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The study of pea pre-treatment effect on pea-based beverage quality

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Abstract. The aim of current study is to evaluate the influence of pre-treatment methods on pea-based beverage quality. The influence of pea variety and pre-treatment on the nutritional composition, physicochemical properties, and volatile profile of pea-based beverages was investigated. Conventionally grown spring pea genotypes were used: 'Lasma', 'Zaiga', H 08-10-15. The analysed parameters included total dietary fibre, proteins, amino acid profile, total phenolic content (TPC), tannin content (TC), pH, viscosity and volatile compounds. Among the evaluated varieties, the grey pea breeding line H 08-10-15 exhibited significantly higher ($p < 0.05$) protein content, while 'Zaiga' had significantly lower protein content but the highest total dietary fibre content ($p < 0.05$). Amino acid composition varied notably by variety, with H 08-10-15 showing higher concentrations of Gly, His, and Leu. Germination significantly reduced total solids, viscosity, total dietary fibre content, while increasing soluble solids in pea-based beverages. Viscosity was highest in boiled samples and those derived from pea breeding line H 08-10-15. TPC was highest in 'Zaiga', and roasting reduced content of both TPC and TC. Volatile compound analysis revealed that pre-treatment significantly affected the aroma profile, with germination reducing undesirable notes such as beany, earthy and mushroom aromas by decreasing 1-octen-3-ol and heptanal. These findings demonstrate that both pea variety and pre-treatment methods critically affect the nutritional and sensory attributes of pea-based beverages, providing insights for the development of improved plant-based products. The most suitable raw material for pea beverage production is grey pea breeding line H 08-10-15, with germination and roasting as pre-treatment methods.
Key words: Boiling, germination, roasting, tannins, phenolic compounds.

Introduction

The global population is predicted to increase to almost 10 billion by 2050, which means that food production will need to rise by 50 to 60% to meet human consumption demands (Ranganathan *et al*., 2018). Pea protein has increasingly emerged as a significant alternative to animal-based proteins over the past 15 years and is anticipated to become the leading protein source in the near and mid-term future (Trindler *et al*., 2022).

Several studies have made substantial efforts to replace animal origin proteins with alternative protein sources (Diaz-Bustamante *et al*., 2023). However, the main challenge is designing new products without compromising their sensory and nutritional properties since all alternative proteins are structurally and functionally different from animal ones. Legumes are an attractive crop for the production of protein-rich food and ingredients. However, flavour, taste and antinutrients are factors limiting the use of legumes in animal origin food alternative production (Roland *et al*., 2017). To make legumes a more attractive food source, efforts need to be focused on developing their sensory properties, including flavour and texture, as well as reducing antinutritional factors (ANF) and allergens (Senanayake *et al*., 2023). The concentrations of the volatile compounds, which could impact the taste and flavour of peas, are affected by variety (Azarnia *et al*., 2011). The sensorial perception of plant-based products in general can be altered at several points along the value-chain: breeding; production of protein concentrates/isolates, formulation using different

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processing aids, application of food additives and different processing technologies. Among the various food processing technologies, extrusion (Pasqualone *et al*., 2020), high-pressure processing (Zink *et al*., 2024), germination (Gan *et al*., 2017), roasting (Dhakal *et al*., 2023), ultrasonication (Roosta & Hematian Sourki, 2024), and fermentation (Shi *et al*., 2021) stand out with a high potential to improve the functional properties of legumes.

Plant-based milk alternatives can be produced by directly extracting the soluble material, either by soaking the plant material in water and then grinding or by dry grinding the plant material and extracting the protein in water by methods such as pH shifting, and removing the slurry of insoluble material (Diaz-Bustamante *et al*., 2023). However, different pre-treatment methods: soaking, germination, boiling and roasting could be applied with aim to increase functionality and sensory properties of the developed products.

The current research aims to evaluate the influence of pre-treatment methods on pea-based beverage quality.

Materials and Methods

Materials

In the research, conventionally grown three spring pea genotypes were used. Two of them were white-flowered pea (*Pisum sativum*) varieties, 'Lasma' with yellow seed colour and 'Zaiga' with green seeds, and breeding line H 08-10-15 pink flowered with grey seed coat (see Table 1).

Pea-based beverage production

Before pea-based beverage production, raw materials were pre-treated with different methods: boiling (B), germination (G) and roasting (R) (see Table 1).

Table 1

Analysed sample characteristics and codes

Pea samples	Characteristics	Treatment	Code		
			Roasting	Boiling	Germination
'Lasma'	Yellow	Roasting (220 ±2°C, 15 min) Boiling (100 ±2°C, 45 min) Germination (22±2 °C, 28 h)	R/L	B/L	G/L
'Zaiga'	Green		R/Z	B/Z	G/Z
H 08-10-15	Grey		R/H	B/H	G/H

