UNIVERSITY OF LIFE SCIENCES ”KING MIHAI I” FROM TIMISOARA
”YOUNG PEOPLE AND MULTIDISCIPLINARY RESEARCH IN APPLIED LIFE SCIENCES”
05-06 November 2026



Physicochemical Characterization of Cookie Formulations with and without Added Sugar: Effects of Inulin and Roasted Chicory Root (*Cichorium intybus L.*)

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Abstract: The reformulation of bakery products through the omission of added sugar presents technological challenges related to maintaining the physicochemical characteristics of the final product. This study investigated the physicochemical properties of cookie formulations developed using inulin and roasted ground chicory as alternative formulation ingredients. Four formulations were comparatively evaluated: a sugar-containing control (CC), cookies containing inulin (IC), cookies containing roasted chicory (ChC), and cookies combining inulin and roasted chicory (ICC). The control formulation contained 50 g of powdered sugar, whereas added sugar was omitted from the three experimental formulations. In the IC and ICC formulations, 50 g of inulin was used as a mass-based replacement for the powdered sugar in the control. In the ChC and ICC formulations, 15% of the initial wheat flour mass was replaced with roasted ground chicory, corresponding to 22.5 g of chicory and 127.5 g of wheat flour per batch. The remaining ingredients were maintained at constant levels as far as possible, and the formulations were prepared under standardized processing conditions. The physicochemical evaluation included moisture content and color parameters, while additional instrumental measurements were performed using a Bruker MPA III analyzer. The comparative assessment focused on the differences between the control and reformulated cookies associated with sugar omission, inulin incorporation, and partial replacement of wheat flour with roasted chicory. The experimental approach provided a basis for examining the suitability of inulin and roasted chicory for cookie reformulation without added sugar and for identifying formulation-related changes in the measured physicochemical properties.

Keywords: cookies; added sugar omission; inulin; roasted chicory; physicochemical characterization; moisture content; color.

Introduction

Sucrose plays a multifunctional role in cookie production, influencing dough properties, spread, browning, texture, and mouthfeel. Its complete omission may therefore affect the physicochemical characteristics of the final product. Inulin, a soluble dietary fiber, has attracted interest as an ingredient for bakery reformulation, while roasted chicory root (*Cichorium intybus L.*) provides a characteristic flavor and may contribute to dietary fiber enrichment. However, the effects of these ingredients depend on their concentration and interactions with other components of the formulation.

Aim of the study: To investigate the physicochemical characteristics of cookies formulated without added sugar using inulin and roasted chicory, individually and in combination, compared with a sugar-containing control.

