

UTILIZATION OF FRUIT PROCESSING BY-PRODUCTS AND EDIBLE FILMS FOR ENHANCING NUTRITIONAL VALUE, BIOACTIVE POTENTIAL AND EXTENDING THE SHELF- LIFE OF COOKIES

**DANI
DOKTORATA
BIOTEHNIČKOG
PODRUČJA**

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dr.sc. Dunja Molnar, mag. nutr.

¹Faculty of Food Technology and Biotechnology

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LITERATURE REVIEW



Research gap on fruit by-products, cookies and packaging

- ❑ Numerous studies have **delved into the antimicrobial properties of grape seed extracts**, especially **in meat and meat products** but none have been conducted to their application in cookies.²
- ❑ Research indicates that **certain food ingredients** like cocoa powder, olive oil, grapes, wine, grape seed extract, and aronia **can inhibit LDL cholesterol oxidation, potentially leading to a reduced CVD risk**.³ A gap in the literature has been identified regarding the **impact of consuming cookies enriched with fruit by-products on the LDL cholesterol oxidation**.
- ❑ **No existing study** has explored the **potential of substituting cocoa powder with fruit by-products and their mixture in cookies**.
- ❑ There are **limited studies** investigating the **effects of grape seed extract-enriched edible films on the quality and shelf life of cookies**.
- ❑ A **noticeable gap exists** in scientific literature regarding the **physicochemical properties of edible films based on chitosan and gum arabic**, specifically when enriched with grape seed extract.
- ❑ Only a **limited number of studies** have **examined the market viability of functional and sustainable cookies**.



HYPOTHESES OF THE RESEARCH



Hypothesis 1

Fruit by-products can successfully replace cocoa powder and extend the shelf-life of whole grain cookies without compromising sensory and physical properties.



Hypothesis 2

Cookies with an edible film based on chitosan and gum arabic, along with fruit by-products, provide improved nutritional value, antioxidant activity, starch digestibility, and consumer acceptance.



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ORIGINAL SCIENTIFIC PAPER

The optimisation of biscuit formulation with grape and aronia pomace powders as cocoa substitutes

Dunja Molnar¹, Dubravka Novotni¹, Judith Krisch², Tomislav Bosiljkov¹, Mario Ščetar¹

¹University of Zagreb, Faculty of Food Technology and Biotechnology, Pierottijeva 6, 10000 Zagreb, Croatia

²Institute of Food Engineering, University of Szeged, 6724 Szeged, Mars tér 7, Hungary

*Corresponding author: dubravka.novotni@pbf.unizg.hr

Abstract

By-products of fruit processing, such as grapes and aronia pomace, are rich in fibre and polyphenols, and their application in bakery products could significantly improve nutritional value, bioactive potential and shelf life of final product. This research aimed at optimising wholemeal biscuit formulation with grape and aronia pomaces as partial substitutes for cocoa powder, using the desirability function. Ten formulations with the mixture of cocoa powder, grape and aronia pomace powders in different ratios (0-100%) were tested. The physical properties (texture, colour, thickness, diameter, spread factor), the sensory acceptability of biscuits, and microbiological safety were investigated. The interaction of all three mixture components significantly affected the instrumentally measured redness a^* and liking of texture. Biscuit diameter, yellowness b^* , and liking of flavour were affected by the interaction of aronia and grape pomace. Biscuit height, spread ratio, hardness, flexibility, toughness, appearance, and odour were not significantly influenced by the mixture composition. The optimized mixture composition contained cocoa, grape pomace, and aronia pomace in the ratio 76.4 : 17.5 : 6.1 (respectively), with the desirability of 0.78. After confirmation, biscuits with that mixture were proven better than the control, that contained 100% cocoa, in terms of decreased hardness (-23%) and toughness (-19%), having the same sensory acceptability, and were microbiologically safe for 5 months. The findings of this study indicate that aronia and grape pomace could be used as partial substitutes for cocoa powder up to 24.3% in the production of wholemeal biscuits.

Keywords: aronia pomace, grape pomace, biscuit formulation optimisation, cocoa substitute



Can grape and aronia pomace effectively substitute a portion of cocoa powder in cookies while preserving their sensory attributes?



DEVELOPING FORMULATION OF COOKIES WITH GRAPE AND ARONIA POMACE: -Methodology-



Table 1. Mixture composition of cookies

Aronia (%)	Grape (%)	Cocoa (%)
0	0	100.00
16.67	16.67	66.67
0	100.00	0
100.00	0	0
16.67	66.67	16.67
0	50.00	50.00
50.00	50.00	0
50.00	0	50.00
66.67	16.67	16.67
33.33	33.33	33.33
6.1	17.5	76.4

DEVELOPMENT OF OPTIMIZED COOKIES

(Design Expert v.1.software (State –Ease))

Minimise: hardness and colour difference

Maximise: diameter (importance 1), **taste and hardness** (importance 5) and **overall acceptability** (importance 3)

Table S1. Optimization and validation of a powdered mixture of aronia (%) and grape pomace (%) for partial replacement of cocoa powder (%) in cookie formulation

Cookie property	Predicted Value	Measured Value	Prediction Error
Diameter (cm)	4.99	4.95	-1 %
Height (cm)	0.66	0.61	-8 %
Spread Ratio	7.56	8.06	7 %
Hardness (N)	23.6	22.1	-6 %
Flexibility (mm)	3.8	3.5	-8 %
Toughness (N)	47.3	42.1	-11 %
Color L*	32.02	31.01	-3 %
Color a*	8.45	7.91	-6 %
Color b*	10.51	9.82	-7 %
Appearance	8	8	-2 %
Flavor	8	8	-2 %
Texture	8	8	0 %
Overall	8	8	-1 %
Acceptability			
Odor	N/A	9	8 %

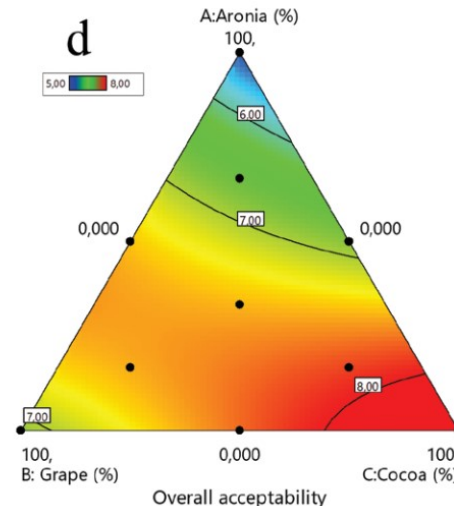
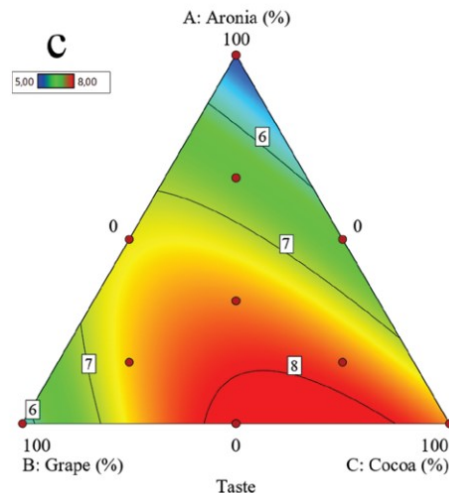
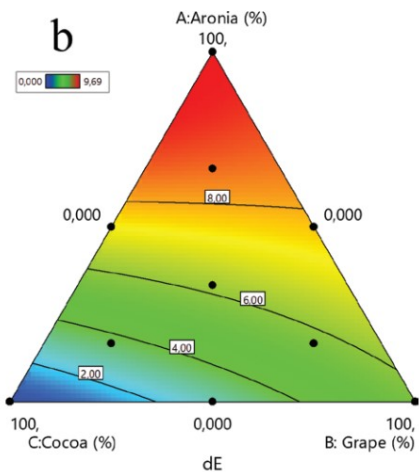