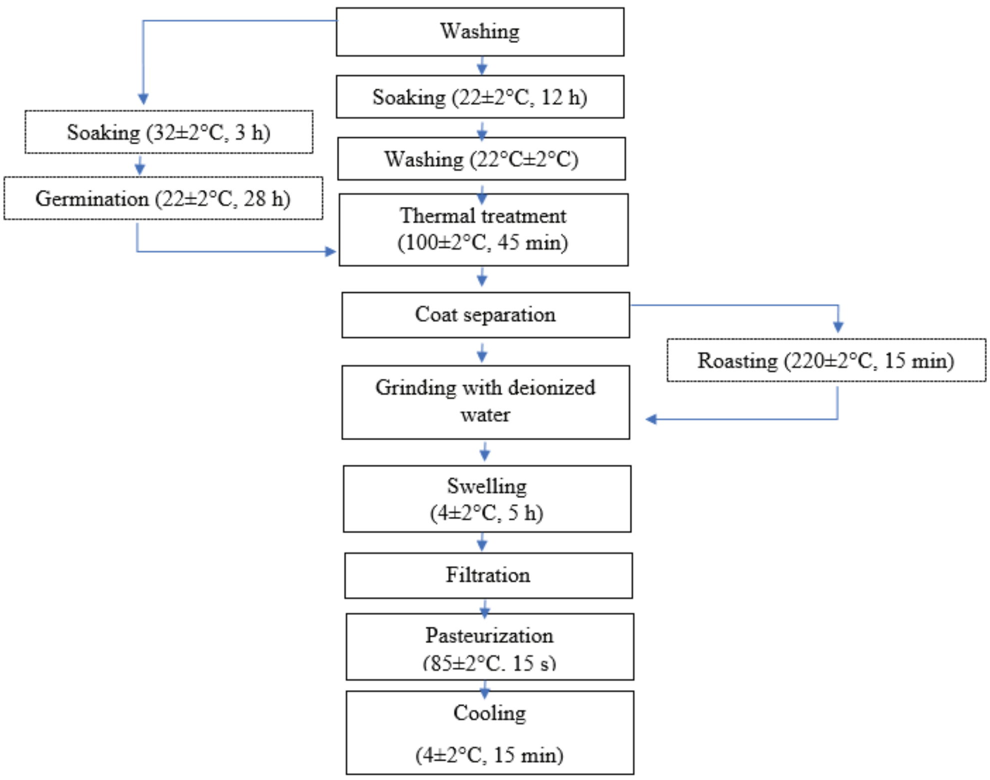

Figure 1. Pea-based beverage production technology.

All technological parameters used in the current research were identified during pre-study (Bicurina, 2022). Before boiling and roasting, peas were soaked in water for 12 h at 22±2°C, then B samples were boiled at 100±2°C for 45 min, and R samples were roasted for 15 min 220±5°C. Before germination, peas were soaked in water for 3 h at 33±2°C, then germinated for 28 h at 22±2°C, and boiled at 100±2°C for 45 min.

After pre-treatment pea was cooled down till 10 °C±1 °C and the seed coat was removed, pea was ground using Foss Knifetec 1095 (Foss, Denmark) and mixed in a proportion 1:4 with deionised water, maturated for 5h at 5±2°C with following filtration and pasteurisation 85±1C°, 15 s.

Methods

All parameters were detected in pea-based beverages, additionally amino acids and chemical composition of pea was analysed.

pH measurements were performed by pouring 50 mL of pea-based beverage into a beaker and immersing a pre-calibrated Jenway 3510 pH meter (Cole Parmer, UK) into it.

Protein content was determined according the Kjeldahl method (LVS NE ISO 8968-1:2014) by Kjeltec™ 2100 (Foss, Denmark).

The *moisture content* of the pea-based beverages was determined using a Memmert UF55 drying oven (Memmert, Germany).

Total solids were calculated knowing the moisture content in the product.

Chemical composition and amino acids were determined with a near-infra red spectrometer (Rapid Analyser XDS, FOSS, Denmark) with a spectral range from 400 to 2498 nm. Spectral data were exported to WinISI 4 software (FOSS, Denmark).

Soluble solids. 1-3 drops of pea beverage were added to the prism of the Mettler Toledo refractometer (Mettler – Toledo GmbH, Japan) and the prism is closed with a cap. The soluble solids content (Brix%) was read.

Total dietary fibre. Before analysis the samples were homogenized and dried in a Memmert IPP200 (Memmert, Germany) thermostat at 40 °C for 24 h. The analysis was performed according to the Total Dietary Fibre Assay according to AOAC Official Method 985.29 "Total dietary fibre in food, enzymatic-gravimetric method, AOAC-AACC Method, Codex-adopted-AOAC method, Dietary fibre determination using Fibertec E system (Foss, Denmark).

The extraction process for total phenols, antiradical activity, reducing power analysis. The homogenized samples were subjected to extraction using a solvent mixture of ethanol, acetone, and water (7:7:6, v/v/v) in an ultrasonic bath (YJ5120-1, Oubo Dental, USA) at a frequency of 35 kHz for 10 min, maintaining a temperature of 20±1 °C. Following extraction, the samples were centrifuged at 3,500 rpm for 5 minutes using a CM-6MT centrifuge (Elmi Ltd., Latvia). The remaining residues underwent reextraction following the same procedure. The entire extraction process was performed in triplicate (Kruma *et al*., 2016).

Total phenols. To determine the total phenol content in the sample, the Folin-Ciocalteu method was used elaborated by (Singleton & Rossi, 1965). A 2.5 mL volume of Folin-Ciocalteu reagent, previously diluted ten times with distilled water, was added to the extract. After 5 minutes, 2 mL of 7.5% Na_2CO_3 was added to the mixture, thoroughly mixed, and incubated for 30 minutes. Absorbance was measured at a wavelength of λ = 765 nm using a Libra S70 PC spectrophotometer (Biochrom Ltd., USA). The total phenol content was determined by performing three repeat measurements. The equation of the standard curve based on TPC is y=0.0973*x-0.0026, R^2=0.9981.

