EVALUATION OF THERMAL PROPERTIES AND CHEMICAL COMPOSITION OF APPLE, BEETROOT, AND CELERY POMACE FLOURS FOR SUSTAINABLE FOOD INDUSTRY APPLICATIONS

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Introduction

Pomace from juice production is a byproduct rich in bioactive compounds and dietary fiber, offering potential for sustainable food applications. This study evaluated the thermal properties and chemical composition of flours derived from apple (AP), beetroot (BT), and celery (CL) pomace to assess their utility in the food industry.

Methodology

Thermogravimetric analysis (TGA) was conducted to analyze the thermal degradation (TD) process of flour samples under controlled heating (25–700°C) with a heating rate of 5°C/min. Additionally, the proximate chemical composition of all three flour samples was determined and correlated with their thermal behavior.

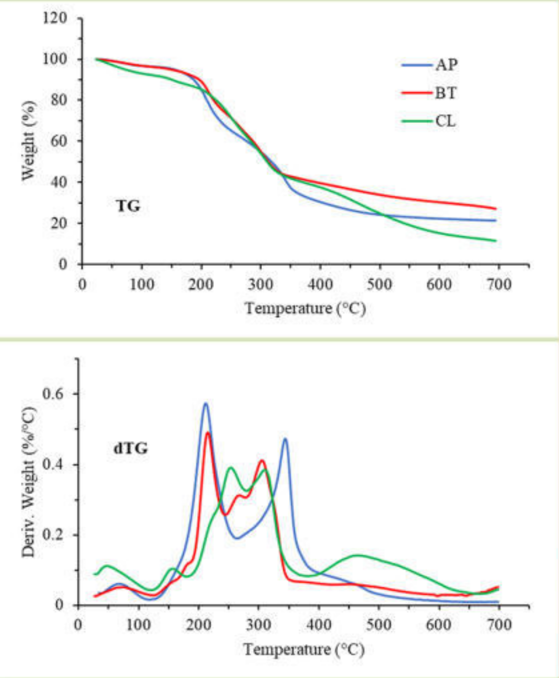

Fig 1. TGA thermograms of Apple (AP), Beetroot (BT) and Celery (CL) Flours

Results

Moisture content was highest in CL (9.8%) and lowest in BT (3.4%), while AP had 4.2%. CL was richest in minerals (9.7% ash), whereas AP had the lowest mineral content (1.7%). CL and BT contained similar protein levels (around 15%), significantly higher than AP (approximately 5%). Simple sugar content (glucose, fructose, sucrose) was notably lower in CL (5%) compared to AP and BT (around 25%). In AP, glucose (11.6%) and fructose (8.2%) predominated, whereas sucrose was dominant in BT (23.3%). Total dietary fiber content across all samples ranged from 46.2% to 48.5%.

Thermograms identified three TD phases. The first phase (TD1) represented moisture loss and volatilization of light compounds (room temperature to ~120°C), with the highest weight loss in CL (7.8%) compared to 3.5–4% in AP and BT, aligning with moisture content. The second phase (TD2; ~120–370°C for CL and BT, up to ~400°C for AP) involved degradation of sugars, proteins, and fibers. Differential thermogravimetric (dTG) curves revealed three peaks for CL and BT, and two for AP. The first peak (~150°C for CL, ~210°C for BT and AP) was attributed to simple sugar degradation, with higher sugar content shifting the peak to higher temperatures in BT and AP. The second peak (~250°C for CL and BT) reflected protein degradation, absent in AP due to its low protein content. Fiber degradation occurred around ~340°C in AP and ~300°C in CL and BT.

