Enzymatic and Thermal Sugar Extraction Methods from Apple Pomace

Lowering Sugar Levels and Modifying Sweetness

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INTRODUCTION

Vegetable and fruit by-products constitute 44% of global food waste. Apple by-products (skin, flesh, seeds, and stems), increasing due to consumer demand for apple juice or cider, are largely wasted or underutilized, despite being rich in dietary fiber, phenolic compounds, proteins, and inorganic salts. Recent processes have focused on extracting polysaccharides and oligosaccharides from these by-products, primarily for fermentation and bioethanol production, with limited use as functional ingredients in the food, pharmaceutical, and cosmetic industries.

OBJECTIVE

This work aims to obtain natural ingredients with sweetening power from apple pomace (skin, flesh, seeds and stems). It aims to evaluate the effect of hydrolysis conditions, namely enzyme concentration (XA: 0,5% to 3%), substrate/solvent ratio (XB: 1:2 to 1:10), and duration (XC: 1h to 4h), on sugars obtained from apple pomace through four Box-Behnken Designs and determine the enzyme (Viscozyme® L or Pectinex® Ultra SP-L) and substrate state (fresh or 30 days frozen) optimal conditions to maximise the °Brix.

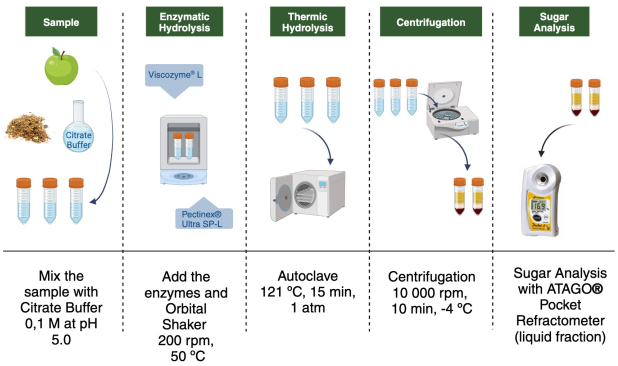
METHODOLOGY

Enzymatic hydrolysis using citrate buffer followed by thermal hydrolysis in an autoclave was performed to release sugars from apple pomace. The supernatant was separated by centrifugation, and sugar content was measured with an ATAGO® Pocket refractometer.

Factors	Levels		
	-1	0	1
XA (%)	0,5	1,75	3
XB (g/ml)	1:2	1:6	1:10
XC (h)	1	2,5	4

Four experimental designs (I, II, III, and IV) were used, considering three independent factors (XA, XB, XC) at three levels (-1, 0, 1). A total of 15 assays, including three central point repetitions, were conducted. The Box-Behnken design and statistical analysis were carried out using Stat-Ease 360 Software.

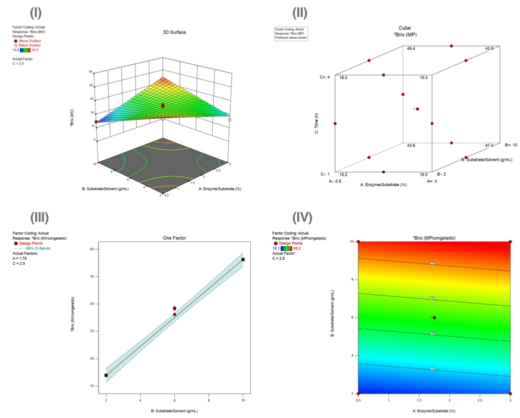
Assays	Factor XA	Factor XB	Factor XC
1	-1	-1	0
2	1	-1	0
3	-1	1	0
4	1	1	0
5	-1	0	-1
6	1	0	-1
7	-1	0	1
8	1	0	1
9	0	-1	-1
10	0	1	-1
11	0	-1	1
12	0	1	1
13	0	0	0
14	0	0	0
15	0	0	0



RESULTS

The results variance of the four experimental designs were well explained by three different models, two-factor interaction (2FI) (Eq (I)), Quadratic (Eq (II)), and Linear (Eq. (III) and (IV)), since it had statistical significance ($p < 0.05$) and a not significant lack of fit.

Design		Lowest °Brix (g/100g)	Highest °Brix (g/100g)	Model	Equation
I	Fresh Apple pomace treated with Viscozyme® L	14,8 (Assay 3)	34,8 (Assay 8)	2FI	$°Brix=44,75-9,78XA-4,72XB+1,79XAB+0,5XBC$ $R^2=0,82$
II	Fresh Apple pomace treated with Pectinex® Ultra SP-L	16,4 (Assay 9)	46,8 (Assay 4)	Quadratic	$°Brix=2,5+2,38XA+4,48XB+3,71XC-0,85AC-0.08XB^2-0,47XC^2$ $R^2=0,99$
III	Frozen Apple pomace treated with Viscozyme® L	15,4 (Assay 1)	39,0 (Assay 12)	Linear	$°Brix=11,68+2,64XB$ $R^2=0,97$
IV	Frozen Apple pomace treated with Pectinex® Ultra SP-L	15.1 (Assay 1)	38,2 (Assay 10)	Linear	$°Brix=9,96+0,73XA+2,70XB$ $R^2=0,98$



CONCLUSION

Minimizing food waste within a circular economy reduces pollution and economically valorizes by-products. Extracting sugars from apple pomace is an effective and affordable method to incorporate these by-products into food products, promoting healthier options.
Statistical models developed in this study enabled evaluation of the impact of XA, XB, and XC on the °Brix obtained after hydrolysis processes. The °Brix was affected by all the factors and their interactions in experimental design (I) and (II). The °Brix was only affected by the substrate/solvent ratio (XB) in experimental design (III), and also affected by enzyme concentration in experimental design (IV). Several other analyses, such as sugar identification and concentration, yield, and sweetness index, should be studied to identify the best conditions to obtain the highest sugar concentration and define the best hydrolysis condition to get the best of apple pomace.

This approach also aligns with the United Nations' Sustainable Development Goals, particularly Goal 3 by reducing the risk of non-communicable diseases through lower sugar intake, and Goal 12 by promoting sustainability in food production and consumption.

3 GOOD HEALTH AND WELL-BEING
12 RESPONSIBLE CONSUMPTION AND PRODUCTION

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