Tannins. The tannin content was determined using ferricyanide reduction method. To prepare the sample, a 0.5 mL pipette was used to transfer the sample into a flask, and 1% $FeCl_3$ was added. Then, 1% $K_3[Fe(CN)_6]$ was added, mixed, and further deionised water was added up to 10 mL. The sample is centrifuged for 2 minutes at 100 rpm and divided into two fractions. Absorbance was measured in the upper layer at a wavelength of 720 nm using the Libra S70 PC spectrophotometer (Biochrom Ltd., USA). The calibration curve was obtained using a $C_{76}H_{52}O_{46}$ standard solution (conversion limits from 5-25 µg mL^{-1}). Three replicates were performed for the samples. The tannin content in the samples is expressed in terms of tannic acid equivalent, derived from the calibration curve equation y = 0.954 * x - 0.0062, R^2=0.9949.

Volatile compounds. Volatile compounds in the pea-based beverages were extracted using solid-phase microextraction (SPME) combined with gas chromatography and mass spectrometry (GC/MS). A blue SPME fibre coated with polydimethylsiloxane (PDMS) was used for detecting non-polar volatile compounds. A polyethene glycol capillary column (60 m × 0.25 mm × 0.25 µm) was used. Chromatograms obtained from the Gas Chromatograph were processed using TurboMassVer 5.3.0 mass spectrometry software for volatile aroma analysis. Helium was used as the carrier gas in the chromatograph. The extraction process starts with the preparation of the sample. 5.0 g of the sample were weighted in a 20 mL SPME vial with a screw cap. The sample was incubated at 40°C for 10 minutes without the fibre and another 20 minutes with the fibre at the same temperature to absorption of vola-tile compounds into the SPME fibre. After extraction, the fibre is placed into the GC/

MS injector. During the GC/MS analysis, the oven temperature was initially set to 40 °C and held for 7 min. It was than ramped up to 160 °C at a rate of 6 °C per minute. The temperature was further increased to 210 °C at a rate of 10 °C per minute and held for 15 min. As it moves through the capillary column along with the carrier gas, the volatile compounds are transported to the mass detector, which identifies them by separating them based on mass and charge. The system reads signals that the software compiles into a chromatogram. Compounds were identified by matching their mass spectra with those in the NIST98 mass spectral library. Furthermore, linear retention indices were calculated using the retention times of alkanes (C8-C20) and compared with literature data.

Viscosity. Using a rotational viscometer DV III Ultra Programmable rheometer (Brookfield Engineering Laboratories Inc., USA), the viscosity of pea-based beverages was determined. The Rheocalc V2.6 program was used to read the data on the computer. The viscosity was determined by pouring 16 mL of the test drink sample into a beaker and immersing a concentric cylinder shaft (model – SC4 – 3) into it. The temperature of the test sample was 25 °C. The speed of the test samples was 20 rpm. Each sample was prepared 2 times and each was determined in 5 repetitions.

Statistical analyses. Data analysis was performed using Microsoft Excel software (Microsoft 365). To determine statistically significant differences among the data groups of different raw materials and pre-treatment methods analysis of variance (ANOVA) was applied. Tukey's test was used for detailed pairwise group comparisons ($p<0.05$). All parameters (except viscosity) were determined in triplicate. Mean value and standard deviation were calculated to visually represent the results.

Results and Discussion

Chemical composition of pea

Peas have long been consumed due to high protein, dietary fibre, minerals, and vitamins (Tulbek *et al*., 2017), chemical composition of pea is significantly influenced by the environment and genotype (Harmankaya *et al*., 2010). The chemical composition of the studied pea varieties and breeding line is shown in Table 2.

The significantly higher ($p<0.05$) fat and protein content was in the grey pea breeding line H 08-10-15. Some studies report that the seed color accompanies significant changes in the chemical compositions of peas (Tzitzikas *et al*., 2006; Bastianelli *et al*., 1998). The authors observed that pea cultivars with grey seed coatings provide a higher protein content than green and yellow pea cultivars, which is consistent with our results. However, studies in Germany and Canada, which analyzed the protein content of pea samples collected from production fields, revealed that no apparent effect was found on the protein content in relation to phenotypic characteristics, such as seed color (Bestwick *et al*., 2018; Walter *et al*., 2022). The variety 'Zaiga' has a significantly lower ($p<0.05$) protein content ($p< 0.05$) among the analysed samples. The cellulose content was significantly different. Pea seed coats contain the largest proportion of the cellulose, which adversely affects the production of pea beverages (Denkova *et al*., 2013). For pea beverage production, it is recommended to choose peas with a lower cellulose content or mechanical separation of the coats (Xing *et al*., 2022). According to Azarnia *et al*. (2011) in smaller-sized peas ('Zaiga'), the seed coat makes up a larger portion of the total pea mass than in larger-sized peas ('Lāsma' and H – 08-10-15) (Azarnia *et al*., 2011). The variety 'Zaiga' stand out with significantly higher ($p<0.05$) total dietary fibre content.