SENSORY LIKING OF BISCUITS WITH THE MIXTURE OF COCOA POWDER, GRAPE AND ARONIA POMACE IN DIFFERENT RATIOS (0-100%)

Aronia (%)	Grape (%)	Cocoa (%)	Appearance	Odour	Flavour	Texture	Overall acceptability
0	0	100.00	8 ± 0.7	8 ± 1.8	8 ± 1.6	7 ± 1.9	8 ± 0.6
16.67	16.67	66.67	7 ± 1.1	8 ± 1.2	8 ± 0.3	7 ± 1.0	8 ± 0.8
0	100.00	0	7 ± 1.7	7 ± 1.2	6 ± 1.2	7 ± 0	6 ± 1.1
100.00	0	0	7 ± 1.3	7 ± 1.2	5 ± 2.7	7 ± 2.1	5 ± 2.5
16.67	66.67	16.67	7 ± 0.9	7 ± 1.2	7 ± 0.5	7 ± 1.6	8 ± 0.8
0	50.00	50.00	8 ± 0.8	9 ± 0.7	8 ± 0.6	7 ± 1.4	8 ± 0.9
50.00	50.00	0	8 ± 0	8 ± 1.3	7 ± 1.4	8 ± 1.4	7 ± 1.3
50.00	0	50.00	8 ± 0.9	8 ± 1.7	6 ± 1.5	7 ± 1.8	7 ± 1.2
66.67	16.67	16.67	8 ± 0.6	7 ± 1.2	7 ± 0.6	7 ± 1.3	7 ± 0.8
33.33	33.33	33.33	8 ± 0.5	8 ± 1.0	8 ± 0.6	7 ± 1.0	8 ± 0.8
6.1	17.5	76.4	8.3 ± 1.0	8.5 ± 1.0	8.4 ± 1.0	7.9 ± 1.0	8.3 ± 1.0

THE ADDITION OF GRAPE- AND ARONIA POMACE POWDERS IMPACTED:

- positively influenced the texture preference (up to 30 %) and overall acceptability of cookies
- the highest overall acceptability → when cocoa was dominant and in optimized recipe
- the lowest overall acceptability → when aronia was dominant



PUBLICATION No.1

Food Hydrocolloids 135 (2023) 108191

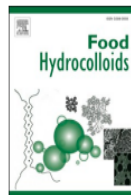


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Characteristics of edible films enriched with fruit by-products and their application on cookies

Dunja Molnar, Dubravka Novotni, Mia Kurek, Kata Galić, Damir Iveković, Helena Bionda, Mario Ščetar*

University of Zagreb, Faculty of Food Technology and Biotechnology, Pierottijeva 6, 10000, Zagreb, Croatia

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ABSTRACT

Edible coatings and films provide an environmentally-conscious alternative to plastic food packaging options. This study investigated physico-chemical, morphological and thermal properties of edible coatings and films based on chitosan and gum arabic (GA) enriched with grape seed extract (GSE). Their influence on the quality and shelf-life of whole grain cookies with grape and aronia (chokeberry) pomace (GAP) was also investigated. The addition of 0.1% GSE to the film formulations significantly increased thickness and resistance to water vapor, while reducing water solubility, visible light transmission, and rotational force. Moreover, the addition of GSE influenced the film color (turning it dark, reddish, and yellowish) and microstructure as shown by thermal, scanning electron microscopy and Fourier transform-infrared analysis. The addition of GSE led to an increase in the total phenolic content. Thus, edible coating led to lower formation of peroxides in cookies during storage. Cookies with edible coatings were harder and tougher but with much better sensory properties than control during six months of storage. Both, an accelerated shelf-life test and a direct shelf-life method confirmed that the GAP cookies with edible film were safe and of acceptable quality after six months of storage. The results of this study showed that GA and chitosan edible film enhanced with GSE had a positive impact on cookie shelf-life.



- What are the **physicochemical, thermal and structural** properties of **edible films** based on chitosan and gum arabic, enriched with grape seed extract?
- Does the **application of edible films** composed of chitosan and gum arabic, enhanced with grape seed extract, **impact the quality and shelf-life of cookies**?



DEVELOPMENT OF EDIBLE FILMS BASED ON CHITOSAN AND GUM ARABIC ENRICHED WITH GRAPE SEED EXTRACT -Methodology-

PHYSICAL AND CHEMICAL CHARACTERISATION OF FILM

FILM PREPARATION

film thickness (digital micrometer), **water vapor permeability** (gravimetrically), **water solubility** (according to Shingel⁸), **transparency** (spectrophotometer), **color** (CIE lab), **pH** (pH meter), **viscosity** (viscometer), **thermal properties** (differential scanning calorimetry DSC), **structure** (Fourier Transform-Infrared FTIR), **surface topography** (scanning electron microscopy SEM), **total phenol content**

KGA - Gum arabic, chitosan, glycerol

KGAE - Gum arabic, chitosan, glycerol, grape seed extract

COOKIES PREPARATION

APPLICATION OF EDIBLE COATING ON COOKIES

COOKIES STORAGE AND SHELF-LIFE

(CC, GAP, GAP with KGAE)
peroxide value, **moisture**, **sensory** evaluation

ASLT – 90 days
(22°C, 30°C, 35°C)

Direct method – 180 days
(22°C)



PHYSICOCHEMICAL, THERMAL AND STRUCTURAL PROPERTIES OF EDIBLE FILMS BASED ON CHITOSAN AND GUM ARABIC, ENRICHED WITH GRAPE SEED EXTRACT

Table 1

Thickness, water vapor permeability (WVP), water solubility (WS), transparency (T) at 600 nm, color properties (L^* , a^* , b^* , ΔE) of chitosan and gum arabic (GA) based films without (KGA) or with grape seed extract GSE (KGAE).

