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Direct coupling of low frequency ultrasound to a crossflow microfiltration pilot plant for pulpy fruit juice clarification (*Artocarpus heterophyllus* Lam.)

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Context and objective

Jackfruit (*Artocarpus heterophyllus* Lam.) bulbs are a rich source of bioactive compounds with important properties for human nutrition. Therefore, non-thermal processing of fruits is of interest to preserve their sensory, nutritional and biological properties. Crossflow microfiltration (CFM) allows microbial stabilization, clarification of liquids and recovery of insoluble compounds. However, membrane fouling due to the accumulation of matter on and in the membrane reduces filtration performance. The application of low frequency ultrasound (US) inducing cavitation effects at the membrane surface in the filtration module (sono-microfiltration) is a new way to reduce its fouling.



The aim of this study was to evaluate the effect of a direct coupling of low frequency ultrasound (20 kHz) to a crossflow microfiltration system on membrane fouling during the clarification of a pulpy jackfruit juice. The effect on the product composition was also evaluated through the content of phenolic compounds.

Materials and methods

Jackfruit juice processing: pulping with 0.8 mm mesh size; enzymatic hydrolysis 1% (pectinase:cellulase 1:1) formulation with pulp:water 1:2 to reach a viscosity of 11 mPa·s



CFM device (Figure 1) and operating conditions: $\varnothing_{\text{pores}} = 0.2 \mu\text{m}$, ceramic membrane ($\text{TiO}_2 - \text{ZrO}_2$), 23 channels, filtration area 0.17 m^2 transmembrane pressure (TmP) 2.7 bar, temperature (T) $< 35^\circ\text{C}$, crossflow velocity (U) $6 \text{ m}\cdot\text{s}^{-1}$, volume reduction factor (VRF) 1.85 **Ultrasound (US):** 20 kHz, 700 W, 25 mm diameter probe, 30 and 40% amplitude (A), ultrasound pulses with application of 0.2 and 1 min (ON) with frequency of application every 1 and 5 min (OFF)

Evaluation of the sono-crossflow-microfiltration process (SCFM): permeate flux (J_p), ultrasonic energy (USE) and total soluble phenols (TSP).