Pea variety significantly ($p < 0.05$) affects the amino acid content. Arg, Gly, His, Ile, Leu, Pro, Thr content was significantly lower in pea variety 'Zaiga', significantly higher ($p<0.05$) content of Gly, His, Leu was established in a breeding line H 08-10-15. Previous research results established that the content of amino acids in yellow pea varieties is higher than in green pea (Tshovhote *et al*., 2003). Bastianelli *et*

Table 2

Chemical composition of pea

Pea samples	**Content g 100 g^{-1}**				
	fat	**proteins**	**ash**	**cellulose**	**total dietary fibre, mg 100g^{-1}**
'Lāsma'	$0.86^a \pm 0.12$	$30.18^b \pm 0.21$	$3.44^a \pm 0.27$	$7.37^a \pm 0.07$	$22.74^a \pm 0.16$
'Zaiga'	$0.93^b \pm 0.08$	$27.57^a \pm 0.12$	$3.77^a \pm 0.41$	$7.69^a \pm 0.15$	$24.13^b \pm 0.25$
H 08-10-15	$0.94^b \pm 0.05$	$31.11^c \pm 0.31$	$3.62^a \pm 0.11$	$6.92^a \pm 0.04$	$22.88^a \pm 0.13$

Values marked with the same letters in columns are not significantly different ($p > 0.05$)

Table 3

Amino acids content in peas, DW mg 100 g^{-1}

Amino acids	Pea samples		
	‘Lāsma’	**‘Zaiga’**	**H 08-10-15**
Ala	10.04^{a} ± 0.17	9.52^{a} ± 0.08	9.97^{a} ± 0.24
Arg	22.56^{b} ± 0.43	18.08^{a} ± 0.15	22.19^{b} ± 0.10
Gly	11.22^{b} ± 0.12	10.88^{a} ± 0.03	36.78^{c} ± 0.07
His	7.28^{b} ± 0.09	6.17^{a} ± 0.23	10.97^{c} ± 0.33
Ile	9.49^{b} ± 0.14	8.77^{a} ±0.07	9.35^{b} ± 0.11
Leu	16.52^{b} ± 0.33	15.36^{a} ± 0.29	17.15^{c} ± 0.13
Met	3.82^{a} ± 0.11	3.74^{a} ± 0.05	3.94^{a} ± 0.03
Pro	10.27^{b} ± 0.21	9.30^{a} ± 0.24	10.67^{b} ± 0.22
Thr	8.11^{b} ± 0.04	7.65^{a} ± 0.10	8.71^{b} ± 0.11
Val	11.48^{a} ± 0.01	10.63^{a} ± 0.21	11.25^{a} ± 0.02

Values marked with the same letters in columns are not significantly different (p > 0.05)

al. (1998), who studied the chemical composition of peas with different seed coat colors, observed no remarkable differences in the amount of amino acid composition in white flowered pea samples, which had yellow and green seed coat and samples of peas with colored flowers and seed coats. The author observed that the Met content was slightly higher in yellow peas than in coloured peas. We found that there is no difference in Met content between yellow and grey pea seed samples.

Pea-based beverage quality

pH, total and soluble solid concentration of pea-based beverage differs depending on the type of pre-treatment: germination, boiling and roasting (see Table 4).

Pea processing methods did not significantly (p > 0.05) affect the pH of beverages. All pea-based beverages have a pH close to 7.0. Total solid content significantly decreased (p<0.05) during germination.

In the first germination stage, the hydrolysis of reserve starch in the pea under the influence of enzymes occurs much faster than the synthesis of substances. Therefore, in the first germination stage (up to 48h) the total solid content decreased significantly, under the influence of enzyme activity (Wei *et al*., 2022), as result the content of protein, starch, total fat, insoluble

Table 4

Physico-chemical parameters in pea-based beverages depending on pre-treatment method

Code	Total solids, g 100 g^{-1}	Protein content, g 100 g^{-1}	Soluble solids, Brix%	Total dietary fibre, g 100 g^{-1} DW	Viscosity, mPa s^{-1}	pH
B/L	7.14 ± 0.11^{d}	3.54 ± 0.29^{b}	2.46 ± 0.02^{a}	7.12 ± 0.27^{c}	49.41 ± 0.03^{g}	7.32 ± 0.15^{ab}
G/L	6.90 ± 0.24^{d}	3.19 ± 0.01^{b}	2.79 ± 0.05^{a}	6.92 ± 0.05^{b}	32.20 ± 0.03^{c}	7.50 ± 0.14^{b}
R/L	7.04 ± 0.03^{d}	3.41 ± 0.18^{b}	2.47 ± 0.07^{a}	7.45 ± 0.10^{c}	40.312 ± 0.14^{e}	7.44 ± 0.07^{b}
B/Z	6.40 ± 0.05^{c}	3.28 ± 0.17^{a}	2.88 ± 0.08^{a}	8.39 ± 0.08^{d}	33.35 ± 0.13^{c}	7.17 ±0.09^{a}
G/Z	5.80 ± 0.24^{a}	3.01 ± 0.09^{a}	2.92 ± 0.13^{a}	7.31 ± 0.21^{c}	25.384 ± 0.27^{a}	7.32 ± 0.02^{ab}
R/Z	6.23 ± 0.15^{b}	3.11 ± 0.02^{a}	2.65 ± 0.09^{a}	8.65 ± 0.09^{d}	29.09 ± 0.22^{b}	7.12 ± 0.11^{a}
B/H	8.29 ± 0.07^{f}	3.83 ± 0.01^{c}	3.01 ± 0.14^{b}	6.39 ± 0.03^{b}	65.02 ± 0.25^{h}	7.01 ± 0.17^{a}
G/H	7.34 ± 0.03^{e}	3.38 ± 0.33^{c}	3.88 ± 0.08^{c}	5.83 ± 0.08^{a}	38.434 ± 0.09^{d}	7.20 ± 0.05^{ab}
R/H	8.71 ± 0.31^{f}	3.79 ± 0.16^{c}	2.80 ± 0.03^{b}	6.73 ± 0.37^{b}	47.04 ± 0.19^{f}	7.12 ± 0.14^{a}