Property	KGA	KGAE
Thickness (μm)	61.9 ± 1.3^b	104.4 ± 7.8^a
WVP ($\times 10^{-10} \text{ g m}^{-1} \text{ s}^{-1} \text{ Pa}^{-1}$)	2.38 ± 0.15^b	3.31 ± 0.15^a
WS (%)	18.67 ± 3.28^b	12.44 ± 0.56^b
T (600 nm)	0.045 ± 0.001^b	0.618 ± 0.038^a
L^*	91.05 ± 0.23^a	49.32 ± 0.38^b
a^*	1.98 ± 0.11^b	14.58 ± 1.14^a
b^*	-5.24 ± 0.47^b	8.25 ± 1.04^a
ΔE	0	45.65 ± 0.56^a



KGA



KGAE

Films containing GSE (KGAE) have:

- ✓ twice the thickness compared to those without GSE
- ✓ higher water vapor permeability (WVP)
- ✓ greater light-blocking ability at 600 nm
- ✓ reduced water solubility (WS)
- ✓ higher redness (a^*) and yellowness (b^*) levels with GSE concentration

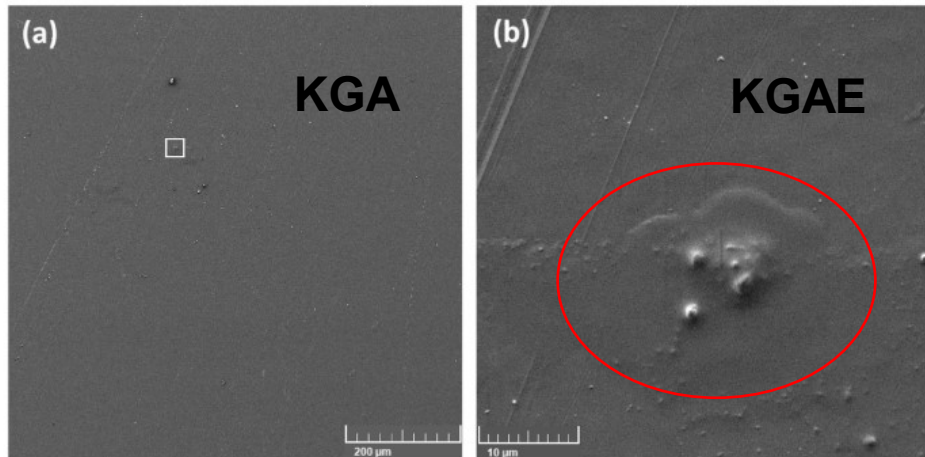


PHYSICOCHEMICAL, THERMAL AND STRUCTURAL PROPERTIES OF EDIBLE FILMS BASED ON CHITOSAN AND GUM ARABIC, ENRICHED WITH GRAPE SEED EXTRACT

Sample	pH value	V (m Pa s)	T (m N m ⁻¹)
K	4.70 ± 0.04 ^d	68 ± 0 ^c	2.622 ± 0.064 ^a
KE	4.70 ± 0.04 ^{cd}	74 ± 0 ^b	2.861 ± 0.014 ^a
GA	4.93 ± 0.09 ^{ab}	40 ± 0 ^{de}	0.145 ± 0.004 ^b
GAE	4.96 ± 0.05 ^a	50 ± 0 ^d	0.209 ± 0.003 ^b
KGA	4.86 ± 0.01 ^{ab}	20 ± 0 ^e	0.093 ± 0.002 ^b
KGAE	4.83 ± 0.02 ^{bc}	20 ± 0 ^e	0.067 ± 0.001 ^b

Addition of **GSE** have:

- **no significant effect** on the **pH value**
- **increased viscosity** in simple formulations,
- **no significant impact** on **chitosan-GA complex**

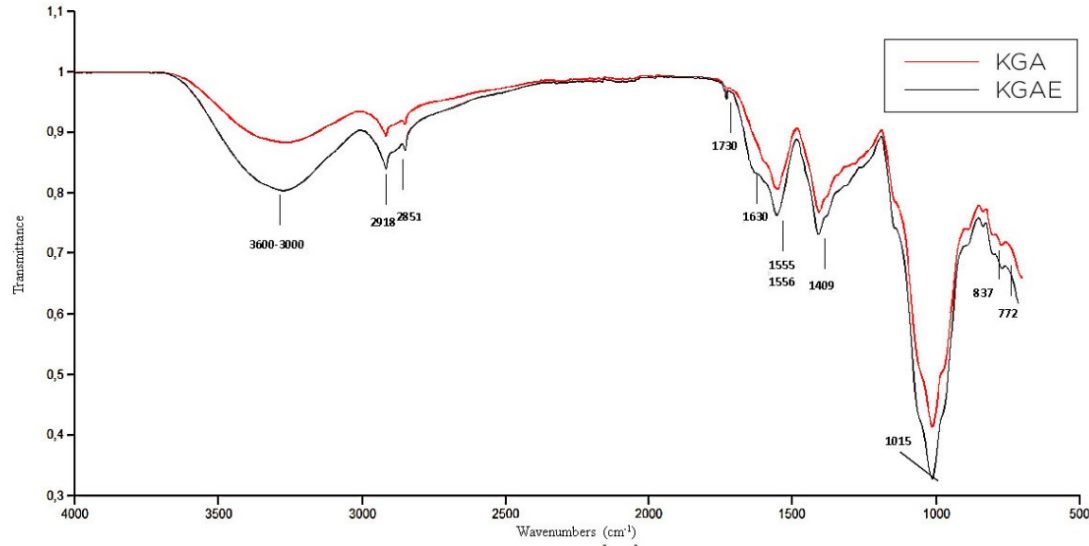


Despite the presence of agglomerates, the **surface of the KGAE** remained smooth, indicating **excellent structural integrity and compactness**.

Scanning electron microscopy (SEM) of the chitosan-GA film with and without GSE



PHYSICOCHEMICAL, THERMAL AND STRUCTURAL PROPERTIES OF EDIBLE FILMS BASED ON CHITOSAN AND GUM ARABIC, ENRICHED WITH GRAPE SEED EXTRACT



No significant changes
between KGA and KGAE

- KGA and KGAE films remained stable at higher temperatures.
- 80°C was chosen as the most suitable drying temperature for cookies after the FFS application.