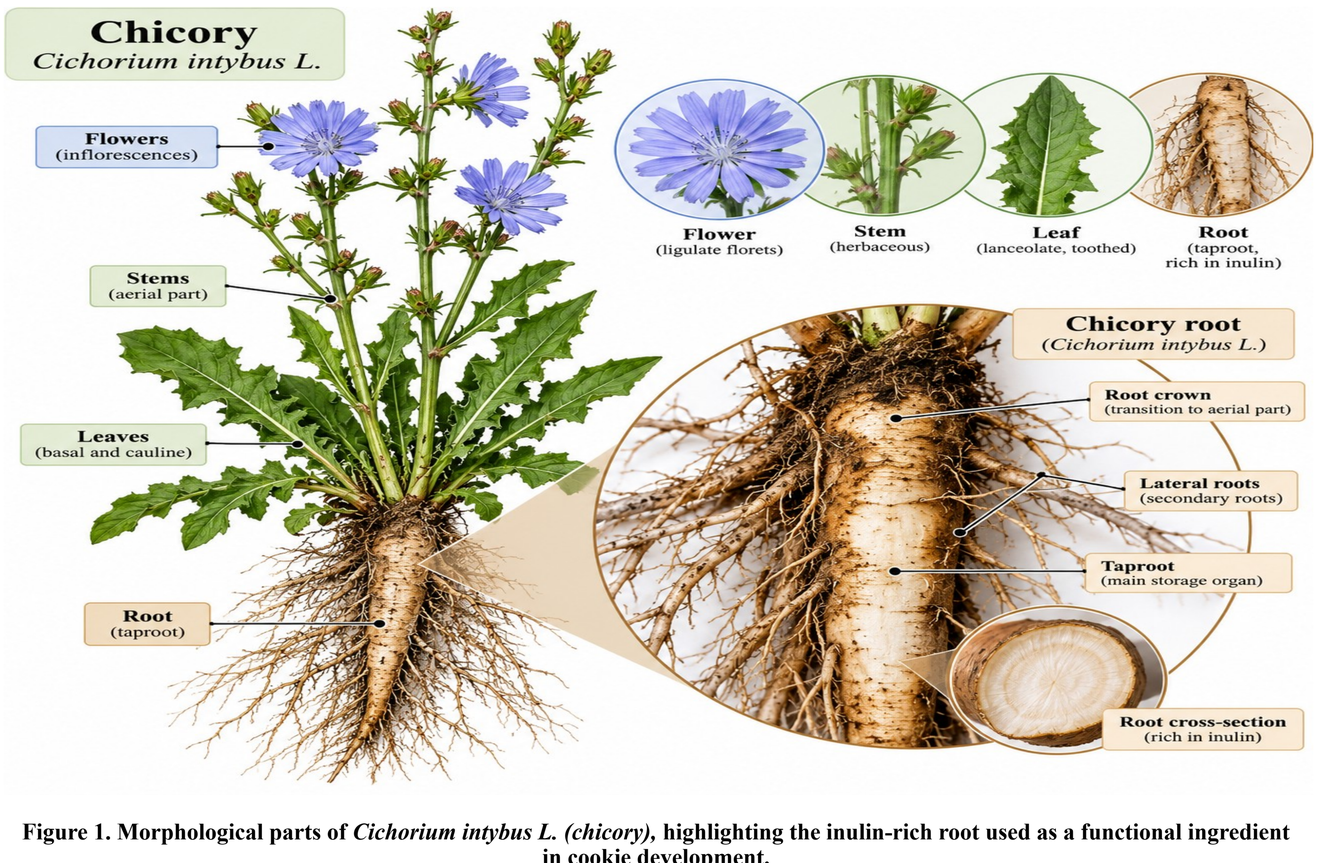
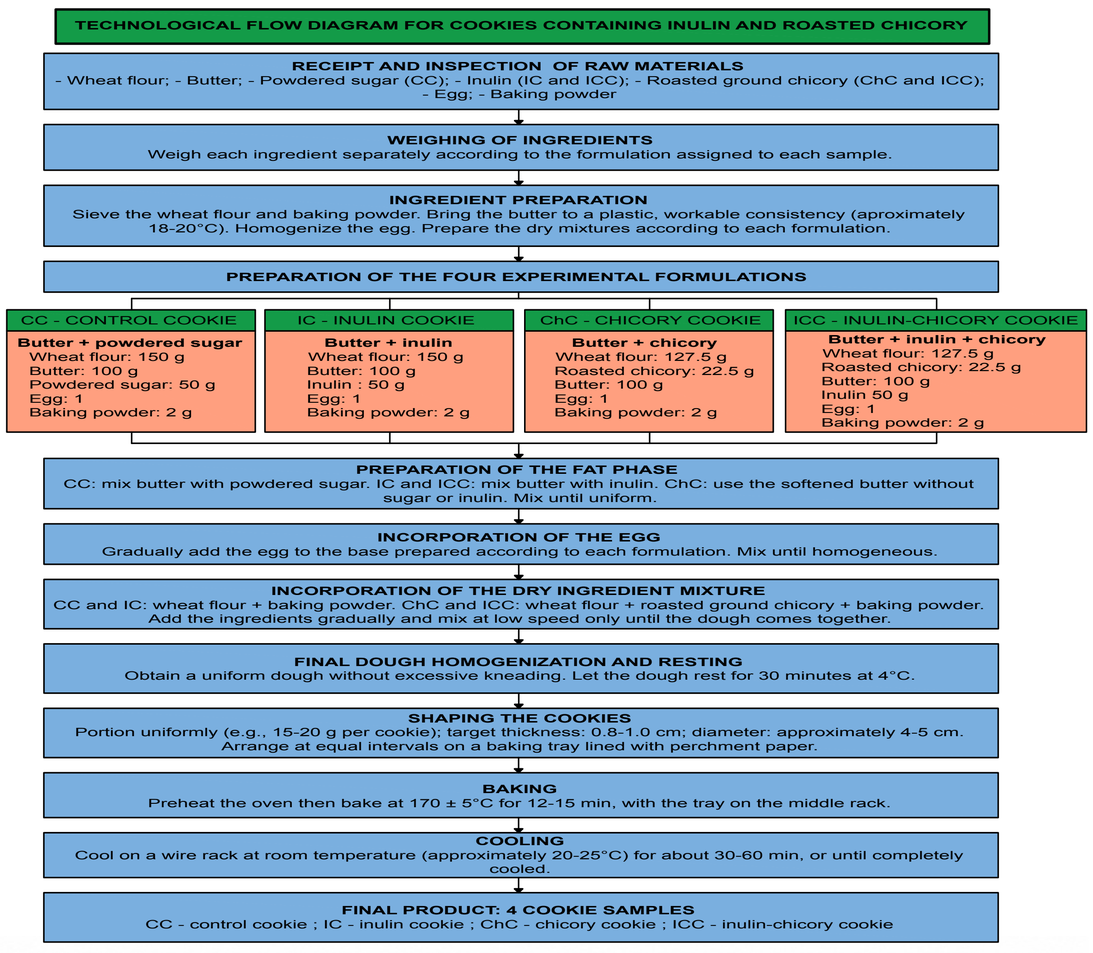


