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Original Paper

Sensory Analysis of Edible Gels Enriched with Bioactive Compounds Intended for the Nutrition of Seniors

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Edible gels are a promising form of functional food suitable for seniors, who often face difficulties with swallowing and insufficient nutrient intake. Their structure allows for the incorporation of bioactive compounds with good gastrointestinal absorption and subsequent health benefits. The aim of this study was to evaluate the sensory acceptability of prototypes of edible gels enriched with bioactive substances and to propose recipe optimisation. Curcumin, known for its antioxidant and anti-inflammatory effects, was selected as the model bioactive compound. The gel matrices were prepared using two polysaccharides, arabinogalactan or beta-glucan and two flavours (apple pulp or vanilla). Each variant was produced in two versions, without bioactive substances or with added curcumin resulting in eight samples. The samples were stored at 4 °C and equilibrated to room temperature for 2 hours before evaluation. Eighty senior participants (40 in Slovakia, 40 in the Czech Republic) aged 65 and over took part in the sensory evaluation, assessing anonymised samples presented in random order. The evaluation was conducted in accordance with ISO 8589:2007 guidelines, using descriptive analysis with a 9-point hedonic scale (1 = very poor, 9 = very good). The results showed that edible gels represent a promising platform for the application of geroprotective agents for seniors. Arabinogalactan in combination with fruit flavours proved to be the best accepted matrix, while beta-glucan and curcumin require technological interventions to improve the sensory profile. From a practical point of view, these results are relevant for the development of new functional foods intended for the aging population.

Keywords: edible gels, geroprotective substances, nootropics, seniors, development of new food products, sensory analysis

1 Introduction

Population ageing is one of the most significant demographic trends of our time, creating growing pressure on the area of nutrition for seniors (Methven et al., 2012; Chen et al., 2021). This group of consumers has specific needs and limitations, so it is necessary to find solutions that improve their quality of life while promoting health and vitality. There is a wide range of nutritional supplements and foods with added bioactive substances on the market, but their use is often limited by the presence of technological additives, problematic application, or insufficient information on contraindications and recommended doses. This is particularly risky for seniors, who are among the most sensitive consumers (Sura et al., 2012).

Edible gels appear to be a promising solution, as they are easy to apply and allow for high absorption of bioactive substances. Thanks to their technological properties, they are a suitable carrier for substances with geroprotective effects that can promote longer and healthier survival (Kaur et al., 2019). The aim of the research was to evaluate the prepared samples of edible gels sensorily and optimise their recipe so that it meets not only nutritional requirements but also the consumer preferences of seniors (Mojet et al., 2003; Methven et al., 2012).

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Among the most studied edible gel matrices is beta-glucan, a polysaccharide found in yeast, fungi, algae and cereals (oats, barley) (Khoury et al., 2012; Vetvicka and Vannucci, 2019). Its properties depend on its origin, structure and molecular weight, and these factors also influence its bioactivity and technological use. Beta-glucans are important for their immunomodulatory effects, which have been confirmed in more than 20,000 scientific studies, and improve the regulation of cholesterol, postprandial glycaemia, reduce insulin resistance and promote the health of the intestinal microbiome (Khoury et al., 2012).

Another promising component is arabinogalactans, highly branched polysaccharides found mainly in woody plants, especially larch. This substance is also recognised by the Food and Drug Administration as a source of fibre and has been shown to have a beneficial effect on the gut microbiome – improving the ratio of bacterial strains, promoting the production of beneficial metabolites and reducing inflammatory processes (Szymańska et al., 2020). Clinical studies point to their ability to reduce the incidence of upper respiratory tract infections and support the effectiveness of vaccination, which also demonstrates their immunostimulatory potential (Vetvicka and Vannucci, 2019).

Edible gels are therefore an innovative form of administering bioactive substances, combining ease of application, high absorption and sensory acceptability. Their use in the field of nutrition for the elderly is extremely promising, especially in combination with polysaccharides such as beta-glucans and arabinogalactans, which have scientifically proven health benefits (Khoury et al., 2012; Vetvicka and Vannucci, 2019). Research was focused on optimising the recipes for these gels with an emphasis on their functionality and consumer preferences, which may contribute to a higher quality of life for the elderly population (Verbeke, 2005).

The aim of this study was to evaluate the sensory acceptability of prototypes of edible gels enriched with bioactive substances and to propose optimisation of the proposed recipe. The aim of the sensory analysis was to comprehensively assess the influence of the polysaccharide base, flavour type and presence of a bioactive substance (curcumin) on the sensory acceptance of edible gels intended for the elderly population.