Table 3. Thermal transition temperatures of tested samples

Sample	T _d (°C)	T _{DS} (°C)
CS powder	80.4	186.8
GA powder	nd	167.7
GA	nd	nd
CS	nd	175.5
KGA	nd	178.8
KGAE	nd	191.6
		179.2



EXTENDING THE SHELF-LIFE OF COOKIES THROUGH THE APPLICATION OF EDIBLE FILMS

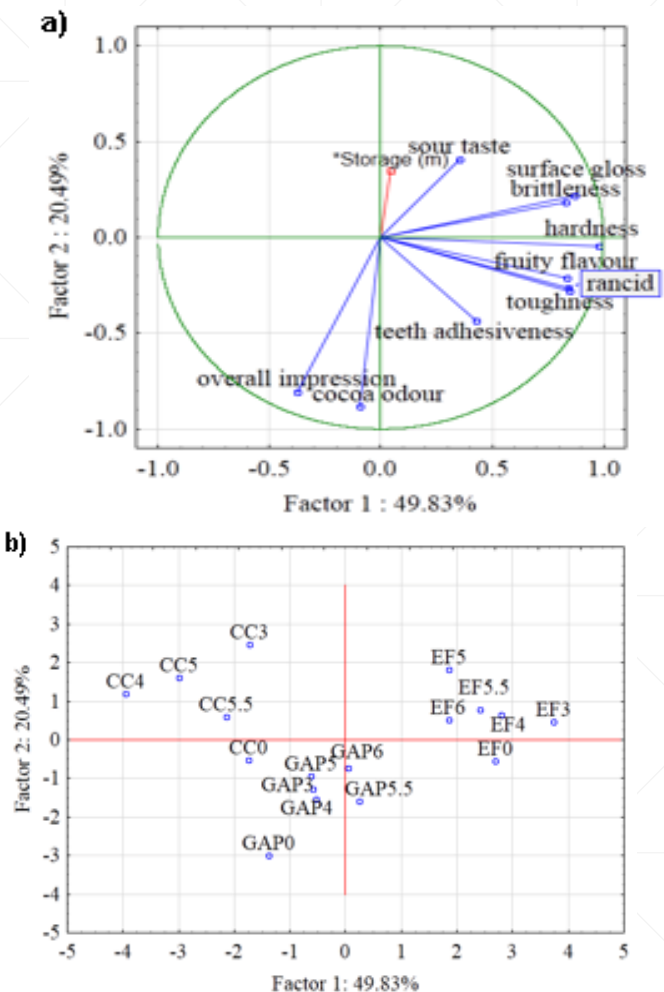


Figure 3. Principal component loadings (a) and score (b) plots of instrumental (brittleness, breaking strength) and sensory attributes of control cookies (CC), GAP and GAP with KGAE (EF) during 0, 1, 3, 4, 5, 5.5 and 6 months of ambient storage.

Parameters	CC	GAP	GAP with KGAE
TPC of fresh cookies ($\mu\text{g GA g d. w}^{-1}$)	1.39 ± 0.01^a	1.58 ± 0.02^b	1.63 ± 0.03^b
Moisture of fresh cookies (%)	3.55 ± 0.06^{aC}	3.67 ± 0.06^{aB}	2.72 ± 0.05^{bB}
PV of fresh cookies (mmol/kg)	3.09 ± 0.09^{aA}	1.59 ± 0.10^{cD}	2.57 ± 0.13^{bD}
After 3 months of storage			
Moisture T22°C (%)	3.82 ± 0.03^{bB}	4.09 ± 0.12^{aA}	3.16 ± 0.04^{cA}
Moisture T30°C (%)	4.51 ± 0.09^{aA}	3.09 ± 0.08^{bC}	2.98 ± 0.04^{bA}
Moisture T35°C (%)	2.52 ± 0.07^{aD}	2.89 ± 0.03^{bC}	2.96 ± 0.09^{bA}
PV (mmol/kg) T22°C	4.66 ± 0.04^{aB}	2.67 ± 0.09^{bC}	4.46 ± 0.07^{aC}
PV (mmol/kg) T30°C	4.53 ± 0.07^{bB}	3.94 ± 0.04^{cB}	4.81 ± 0.09^{aB}
PV (mmol/kg) T35°C	4.97 ± 0.04^{cA}	8.3 ± 0.13^{aA}	6.99 ± 0.10^{bA}

- The peroxide value (PV) increased over 3 months but stayed below the critical level of $10 \text{ mmol O}_2 \text{ kg}^{-1}$
- After 6 months, a rancid odor was detected only in 100 % cocoa cookies indicating the development of secondary oxidation products and the end of its shelf-life.



Article

Application of Fruit By-Products and Edible Film to Cookies: Antioxidant Activity and Concentration of Oxidized LDL Receptor in Women—A First Approach

Dunja Molnar ¹, Nora Nikolac Gabaj ^{2,3}, Lovorka Vujčić ^{2,*}, Mario Ščetar ¹, Judit Krisch ⁴, Marijana Miler ³, Mario Štefanović ³ and Dubravka Novotni ^{1,*}

- ¹ Faculty of Food Technology and Biotechnology, University of Zagreb, Pierottijeva 6, 10000 Zagreb, Croatia; dunjamolnar151@gmail.com (D.M.); mscetar@pbf.hr (M.Š.)
 - ² Faculty of Pharmacy and Biochemistry, University of Zagreb, A. Kovačića 1, 10000 Zagreb, Croatia; nora.nikolac@gmail.com
 - ³ University Department of Chemistry, University Hospital Center Sestre Milosrdnice, Vinogradska Cesta 29, 10000 Zagreb, Croatia; marijana.miler@gmail.com (M.M.); mario.stefanovic@kbcsm.hr (M.Š.)
 - ⁴ Institute of Food Engineering, University of Szeged, Mars Tér 7, 6724 Szeged, Hungary; krisch@mk.u-szeged.hu
- * Correspondence: lvujc@pharma.hr (L.V.); dubravka.novotni@pbf.unizg.hr (D.N.)

Abstract: Cookie consumption can change the serum level of oxidized low-density lipoprotein (oxLDL) and oxLDL receptors, both playing important roles in the pathogenesis of atherosclerosis and cardiovascular diseases. This study investigated the nutritional value and the antioxidant activity of whole grain cookies in which 24% of the cocoa powder was substituted with grape and aronia pomace and were further coated with edible films enriched with grape seed extract (GAP with KGAE) as well as the effects of their consumption on the serum level of oxLDL receptors in women. The proximate composition, mineral content, antioxidant activity, and starch digestibility in vitro of experimental and control cookies were determined. A group of 12–13 healthy women (median age 36) consumed 45 g of GAP with KGAE or commercial cookies for 10 days. The results showed that GAP and KGAE cookies had increased flavonoid content (22%) and antioxidant potential (27–73%) compared to the control. The content of slowly digestible starch prevailed over rapidly digestible starch. The serum concentrations of the oxLDL receptors between the test and control groups were similar. We can conclude that the moderate consumption of whole grain cookies with fruit by-products does not lead to the formation of oxLDL receptors in healthy women.

Keywords: oxidized LDL receptor; starch digestibility; biscuits; chitosan; gum arabic; grape pomace; aronia; chokeberry pomace; cocoa substitute; grape seed extract



- How does the substitution of cocoa powder with fruit by-products, coupled with the application of edible films, affect the nutritional composition, antioxidant capacity, and starch digestibility of cookies?
- Can the regular consumption of cookies where 24 % of cocoa is replaced by grape- and aronia pomace and further coated with edible films enriched with grape seed extract modulate oxLDL receptor levels in healthy women?



