Solids circulation rate (Ws)

- Assays performed in triplicate for each experimental condition

Table 1. Summary of the experimental conditions.

Experimental condition	SCG sample	U (L/min)
Number 1	B_{100}	7.0
No. 2	B_{100}	7.0
No. 3	B_{100}	7.0
No. 4	B_{100}	14.0
No. 5	B_{100}	14.0
No. 6	B_{100}	14.0
No. 7	B_{100}	21.0
No. 8	B_{100}	21.0
No. 9	B_{100}	21.0
No. 10	B_{100}	28.0
No. 11	B_{100}	28.0
No. 12	B_{100}	28.0
No. 13	B_{100wet}	7.0
No. 14	B_{100wet}	7.0
No. 15	B_{100wet}	14.0
No. 16	B_{100wet}	21.0
No. 17	B_{100wet}	28.0

1) The effect of the riser gas flowrate (Q) on the solids circulation rate (Ws)

- Ws is not affected by small changes in Q for any SCG sample;
- L-valve operation is not affected by small variations/fluctuations in Q;

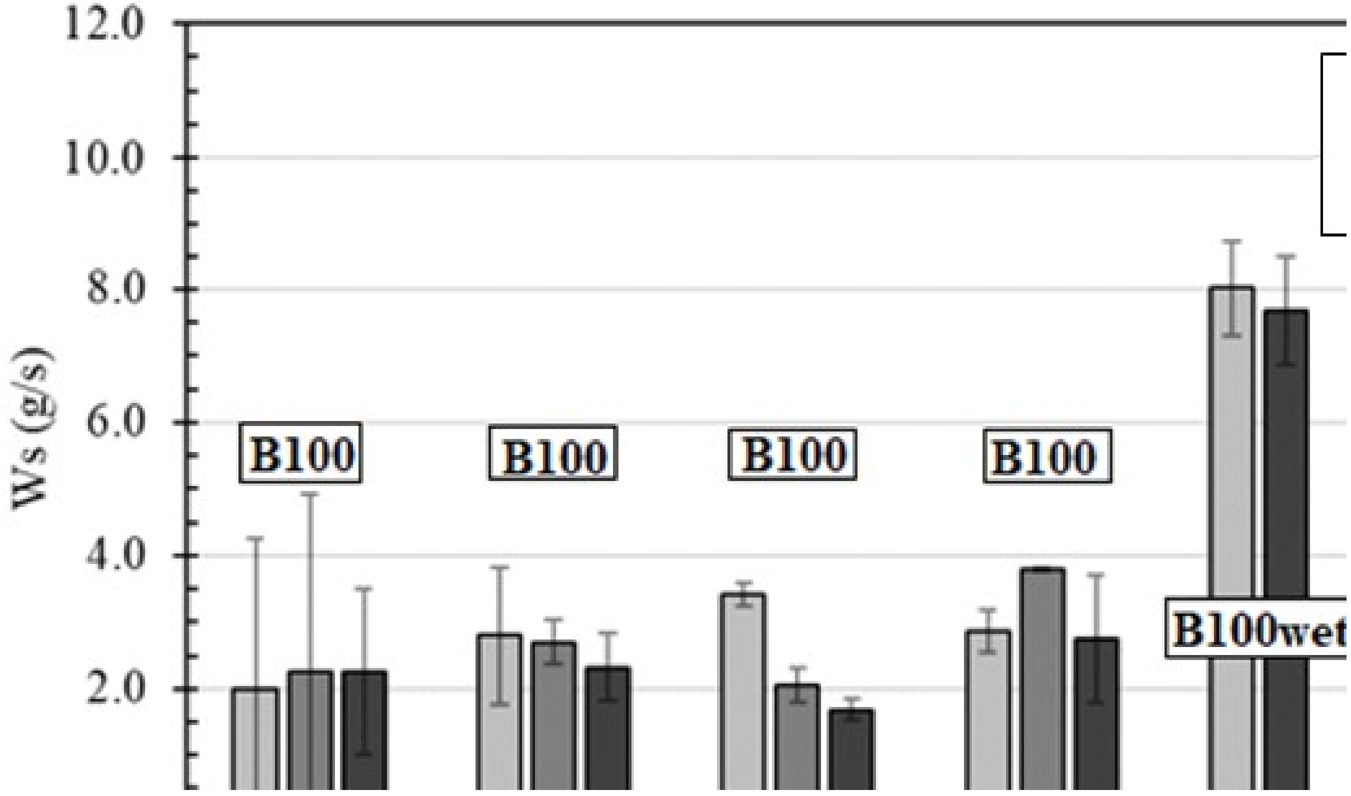


Fig. 4. Influence of Q on Ws for dry and wet SCG samples: B_{100} (assays 1 to 12), B_{100wet} (assays 13-14), and $B_{90}C_{10}$ (assays 19-20).

2) The effect of aeration gas flowrate (U) on the solids circulation rate (Ws)

- Wet sample is normally controlled in the L-valve;

- The Ws can not be varied by adjusting U for the dry samples ($B_{100}/B_{90}C_{10}$);
  Not all Geldart B powders could be normally controlled using L-valves.

