JUICE SUMMIT 2024
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Utilizing of enzymatic reactions to decrease sugar content in apple juices

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Introduction

Nowadays, the growing demand to establish modern nutritional solutions to improve the diet of societies and ensure the prevention of civilization diseases such as diabetes type 2 or obesity can be observed. Moreover, consumers' increasing consciousness of the impact of consumed food type and maintaining or losing good health can be noted. Consumers seek food with high nutritional value and health-promoting properties.

Since fruit juices contain antioxidant compounds, minerals, vitamins, or dietary fiber, these products occupy an undeniably high position among products having a particularly beneficial effect on health, and consumption of these should be encouraged. Moreover, a portion of juice can be treated as one of the five daily servings of fruits and vegetables**.** However, the intrinsic sugar levels in 100% fruit juices (no added sugar) may be comparable or even higher than that in sugar-sweetened beverages.

Reducing natural sugar levels in fruit juices can be a crucial aspect of the increasing consumption of this beneficial drink. Following the current legal regulations in the European Union, at least 30% of overall sugar content should be reduced compared to similar fruit juices to use a nutritional claim of „reduced-sugar"-- according to Regulation (EC) No 1924/2006 of the European Parliament and of the Council of 20 December 2006 on nutrition and health claims made on foods.

The method particularly worth the interest in reduced-sugar fruit juice processing is the application of enzymes.

Aim, scope and focus of the study

The research aim and scope:

- Reduction of sucrose concentration in FC and NFC as a result of the application of the enzyme preparation having fructosyltransferase activity
- Reduction of glucose concentration in FC apple juice as a result of the application of glucose oxidase/catalase enzymes
- Investigation of the effect of enzymatic reactions on selected parameters of apple juices

Focus of the study:

- Clear apple juice from concentrate (FC)
- Naturally cloudy apple juice (NFC)

Mechanism of the reactions

$$\textbf{\textit{Sucrose}} \xrightarrow{fructosyltransferase} sc-FOS + Glucose + Fructose$$

$$\textbf{\textit{Glucose}} \xrightarrow[O_2]{glucose\ oxidase} Gluconic\ acid + H_2O_2$$

$$2\,H_2O_2 \xrightarrow{catalase} 2\,H_2O + O_2$$

Analytics

Physicochemical methods

- **pH** (PN-EN 1132:1999),
- **Total soluble solids** (PN-EN 12143:2000),
- **Color parameters** (CIE L*a*b* system) (according to the instructions of Color Quest XE (HunterLab, 166 USA)),
- **Sugar profile** (PN-EN 12630).

HPLC-RI

Mobile phase: 0.1% EDTA
Reaction time = 20 min
Flow-rate = 0.5 ml/min
$T_{detector}$ = 35 °C, T_{column}= 90 °C

Biochemical methods

- **D-lactic acid-** using commercially available enzymatic kit-BioSystem,
- **L-lactic acid-** using commercially available enzymatic kit-BioSystem,
- **Citric acid-** using commercially available enzymatic kit-BioSystem,
- **L-malic acid-** using commercially available enzymatic kit-BioSystem,
- **Total polyphenols content -** using commercially available enzymatic kit-BioSystem,

Calculated

- **Browning index** (BI) (Szczepańska et al., 2021).