‘Lasma’ (L), ‘Zaiga’ (Z), ‘Hybrid 08-10-15’ (H); boiling (B), germination (G) and roasting (R)
Values with the same letters in columns are not significantly different (p > 0.05)

fibre, and phytate decreases. Fats are hydrolysed by enzymes to glycerol and fatty acids, starch into simple sugars, which are then oxidized to carbon dioxide and water (Kassegn *et al*., 2018).

All of the above-mentioned biochemical processes significantly ($p < 0.05$) increased the soluble solid content in beverage from germinated pea, except G/Z sample. This could be explained with starch decomposition during germination, forming soluble low-molecular compounds (Sharma *et al*., 2016). Several processes occur during germination, which in turn both increase and decrease the soluble solid content in a product. Gibberellin hormones activate α – amylase, which intensively breaks down starch and forms simple soluble sugars. The amount of starch decreases significantly during germination. β – amylase also participates in the breakdown of starch into simple sugars. α – amylase cleaves α – (1,4) bonds and amyloglucosidase cleaves α – (1,4) or α – (1,6) glycosidic bonds in starch. In turn, the sugars in peas dissolve in water that has penetrated the membrane during germination and are further oxidized during natural respiration (Kassegn *et al*., 2018). During germination of legumes, approximately 24% of the starch is converted into simple sugars, of which 10% is consumed for respiration and 3 – 4% for sprout formation and 10% remains in the form of sugar (Wei *et al*., 2022). At the same time, the assimilation of macro- and microelements from water and the synthesis of vitamins occur with the active action of phytohormones. Wei *et.al*. (2022) observed that after 72 hours of germination, a significant reduction was observed in the content of raffinose (100%), stachyose (60%), and verbacose (80%) in legumes. It can be observed that the total solid content was significantly higher ($p < 0.05$) for breeding line H 08-10-15, then 'Lāsma' and 'Zaiga' follow, the trend remains during germination and roasting.

The content of protein and total dietary fibre. Pre-treatment methods significantly ($p < 0.05$) affect changes in protein content in pea-based beverages. The protein content in peas decreased during germination. The content of amino acids is significantly affected by soaking, germination and heat treatment. Soaking and germination release endogenous enzymes that break down proteins and other existing nutrient reserves to low-molecular compounds (Kassegn *et al*., 2018). Cooking has a beneficial effect on the emulsifying properties of pea proteins. During heat treatment (95 °C, 30 min), the degree of aggregation and hydrodynamic diameter of pea proteins increase (Kassegn *et al*., 2018). Prolonged soaking contributes to increase in Val, Leu, and a decrease in Met and Lys (EL-Suhaibani *et al*., 2020). The content of essential amino acids increases during protein hydrolysis. Proteins enter an easily digestible state during germination (Rakcejeva *et al*., 2006). The amino acid content of germinated legumes is close to the content of animal origin products (Kassegn *et al*., 2018). Similarly, the total protein content in roasted samples (R/L, R/Z, R/H beverage) was lower than in B/L, B/Z, and B/H samples. At elevated temperatures, partial decomposition of the ferritin (a protein complex that binds phosphate and iron hydroxide) complex occurs. The natural ferritin molecule is protected by iron cores that protect the molecule in a "shell"-like structure. During heat treatment, the primary, secondary and tertiary structures of pea seed ferritin are changed, as a result of which the structure of the protein complex is not protected. Heat treatment (100 °C for 45 min) leads to partial decomposition of ferritin complexes and release of iron (II) ions. Xing *et al*. (2022) in their study, determining the content of released iron (II) ions, found that at a temperature of 250 °C for 10 min almost all of the ferritin complex in pea drinks is denatured. The dynamics of denaturation occur proportionally – as the treatment temperature increases, the denaturation of the ferritin complex in pea drinks increases (Xing *et al*., 2022). The data of the current research are consistent with the results of the Xing *et al*., (2022) study, during roasting (220 °C, 15 min) the greatest irreversible denaturation of the ferritin complex occurred in the R/L, R/Z, R/H samples, compared to the B/L, B/Z, B/H samples, processed at a temperature of 100 °C.

The content of total dietary fibre in pea-based beverage samples was significantly lower ($p < 0.05$) in germinated samples - G/Z and G/H. Dietary fibre is the difficulty digestible part of the plant, which has a beneficial effect on the functioning of the intestine (Xing *et al*., 2022). During germination, the content of insoluble fibre decreases and at the same time the proportion of soluble fibre increases. Under the influence of cytolytic enzymes, hemicellulose and resin are hydrolysed producing dextrins, glucose, xylose and arabinose, which are used for sprout tissue formation. Significantly higher ($p < 0.05$) dietary fibre content was found for the beverage produced from variety 'Zaiga' regardless of pre-treatment methods.