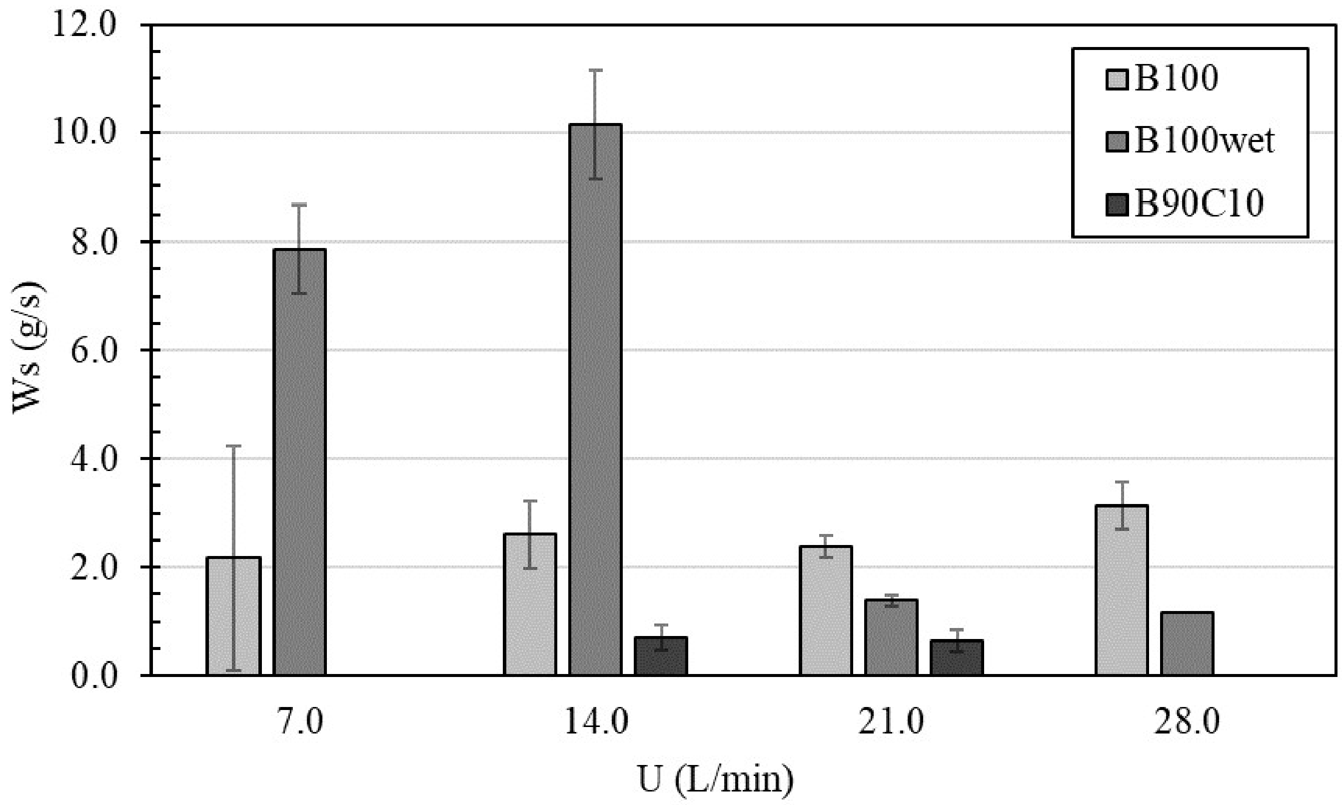


Fig. 5. Influence of U on Ws for dry and moist SCG samples.

Results

● The workability of the L-valve and Ws seems to be limited by the deterioration of the flowability of the sample. ($Ws_{B100wet} > Ws_{B100} > Ws_{B90C10}$)

Table 2. SCG properties.

SCG sample	d_{SV} (μm)	MC (% w.b.)	AoR[d] (°)	Flo class
B_{100wet}	400	30.0 ± 0.3[a]	42 ± 2[a]	Pa
B_{100}	400	2.8 ± 0.1[b]	62 ± 3[b]	Ve

