OBTAINING CLARIFIED PITAYA (*Hylocereus* spp.) JUICE BY TANGENTIAL MICROFILTRATION - A PROCESS STUDY

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ABSTRACT

Due to the increasing production of pitaya due to its physical and functional characteristics, such as a high concentration of betalains, it is necessary to develop and present viable processes for the possible use of such compounds. Thus, the present study aims to provide a possible strategy to process the pitaya juice with and without peel by tangential microfiltration. The pitaya juice with peel and without peel was submitted to an enzymatic treatment with 2000 mg.L^{-1} of commercial pectinolytic enzyme for 60 minutes, later the tangential microfiltration process was studied. The process parameters such as permeate flow, fouling and energy consumption were evaluated, in addition to a rheological study of all the fractions obtained. The processes with pitaya without peel obtained better permeate fluxes (±25% higher than the process with peel) and lower energy expenditure. The predominant resistance of the shelled process is concentration polarization and the resistance of the shelled process is fouling (reversible + irreversible). Only the clarified juice from both processes came close to a Newtonian fluid. It is concluded, therefore, that there is feasibility for a future industrial scale-up study.
Keywords: energy consumption, fouling, rheology

INTRODUCTION

Pitaya (Hylocereus spp.) is native to Central and South America (1) and is commercially cultivated on a large scale in Mexico, Guatemala, and the United States (South Florida. Pitaya cultivation has recently been initiated in the semi-arid region of Brazil, such as in the state of Ceará (2). A particular advantage of growing pitaya as a crop in dry locations is its potential to contribute to agricultural development in these regions due to its high tolerance to drought stress over long periods and poor soils (3). Due to the attractiveness of its color and flavor, world production is increasing rapidly, as well as the insertion of new technologies for full utilization of the fruit (4).

Another advantage of pitaya and its great agricultural expansion occurs due to its high content of betalains that are characteristic of red pitaya varieties (5). The most common betalains are present in red beet (Beta vulgaris L. ssp. vulgaris), however, this has high nitrate contents (6) and an earthy smell caused by pyrazine derivatives (7). In the search for new plants containing betalain devoid of these disadvantages, pitaya emerges as an interesting alternative. In this regard, studies describing the processing of pitaya into fruit juices and related products (8) have been intensified in recent years.

Considering that industrial scale processing requires, among other conditions, high productivity and improved quality of the final product, tangential microfiltration presents itself as a potentially efficient technology for obtaining clarified fruit juices being the organoleptic and chemical characteristics close to a whole juice (9). Lower energy expenditure, high selectivity, high capacity of separation and clarification, ease of scale-up and consequently quality of the final product preserving the natural flavor and nutritional components of the raw material, due to not using high temperatures, are some advantages of this process (10). The performance of the process will be influenced by factors such as concentration and molecular size of the compounds, temperature, type of enzyme, if used, and chemical interactions of product components with the membrane (11). It should be noted that microfiltration is generally used for clarification and separation of suspended solids, but the clogging that occurs during the process is the main factor for the decay of the permeate flux (12).

The present study aims to enable the use of the tangential microfiltration process for pitaya juice, comparing the processes using pulp with peel and without peel in order to validate the applied technology.

OBJECTIVE

To enable the use of tangential microfiltration for clarification of pitaya juice with and without peel (Hylocereus spp.) through process parameters such as permeate flow and fouling resistance and rheological behavior aiming at future implementation on an industrial scale.

MATERIALS AND METHODS

Pitaya (*Hylocereus* spp.) was supplied by Frutacor, located in Vale do Jaguaribe, Ceará state, Brazil (05°53′26″S, 38°37′19″W). After washing and sanitization, the fruit was cut into pieces and the peel was manually removed before the pulping process (the sieve used in the pulper was 0.8″) (13).

The tangential microfiltration step was performed in a pilot microfiltration unit equipped with four single-channel alumina (Al_2O_3) series membranes with an average pore diameter of 0.2 µm (total system area of 0.022 m²). The unit has a ± 10 L feed tank and a 1.5 HP positive displacement NEMO helical pump, which allows recirculation of pitaya pulp under pressure in the tangential microfiltration system (14). All microfiltration processes occurred in triplicate at 300 kPa, 40 ºC and increasing volumetric reduction factor (VRR).

