OPTIMIZATION BY ARTIFICIAL NEURAL NETWORKS OF A COMBINED METHOD FOR OBTAINING DRIED CASHEW JUICE (*Anacardium occidentale* L.)

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ABSTRACT

In this study, cashew juice powder was obtained by the combined method of microfiltration and atomization processes having the drying process modeled and optimized by a multi-layer artificial neural network (ANN) associated with a genetic algorithm (GA). The effect of maltodextrin concentration and drying temperature on two responses, such as yield and moisture, was also determined. The developed ANN has minimum mean squared error and maximum R^2 values of 0.99, 0.99, 0.99, and 0.99 for training, testing, validation, and all data sets, respectively, which shows good agreement between actual and predicted values. The optimal extraction parameters obtained using the developed ANN-GA were the maltodextrin concentration of 10% and the process temperature of 150 °C. The SiC membrane proved to be viable for future industrial scale-up due to considerable permeate fluxes at increasing FRV and preponderant resistance related to concentration polarization, which facilitates the cleaning process. The cashew juice powder was classified as cohesive and presented good fluidity, with low wall friction angles and low bulk density.
Keywords: genetic algorithm, microfiltration, fouling, spray-dryer, powder flow tester

INTRODUCTION

The processing of tropical juices, clarified, has been a significant and important option for the development and valorization of agro-industrial products. Fruit juices are becoming more and more popular and viable as substitutes for more traditional beverages such as soft drinks, coffee and tea.

In view of consumers' needs, industries are seeking products that present greater preservation of bioactive compounds present in juices, as well as substances that are associated with sensory characteristics, which are often sensitive to heat treatments, usually used to extend the shelf life of these products. Thus, studies addressing the use of processing technologies used alone or in combination, which present advantages over heat treatments are of extreme importance.

One of the alternatives for process optimization is the use of the methodology of artificial neural networks with genetic algorithms (ANN-GA), being an efficient modeling tool with numerous advantages over other statistical techniques, such as response surface methodology (RSM). ANN handles various parameters for modeling nonlinear and linear multivariable regression problems (1). ANN can accommodate nonlinear multivariate variables with undefined interactions, has better prediction capability, and has the ability to learn from experimental data (2).

A genetic algorithm (GA) is an efficient optimization technique that incorporates a frequent probabilistic global search system that depends on the fitness function, embodying the principle of biological evolution (3).

Some recent cashew studies have been conducted using ANN-GA implementation for simulation and optimization (4,5,6).

In this sense, this research aimed to develop and optimize a combined method for cashew juice using microfiltration and spray-dryer technologies as an option for high value-added juice enrichment and future industrial scale-up.

OBJECTIVE

In view of the above and due to the lack of studies in the literature with similar proposals, the objective of this study was to obtain cashew pulp powder by the combined method of microfiltration and spray-dryer through the optimization of drying parameters by ANN-GA.

MATERIALS AND METHODS

The research was performed with the cashew pseudofruit (Anacardium occidentale L.), having as methodology of obtaining the pulp the same performed by (7,8).

The tangential microfiltration step was performed in a pilot microfiltration unit equipped with a multichannel silicon carbide (SiC) membrane with an average pore diameter of 0.3 µm. The unit has a ± 20 L feed tank and a NEMO 1.5 HP helical pump that allows cashew pulp to be recirculated under pressure in the tangential microfiltration system.

The microfiltration parameters such as permeate flux, volumetric reduction value (VRR) and resistance models were calculated according to Onsekizoglu, (9) as well as the fouling index (10). Enzymatic treatments were performed with commercial enzyme ®Rapidase at a concentration of 200 $mg.L^{-1}$, at 40 °C and 60 minutes of exposure.

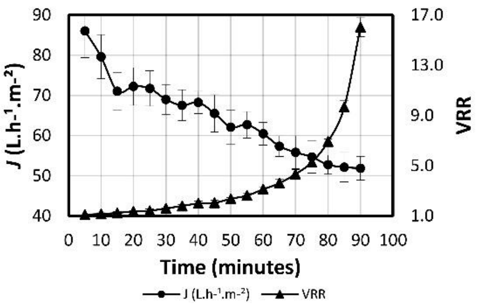
The drying was performed in the Laboratory of Food Quality Control and Drying of the Federal University of Ceará, Fortaleza - CE. Formulations composed of the microfiltered juice and maltodextrin DE20 were prepared according to the experimental design.

A Box-Behnken design generated by Protimiza Experimental Design (11) was used to generate the different combinations of the two independent variables (maltodextrin concentration and drying temperature) evaluated, generating a 2^2 matrix with 5 central points, having as dependent variables the yield and drying humidity, totalizing 13 experiments. For modeling and optimization of the process parameters, ANN and genetic algorithm (GA) were performed using the neural adaptation application and the optimization tool, respectively, of the software MATLAB® software (Version R2021a, The MathWorks, Inc., Natick USA). The ANN used was multilayer feed forward (MFF) (5).

The humidity was measured using a Marconi humidity balance model ID50 at 105 °C. The hygroscopicity was measured by the Goula & Adamopoulos methodology (12). The flowability analyses were determined using a Brookfield Powder Flow Tester 104 (PFT-104), according to the equipment's technical manual.

RESULTS AND DISCUSSION

It can be observed in Figure 1 that the average permeate flux obtained was 65 $L.h^{-1}.m^{-2}$ in increasing VRR (up to 16), which demonstrates a good response of the process aiming industrial scale-up. Studies by Servent et al., (13) in VRR = 1 obtained fluxes of 75 L.h-1.m-2 for cashew juice in single channel ceramic membrane of alumina (Al^2O^3) with average pore diameter of 0.2 µm, the process was performed at 200 kPa pressure.