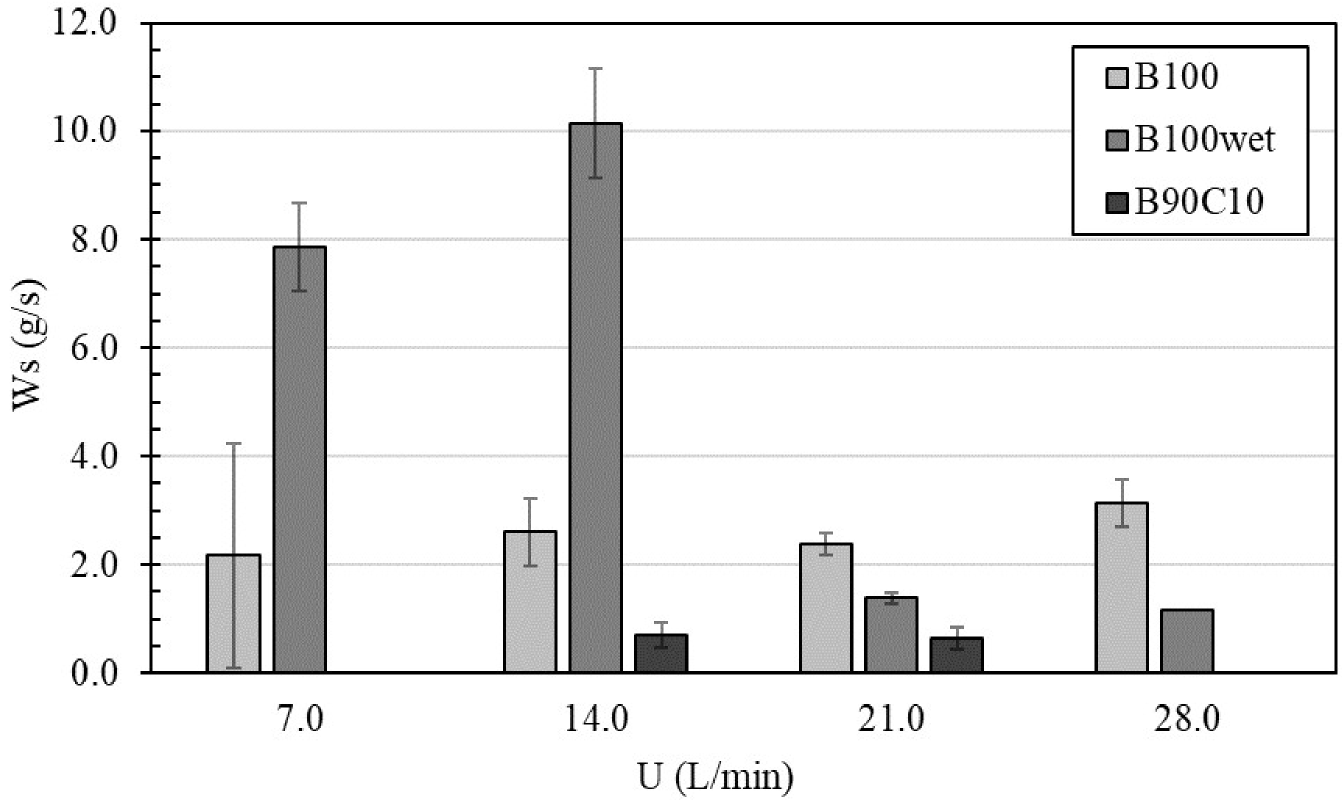


Fig. 5. Influence of U on Ws for dry and moist SCG samples.

3) The effect of aeration gas flowrate (U) on the pressure around the CFB loop

- The pressure in the CFB loop changes only when Ws changes with U (wet samples).