Microfiltration parameters such as permeate flow rate and resistance and fouling models were calculated according to Ghosh et al., (15), equation 2 and 3.

$$J = {}^{V_P}\!/_{t \times A} \quad (1)$$

$$R_T = R_m + R_c + R_f \quad (2)$$

Enzymatic treatments were performed with commercial enzyme ®Pectinex Ultra AFP at a concentration of 2000 mg.L^{-1}, at 40 ºC and 60 minutes of exposure.

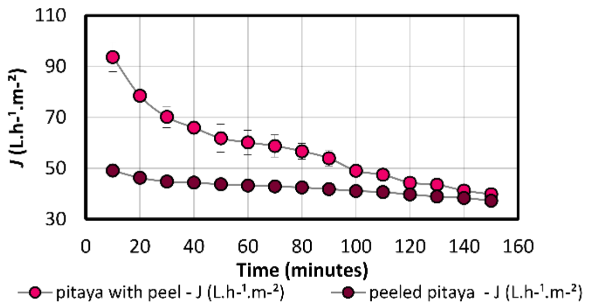
Equation (1) was used to estimate the energy consumption (*E*) of the processes in kWh/m^3 (or 0.001 kWh/L), as described by Moraes et al., (16), where: Δp is the transmembrane pressure in kPa, Q_{feed} is the feed recirculation flow rate in m^3/h, η is the pump efficiency factor (0.73), J_v is the volumetric permeate flow rate in m^3/(m^2.h) or and A is the membrane area in m^2 (0.022).

$$E = {}^{\Delta_P \times Q_{feed}}\!/_{\eta \times J_V \times A} \quad (3)$$

The rheological models applied to the fractions of the processes with and without pitaya juice peel (whole juice, enzymatically macerated whole juice, permeate, and retained juice) follow the methodology described by Viana et al., (14).

RESULTS AND DISCUSSION

It can be seen in Figure 1 that the average permeates flow rate for the shelled process (±57 $L.h^{-1}.m^{-2}$) was ±26% higher than the shelled pitaya process (±42 $L.h^{-1}.m^{-2}$), which shows that the enzymatic maceration process was not completely satisfactory for the whole juice with shells, which interferes with the energy expenditure shown in Figure 2.



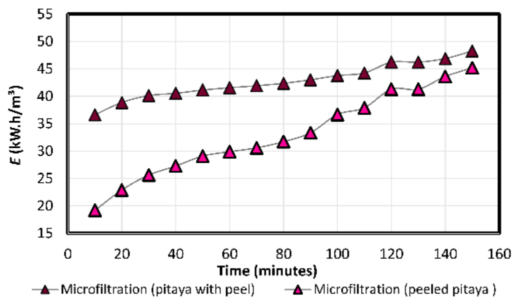


Figure 1. Effect of time on VRR and permeate flux during microfiltration of cashew juice in concentration mode.

Figura 2. Comparative of the resistances in relation to the total resistance of the membranes.

The low permeate fluxes obtained in the filtrations with peel resulted in an increase in energy consumption, this is expected. Moraes et al., (16) obtained a higher energy consumption in studies with soursop leaf, in ultrafiltration processes the energy consumption was lower than the nanofiltration processes in view of the permeate flows and pressures employed, so the lower and higher the flows and pressures, respectively, the higher the energy expenditure. The average energy consumption was 80.41 kWh/m^3 for processes performed with pitaya with peel at 2 and 113.4 kWh/m^3 in processes performed with pitaya without peel. These results are important when considering scale-up to commercial units.

According to Figure 3. the preponderant resistance in the shelled pitaya process is the concentration polarization (R_c= 45.78%), while in the shelled pitaya process is the resistance related to reversible and irreversible fouling (R_f= 57.88). The membrane resistance (R_m) did not change so considerably in the processes, which indicates to us that the other resistances have a much greater influence on the fouling phenomena.

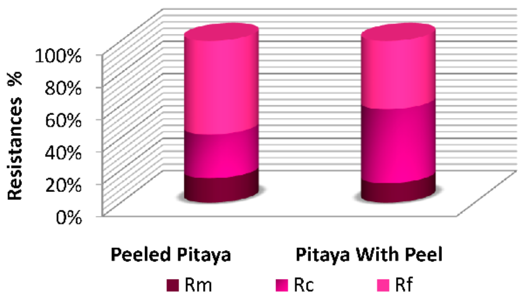


Figure 3. Resistances in the microfiltration processes of pitaya with and without peel.

