Extruded snacks from maize flour with red grape pomace

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Abstract

Introduction. Grape pomace is a promising ingredient that can be valorized to obtain functional foods. The development of new ready-to-eat products with increased nutritional value is a current research topic.

Materials and methods. Seedless (SGPR) and whole (GPR) red grape pomace was used to obtain maize-based snacks by extrusion. The protein, ash, fiber, lipids, total polyphenols, starch fractions, color, cutting force, and sensory acceptability parameters were investigated to evaluate the impact of grape pomace type (seedless and whole) and addition level (10-40%) on maize snacks quality.

Results and discussion. The amounts of added grape pomace showed significant ($p < 0.05$) effects on almost all the characteristics considered, while grape pomace type had a significant effect only on polyphenol content, antioxidant activity, starch fractions, cutting force and color parameters. The raise of grape pomace level led to the increase of the content of protein, lipids, ash, fiber, total polyphenols, and slowly and resistant digestible starch (up to 30% addition level) in the extruded snacks. The luminosity of the extruded snacks decreased along with the a* color parameter, while b* increased as the amount of grape pomace was higher. A significant reduction of the cutting force was observed as the addition level of grape pomace increased. As for sensory acceptability, it increased with increasing content of seedless or whole grape pomace up to 30%, and decreased with further SGPR or GPR content increase. The best amount of additive was 30% for seedless grape pomace and about 20% for whole grape pomace. The improved samples exhibited higher nutrients content, antioxidant properties and polyphenols content compared with the control. The improved maize-based snacks presented higher FT-IR absorbances and an enhanced amino acid profile compared with the control. Among the essential amino acids in the improved and control extruded snacks, threonine and methionine predominated, and among the nonessential ones, the highest content was noted for aspartic acid, alanine, and tyrosine.

Conclusion. Addition of seedless grape pomace, 30%, or whole grape pomace, 20%, allowed to produce extruded maize snacks with increased nutritional value.

Introduction

The demand for healthier and more nutritious snacks is increasing, and for this reason, various approaches to enhance the quality of snacks production from maize flour are presented in the scientific papers. The maize snacks products are usually have high glycemic index and low nutrients. The partial substitution of maize flour with grape by-products in the extrusion process represents a significant opportunity for wine by-products upcycling. At the same time, the extrusion processing is a technology recognized for its functionality and versatility that looks as a promising option for the incorporation of various by-products types (Garcia-Amezquita et al., 2018; Mironeasa et al., 2019). It produces dietary fiber enriched foods or products improved nutritionally which cannot be made easily by any other process (Grasso, 2020).

Red grape pomace, a by-product of red wine production, available in high amount at low prices, is characterized by a high dietary fiber content and phenolic compounds because during winemaking only a minor part of grape phytochemicals are extracted into the wine (Grevtseva et al., 2023; Rainero et al., 2022; Stabnikova et al., 2023). The pomace is still rich in phenolic compounds, dietary fibres, proteins of high value, lipids, and minerals (Beres et al., 2017; Yu and Ahmedna, 2013), being suitable to enhance the nutritional value of various food products (Iuga and Mironeasa, 2020). Moreover, the bioactive molecules from grape pomace have been proven to be of vast health benefits, including their ability to influence carbohydrates metabolism (Rudra et al., 2015). The dietary fibers include pectin, cellulose and hemicelluloses (Deng et al., 2011) and were associated with lower rate of starch hydrolysis (Hardacre et al., 2016), reduction in glucose absorption (Villemejane et al., 2016), helping in obesity prevention, blood cholesterol levels reduction and fecal transit time decrease (Dhingra et al., 2012; Rainero et al., 2022). Phenolic compounds containing mainly condensed tannins, anthocyanins, and resveratrol with antioxidant and radical scavenging properties (Yu and Ahmedna, 2013) play a crucial role in preventing of some diseases (Rothwell et al., 2017). Some studies have reported that phenolic compounds can affect carbohydrate hydrolysis (Zhu, 2015), are premised to bind to active or secondary sites of digestive enzymes (Barrett et al., 2015) and/or bind to substrate thus reducing starch hydrolysis (Podsedek et al., 2014).

During extrusion cooking, snacks ingredients and their components undergo different changes resulting extrudates with enhanced functionalities. The transformations in the functional features are related to the nutritional characteristics of the extruded snacks (Alam et al., 2016). There have been carried out researches on improving the nutritional properties of extruded snacks based on corn grits by adding tomato skin, seed, and paste (Dehghan-Shoar et al., 2010). The authors reported that starch digestibility decreased as the proportion of tomato derivates was higher. This was attributed to the complex formation between starch and pectin that limited the contact of starch with the digestive enzyme like alpha-amylase. In another study (Karkle et al., 2012), when cornmeal was substituted with apple pomace, it was found that this pomace limits starch digestibility by reducing starch transformation and creating a more compact structure. The diversity in the composition of the vegetable pomace determined different hardness and expansion between the different pomace-incorporated samples obtained in the same processing conditions (Potter et al., 2013).

Grape pomace at levels of 10 and 20% was extruded with cassava-soy composite by Oladiran and Emmambux (2018). The authors reported that the addition of grape pomace lowers the rate of starch digestion, increasing slowly digestible starch and decreasing rapidly digestible starch. An increase in grape pomace level determines an increase in protein and lipid content of extrudates, which can cause decreased digestibility of extrudates (Oladiran and Emmambux, 2018). The total phenolic content and antioxidant activity also increased in extruded snacks as the level of grape pomace increased. As the amount of grape pomace increased, FTIR spectra showed a significant decrease in α-helical conformation, promoting an increase in β-sheet formation (Oladiran and Emmambux, 2018). Grape peel flour has been used in extrusion cooking (Fontoura et al., 2022) by mixing with brown sorghum flour in proportions of 10%-20%. Using response surface methodology, responses including proximate composition, pasting and expansion properties were influenced by the addition of grape peel, but acceptable extrudates were obtained. The resulting products presented significant values of antioxidants and phenolic compounds and can contribute to the health of consumer.