APPLICATION OF FRUIT BY-PRODUCTS AND EDIBLE FILM TO COOKIES: ANTIOXIDANT ACTIVITY AND CONCENTRATION OF OXIDIZED LDL RECEPTOR IN WOMEN -Study design and methodology-

Nutritional composition

ash (AACC 08-01), moisture (gravimetically), protein (Kjeldahl method), fat (Soxhlet method), methyl ester of fatty acids (gas chromatography), crude fiber content (AOAC method),

Antioxidant activity

Total phenol content (modified Folin Ciocalteu method), flavonoides (spectrophotometric method), antioxidant activity (FRAP, DPPH, ABTS)

In vitro starch digestibility

method by Englyst⁹

Randomized controlled trial

25 healthy women, 36 years on average

GAP with KGAE (test) or commercial cookies (control) for 10 days

45 g of cookies
(30 g for breakfast and 15 g between meals)

Dietary methods*
(Food frequency questionnaire)

Anthropometric measurements*
(BH, BW, BMI, waist and hip circumference)

Biochemical methods*
(glucose, triglycerides, total cholesterol, LDL, HDL, oxLDL receptor, iron in blood/serum)

*Beginning of the study

**Beginning of the study in the fasting state, 2h after cookies consumption, after 10 days of the intervention

THE NUTRITIVE PROFILE OF COOKIES WITH FRUIT BY-PRODUCTS AND EDIBLE FILMS

Table 1. Proximate composition, starch digestibility in vitro, minerals and antioxidant activity (FRAP, ABTS and DPPH) of different types of cookies.

CONTENT	CC	GAP	GAP with KGAE
Total Fat (g/ 100g)	18.65 ± 0.17 ^a	18.35 ± 0.16 ^a	19.16 ± 0.08 ^b
SFA (g/ 100g)	8.2 ± 0.08 ^a	8.1 ± 0.08 ^a	8.4 ± 0.04 ^b
MUFA (g/ 100g)	6.6 ± 0.06 ^a	6.5 ± 0.09 ^a	6.8 ± 0.03 ^b
PUFA (g/ 100g)	3.4 ± 0.03 ^a	3.3 ± 0.05 ^b	3.4 ± 0.01 ^{a,b}
TS (% dry weight)	39.99 ± 0.54 ^a	42.69 ± 1.49 ^a	41.96 ± 0.94 ^a
RDS (% dry weight)	17.63 ± 14.41 ^a	18.63 ± 0.47 ^{a,b}	21.06 ± 1.45 ^b
SDS (% dry weight)	21.46 ± 2.03 ^a	21.40 ± 2.62 ^a	19.02 ± 3.40 ^a
RS (% dry weight)	0.88 ± 0.43 ^a	2.65 ± 1.45 ^a	1.88 ± 1.87 ^a
RAG (% dry weight)	29.49 ± 1.23 ^a	30.71 ± 0.47 ^a	32.70 ± 1.82 ^a
Free Glucose (% dry weight)	9.89 ± 0.33 ^a	10.01 ± 0.21 ^a	9.30 ± 0.32 ^a
Protein (g /100g)	10.1 ± 0.01 ^a	8.9 ± 0.16 ^a	9.3 ± 0.01 ^b
Crude fiber (g /100g)	2.29 ± 0.06 ^a	2.20 ± 0.01 ^a	2.15 ± 0.05 ^a
Minerals as ash (g/100g dry weight)	2.04 ± 0.18 ^a	1.99 ± 0.11 ^a	1.99 ± 0.17 ^a
Iron (mg/ kg)	33 ± 2 ^b	35 ± 1 ^a	33 ± 2 ^b
Calcium (mg/ kg)	60 ± 3 ^a	59 ± 3 ^a	52 ± 2 ^b
Magnesium (mg/ kg)	326 ± 12 ^a	292 ± 24 ^b	239 ± 19 ^c
Sodium (mg/ kg)	4206 ± 25 ^a	3649 ± 31 ^b	3376 ± 29 ^c
Flavonoid (mmol rutin/ 100 g dry weight)	0.145 ± 0.02 ^a	0.139 ± 0.02 ^a	0.177 ± 0.02 ^b
FRAP (mmol Trolox/ 100 g dry weight)	3.022 ± 0.11 ^c	3.963 ± 0.03 ^b	4.316 ± 0.21 ^a
ABTS (mmol Trolox/ 100 g dry weight)	11.47 ± 0.58 ^a	13.88 ± 0.46 ^b	14.58 ± 0.90 ^c
DPPH (mmol Trolox/ 100 g dry weight)	0.074 ± 0.01 ^a	0.110 ± 0.01 ^b	0.128 ± 0.01 ^c
TPC of fresh cookies (μ GA gd.w ⁻¹)	1.39 ± 0.01 ^a	1.58 ± 0.02 ^b	1.63 ± 0.03 ^b

Slowly digestible starch (SDS)

- increased in all three type of cookies, → **low to medium GI, potential benefit for satiety**

Resistant starch (RS)

- GAP and GAP with KGAE statistically not significant

Rapidly digestible starch (RDS)

- GAP with KGAE statistically not significant → thicker layer of edible film needed

GAP in combination with KGAE:

- increased flavonoid** content (22 %)
- increased antioxidant activity** (27 % to 73 %)
- Increased TPC**



EFFECTS OF THE CONSUMPTION OF COOKIES CONTAINING GAP WITH KGAE ON oxLDL RECEPTOR IN HEALTH WOMEN

Table 3. Concentration of oxidized low-density lipoprotein (oxLDL) receptor in control and test group at the beginning of the study and after intervention.

Parameter	Total	Control Group	Test Group	P (control vs. test group)
oxLDL receptor (0) (ng/mL)	0.29 (0.18-0.47)	0.29 (0.19-0.52)	0.29 (0.18-0.47)	0.765*
oxLDL receptor (after 2h) (ng/mL)	0.42 (0.25-0.48)	0.37 (0.24-0.45)	0.45 (0.30-0.60)	0.276*
P (0 vs. 2h)		0.753**	0.917**	
oxLDL receptor (after 10 days) (ng/mL)	0.42 (0.27-0.46)	0.43 (0.24-0.45)	0.37 (0.27-0.50)	0.744*
P (0 vs. 10 d)		0.583**	1.000**	
P (2h vs. 10 d)		0.480**	0.600**	

Table 5. Correlation of concentration of oxidized low-density lipoprotein (oxLDL) receptor with anthropometric and biochemical parameters