2 Material and Methods

2.1 Study Design, Sensory Panel Characteristics and Sensory Analysis

Sensory analysis was performed in premises complying with ISO 8589:2007, which provides guidelines for the design of test rooms. A 9-point hedonic scale is most commonly used to measure food acceptability. It was developed in 1947 by Peryam and Girardot. This scale is a well-established tool in sensory evaluation for measuring the acceptability of food and beverages, personal care products, household products and cosmetics. Each point on the scale represents a subjective measure of intensity or liking that the evaluator assigns to a given sample (Smith et al., 2021). The sensory evaluation of eight types of edible gel samples was performed using 9PHS descriptive analysis. The target group of evaluators to complete the questionnaire was senior citizens. Eighty untrained evaluators aged 65 and over participated, 40 of them in Slovakia and 40 in the Czech Republic. In Slovakia, the evaluation took place at a senior citizens' facility in Žilina.

Each evaluator had eight samples at their disposal, labelled in such a way that the composition or flavour of the sample was not apparent, in order to avoid influencing the evaluation. The samples were displayed in random order. First, the participants were given information on how to proceed with the analysis and how to correctly record the information obtained in the questionnaire, and then they subjectively recorded the information in the evaluation questionnaire. The sensory panel assessed the following attributes: appearance, aroma, taste, aftertaste, overall impression, fluidity, colour, sweetness intensity, bitterness intensity and intensity of the flavour. The sensory analysis was carried out at room temperature and under suitable lighting conditions necessary for the analysis.

The questionnaire contained 10 questions rated on a 9-point scale. A score of 1 on this scale corresponds to the answer "very bad", a score of 5 corresponds to "average" and a score of 9 corresponds to "very good". The questionnaires were collected and the data were statistically processed and then visualised in the form of graphical representations.

The equal spacing between the points on the scale allows the use of numerical values from 1 to 9 in the analysis of responses, which supports the use of parametric statistical methods in data processing. This practice is also justified by the fact that the validity and reliability of the scale has been demonstrated in sensory tests focused on food acceptability (Lim, 2011). The points on the scale were as follows: 1 = I don't like it at all – very unpleasant; 2 = I don't like it; 3 = I dislike it slightly; 4 = I dislike it a little; 5 = neutral – neither like nor dislike; 6 = I like it a little; 7 = I like it slightly; 8 = I like it; 9 = I like it very much – very pleasant (Singh et al., 2014).

For sensory analysis, we used eight combinations of edible gels with a polysaccharide base of arabinogalactan

or beta-glucan and apple crush or vanilla flavours, as well as variants of gels without bioactive substances and variants of gels with added bioactive substances (BAS). Based on an overview of geroprotective substances, we selected curcumin as the target bioactive substance for further analysis and application design. This selection was not random, but was based on several key criteria – biological efficacy, safety, availability and economic feasibility in practice. Curcumin, a natural polyphenol extracted from the root of the *Curcuma longa* plant, has been studied for decades for its anti-inflammatory, antioxidant and potential anti-tumour effects. It is also significantly mentioned in connection with its possible geroprotective effect, i.e. the ability to influence the ageing process and improve the quality of life in old age (Gupta et al., 2013). Compared to other promising substances such as rapamycin, which requires strict dosage control and is also financially demanding, curcumin is a more affordable alternative with a favourable safety profile. From a practical point of view, the possibility of administering it in various forms suitable for seniors (forms with improved bioavailability) makes it an ideal candidate for further research and practical use in preventive or supportive health programmes for seniors. Overall, it can be concluded that curcumin combines the potential of an active substance with a favourable availability and price profile, which are essential conditions for practical application in the wider elderly population. An overview of the gel samples used with the corresponding polysaccharide and flavour is shown in Table 1.

The composition of the analysed edible gel samples is protected by copyright. Selected prototypes can be found in utility model 9963.

Samples of edible gels were stored in a refrigerator at 4 °C. Before analysis, the samples were removed from the refrigerator and left to stand at room temperature for 2 hours.

2.2 Statistical analysis

We used Jamovi software designed for data analysis and statistical testing to process the input data. Based on the sensory evaluation of the panels, the results were processed for three main sensory attributes: taste, fluidity, and flavour intensity. The evaluations were visualised using violin graphs, which show the distribution of the evaluations of individual samples together with the mean value (black square).