Most of the studies from recent years found that the addition of pomace at levels up to 100 g/kg by weight of the final product shows no considerable negative effects on the eating quality, whereas detrimental impact was often observed beyond this incorporation level (Altan et al., 2008a; Altan et al., 2008b; Bajerska et al., 2016). However, the valorization of grape by-products has become a growing trend in the food industry due to these nutritionally valuable raw materials, and thus reducing the total waste and determining increase the nutritional value of the new products. By incorporating high amounts of pomace in corn extrudates, changes in the nutritional and functional properties, and also color, texture parameters and acceptability of these products occur.

Conducting research on the incorporation of different grape by-products in high percentages into extrudates can enhance our understanding of how various ingredients interact in the extrusion process and affect extruded snacks quality. Therefore, this study aims to investigate the impact of red seedless and whole grape pomace in various amounts (10-40%) in a mixture with maize flour on some features of extruded snacks. Furthermore, the properties of the best snacks from nutritional and functional properties point of view were investigated.

Materials and methods

Materials

The red grape pomace was sourced from the Iași Research and Development Center for Viticulture and Vinification, while the maize flour, a commercial variety, was obtained from a producer in northern Romania. The grape pomace was dried in a ZRD-A5055 convection oven (Zhicheng Analysis Instrument, Shanghai, China) at 50°C for 20 h, reducing its moisture content to below 10%. After drying, the pomace was divided into two categories: seedless grape pomace and whole grape pomace. Both were ground using a laboratory mill (Perten 3100, Perten Instruments, Huddinge, Sweden) and passed through 0.20 mm sieves to achieve a uniform particle size. Maize flour, initially sieved to a uniform size of 1.00 mm, was then thoroughly mixed with the seedless grape pomace (SGPR) and whole grape pomace (GPR). Maize flour alone served as the control (M). During the mixing process, water was gradually added at medium speed using a Bosch MFQ3520 mixer (Gerlinger, Germany) to achieve a final moisture content of 15% (wet basis) in the mixtures.

Extrusion process

The flour mixtures were processed using a laboratory single-screw extruder (Kompakt extruder KE 19/25, Brabender, Duisburg, Germany). This extruder featured a barrel with a

19 mm diameter, a length-to-diameter ratio of 25:1, and a 2 mm nozzle diameter. The extrusion was carried out at a constant feeding speed of 24 rpm, a screw speed of 150 rpm, which operate, with a compression ratio of 3:1. The barrel temperature, divided into four sections from the feeder to the nozzle, was set at 50°C, 95°C, 175°C, and 180°C. After extrusion, the snacks were left to cool at room temperature for 16 h, then cut into small pieces before being packaged in polyethylene bags for future analysis. When needed, the dried samples were ground, using a mortar and pestle, and passed through a 250 mm sieve to ensure uniform particle size distribution.

Methods

Chemical composition

The proximate composition was analyzed using both International and Romanian standard methods: ash content was measured according to SR ISO 2171:2023, protein content following SR EN ISO 20483:2014, and lipid content using SR 91:2007. Total dietary fiber was determined with a Megazyme kit (K-TDFR-200a 04/17) based on the AACC 32-05.01 method.

Total polyphenols content (TPC) and DPPH antiradical activity

The total polyphenols were extracted from the samples using a solution of 70% acetone, 28% water, and 2% acetic acid (v/v/v) with a solid-to-liquid ratio of 1:10 (w/v). The extraction process was carried out in an ultrasonic bath for 60 min at 45 Hz. After extraction, the liquid phase was separated from the solid phase by centrifugation (3234 g for 15 min). The extraction of the solid residue was repeated twice, and the resulting supernatants were combined and filtered.

The total polyphenol content (TPC) was determined using the Folin-Ciocalteu method (FAO/IAEA, 2000). A 0.2 mL aliquot of the extract was diluted with 0.8 mL distilled water, mixed with 0.5 mL of 1N Folin–Ciocalteu reagent, and 2.5 mL of 20% sodium carbonate. The samples were then incubated at room temperature for 40 min. Absorbance was measured at 725 nm using a Shimadzu 3600 UV-Vis-NIR spectrophotometer (Tokyo, Japan), with gallic acid (GAE) as the standard.

The antiradical activity (AA) of the grape-maize snack extracts was determined using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) method, based on previous studies (Bajerska et al., 2016). A 0.5 mL aliquot of the sample extract, diluted with 0.5 mL of 80% methanol, was added to 5 mL of DPPH solution and incubated in the dark at 25°C for 30 min. Absorbance was measured at 517 nm using the same Shimadzu 3600 spectrophotometer, with gallic acid as the standard. A blank sample was prepared, and the results were calculated using Equation (1), where A sample represents the absorbance of the analyzed sample at 517 nm, and A blank represents the absorbance of the blank at 517 nm.

$$AA(\%) = \frac{A_{blank} - A_{sample}}{A_{blank}} \quad (1)$$

Rapid (RDS), slowly (SDS) digestible and resistant (RS) starch

The analysis of starch fractions was conducted according to the international AOAC 2017.16 protocol, using a Megazyme kit (K-DSTRS; Megazyme, Bray, Ireland), following the manufacturer's instructions. Spectrophotometric methods were used to measure the contents of rapidly digestible starch (RDS, after 20 min), slowly digestible starch (SDS, after 120 min), and resistant starch (RS, not digested after 240 min) in the extruded snacks.

Color parameters

The color parameters of the flour mixes were evaluated using a CR-400 chromameter (Konica Minolta, Tokyo, Japan).