*Viscosity***.** The quality of plant-based beverages is determined by their viscosity, which is often associated with the completeness of the product. Viscosity measurements for pea beverages are given in Table 4. Comparing the viscosity among the pea-based beverages, a significant difference was determined ($p < 0.05$). Significantly higher viscosity was determined in samples with pre-treatment – boiling. Comparing raw material, the highest viscosity was observed in the pea beverages of the breeding line H 08-10-15, while the lowest viscosity for the pea

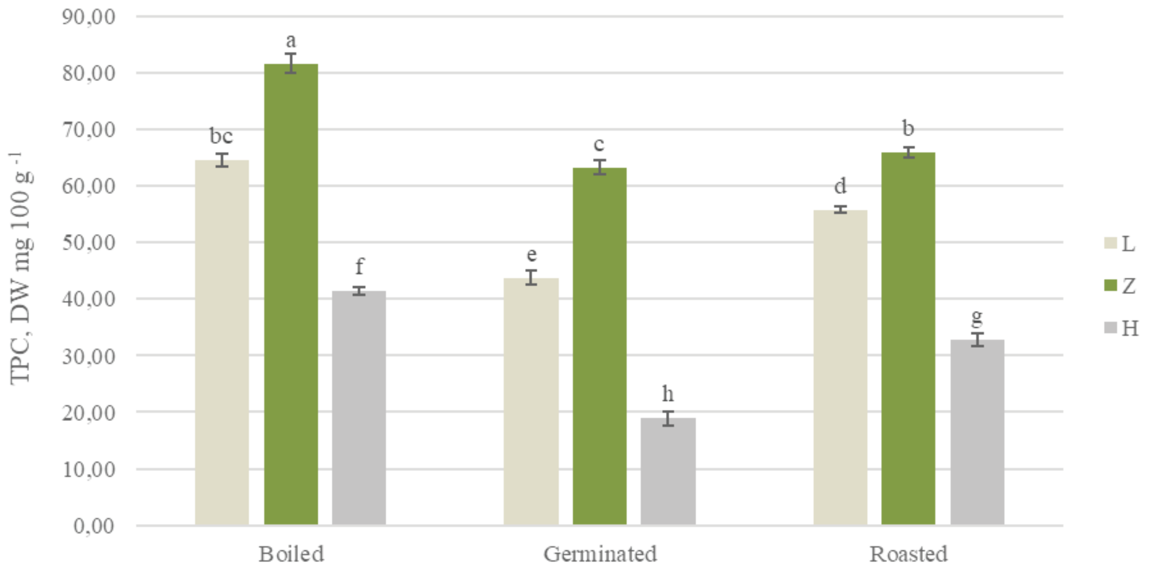

Figure 2. Total phenol concentration (TPC) in pea-based beverages, DW mg 100 g^{-1}.

Values with the same letters are not significantly different (p>0.05)

variety 'Zaiga'. A significant ($p < 0.05$) viscosity decrease was observed in pea beverages with pre-treatment - germination. This can be explained by the increased starch content of the pea breeding line H 08-10-15 (by 10% compared to other two varieties included in the study), which gelatinizes at elevated temperatures and increases viscosity (Kokare, 2022). Also, the degree of protein aggregation and the hydrodynamic diameter of molecules increase during heat treatment (Kassegn *et al*., 2018). The results Lopes *et al*. (2020) study showed, that grey peas extraction in water resulted in a higher particle density compared to green and yellow peas (Ojo, 2022). Sethi's *et al*. (2016) study results showed that comparing to other alternative drinks viscosity of the legume beverage is closest to the viscosity of cow's milk, which range from 2.6 to 3.0 mPa s^{-1}.

The *total phenolic content* of differently pre-treated pea beverages (see Figure 2) was higher than that of beverages produced from germinated raw material. Some of the phenolic compounds (salavin A, protocatechuic acid, ferulic acid) lose their stability at