3 Results and Discussion

Sensory analysis focused on comparing samples of edible gels with different polysaccharide bases (arabinogalactan, beta-glucan), flavours (apple crush, vanilla) and the presence of a bioactive substance (curcumin). The attributes of taste, fluidity and flavour intensity were evaluated. As already mentioned, the evaluations were visualised using violin graphs, which show the distribution of the evaluations of individual samples together with the mean value (black square). The samples are arranged so that each pair of samples contains the ones we want to compare – in this case, the first sample in each pair is without BAS and the second with BAS.

The sensory evaluation attribute is plotted on the y-axis. The *x*-axis shows the same gel samples, but under a different designation, which includes the abbreviation SK or CZ depending on the country in which it was analysed (Table 2). Based on the evaluations of the Slovak and Czech panels, the following main trends were identified:

Arabinogalactan gels achieved higher ratings than beta-glucan gels in all attributes, especially in taste and flavour intensity. The addition of a bioactive substance (BAS) led to a slight increase in fluidity, but also to a decrease in taste and flavour perception, which was more pronounced in the Slovak results. The best-rated sample was the combination of arabinogalactan + apple crush + BAS (AG_AC_BAS), which received the highest scores for taste and fluidity. The least acceptable were gels with

Table 1 Designation of edible gel samples according to ingredients

Sample	Polysaccharide	Flavour	BAS
AG_AC	arabinogalactan	apple crush apple pulp	X
AG_V	arabinogalactan	vanilla	X
BG_AC	beta-glucan	apple crush apple pulp	X
BG_V	beta-glucan	vanilla	X
AG_AC_BAS	arabinogalactan	apple crush apple pulp	O
AG_V_BAS	arabinogalactan	vanilla	O
BG_AC_BAS	beta-glucan	apple crush apple pulp	O
BG_V_BAS	beta-glucan	vanilla	O

AG – arabinogalactan; BG – beta-glucan; AC – apple crush; V – vanilla; BAS – with added curcumin

Table 2 Designation of edible gel samples by country

Sample	Polysaccharide	Flavour	BAS
111CZ, 111SK	Arabinogalactan	apple crush apple pulp	x
222CZ, 222SK	Arabinogalactan	vanilla	x
333CZ, 333SK	beta-glucan	apple crush apple pulp	x
444CZ, 444SK	beta-glucan	vanilla	x
555CZ, 555SK	Arabinogalactan	apple crush apple pulp	o
666CZ, 666SK	Arabinogalactan	vanilla	o
777CZ, 777SK	beta-glucan	vanilla	o
888CZ, 888SK	beta-glucan	apple crush apple pulp	o

BAS – with added curcumin; CZ – Czech Republic; SK – Slovak Republic

beta-glucan and vanilla, regardless of the presence of BAS. An international comparison (SK vs. CZ) confirmed the consistency of the trends – arabinogalactan samples were preferred in both countries, although the Czech panel was generally more tolerant of samples with BAS (Figure 1 and 2).

An international comparison showed a high degree of agreement between panels in evaluating the attractiveness of the gels. Arabinogalactan samples were clearly preferred in all attributes (taste, flavour, fluidity). Beta-glucan samples repeatedly lagged behind, possibly due to their thicker consistency and weaker flavour perception (Figure 3). The addition of BAS affected the sensory attributes in different ways – a positive increase in fluidity, but a slight decrease in the perception of taste and sweetness, especially in beta-glucan samples. The panellists again preferred the AG samples with apple crush, even after the addition of curcumin (Figure 4). The consistency of the results between the SK and CZ panels supports the reliability of the sensory analysis. The results from both national panels – Slovak and Czech – pointed to clear trends that reveal not only consumer preferences but also technological aspects related to the creation of a suitable gel matrix.

The results of the sensory analysis revealed significant differences in the acceptance of edible gels with bioactive substances (BAS) among seniors in Slovakia and the Czech Republic. These findings need to be interpreted not only in the context of sensory evaluation itself, but also in the broader context of the nutritional needs of an