Parameter	oxLDL receptor (2h)				oxLDL receptor (10 d)			
	Control Group		Test Group		Control Group		Test Group	
	r*	P	r*	P	r*	P	r*	P
Body mass index (kg/m ²)	-0.14	0.665	-0.11	0.734	-0.42	0.176	0.48	0.094
Waist circumference (cm)	-0.18	0.614	-0.13	0.680	-0.67	0.034	0.31	0.336
Hip circumference (cm)	-0.34	0.334	-0.25	0.429	-0.31	0.390	0.25	0.436
Waist-hip ratio	-0.12	0.748	0	0.983	-0.60	0.068	0.39	0.216
Iron (Fe) (μmol/L)	0.25	0.434	0.08	0.788	0.69	0.012	-0.62	0.022
UIBC (μmol/L)	-0.23	0.476	-0.19	0.530	-0.47	0.121	0.23	0.452
TIBC (μmol/L)	-0.31	0.331	-0.39	0.193	-0.02	0.948	-0.28	0.356
Fe saturation (%)	0.29	0.358	0.04	0.897	0.61	0.037	-0.47	0.105

CONCENTRATION OF oxLDL RECEPTORS:

- ✓ **NO** statistically significant difference between the test or control group at the beginning or the end of the study
- ✓ **NO** statistically significant predictor of change in concentration of oxLDL at day 10 in either group

WAIST CIRCUMFERENCE AND oxLDL RECEPTOR CONCENTRATION

- an **inverse correlation** between waist circumference and oxLDL receptor concentration on the **10th day** of cookies consumption in **CONTROL** group

IRON CONCENTRATION AND oxLDL

- **Inverse correlation** between oxLDL receptor levels and :
 - serum iron
 - iron saturation in **TEST** group





Article

Consumer Nutritional Awareness, Sustainability Knowledge, and Purchase Intention of Environmentally Friendly Cookies in Croatia, France, and North Macedonia

Dunja Molnar ¹, Elena Velickova ², Carole Prost ³, Mishela Temkov ², Mario Ščetar ¹ and Dubravka Novotni ^{1,*}

¹ University of Zagreb Faculty of Food Technology and Biotechnology, Pierottijeva 6, 10000 Zagreb, Croatia; dunjamolnar151@gmail.com (D.M.); mscetar@pbf.hr (M.Š.)

² Faculty of Technology and Metallurgy, Ss. Cyril and Methodius University in Skopje, Rudger Boskovic 16, 1000 Skopje, North Macedonia; velickova@tmf.ukim.edu.mk (E.V.); mishela@tmf.ukim.edu.mk (M.T.)

³ ONIRIS, Nantes Université, CNRS, GEPEA, UMR 6144, F-44322 Nantes, France; carole.prost@oniris-nantes.fr

* Correspondence: dubravka.novotni@pbf.unizg.hr; Tel.: +385-14606167

Abstract: The increasing demand for greater utilization of byproducts in the food industry has been driven by growing interest in environmental sustainability. This paper examines the market potential and consumer attitudes toward whole-grain and sustainable cookies made with food byproducts and edible films. Additionally, particular attention was given to evaluating levels of sustainability knowledge and nutritional awareness, willingness to purchase environmentally friendly cookies with food byproducts, and to appraise differences in answers between countries and generations. An online questionnaire was used to collect data from Croatian ($n = 472$), French ($n = 166$), and North Macedonian consumers ($n = 119$) aged between 18 and 62, predominantly women (82%) with higher education degrees. Results showed that even if chocolate-coated cookies remain very popular, North Macedonians prefer whole-grain and plain cookies, while the French prefer chocolate-coated cookies and Croats prefer both types of cookie. The majority of consumers (96%) were interested in purchasing environmentally friendly cookies. However, consumers' interest in purchasing cookies with food byproducts was generally low, which may be related to their limited knowledge of byproducts. In conclusion, there is market potential for whole-grain cookies with food byproducts, but brand, price, and consumer education may be critical to their success.

Keywords: food byproducts; generational differences; nutritional awareness; sustainability knowledge



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- What is the market potential for eco-friendly cookies in Croatia, France, and North Macedonia?
- Examine consumers' nutritional awareness, sustainability knowledge and their purchasing intentions towards environmentally friendly cookies in Croatia, France, and North Macedonia
- Is a purchase intention positively influenced by consumer education degree and does it differ between generations and countries?



CONSUMER NUTRITIONAL AWARENESS, SUSTAINABILITY KNOWLEDGE, AND PURCHASE INTENTION OF ENVIRONMENTALLY FRIENDLY COOKIES

-Study design-

STUDY DESIGN AND STUDY POPULATION

Cross-sectional study

(Croatia, France, North Macedonia)

Online questionnaire (Google Forms)

43 multiple-choice questions divided into several sections: sociodemographic (5 questions), cookie consumption (9 questions), purchase intention (8 questions), brand (4 questions), nutrition and health (9 questions), and sustainability (3 questions) – **Likert** scaled (5)

E-mail and social networks

(Facebook® and LinkedIn®)

797 participants

(Croatia (n = 500), France (n = 172), North Macedonia (n = 125))

Descriptive statistics, frequency distribution, and correlation analyses

Kruskal–Wallis analysis of variance (ANOVA)

PCA and hierarchical cluster analysis using Ward's method
classification and regression tree (C&RT)

GENERATION Z¹⁰

(born between 1997 and 2004)

GENERATION Y¹⁰

(born between 1981 and 1996)

GENERATION X¹⁰

(born between 1972 and 1980)

GENERATION SILVER¹⁰

(born between 1952 and 1971)

STATISTICS



CONSUMER NUTRITIONAL AWARENESS AND SUSTAINABILITY KNOWLEDGE OF ENVIRONMENTALLY FRIENDLY COOKIES

Index of nutrition awareness	Component
Do you introduce biologically active compounds into your body daily	0.608
How often do you consume food rich in dietary fiber	0.713
To what extent do you agree with the following statement: I watch what I eat to maintain my health	0.765
How much do you agree with the following statement: I watch what I eat to maintain a good appearance and prevent weight gain	0.644
Are you reading food labels; particularly nutritional values and ingredient list on food products?	0.615
Explanation of variance	45%
Eigenvalue	2.257
Sustainability knowledge score	
Are you familiar with the term Sustainable Development?	0.533
How much do you agree with the following statement Edible films are active packaging systems that extend product shelf life, improve product quality, and contribute to the nutritional quality of the final product	-0.798
To what extent do you agree with the following statement: Grape and/or aronia pomace is a by-product of the food industry rich in dietary fiber and polyphenols	-0.806
Explanation of variance	52%
Eigenvalue	1.57

The index of nutritional awareness (INA)

The sustainability knowledge score (SKS)

Upitnik o keksima/ čajnom pecivu

B I U

(prilagođeno prema Čukelj, N., 2013)

Upitnik se provodi kao dio doktorskog projekta te će rezultati ankete bit će obrađeni i prikazani u doktorskoj disertaciji Dunje Molnar, mag. nutricionizma.