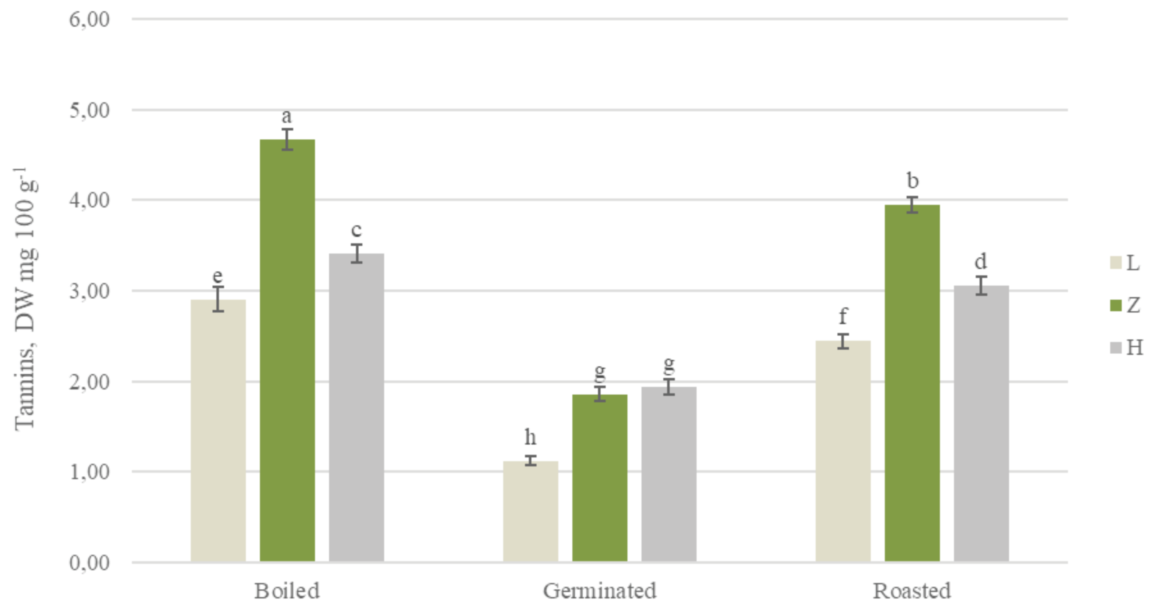

Figure 3. Tannin concentration (TC) in pea-based beverages, DW mg 100 g^{-1}.

Values with the same letters are not significantly different ($p > 0.05$)

elevated temperatures. The decomposition of phenolic compounds was observed at a temperature ~200 °C, and their complete decomposition occurs at a temperature of 300 – 350 °C (Cheng *et al*., 2014). The significant decrease ($p<0.05$) in TPC was observed germinated samples. The significantly lower ($p < 0.05$) TPC was in G/H sample among all analysed samples. These observations are consistent with previous studies, the TPC decreases at the beginning of germination (Paśko *et al*., 2009). The decrease in TPC, tannins and phytic acid content is associated with changes made by enzymes during the germination (Megat Rusydi & Azrina, 2012). At the beginning of germination, biologically active compounds, including phenols, are synthesized in peas, but are also rapidly degraded by enzymatic activity (Gan *et al*., 2017). Among the undesirable compounds present in food products, chelates formed by phenols by binding metal ions should be mentioned, which also have anti-nutrient properties (Popova & Mihaylova, 2019). During legume germination, TPC increase is observed after 72 h (Tarasevičienė *et al*., 2019). Phenols participate in the formation of a bitter, pungent taste, ensuring oxidative stability of products. The phenol content in peas is significantly influenced by the pea variety (Chen *et al*., 2023). The current study results show that higher TPC was in the variety 'Zaiga' compared to 'Lāsma' and the breeding line H 08-10-15. The content is also significantly influenced by climatic conditions, degree of maturity, storage conditions and genetic factors (Tarasevičiene *et al*., 2018).

For understanding effect of pre-treatment on undesirable anti-nutrient content in the pea beverages, *tannin content* (TC) was detected in samples. The processing method significantly affects the TC in pea-based beverages. The decrease in TC in pea is associated with the hydrolysis of insoluble polymers into smaller, soluble molecules with lower molecular weight (Singh *et al*., 2017). The current study results agree with other studies, where authors have shown that TC in grey and green pea is usually higher than yellow varieties of peas (Troszyńska & Ciska, 2002). In peas, tannins are mostly located in the pea coat which were removed, and could significantly reduce the tannin content in all samples.

When analysing the content of *volatile compounds* in pea-based beverages, it is observed that the aroma profile changes depending on the pre-treatment methods applied. The study identified the most important legume aroma compounds as aldehydes (hexanal, benzaldehyde), alcohols (1-octen-3-ol), ketones (2-heptanone), pyrazines (2-methoxypyrizine) (Cichońska & Ziarno, 2022).

Of the alcohols, 1-octen-3-ol gives pea products a mushroom and earthy aroma (Zhang *et al*., 2021). In the current study, the variety significantly affects the concentration of 1-octen-3-ol and it was significantly higher in the samples of variety 'Zaiga'. Roasted samples contained the lowest concentration of octen-3-ol and also other pre-treatments (as germination) coupled with extrusion showed a significant decrease of pea off-flavours (Chen *et al*., 2021).

Germination leads to a decrease of 1-octen-3-ol, and the other research data about faba beans showed that beany flavours decreased after germination