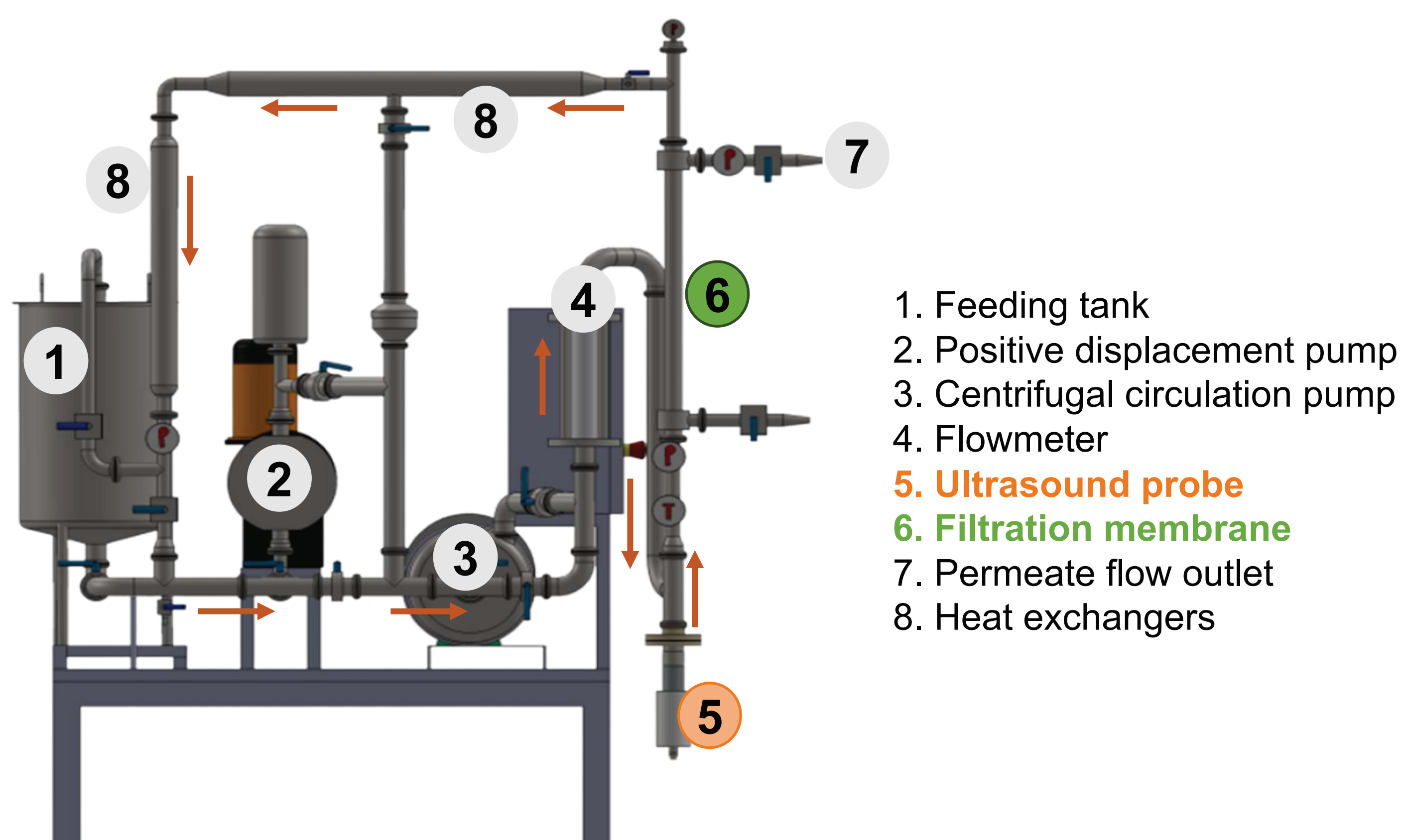


Figure 1. Sono-microfiltration pilot device

Results and discussion

The initial J_p are all between 240 and $290 \text{ L}\cdot\text{h}^{-1}\cdot\text{m}^{-2}$ (Figure 2) with a reduction observed in the first 12 min of the process, caused mainly by the blockage of pores due to the high turbidity and concentration of solids in the juice, quickly fouling the membrane. The CFM process without US showed the lowest J_p at 12 min, while the operating conditions of US2 showed the highest J_p .