O UPITNIKU: Žitarice su važan izvor energije i ugljikohidrata u svakodnevnoj prehrani. Spekter proizvoda iz žitarica koji se mogu naći na tržištu je širok, a među njima se nalaze fini pekarski proizvodi poput keksa i čajnog peciva. Na žalost mnogih, njihova se konzumacija preporuča u ograničenim količinama zbog velike energetske i male hranjive vrijednosti. Dobra vijest u čitavoj priči je ta da se na policama dućana mogu pronaći i vrste keksa i čajnog peciva od cjelovitih žitarica koje zahvaljujući svojoj povećanoj prehrambenoj vrijednosti mogu čak i pridonijeti pozitivnom zdravstvenom statusu organizma.

Nadalje, primjenom nusproizvoda prehrambene industrije, poput tropa grožđa i tropa aronije, koji su bogati izvori polifenola, moguće je značajno poboljšati nutritivnu vrijednost i trajnost hrane. Primjenom jestive ambalaže moguće je pak pridonijeti sveukupnoj kvaliteti hrane, nutritivno obogatiti hranu, produljiti njenu trajnost te smanjiti udio upotrebene ambalaže. Na Prehrambeno-biotehničkom fakultetu Sveučilišta u Zagrebu provodi se istraživanje vezano uz dodatak tropa grožđa i aronije i primjenu jestivog filma u čajnom pecivu.

Dio istraživanja čini i ovaj upitnik. Cilj upitnika je dobiti informacije o navikama jedenja keksa i čajnog peciva te uvid u znanja, stavove i faktore koji utječu na odabir klasičnih i obogaćenih keksa/ čajnog peciva. Upitnik se sastoji od niza pitanja i tvrdnji na koja treba odgovoriti odabirom jednog odgovora odnosno tvrdnje. Molimo da svojim odgovorima doprinesete istraživanju te pokušate odgovoriti na svako pitanje, ukoliko se odnosi na Vas.

Upitnik je anonimn.

Za ispunjavanje upitnika potrebno je 10 - 12 min.

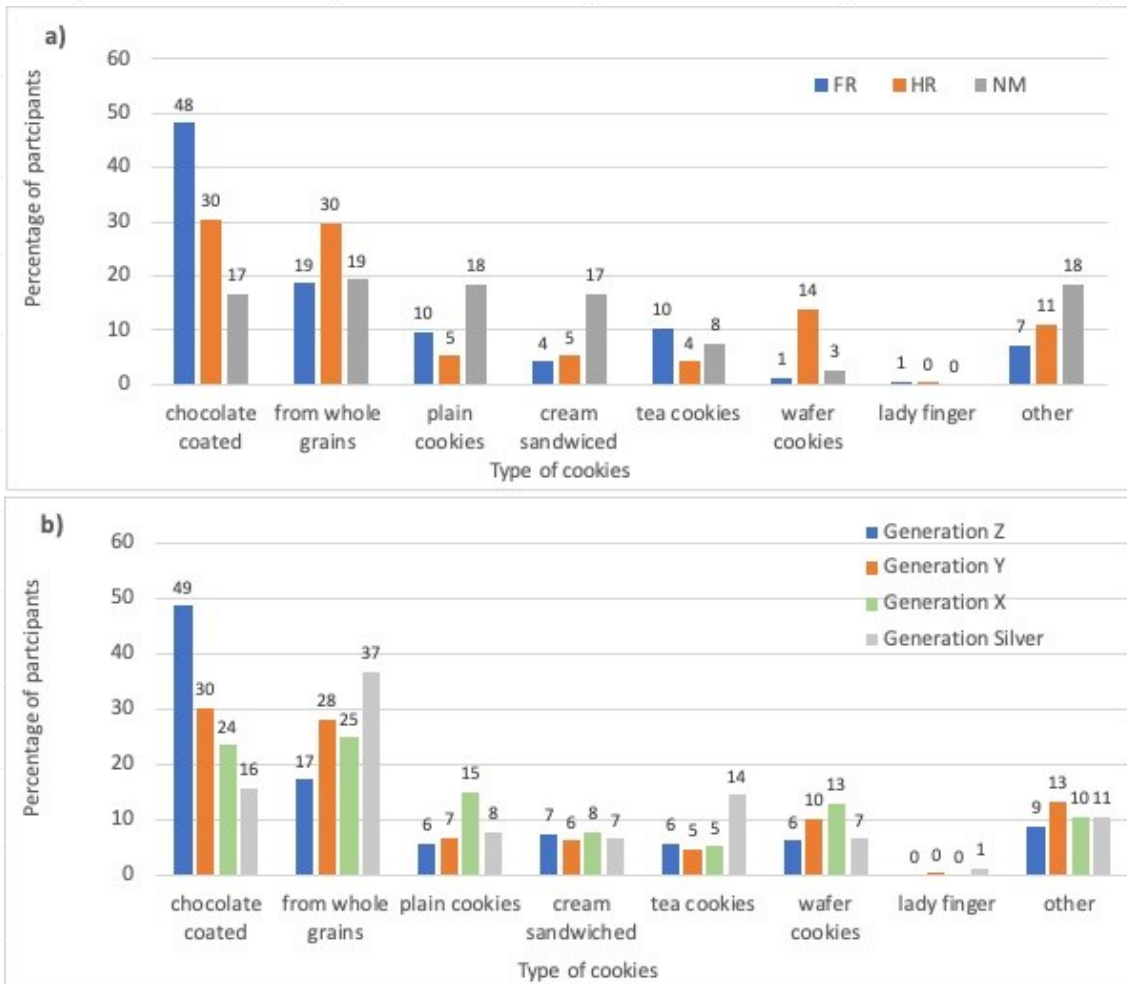
Autorica upitnika: doc. dr. sc. Nikola Čukelj Mustač, LABORATORIJ ZA KEMIJU I TEHNOLOGIJU ŽITARICA, PREHRAMBENO-BIOTEHNIČKI FAKULTET, SVEUČILIŠTE U ZAGREBU

1. Jedete li žitarice i njihove proizvode? *

☐ DA

☐ NE

MARKET POTENTIAL TOWARDS WHOLE GRAIN AND SUSTAINABLE COOKIES



TYPE OF COOKIES PREFERRED:

- Generation Silver and North Macedonians favored whole grain cookies
- Generation Z and French preferred chocolate-coated cookies

Figure 1. Preference (in percentage) of cookies type by a) country of residence (FR=France, HR= Croatia, NM= North Macedonia) and b) generations.