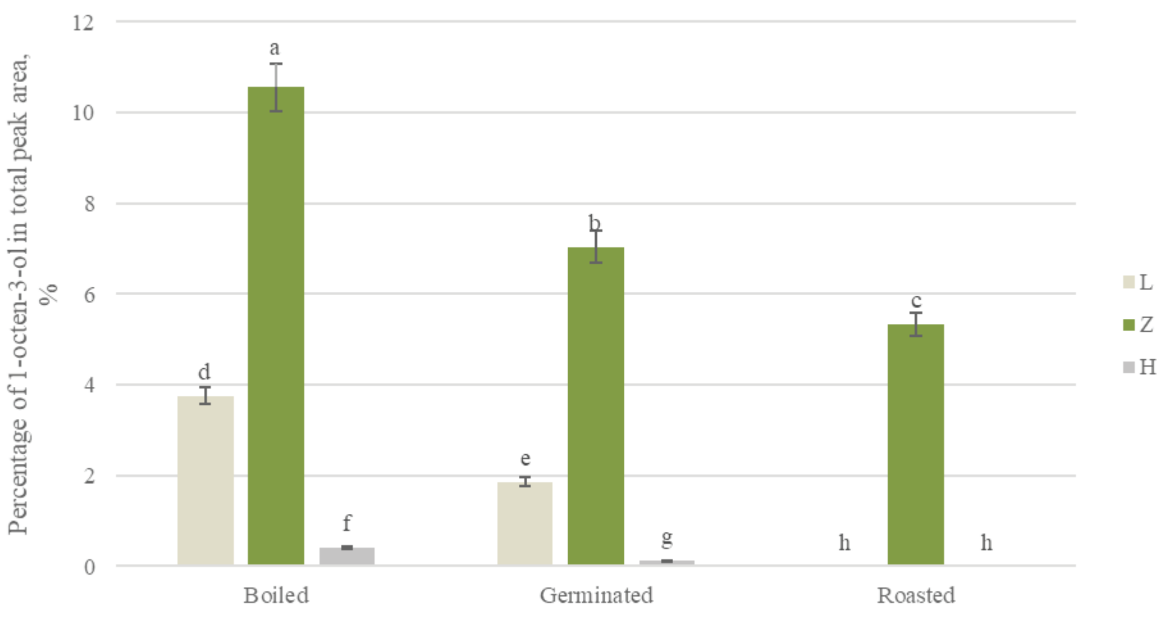

Figure 4. Percentage of 1-octen-3-ol in the total peak area of pea-based beverages.
Values with the same letters are not significantly different ($p > 0.05$)

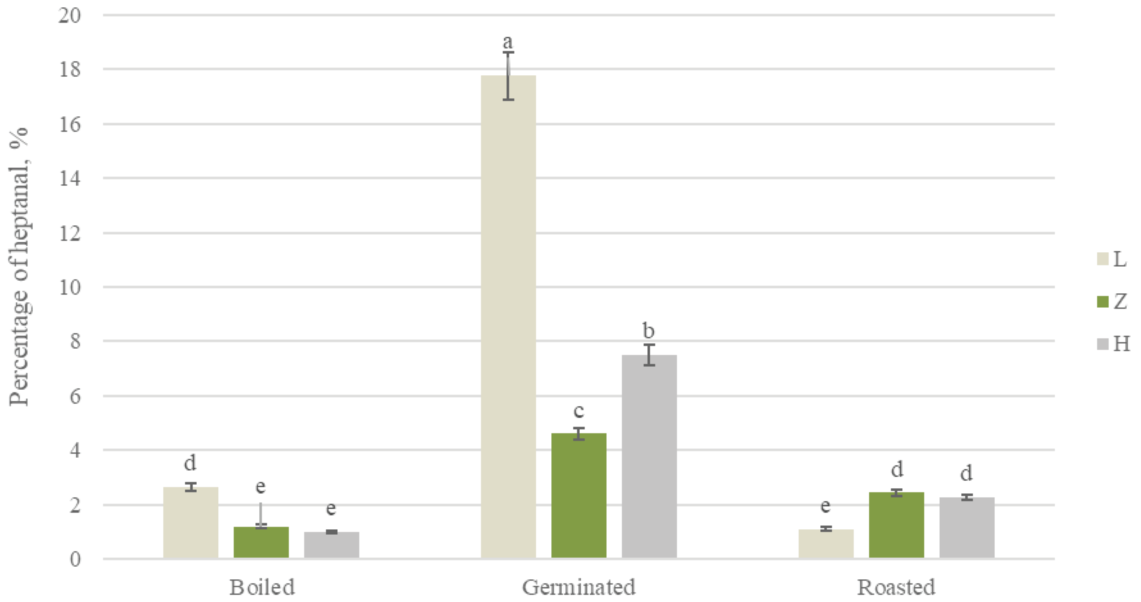

Figure 5. Percentage of heptanal in total peak area of pea-based beverages.

Values with the same letters are not significantly different (p > 0.05)

(Akkad *et al*., 2021). During pea germination, lipoxygenases promote the degradation of fatty acids. As a result of the lipoxygenase activity from fatty acids, mainly linoleic and linolenic acid, new aroma compounds (heptanal, octanal) are formed, which is associated with off-flavours described as beany, green and grassy (Sedó Molina *et al*., 2024) (Fig.5). Such results are consistent with the data obtained in the current study, and the increase of heptanal was an observation in germinated samples of all varieties. It contributes to the overall flavor profile, often associated with undesirable off-flavors such as fishy, earthy, and beany notes (Karolkowski *et al*., 2021).

Although early studies focused on specific compounds responsible for pea flavour, it is clear that the aroma profile is largely influenced by the concentration of several volatile compounds and the processing or pre-treatment of the peas (Mehle, Paravisini, Peterson, 2002). Some of the volatile compounds with attributed “pea flavour” properties are only expressed at certain compound concentrations (Vara-Ubol, Chambers, Chambers, 2004). For example, hexanal contributes to an unpleasant aroma, but it does not itself have a characteristic “pea flavour”. In turn, it contributes to the intensity of the pea aroma. Only a few molecular aroma-forming compounds directly contribute to the characteristic pea aroma (Mehle, Paravisini, Peterson, 2002). According to the current research results pre-treatment methods as germination and roasting could be recommended for decreasing leguminous aroma in the pea beverage.

Conclusions

The most suitable raw material for pea-based beverage production is the grey pea breeding line H 08-10-15, which is characterized by a higher content of essential amino acids and proteins. Analyzing the effect of pre-treatment methods on the quality of pea-based beverage, it was found that germination and roasting of pea could be recommended. After pea germination, the content of soluble dry matter increases, but the content of undesirable aroma forming compounds, total phenols and tannins decreases in pea-based beverage. During roasting, the content of total phenolic compounds and tannins decreases in the pea-based beverage.

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