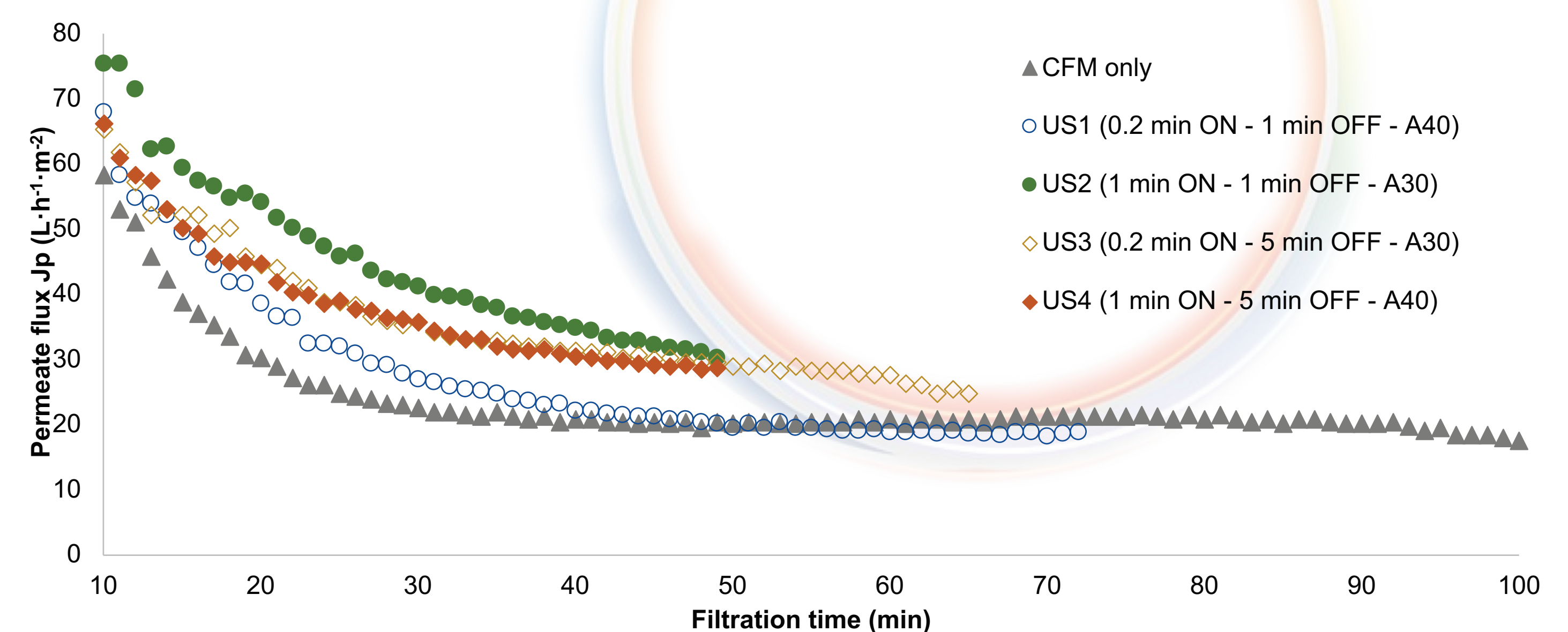


Figure 2. Effect of US application on J_p during SCFM of jackfruit juice

The CFM of a 20 L batch of jackfruit juice (JJ) required 100 min to achieve a VRF of 1.85 with a J_p of $21 \text{ L}\cdot\text{h}^{-1}\cdot\text{m}^{-2}$ at the end, while the application of US showed a reduction of 50% (50 min), 47% (53 min), 35% (65 min) and 28% (72 min) of needed time for US2, US4, US3 and US1, respectively. The two best treatments for reaching a concentration factor of 1.85 were US4 and US2, which presented the highest J_p at the end ($39 \text{ L}\cdot\text{h}^{-1}\cdot\text{m}^{-2}$). So the sono-microfiltration system is effective in achieving higher juice production in less processing time. The use of US increased 81% in flux, in addition to reducing 50% of the processing time to reach VRF 1.85.

The impact of US on deposited particles is mainly governed by the power and the effective distance between the probe and the membrane surface. Of the 4 phenomena that can explain the effect of US on permeate flux, acoustic streaming and radiation strength are the most likely, as they are known to be effective up to a distance of several centimeters from the sonotrode, whereas micro-jets and microstreaming that only act a few micrometres far from the ultrasonic probe, cannot reach, in the tested configuration, the membrane to reduce fouling.