Cutting force

The cutting force of the extruded snacks was evaluated using a TVT 6700 texturometer (Perten Instruments, Hägersten, Sweden), equipped with a 10.00 kg load cell. A Warner-Bratzler shear blade probe was used for cutting, with the cut made perpendicularly to the main axis of the snack. The test was conducted at a speed of 1 mm/s until the snack was completely broken.

Determination of acceptability

A sensory analysis to determine the acceptability of the snacks was carried out by 65 semi-trained panelists. Prior to evaluating the products, panelists were provided with a brief explanation of the 9-point hedonic scale and instructed on how to score the extruded snacks. To neutralize their taste buds, panelists were asked to rinse their mouths with water before each evaluation.

Amino acids determination

The amino acid content of the control and improved samples was quantified using a high-performance liquid chromatography (HPLC) system (Shimadzu LC40-PDA-40). The samples were homogenized with 0.1 N HCl in a 1:5 (w/w) ratio and then centrifuged at 10,000 x g for 20 min at 4°C. The supernatant was filtered through a 0.45 µm membrane filter (Igual et al., 2021). A 300 µL portion of the supernatant was deproteinized by adding 900 µL of acetonitrile and then filtered again using a 0.45 µm membrane filter. Pre-column derivatization was carried out following the Agilent Amino Acid Analysis protocol, using OPA (o-phthalaldehyde) and FMOC (9-fluorenylmethyl chloroformate) reagents.

Separation was achieved on a 4.6 x 100 mm LC column, with quantification performed on the Shimadzu LC40-PDA-40 system (Shimadzu, Japan) at a wavelength of 338 nm (bandwidth 10 nm). The mobile phase A was composed of 10 mM Na2HPO4 and 10 mM Na2B4O7 at pH 8.2, while mobile phase B was a mixture of acetonitrile, methanol, and water (45:45:10).

FT-IR analysis

Fourier transform infrared (FTIR) spectroscopy was employed to investigate the molecular properties of the improved and control samples using a Thermo Scientific Nicolet iS20 spectrophotometer (Waltham, MA, USA) in attenuated total reflection (ATR) mode. The spectral range analyzed was from 4000 to 650 cm^{-1}, with a resolution of 4 cm^{-1} and 32 scans per spectrum. Molecular characteristics were assessed by analyzing the peak areas reported in the literature using OMNIC software (version 9.9.549, Thermo Fisher Scientific, Waltham, MA, USA).

Experimental design and statistical analysis

The effects of the addition level (A) at 4 levels (10, 20, 30, 40%) and type of red grape pomace (B) at 2 levels (seedless - SGPR and whole - GPR) on maize extruded snacks characteristics (protein, ash, lipids, fibers content, TPC, DPPH, SDS, RDS, RS, L*, a*, b*, acceptability and cutting force) were investigated.

The experimental data for each characteristic was fitted to polynomial cubic regression equation. Model adequacy was evaluated by using sequential *F*-test, coefficients of determination (R^2), adjusted coefficients of determination ($Adj.\text{-}R^2$), and significant probabilities. The significance of the coefficients of the models were evaluated by using ANOVA at a confidence level of 95%.

The best formulations were chosen based on the highest level of fiber, TPC, DPPH, SDS, RS, and L*, and the lowest values of RDS and cutting force. XL STAT and Ease Design-Expert software (trial version) were used for data processing.

Results and discussion

The impact of type of grape pomace and addition level on maize extruded snack properties was evaluated by means of ANOVA and the results are presented in Table 1. Protein content was influenced significantly ($p < 0.05$) by the addition level and its interaction with grape pomace type. On the other hand, the fibers content was affected significantly ($p < 0.05$) by both addition level and its interaction with type of grape pomace. The increase of grape pomace amount led to the increase of protein, ash, lipids, and fiber content. Alshawi (2024) also reported a significant enrichment of wheat snacks fiber, lipids and ash content when grape pomace was added in 5-15% proportion. The snacks with more than 20% SGPR or GPR can be considered as „high-fiber products" because they contain > 6g/100g fibers (Alshawi, 2024). The dietary fiber from grape pomace is mainly formed by pectin, cellulose and hemicelluloses (Deng et al., 2011). The intake of nutrients from grape pomace is responsible for the increasing trends obtained in this study. The chemical composition of the enriched extruded snacks depend on the nutrients profile of the ingredients added. For instance, the addition of brewer's spent grain in corn snacks resulted in higher protein, and fat content, while when apple and sugar beet pulp were incorporated the protein content decreased (Jozinović et al., 2021).

The TPC and DPPH antioxidant activity was significantly influenced ($p < 0.05$) by both type of grape pomace and addition level (Table 1). The incorporation of grape pomace determined the increase of TPC and antioxidant activity due to the intake of polyphenols from the ingredient added. Yagci et al. (2022) also obtained a significant proportional increase of the snacks TPC as the amount of tomato powder incorporated was higher, with the DPPH antioxidant activity being 1.3–1.8 fold higher compared with the control. It was proved that the incorporation of rosehip and apple pomace in extrudates led to positive changes of total polyphenols content and antioxidant activity of corn extruded snacks, depending on the addition level and fruit pomace variety (Drozdz et al., 2014). The main polyphenols from grape pomace are represented by condensed tannins, anthocyanins, and resveratrol which exert high antioxidant and radical scavenging activity (Yu and Ahmedna, 2013).