Table 1. Results of proximate chemical compostion

g/100g	AP	BT	CL
Moisture	4.2 ± 1.1 ^{b}	3.4 ± 1.0 ^{b}	9.8 ± 0.6 ^{a}
Ash	1.7 ± 0.9 ^{c}	6.5 ± 0.8 ^{b}	9.7 ± 1.3 ^{a}
Lipid	1.4 ± 0.7 ^{a}	1.3 ± 0.9 ^{a}	1.5 ± 0.4 ^{a}
Protein	4.8 ± 1.2 ^{b}	14.8 ± 0.9 ^{a}	15.5 ± 0.8 ^{a}
Glucose	11.6 ± 1.5 ^{a}	1.3 ± 0.3 ^{b}	2.0 ± 0.6 ^{b}
Fructose	8.2 ± 1.2 ^{a}	1.4 ± 0.4 ^{b}	1.5 ± 0.3 ^{b}
Sucrose	5.3 ± 1.2 ^{b}	23.4 ± 1.0 ^{a}	1.7 ± 0.7 ^{c}
Sugar (gl+fr+suc)	25.1 ± 0.9 ^{a}	26.0 ± 0.7 ^{a}	5.2 ± 1.1 ^{b}
Insoluble fibre	37.0 ± 0.8 ^{a}	36.0 ± 0.8 ^{a}	35.6 ± 1.2 ^{a}
Soluble fibre	11.5 ± 1.2 ^{a}	10.2 ± 0.9 ^{a}	11.3 ± 0.5 ^{a}
Total fibre	48.5 ± 1.1 ^{a}	46.2 ± 1.5 ^{a}	46.9 ± 1.1 ^{a}
Total carbohydrate	87.9 ± 1.4 ^{a}	74.0 ± 1.3 ^{b}	63.5 ± 1.2 ^{c}
Carbohydrate without fibre	39.4 ± 0.7 ^{a}	27.8 ± 1.1 ^{b}	16.6 ± 0.7 ^{c}

The results are presented as mean ± SD; different letter in superscript within the same row indicate significant differences ($p < 0.05$), according to Tukey's test, number of repetitions: n = 3.

Table 2. Results of thermogravimetric analysis

	AP	BT	CL
Ts1 (°C)	30.4 ± 0.8 ^{a}	23.1 ± 1.1 ^{b}	22.5 ± 1.1 ^{b}
Tend1 (°C)	114.9 ± 1.1 ^{c}	123.7 ± 1.4 ^{a}	118.2 ± 1.5 ^{b}
Tp1 (°C)	64.5 ± 0.5 ^{b}	72.9 ± 1.1 ^{a}	43.5 ± 1.3 ^{c}
WL1 (%)	3.6 ± 0.8 ^{b}	3.9 ± 0.9 ^{b}	7.8 ± 1.4 ^{a}
Ts2 (°C)	114.9 ± 1.2 ^{c}	123.7 ± 1.1 ^{a}	118.2 ± 0.7 ^{b}
Tend2 (°C)	398.1 ± 1.0 ^{a}	363.1 ± 0.8 ^{c}	377.3 ± 1.5 ^{b}
Tp1 (°C)	-	212.2 ± 1.1 ^{a}	152.6 ± 0.6 ^{b}
Tp2 (°C)	208.9 ± 1.0 ^{c}	265.0 ± 1.5 ^{a}	249.9 ± 1.2 ^{b}
Tp3 (°C)	340.9 ± 1.0 ^{a}	302.4 ± 0.8 ^{b}	306.5 ± 1.4 ^{b}
WL2 (%)	65.8 ± 1.2 ^{a}	54.0 ± 1.1 ^{b}	52.7 ± 0.8 ^{b}
Ts3 (°C)	398.1 ± 0.9 ^{a}	363.1 ± 1.2 ^{c}	377.3 ± 0.6 ^{b}
Tend3 (°C)	683.5 ± 1.4 ^{a}	683.5 ± 0.9 ^{a}	684.6 ± 1.0 ^{a}
WL3 (%)	9.1 ± 1.3 ^{c}	14.2 ± 0.5 ^{b}	27.6 ± 1.4 ^{a}
Residual (%)	21.5 ± 1.1 ^{b}	27.8 ± 1.4 ^{a}	11.8 ± 1.4 ^{c}

The results are presented as mean ± SD; different letter in superscript within the same row indicate significant differences ($p < 0.05$), according to Tukey's test, number of repetitions: n = 3.

Ts – start temperature, Tend – end temperature, Tp – peak temperature, WL – weight loss

Conclusion

Based on composition and thermal analysis, celery flour is suited for savory products due to its high protein and low sugar content, while apple flour is better for confectionery applications due to its high sugar level. Beetroot flour has potential for both savory and sweet products, given its balanced protein and sugar content. However, caution is required when processing celery and beetroot flours due to their lower thermal stability compared to apple flour.

Science Fund of the Republic of Serbia

Acknowledgement

This research was supported by the Science Fund of the Republic of Serbia, 7439 GRANT No, From Waste to Food and Soil Enrichment - minimizing waste by applying circular economy in fruits/vegetables processing industry – ***WasteBridge***, and by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia, grant numbers: 451-03-136/2025-03/200051.

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