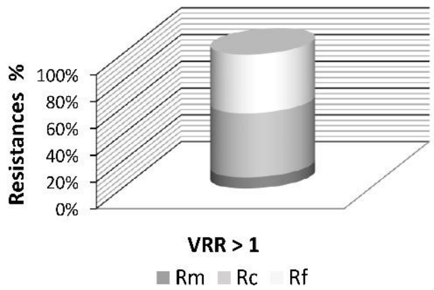


Figure 1. Effect of time on VRR and permeate flux during microfiltration of cashew juice in concentration mode.

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

According to Figure 2 the resistance related to concentration polarization (R_C = 54.54%) and the resistance related to fouling (R_F = 43.22%) add up to almost all the resistances, therefore, the mechanical resistance (R_M) is 2.23%. According to the calculated hydraulic permeabilities it is possible to obtain the fouling index that shows 97% fouling of the membrane. After the cleaning procedure the membrane returned 99% of its filtering capacity, which is corroborated with the obtained result of the fouling resistances (reversible and irreversible).

According to Figure 3 we have the contour surfaces obtained by ANN-GA. It can be seen that the second dependent variable (Y2 - Moisture) had a result variation of ± 0.3%, so it is feasible to optimize the process parameters only by the yield values.

Thus it can be evaluated that in the optimal zone of the contour surface the yield ranges from 80 - 88%, the maltodextrin concentration ranges from 22 - 30% and the temperature ranges from 155º - 170ºC. The most feasible parameters are a temperature of 155 ºC and 25% maltodextrin, which would give a yield of 80.51 ± 0.24% and a humidity of 1.38 ± 0.01%.

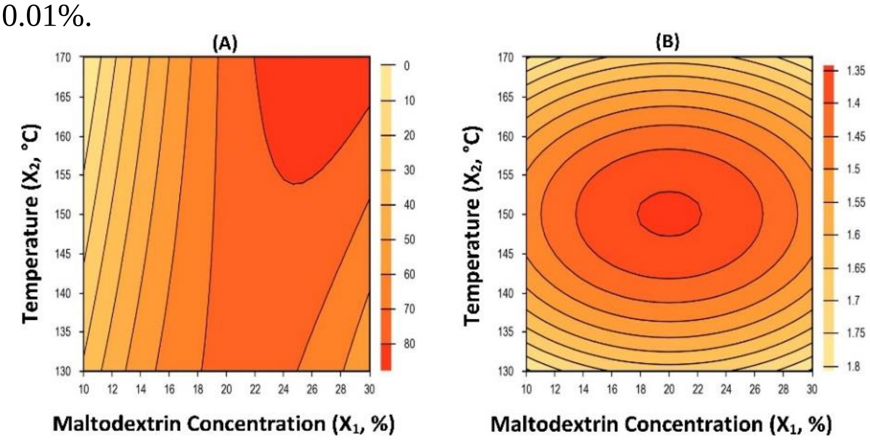


Figure 3. Contour surfaces of the dependent variables yield (A) and humidity (B), respectively.

After repeated training, the number of neurons in the hidden layer was selected as 10 since a minimum mean square error (MSE) of 0.16, 0.02, 0.00, and 0.11 and maximum R^2 of 0.999, 0.999, 0.999, and 0.999 for training, testing, validation, and all data sets, respectively, demonstrating high reproducibility and confidence in the modulated prediction.

Table 1 shows the mean values of solubility, hygroscopicity, bulk density, the angles of internal friction, angle of friction with the wall (stainless), and the flow rate for the powder sample.

Table 1. Physical characterization of clarified dehydrated juice.

Parameters		Sample (Dehydrated)
Solubility (%)		99.61 ± 0.48
Hygroscopicity (%)		9.40 ± 0.51
Apparently Density ($kg.m^{-3}$)		543.1
Internal Friction Angle (°)	Maximum	33.3
	Minimum	45.8
Wall Friction Angle (°)	Maximum	17.7
	Minimum	21.8
Flow Index		3.33

The sample showed high solubility and low hygroscopicity. The solubility performance occurred due to the low humidity and the presence of sugars. According to Phisut, (2012) (14) the lower the humidity, the less sticky is the powder and, therefore, the greater the surface area in contact with the rehydration water. The low hygroscopicity occurred due to the presence of maltodextrin.

The low bulk density was due to the fact that the water molecules evaporated inside the particle that were subsequently expelled, creating pores in the dry fraction.

The angle of internal friction refers to a measure of interactions between powder particles and characterizes the flowability properties (15,16). The angle of friction with the wall, on the other hand, is the resistance between the powder and the wall material of the place where it is stored (17). The smaller the angles are, the easier it is for the product to flow out. The internal and wall friction angles showed values between 45.8 and 33.3 and 17.7 and 21.8°, respectively. Similar behavior was found in Afonso et al., (2019) (18) and Maciel et al., (2020) (19) who obtained internal friction angle values between 45.3° and 48.2° and 16.7° and 21.4° in freeze dried mango pulp and cupuaçu powder, respectively.

CONCLUSIONS

The SiC membrane proved to be viable for future industrial expansion due to the considerable permeate fluxes at increasing FRV and the preponderant resistance related to concentration polarization, which facilitates the cleaning process. The neural networks were extremely efficient in predicting the independent variables, with minimum MSE at 0.16, 0.02, 0.00, and 0.11 and maximum R^2 of 0.999, 0.999, 0.999, and 0.999 for training, testing, validation, and all data sets, respectively. The optimal drying parameters were 155 oC and 25% maltodextrin which predicts a yield of 80.51 ± 0.24% and a moisture content of 1.38 ± 0.01%. The cashew juice powder was classified as cohesive and exhibited good flowability, with low wall friction angles and low bulk density.

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