Starch digestibility registered changes depending on the type of grape pomace and the amount used. Grape pomace type and its interaction with grape pomace addition level exhibited a significant effect ($p < 0.05$) on starch fractions content (Table 1). The RDS content increased as the addition level raised, while SDS and RS increased first, then decreased. In another study, Altan et al. (2008b) used extrusion cooking of barley flour-grape pomace blend, grape pomace being added at levels of 2 to 10% (w/w). The authors reported a reduction in starch digestibility of extrudates with the increasing level of grape pomace. It was suggested that this might be due to fiber content, which tends to reduce starch digestibility by trapping starch granules within a viscous protein-fiber-starch network (Altan et al., 2008b). Dehghan-Shoar et al. (2010) demonstrated that starch digestibility decreased with the increase of tomato by-product amount due to the formation of a complex between starch and pectin, which led to a less contact surface with the digestive enzyme like alpha-amylase. In another study (Karkle et al., 2012), the addition of apple pomace in maize snacks resulted in starch digestibility reduction due to the modifications of starch grains and the formation of a more compact structure.

Sensory acceptability was significantly affected ($p < 0.05$) by the addition level and type of grape pomace and their interaction and increased proportionally with the addition level increase up to 30%, and then it decreased. The extrudates with 2% grape pomace in barley flour has found to present higher preferences for overall product quality, while rising grape pomace above 6% diminished the expansion (Altan et al., 2008b). The acceptability of the maize-soy-apple pomace extruded snacks obtained by Shahzad et al. (2018) ranged between 6.4 and 7.4, which is in agreement with our results. The decrease of acceptability at high grape pomace levels could be due to the presence of polyphenols (Shahzad et al., 2018).

The color parameters (L*, a* and b*) of the extruded snacks were significantly influenced ($p < 0.05$) by both type and addition level of grape pomace, as well as by their interaction (Table 2). The L* and b* values decreased as the amount of grape pomace raised, while a* parameter exhibited the opposite trend. These changes could be related with the pigments of the grape pomace, as well as the Maillard reactions that occur during extrusion. Similar results were reported by Yu et al. (2018) which demonstrated that by adding grape pomace in maize snacks resulted in smaller L* (lightness) and b* values (yellowness), and raised a* value (redness).

The cutting force was significantly affected ($p < 0.05$) by both grape pomace types and level and their interaction, and it was reduced proportionally with the increase of grape pomace amount (Table 1). Grape pomace contains soluble pectin which may determine the reduction of snacks hardness by playing a lubrification role, and thus, leading to a crispier rather than a harder product. Similar finding was reported by Singha et al. (2019) for snack made from maize, soy, and apple pomace.

Figure 1 illustrates the variations of protein, ash, lipids and fiber with the addition level of grape pomace.

The relationship between the addition level of grape pomace and the values obtained for TPC and DPPH are displayed in Figure 2. The decreasing trend of TPC and DPPH antiradical activity at addition levels > 30% could be possibly related to a more intense binding of polyphenols on maize starch and proteins. Antiradical activity of polyphenols can be modulated through intra or intermolecular hydrogen linkage of active or neighboring –OH groups (Stojadinovic et al. 2013). The reduction in antiradical activity was observed when polyphenols are non-covalently linked to proteins for example (Stojadinovic et al. 2013).

Figure 3 represents the variations of starch fractions with the addition level of grape pomace.

Table 1

ANOVA results for the cubic model fitted for the extruded snacks properties

Factor	Protein (%)	Ash (%)	Lipids (%)	Fibers (%)	TPC (mg GAE/g)	DPPH (%)	RDS (%)	SDS (%)	RS (%)	Acceptability	L*	a*	b*	Cutting force (g)
Intercept	9.13	1.28	1.74	7.36	28.97	92.70	34.74	4.82	3.54	6.74	49.84	6.90	6.48	1007.32
A-Type	0.03	-0.12	0.04	-0.49	1.76**	-0.78*	-1.91**	-0.21*	5.19*	-0.01	0.84**	0.64**	0.75**	80.33**
B-Level	2.22*	0.03	0.26	9.65**	8.37**	3.62**	0.34	-1.08*	-0.26*	0.60**	-6.64**	1.53**	-1.37**	108.49**
AB	-1.76**	-0.61**	-0.65**	-3.80**	0.80**	3.34**	-0.94**	-0.70**	-0.74**	0.02*	0.26	0.68**	0.42**	177.83*
B^2	2.44**	0.72**	0.31*	6.22**	-1.60**	-3.50**	3.56**	-1.34**	-0.84**	-0.14**	1.87**	-0.43	0.97**	-69.88
AB^2	1.11**	0.65**	0.56**	7.53**	-0.65	3.50**	5.32**	1.10**	-1.35**	0.07**	0.82**	-0.84**	-0.33**	-56.21
B^3	-1.47	0.29	0.11	-7.78**	-4.87**	-4.98**	0.37**	1.10	1.23	-0.40**	-0.21	-0.72	-0.61**	-30.06
***p*-value**	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
R^2	0.89	0.91	0.92	0.98	0.97	0.96	0.99	0.96	0.96	0.98	0.99	0.94	0.99	0.88
Adj.-R^2	0.85	0.88	0.89	0.97	0.96	0.94	0.99	0.94	0.95	0.97	0.99	0.92	0.98	0.84