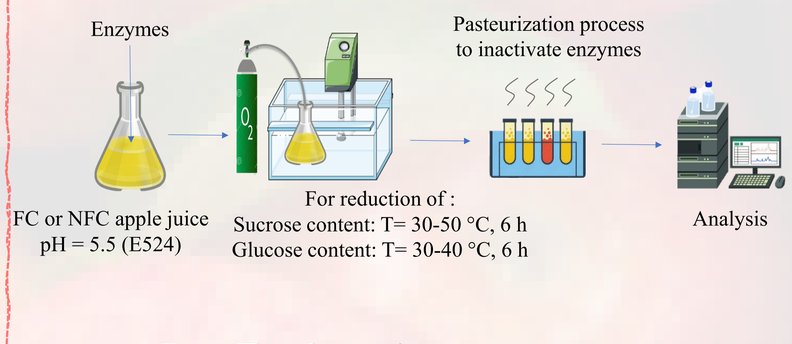

Fig. 1. The scheme of enzymatic process

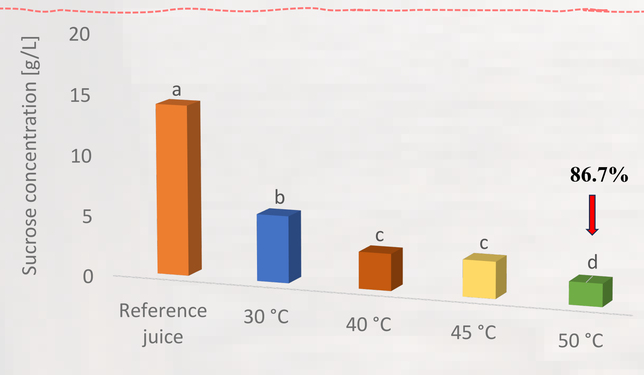

Fig. 2. Sucrose concentration after fructosyltransferase treatment of FC apple juice

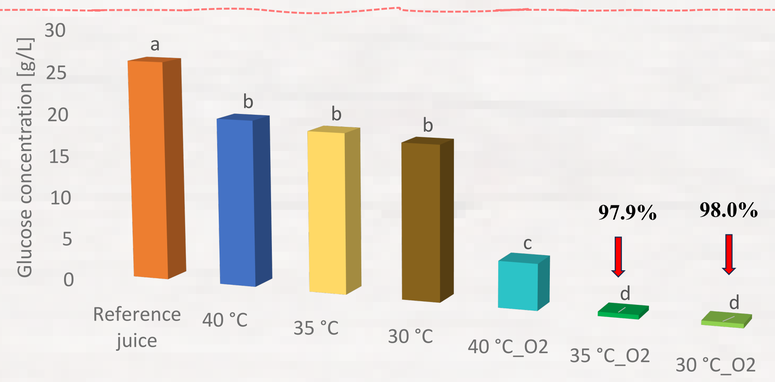

Fig. 3. Glucose concentration after glucose oxidase and catalase treatment of FC apple juice

Reducing sugar content in apple juices

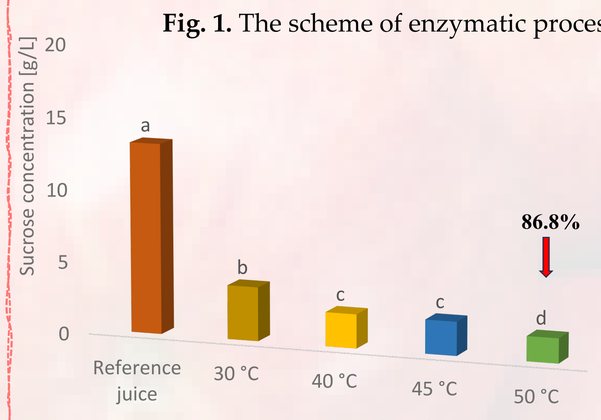

Fig. 4. Sucrose concentration after fructosyltransferase treatment of NFC apple juice

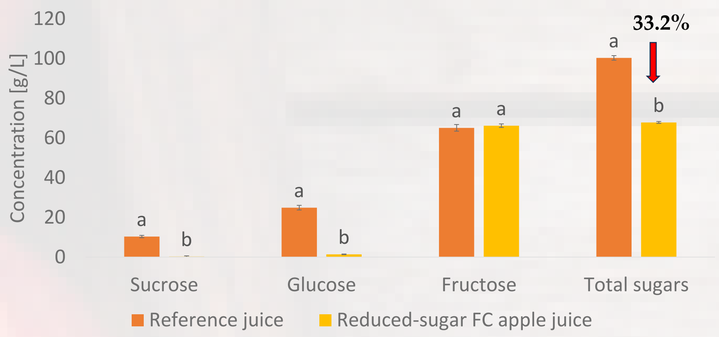

Fig. 5. Sugar profile of FC apple juice after fructosyltransferase, glucose oxidase and catalase treatment under optimal conditions