- Dry samples: no change in the pressure are observed by changing U;

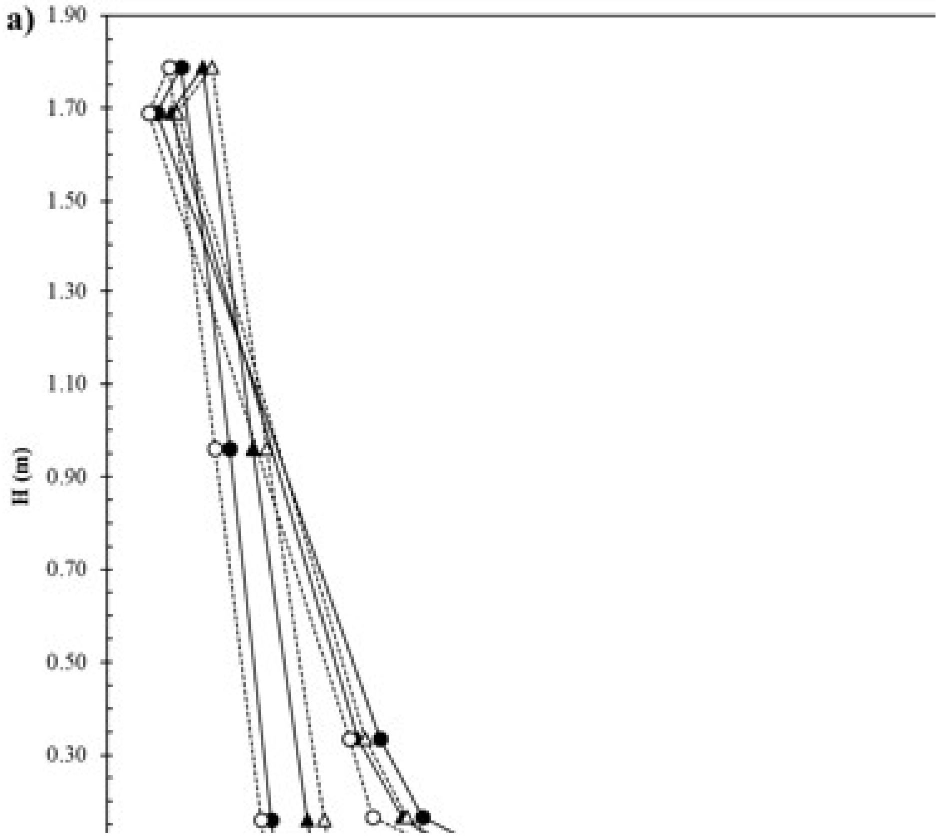


Fig. 7. Example of pressure around the CFB loop for sample B_{100} with different U

- <u>Wet samples</u>: higher pressure is observed when Ws is higher (low aeration flowrate)