* - significant at $p < 0.05$, ** - significant at $p < 0.01$

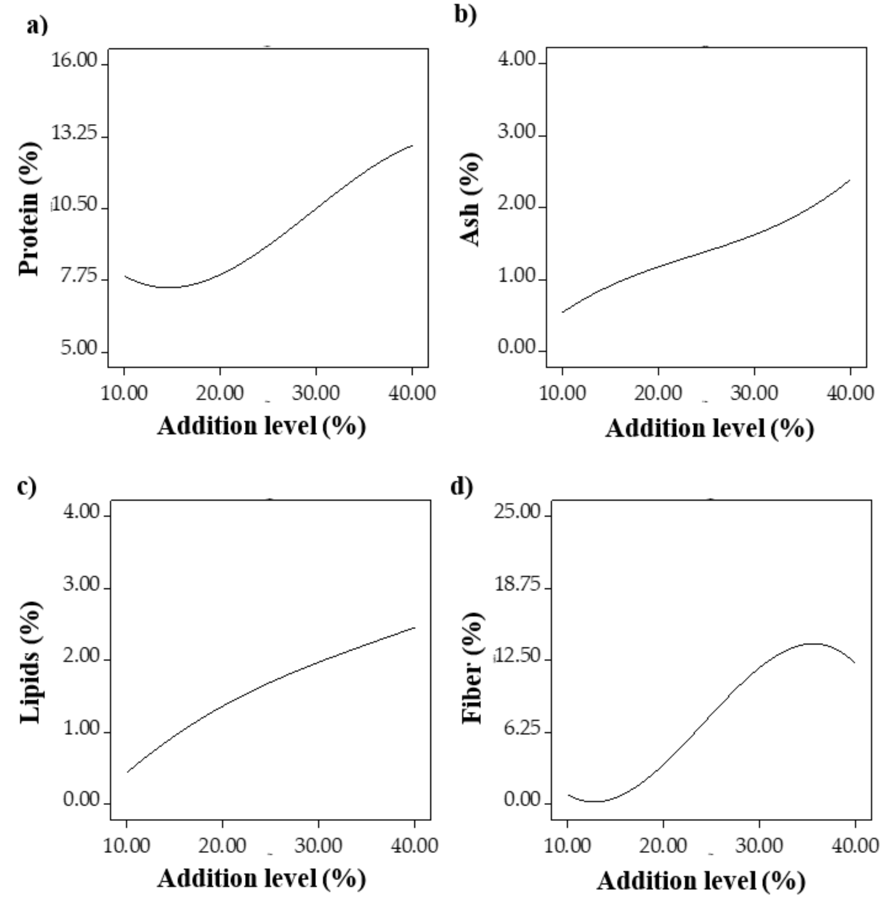


Figure 1. **Variations of protein (a), ash (b), lipids (c), and fiber content (d) with the addition level of grape pomace**

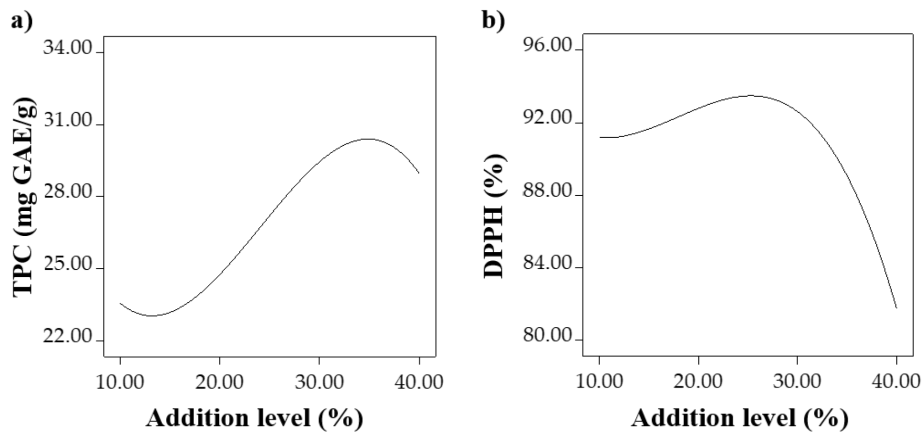


Figure 2. **Variations of TPC (a) and DPPH (b) in function of the addition level of grape pomace**

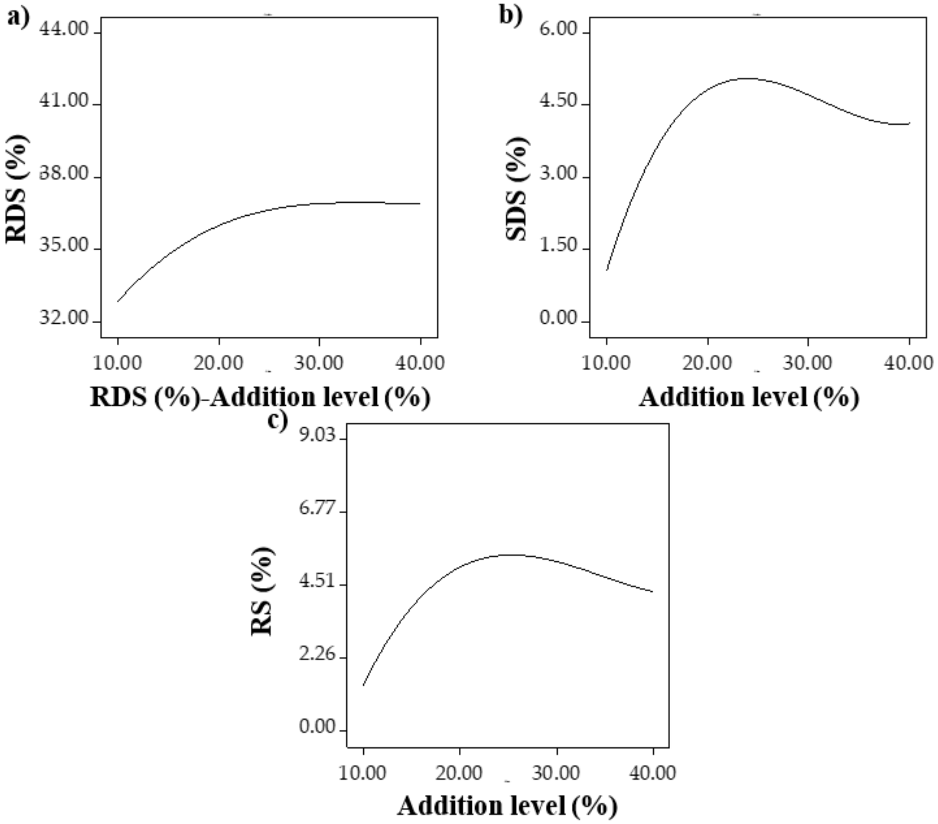


Figure 3. Variations of RDS (a), SDS (b), and RS (c) with the addition level of grape pomace

The variations of color parameters (L*, a*, and b*) with grape pomace addition level are shown in Figure 4.