After the cleaning procedure, the membrane obtained a fouling index of 99% in both processes (with and without peel), which shows that even though the fouling resistances are high, the irreversibility of fouling practically does not occur, so the cleaning was efficient. Viana et al., (14) and Ghosh et al., (15) obtained similar results related to cleaning efficiency for banana and jamun juice, respectively.

The rheological data were fitted to the power law model, usually used in juices and materials of vegetable origin. According to Figure 4, one can observe the behavior of apparent viscosity in relation to shear stress of the fractions studied (whole pitaya juice - INT, whole pitaya juice after enzymatic maceration - ENZ, clarified pitaya juice - CLA and the juice retained from the clarification process - RET).

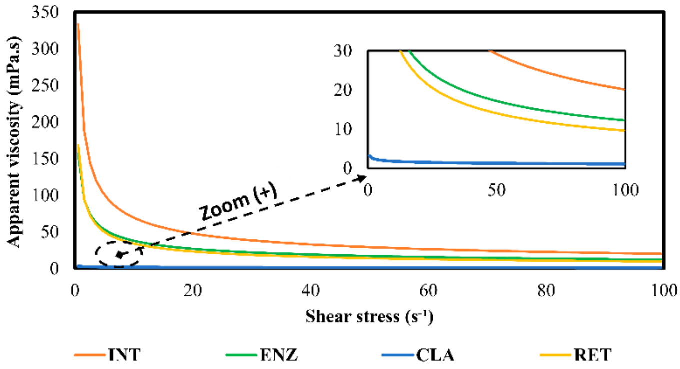


Figure 4. Rheological behavior for enzymatically treated whole pitaya juice and the microfiltration fractions (clarified and retained juice).

The samples "INT", "ENZ" and "RET" showed a reduction in viscosity with increasing shear rate. This phenomenon occurs due to the destruction of weak bonds and decrease of hydrophobic interactions between the molecules, this interaction is greater at the beginning of the process due to hydrodynamic forces (17). Soon after this phase occurs an alignment of the particles with the flow, decreasing viscosity, thus characterizing a non-Newtonian fluid (18).

This phenomenon does not occur with the clarified juice sample, because the viscosity practically does not change with the increase in shear rate.

The data showed a good fit to the model (Power Law), as can be seen by the R^2 values above 0.95 and the root mean square error (RMSE) close to zero, indicating a minimum distance of the experimental points from the analyzed curve (Table 1).

Table 1. Rheological parameters of whole pitaya juice (PIT-INT), enzymatically treated juice (PIT-ENZ), clarified pitaya juice (PIT-CLA) and the retained pitaya juice (PIT-RET) fitted to the power law model.

Amostra	R^2	RMSE	K ($Pa.s^n$)	n (adim.)
PIT-INT	0,972±0.001	0,073±0.0131	0,239±0.031	0,4621±0.034
PIT-ENZ	0,994±0.002	0,023±0.0172	0,117±0.011	0,5085±0.024
PIT-CLA	0,988±0.000	0,003±0.0124	0,003±0.000	0,7927±0.015
PIT-RET	0,951±0.002	0,046±0.0101	0,121±0.001	0,4488±0.018

Regarding the parameters, the behavior index (n) indicates pseudoplastic behavior, with the clarified juice the closest to exhibiting Newtonian behavior.

CONCLUSIONS

It is concluded that the use of pectinolytic enzymes in concentrations of 2000 and for 60 minutes are efficient conditions for the microfiltration system used, but an optimization study of these conditions would be necessary. The resistances (R_f and R_c) are the main responsible for the clogging of the process in increasing VRR for the pitaya juice with peel and without peel, respectively. The cleaning procedure proved satisfactory with almost complete membrane recovery after use. Regarding energy consumption, the microfiltration system proved to be an excellent alternative in the sustainable context, indicating the study of scale evolution. As for rheology, the microfiltrated juice is the closest to a Newtonian fluid, but the samples prior to microfiltration are pseudoplastic fluids.

Finally, there is a need for further studies on energy/economic efficiency, considering the use of enzymes in high concentrations.

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