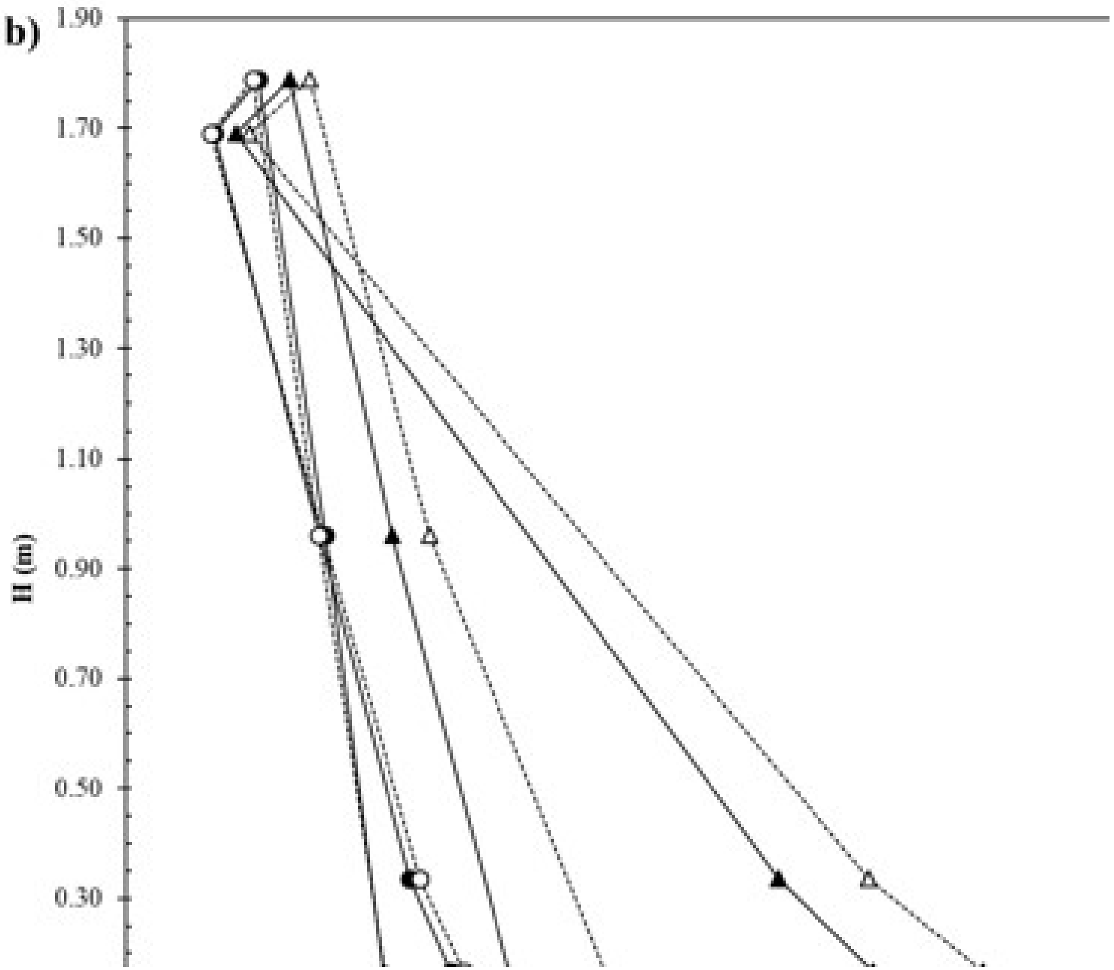


Fig. 8. Example of pressure around the CFB loop for sample B_{100wet} with different U

4) Correlations for solids mass flux (Gs) and pressure drop in the L-valve (ΔP_{LV})

- A new correlation to predict Ws from pressure drop in the L-valve was proposed.