Figure 5 shows the relationships between the addition level of grape pomace and the values obtained for acceptability and cutting force.

Significant correlations (p < 0.05) were found between some of the chemical components and the color parameters, acceptability and cutting force. Similar to our results, Altan et al. (2008a) also obtained a negative correlation between L* and a* values of barley-tomato pomace snack.

The best formulations were chosen based on the highest level of fiber, TPC, DPPH, SDS, RS, and L*, and the lowest values of RDS and cutting force. Thus, the recommended addition level for the seedless grape pomace (O_SGPR) was found to be around 30%, while for whole grape pomace (O_GPR) was about 20% (Figure 6).

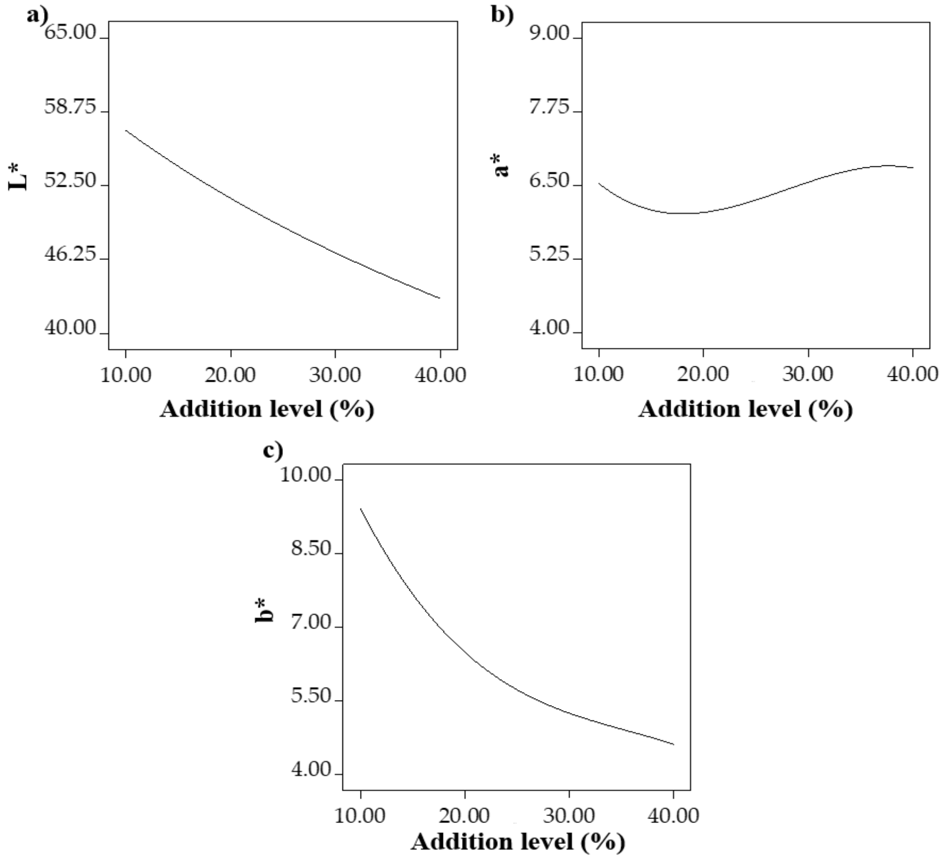


Figure 4. Variations of L* (a), a* (b), and b* (c) with the addition level of grape pomace

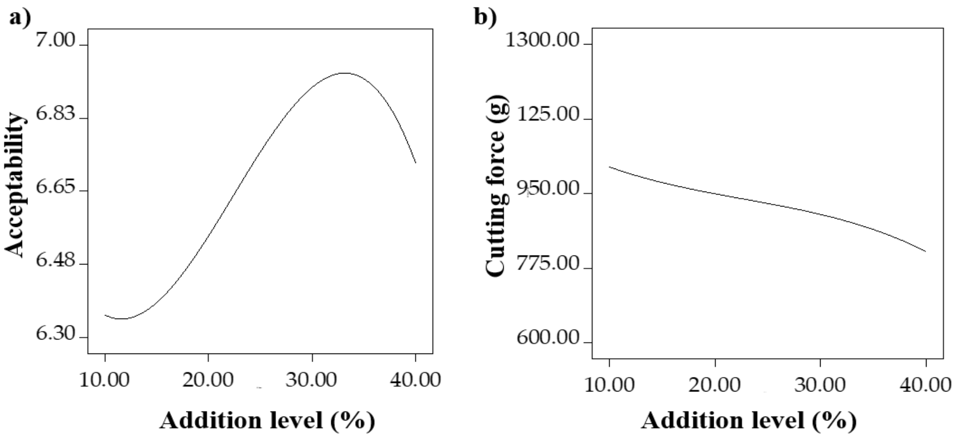


Figure 5. Variations of acceptability (a) and cutting force (b) with the addition level of grape pomace

M **O_SGPR** **O_GPR**

Figure 6. Control and improved snacks appearance

Compared to the control (M), both improved samples were richer in protein, ash, lipids, fiber, TPC, RDS, RS and had lower L*, b* and cutting force value. Compared with the O_GPR, the sample with seedless grape pomace (O_SGPR) had higher protein, ash, fiber, antioxidant activity (DPPH), SDS, RS, and acceptability, while the TPC, cutting force, and color parameters registered lower values (Table 2).