CONSUMER NUTRITIONAL AWARENESS AND SUSTAINABILITY KNOWLEDGE OF ENVIRONMENTALLY FRIENDLY COOKIES

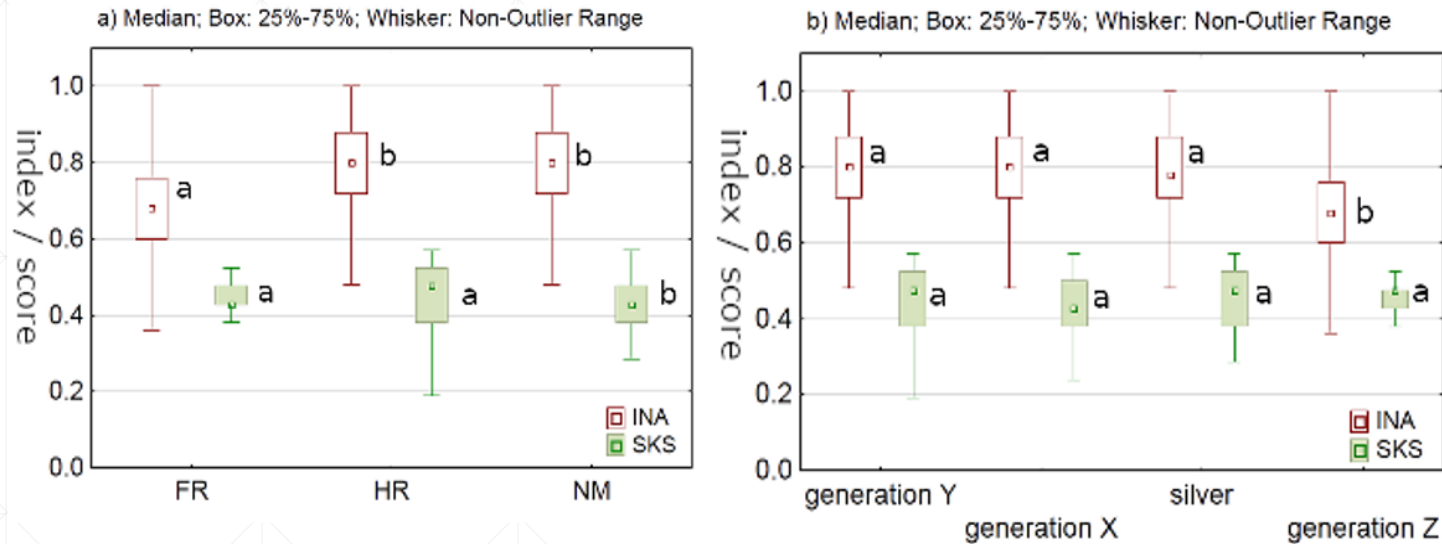


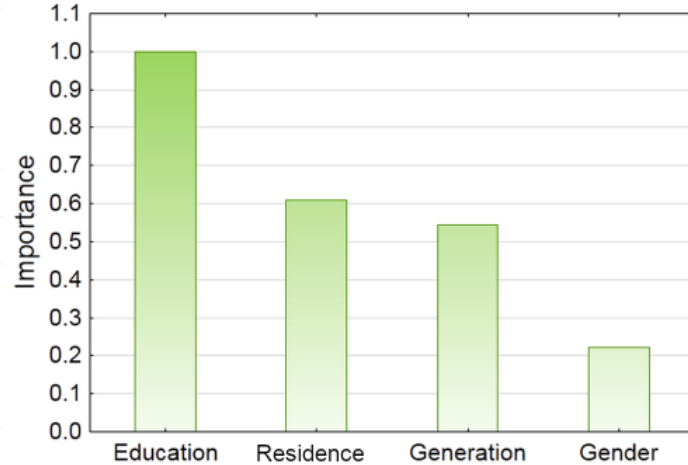
Figure 4. Nutrition awareness index (INA) and sustainability knowledge score (SKS) by a) country of origin; FR =France, HR = Croatia, NM = North Macedonia and b) generations. Boxplots with different letters represent statistical difference ($p < 0.05$) between countries or generations.

- **Generation Z and French** participants showed the **lowest** level of **nutritional awareness**, emphasizing the need for **targeted health education initiatives** aimed at this demographic group.
- **84 %** of **participants demonstrated awareness** regarding the importance of sustainable product development
- significant **variations** in **sustainability knowledge scores** across the different investigated countries exist due to a **lack of understanding** regarding fruit by-products and edible films



MARKET POTENTIAL TOWARDS WHOLE GRAIN AND SUSTAINABLE COOKIES

a) Would you be interested in buying a cookies that, in addition to having a positive impact on human health, also has a positive impact on the environment?



(b) Would you be willing to buy cookies with by-products of the food industry?

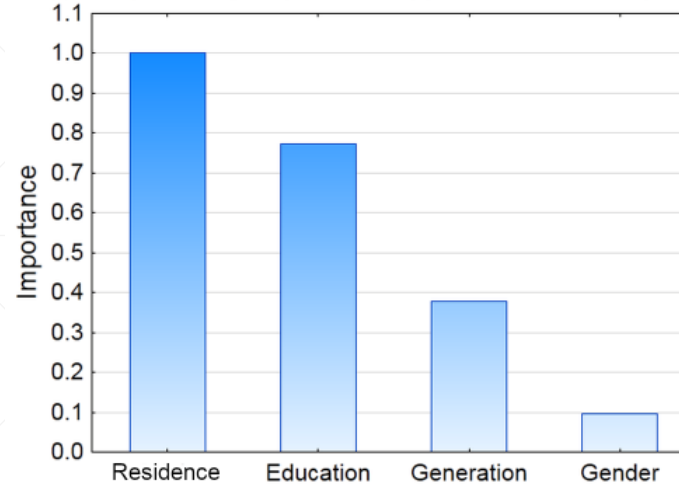


Figure 6. The importance plot of education level, country of residence, generation, and gender on consumer interest in purchasing cookies that a) have a positive impact not only on human health but also on the environment and b) contain by-products of the food industry.

RESULTS SUMMARY:

- **Most consumers** are familiar with sustainability concepts and express interest in purchasing eco-friendly cookies.
- **Awareness on fruit by-products** or edible films, as well as **their willingness to purchase** cookies containing food by-products, remains limited.



CONCLUSIONS



- Grape- and aronia pomace **can effectively substitute up to 24 % of cocoa powder** in cookie formulations without compromising their sensory acceptability.
- The edible films, containing chitosan and gum arabic enhanced with GSE, show **favorable physico-chemical, morphological, and thermal characteristics**.
- Incorporating GSE into the chitosan and gum arabic-based edible film resulted in a **rise in total phenolic content and film thickness by 41 % and water vapor barrier by 30 %, while reduced transparency by 92 %**
- The application of coatings, significantly **prolonging their shelf-life by at least 30 days** compared to the CC **without compromising sensory properties** or the overall quality of the product.



- The addition of fruit by-products and edible films had a beneficial influence, **increasing the flavonoid content by 22 %** and the **antioxidant potential by up to 73 %** compared to the control cookies.
- Moderate consumption of whole grain cookies containing fruit by-products **did not result in the formation of oxLDL receptors** in healthy women.
- The insights garnered from the evaluation of market potential, nutritional awareness, and **sustainability knowledge** across Croatia, France, and North Macedonia will be crucial in formulating a **marketing and education strategy to enhance consumer acceptance of food products containing upcycled ingredients**, thereby fostering the advancement of the circular economy.



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Q & A

Email: dunjamolnar151gmail.com