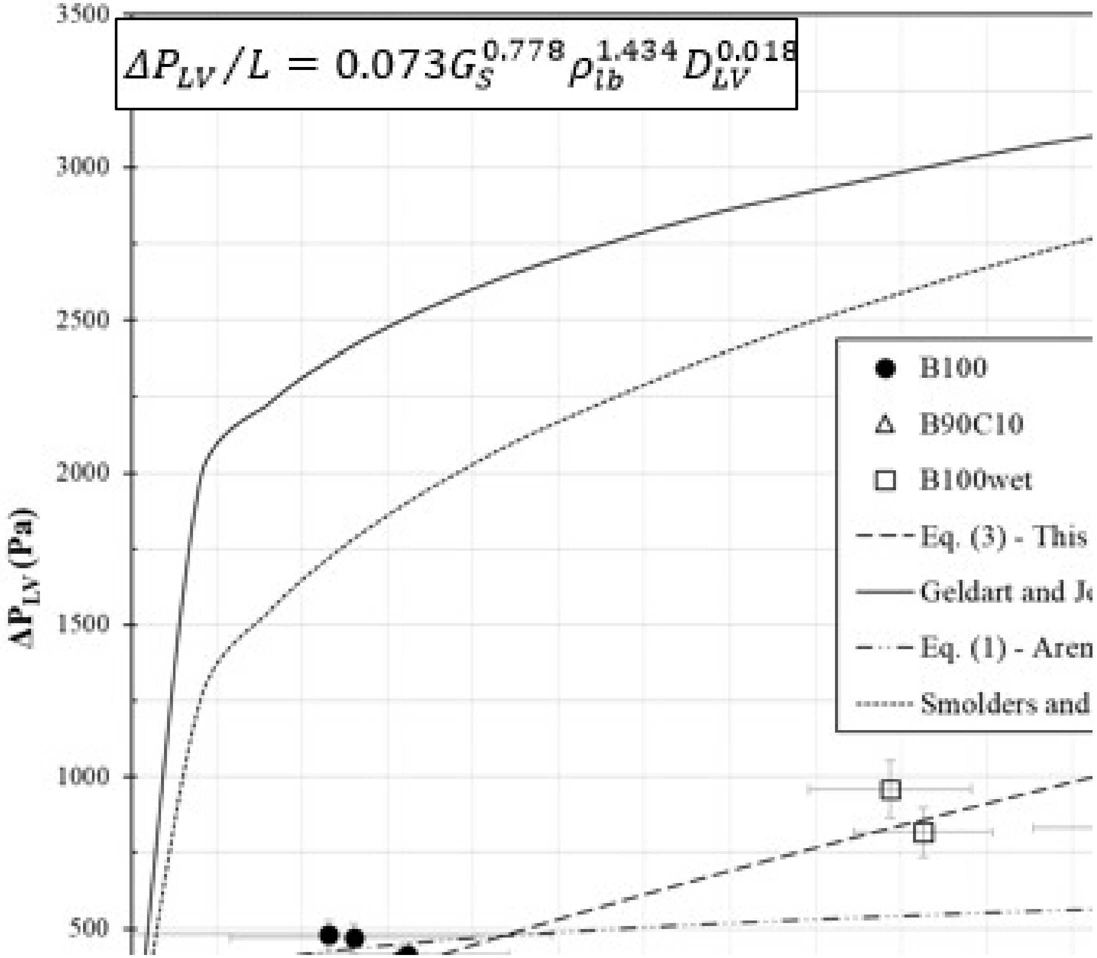


Fig. 9. Comparison of experimental data with correlations predictions.

Conclusions

We verified that the:

- L-valve feeding of Geldart B powders is different when using biomass powders.
- Solids circulation rate of SCGs is limited by the deterioration of the flowability.

Using L-valves to control Ws of SCGs for renewable energy applications looks promising:

> *To burn SCGs effectively in the soluble coffee industry furnaces, the recommended moisture should vary from 25 and 50% w.b. The lower limit is set to avoid spontaneous combustion and the upper one to preserve burning efficiency (Silva et al., 1998).*

- Small fluctuations in the riser air flowrate do not affect the L-valve operation. (Robust)
- Feeding of moist SCGs is normally controlled in the L-valve. (Stable and Adjustable)
- Ws can be predicted from easy pressure measurements in the L-valve. (Process control)

Silva, M. A., Nebra, S. A., Silva, M. J. M., & Sanchez, C. G. (1998). The use of biomass residues in the Brazilian soluble coffee industry. Biomass and Bioenergy, 14(5–6),457–467.

Thank you!

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