Table 2

Characteristics of the best seedless (O_SGPR with 30%) and whole (O_GPR with 20%) grape pomace containing snacks *vs.* control (M) properties

M	O_SGPR	O_GPR	M
Protein (%)	10.16±0.48^{a}	9.15±0.48^{b}	7.61±0.03^{c}
Ash (%)	1.57±0.13^{a}	1.21±0.13^{b}	0.45±0.01^{c}
Lipids (%)	1.92±0.77^{a}	1.82±0.77^{a}	0.35±0.05^{b}
Fiber (%)	11.04±1.02^{a}	6.52±1.02^{b}	0.46±0.03^{c}
TPC (mg GAE/g)	28.47±0.68^{a}	29.57±0.68^{a}	28.85±0.04^{a}
DPPH (%)	93.29±0.95^{a}	91.08±0.95^{b}	38.04±0.10^{c}
RDS (%)	36.87±0.49^{a}	32.92±0.49^{b}	30.03±0.03^{c}
SDS (%)	4.81±2.70^{a}	4.73±2.70^{a}	0.88±0.03^{b}
RS (%)	5.33±0.09^{a}	5.04±0.09^{b}	1.21±0.01^{c}
Acceptability	6.84±0.03^{a}	6.65±0.03^{b}	-
L*	47.84±0.45^{c}	51.51±0.45^{b}	78.48±0.12^{a}
a*	6.41±0.29^{b}	7.24±0.29^{a}	0.71±0.03^{c}
b*	5.45±0.17^{c}	7.36±0.17^{b}	21.75±0.20^{a}
Cutting force (g)	914.45±69.42^{b}	1050.46±69.42^{b}	1625.43±147.86^{a}

Mean values followed by different letters then as are significantly different ($p < 0.05$)

The differences between the two types of grape pomace-containing snacks could be due to the different types of fiber and the lipid content of the two ingredients. It was obvious the enhancement of snacks nutritional value by increasing the nutrients and phenolic compounds content of the maize snacks, which was in agreement with previous studies regarding the fortification of gluten free snacks with different vegetal by-products (Dehghan-Shoar et al., 2010; Oladiran and Emmambux, 2018).

The changes of color properties after grape pomace incorporation could be due to the Maillard reactions which involves a complex series of reactions, the first one being the conjugation between an active carbonyl group (coming from a reducing sugar for example) with an amino group (usually from proteins or amino acids) (Rolandelli et al., 2021). Thus, the presence of sugars in grape pomace could have been promoted the Maillard reactions during extrusion, which generated color differences compared with the control. Another possible explanation can be the caramelization reactions which imply the direct conversion of reducing sugars by 1,2-enolization, dehydration, and cycling reactions (Rolandelli et al., 2021).

Characterization of the improved samples

The molecular characteristics of the improved and control samples are represented in Figure 7. The lowest absorbances intensities were observed for the control sample (M), followed by O_GPR, and O_SGPR. Compared to the control, the enriched samples presented an additional peak at 2855 cm^{-1}, which was more pronounced in O_SGPR snack. This band is due to CH_2 stretching and it suggests the presence of grape pomace cutin, waxes and cutan (Nogales-Bueno et al., 2017). The most prominent peaks were observed in the lipid (2800-3050 cm^{-1}) and carbohydrates region (900-1200 cm^{-1}), similar with the results obtained by Amador-Rodríguez et al. (2019). The peak at 2925 cm^{-1} corresponding to lipids confirm the higher abundance in the grape pomace samples compared to the control.

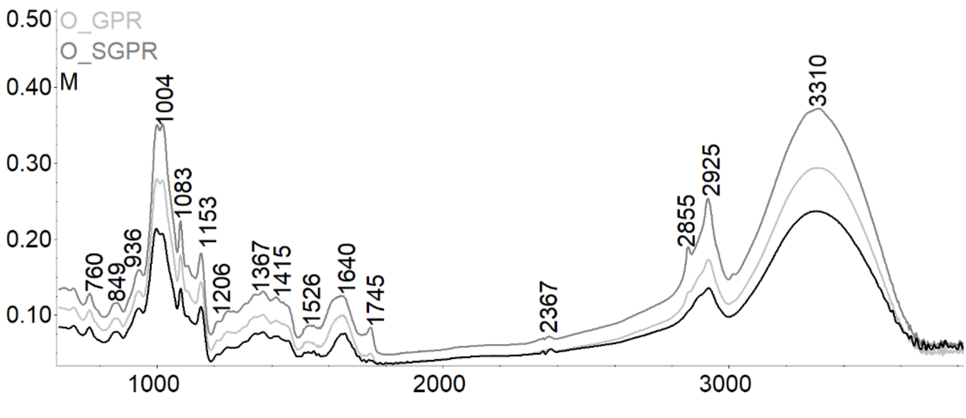
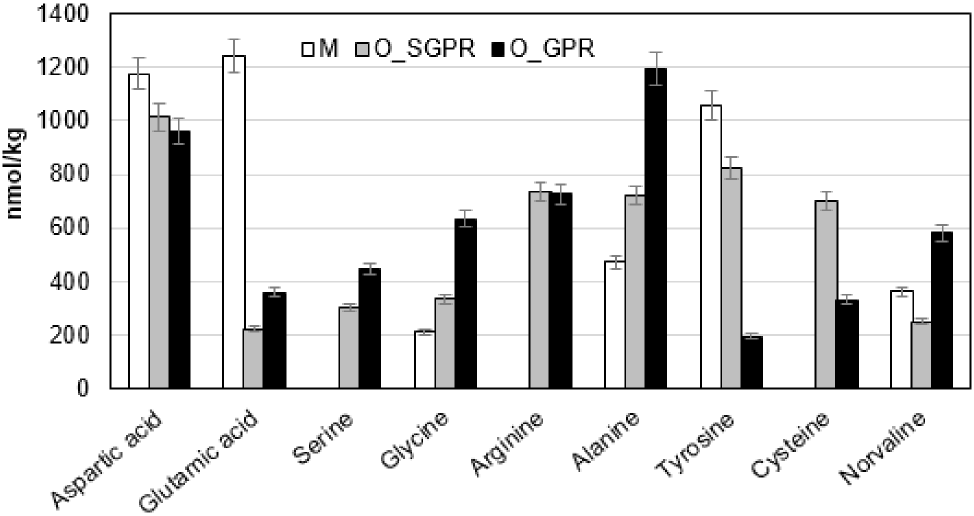