Figure 1. Morphological parts of *Cichorium intybus L. (chicory)*, highlighting the inulin-rich root used as a functional ingredient in cookie development.

Material and method





Results and discussions

Table 1. Predicted compositional characteristics of the experimental cookie formulations determined using the Bruker MPA III analyzer

PARAMETER	UNIT	CC	IC	ChC	ICC
Dry matter	%	96.76	95.57	96.33	96.19
Total fat	%	26.09	27.64	35.69	29.36
Protein	%	9.10	9.03	9.44	8.06
Carbohydrates	%	56.90	55.60	46.30	55.40
Total sugars	%	17.43	20.47	6.11	21.26
Ash	%	1.56	1.88	2.08	1.95
C4:0	%	3.20	3.94	2.90	3.46

Note: All values represent predictions (%) obtained using the calibration models of the Bruker MPA III analyzer. C4:0 refers to the butyric acid component reported by the instrument.

Table 2. Estimated Energy Value and Dietary Fiber Composition of the Baked Cookie Formulations

PARAMETER	UNIT	CC	IC	ChC	ICC
Energy	kj	2208.3	2067.5	2310.7	2074.1
Energy	kcal	528.3	494.1	552.3	495.7
Total dietary fiber	g	1,41	17.13	3.35	18.57
Fibre from wheat flour	g	1,41	1.41	1.45	1.21
Fibre from inulin	g	0.00	15.71	0.00	15.78
Fibre from roated chicory	g	0.00	0.00	1.90	1.58
Contribution of inulin and chicory to total dietary fiber	g	0.00	91.74	56.66	93.50

Note: Energy values and dietary fiber content were theoretically calculated based on the nutritional composition of the ingredients used in each formulation and the final mass of the baked products. All values are expressed per 100 g of baked product.

Conclusions

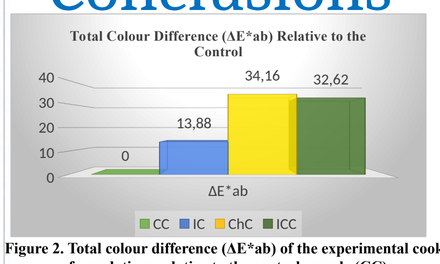


Figure 2. Total colour difference (ΔE*ab) of the experimental cookie formulations relative to the control sample (CC).

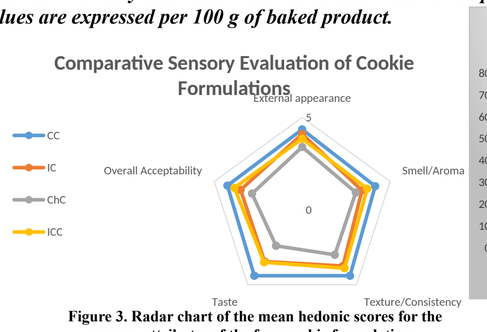


Figure 3. Radar chart of the mean hedonic scores for the sensory attributes of the four cookie formulations.

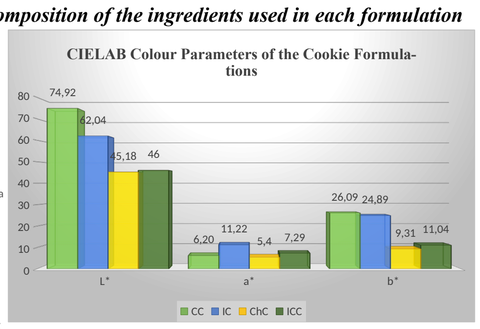


Figure 4. CIELAB colour coordinates (L*, a*, b*) of the four experimental cookie formulations.

Acknowledgement: The authors would like to thank to the Doctoral School “Engineering of Vegetable and Animal Resources”, University of Life Sciences “King Mihai I” from Timişoara (Calea Aradului 119, 300645 Timişoara, Romania), for the academic support and resources provided throughout the development of this research, and the results will be included in the PhD Thesis of Eng. PhD Student Argyelan Cristian, under the supervision of Prof. Habil. PhD. Alexa Ersilia.