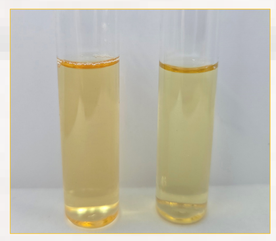

Fig. 6. Reference (←) and reduced--sugar (→) FC apple juices

Table 1. Color parameters of reference and reduced-sugar FC apple juice

Parameter	Reference juice	Reduced-sugar FC juice
L*	8.11 ± 0.05 b	18.89 ± 0.02 a
a*	-0.21 ± 0.04 b	0.19 ± 0.00 a
b*	5.69 ± 0.08 b	12.88 ± 0.04 a
ΔE	-	12.97 ± 0.03
BI	105.72 ± 2.37 a	103.95 ± 0.45 a

Physicochemical quality of apple juices

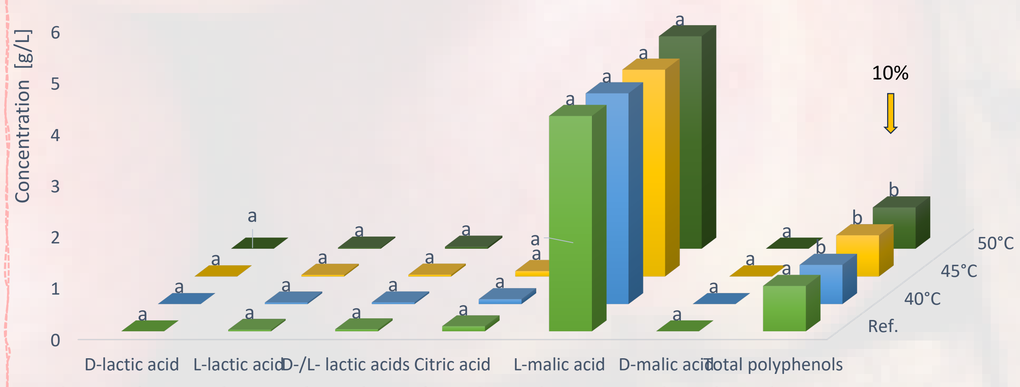

Fig. 7. Physicochemical quality of NFC apple juice with reduced sucrose content

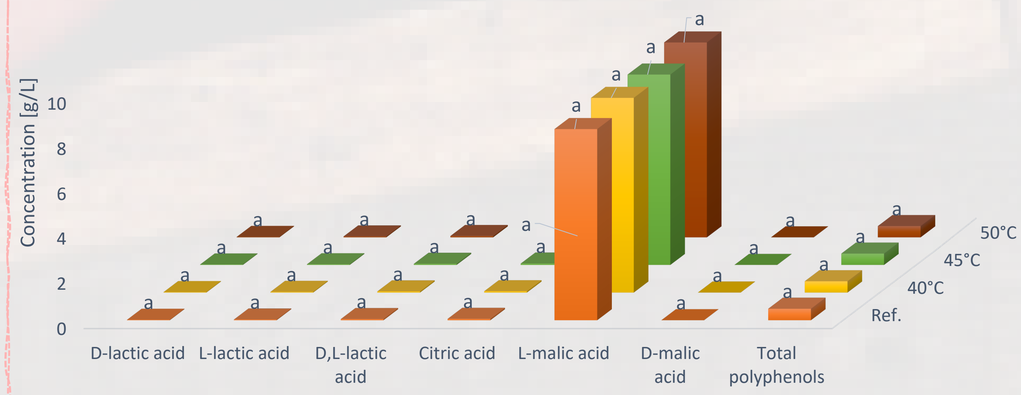

Fig. 8. Physicochemical quality of FC apple juice with reduced sucrose content

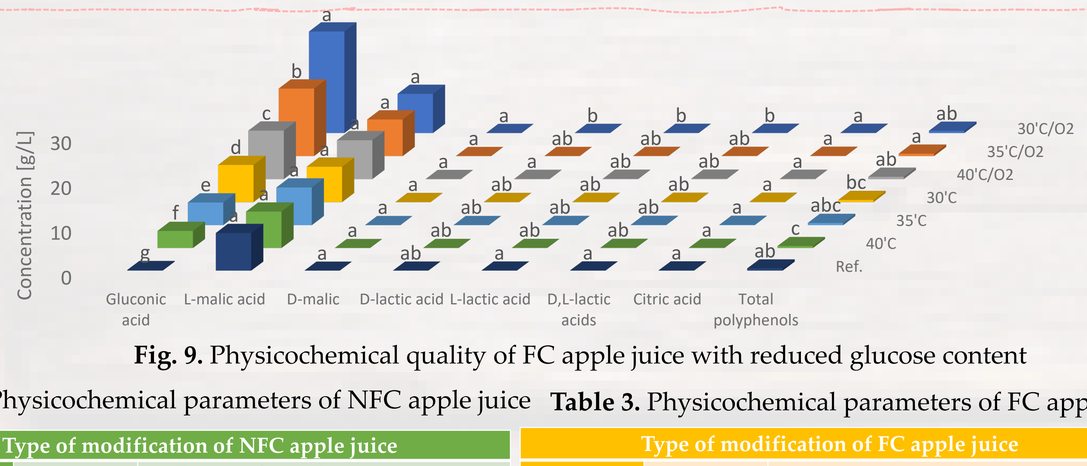

Fig. 9. Physicochemical quality of FC apple juice with reduced glucose content

Table 2. Physicochemical parameters of NFC apple juice

Type of modification of NFC apple juice				
Parameter	**Reference juice**	**Fructosyltransferase treatment**		
		40° C	**45° C**	**50° C**
pH	3.84±0.00 c	5.48±0.01 b	5.47±0.01 b	5.50±0.01 a
BRIX [%]	11.09±0.01 c	11.51±0.03 a	11.46±0.04 ab	11.40±0.03 b

Table 3. Physicochemical parameters of FC apple juice

Type of modification of FC apple juice				
Parameter	**Reference juice**	**Fructosyltransferase treatment**		
		40°C	**45°C**	**50°C**
pH	3.37 ± 0.08 b	5.49±0.01 a	5.49±0.00 a	5.49±0.01 a
BRIX [%]	11.28 ± 0.01 d	11.91±0.01 c	11.95±0.02 b	12.01±0.01 a