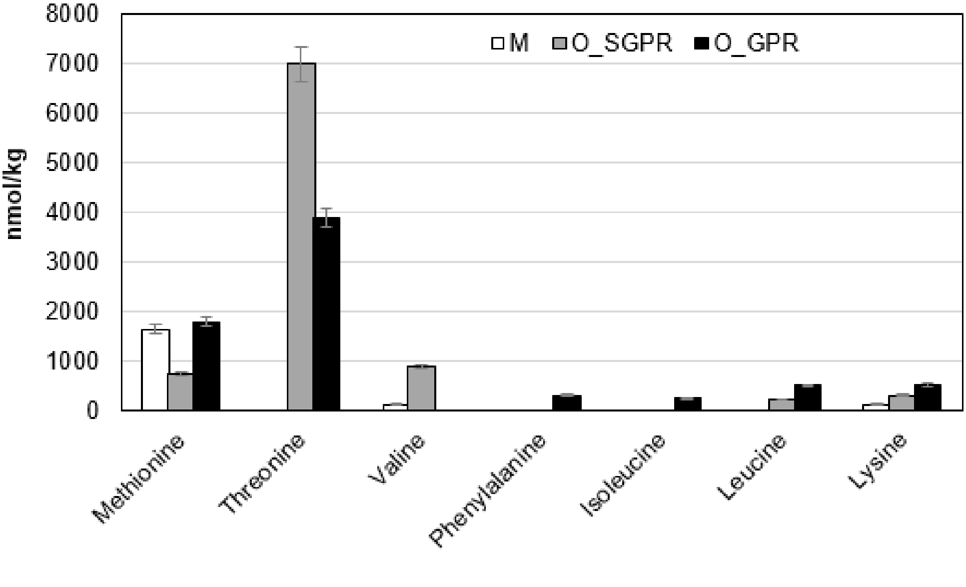
Figure 7. FT-IR spectra for the improved and control samples

The protein regions (1700–1600 and 1570–1534 cm^{-1}) showed changes of the intensities in the grape pomace-containing samples compared with the control. The increase of peak intensity at 1745 cm^{-1} corresponds to pectin (Amador-Rodríguez et al., 2019) and the increase in its intensity after grape pomace addition indicated the intake from the ingredients added.
The amino acid content of the control and the improved samples are shown in Figure 8. Among the essential amino acids, methionine and lysine was found in all the samples, while phenylalanine and isoleucine were present only in O_GPR. Leucine and threonine were identified in both enhanced samples, and O_SGPR had the highest threonine level. Valine was found in M and O_SGPR sample, with the improved sample presenting the highest value (Figure 8a). A study reported some of the main essential amino acids found in grape pomace

are leucine and lysine (Hanušovský et al., 2023), which may explain the increase of these compounds in the improved samples compared with the control. Since lysine is a limiting amino acid in cereals, the incorporation of grape pomace led to an enhanced amino acid profile of the final product. Phenylalanine was also reported in grape pomace and thus the amino acid profile of bakery goods can be improved (Antoniolli et al., 2024). Chikwanha et al. (2018) reported high levels of threonine in grape pomace, which may explain the presence of this amino acid in the improved samples.



(a)



(b)

Figure 8. **Essential (a) and non-essential (b) amino acid content of the improved and control samples**

Regarding the non-essential amino acids content, aspartic acid, alanine and tyrosine were the most abundant amino acids in all the samples (Figure 8b). Control M exhibited the highest concentration of aspartic acid, glutamic acid, and tyrosine. O_GPR was the richest in glycine, alanine and norvaline, while O_SGPR had the biggest concentration of cysteine. Grape pomace was proved to be rich in glycine (Hanušovský et al., 2023), which may explain the higher values found in the improved samples compared with the control. Alanine was identified as being one of the amino acids found in grape pomace (Chikwanha et al., 2018), a fact proved by the increase of this compound content in the improved samples compared with the control. The amino acid composition of grape pomace depend on the grape variety and type (seedless or with seeds) and thus influences the composition of the final product in different ways.

Conclusions

This study highlighted the possibility to valorized two types of grape pomace (seedless and whole) in high amounts to obtain functional extruded snacks. The results obtained revealed the enhancement of the nutritional profile after grape pomace incorporation, with the increase of protein, ash, lipids, fiber, total phenolic content, and antioxidant activity being proportional with the addition level increase for both types of grape pomace. The color, starch digestibility, texture and sensory acceptability of the extruded snacks were also affected by the addition level, depending on the type of grape pomace. The best amount of seedless grape pomace was found to be about 30%, while for whole grape pomace it was about 20%. The improved samples exhibited enhanced nutritional profile compared with the maize snacks used as a control sample. FT-IR molecular characteristics and the amino acid profile were changed after grape pomace addition, depending on the type used.

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Patent
The results were first used in a patent application entitled “Process for obtaining an extruded non-gluten product, direct-expanded and product so obtained” (“Procedeu de obţinere a unui produs aglutenic extrudat, direct-expandat şi produs astfel obţinut”).

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