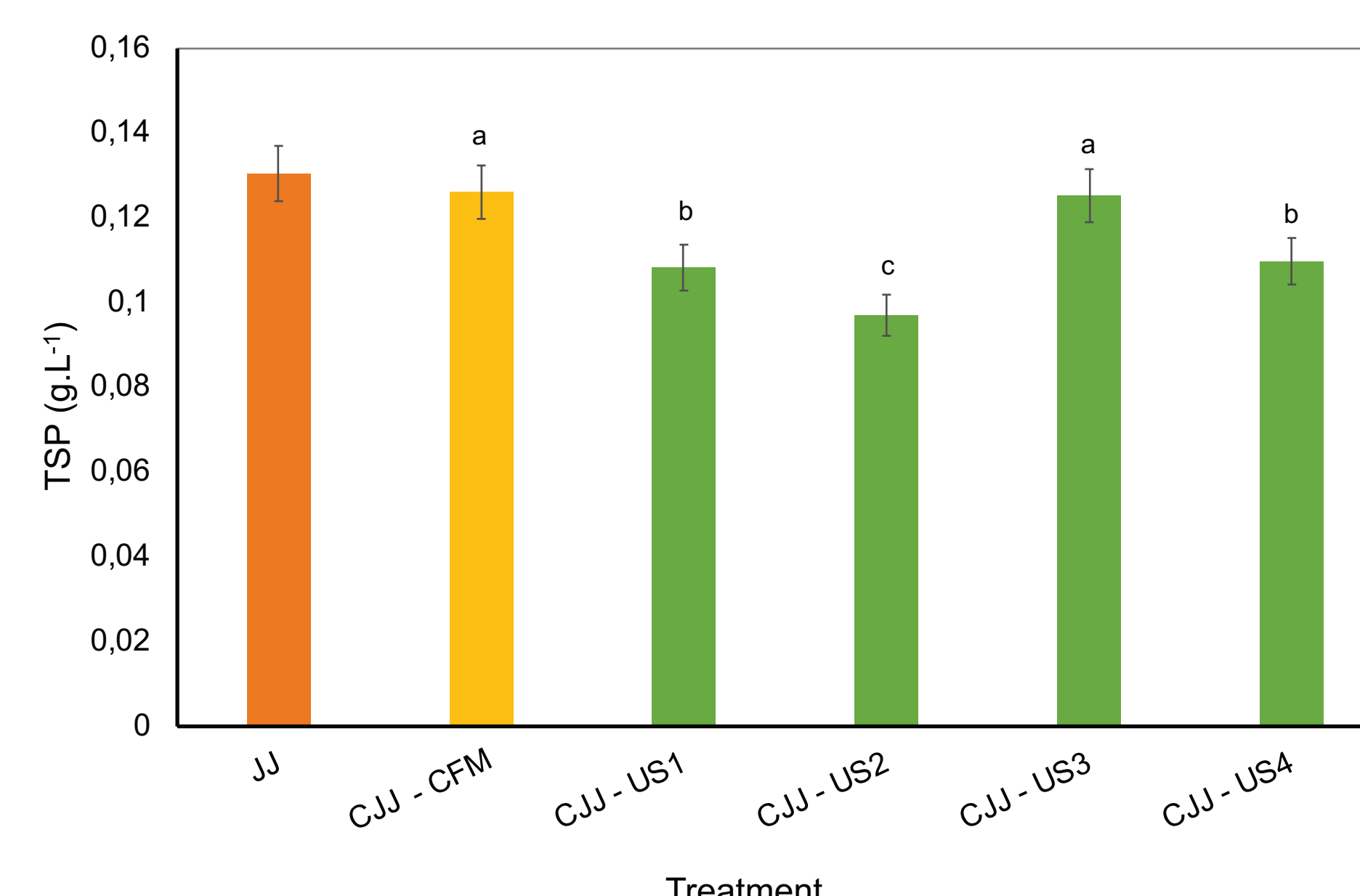


Figure 3. Total soluble phenols (TSP) in jackfruit juice treated by SCMF compared with the raw juice (JJ)

Table 1. Ultrasonic energy USE generated during sono-crossflow-microfiltration

Operating conditions	USE (kJ·L ⁻¹)
US1	5.17 (0.11)
US2	8.44 (0.07)
US3	0.87 (0.14)
US4	4.58 (1.1)

The evaluation of the effect of the CFM without US application on TSP showed a 3% reduction (Figure 3). However, the US caused the degradation of the compounds in the clarified jackfruit juice (CJJ) between 0.6 and 22.2% compared to the initial jackfruit juice (JJ). Values were directly related to the USE generated in the juice probably due to sonolysis (Table 1). Therefore, the best operating conditions to keep the TSP concentration stable were 0.2 min ON – 5 min OFF – A30.

Finally, the statistical analysis showed that to have a higher flux in a juice with high turbidity ($> 11500 \text{ NTU}$), the following conditions must be met in the SCMF system: lower US amplitude, higher ON pulse, and higher OFF pulse.

Conclusion

Low frequency ultrasound coupling to a crossflow microfiltration unit effectively increased the permeate flux during the treatment of a highly pulpy jackfruit juice and reduced the processing time to achieve the same concentration factor compared to a conventional crossflow microfiltration unit. The evaluation of the operating conditions showed that short US pulses had to be applied more frequently with low ultrasound amplitude to obtain higher permeate flux and to preserve total soluble phenolics. Further studies are required to evaluate the effect of the irradiation modes (curative/preventive) correlated with the ultrasonic power applied in the process on the filtration performance, as well as its effect on membrane damaging and preservation of functional compounds in the juice by SCFM.