Table 4. Physicochemical parameters of FC apple juice

Type of modification of FC apple juice							
Parameter	**Reference juice**	**Glucose oxidase and catalase treatment**					
		30° C	**35° C**	**40° C**	**30° C_O_2**	**35° C_O_2**	**40° C_O_2**
pH	3.37 ± 0.08g	4.70 ± 0.08c	4.79 ± 0.05b	4.82 ± 0.06a	3.83 ± 0.04f	3.96 ± 0.08e	4.05 ± 0.10d
BRIX [%]	11.28 ± 0.01c	11.51 ± 0.03a	11.42 ± 0.01b	11.32 ± 0.07c	11.44 ± 0.02ab	11.42 ± 0.01b	11.42 ± 0.01b

Summary

- The enzymatic treatment can effectively reduce the concentration of sucrose and glucose in FC and NFC apple juices.
- By combining fructosyltransferase, glucose oxidase, and catalase treatment, a **33%** reduction in total sugar content was obtained.
- The enzymatic treatment does not affect the concentration of organic acids. However, the concentration of gluconic acid increased after glucose oxidase/catalase treatment.
- The total polyphenols content of FC apple juice was unchanged, simultaneously in NFC juice decreased by ~10%.
- Fructosyltransferase treatment has no impact on a pH value, whereas glucose oxidase leads to a decrease in pH as a result of gluconic acid forming.
- Enzymatic treatment leads to the increase of total soluble solids content.

FC apple juice after enzymatic treatment meets the "reduced-sugar" nutritional claim.

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