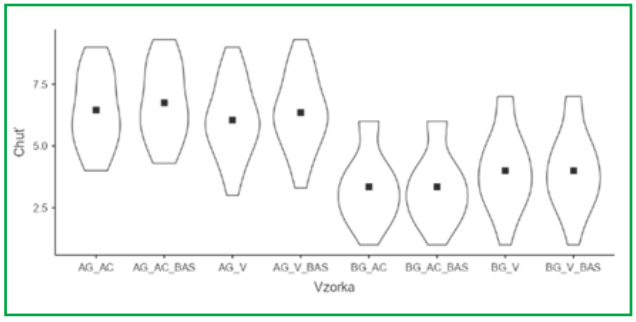

Figure 1 Violin evaluation of the taste attribute
Slovak sensory panel

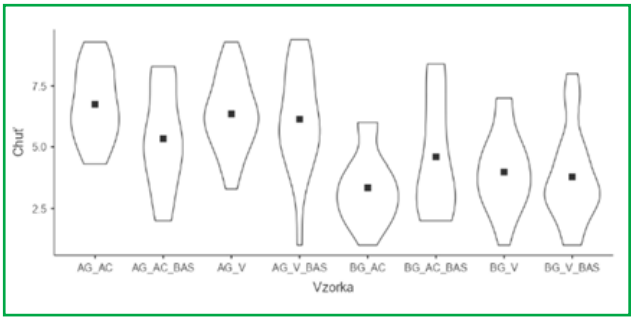

Figure 2 Violin evaluation of the taste attribute
Czech sensory panel

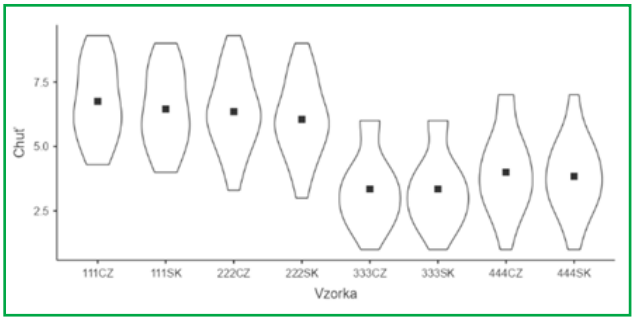

Figure 3 Violin evaluation of the taste attribute
international without BAS

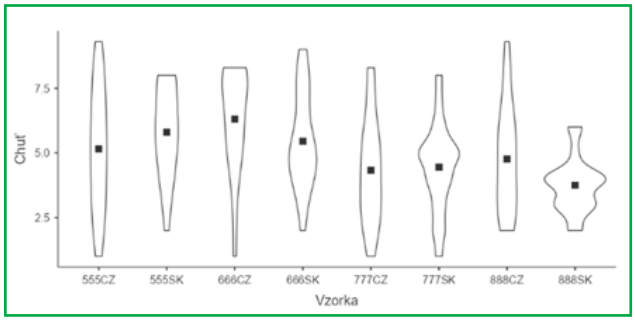

Figure 4 Violin evaluation of the taste attribute
international with BAS

ageing population and the development of functional foods in Europe. Seniors represent a very heterogeneous group in terms of nutrition and health status, and their preferences and tolerance for certain sensory properties can be significantly influenced by physiological changes associated with ageing, health complications and pharmacotherapy. The literature also points out that the success of functional foods on the market is largely determined by their sensory acceptability (Methven et al., 2012; Kaur et al., 2019).

The polysaccharide base is the fundamental matrix that significantly influences texture, taste perception and flavour stability. The data obtained confirmed that arabinogalactan samples were rated higher than beta-glucan samples in both countries, with this difference being consistent across all evaluated attributes (taste, flavour, fluidity). Arabinogalactan creates a finer and smoother structure that is more pleasant to the senses and also better transmits aromatic substances, thereby increasing the intensity of the taste. Beta-glucan, on the other hand, often creates denser and less homogeneous gels that can appear slightly grainy or "heavy". This effect was also evident in visual evaluation, where beta-glucan gels appeared less transparent. Such texture could affect the overall impression of the product, especially among seniors who prefer lighter and smoother consistencies. At the same time, arabinogalactan was also found to improve the rheological stability of the gels, which could be important for longer storage or transport of the products. These results are consistent with the findings of previous studies, which report that arabinogalactan increases sensory acceptance in products with functional ingredients (Szymańska et al., 2020). In contrast, beta-glucan, although technologically and nutritionally interesting (due to its hypocholesterolemic effect), may impair taste perception and mouthfeel (Vasile et al., 2019).

A comparison of flavours showed that apple crush was clearly preferred over vanilla. The fruit aroma improved the perception of freshness and flavour intensity, while vanilla was rated more neutrally to bland. This result is not surprising, as several sensory studies have shown that older consumers respond more positively to fruity, sour and refreshing flavours that stimulate the salivary glands and improve taste perception (Mojet et al., 2003; Methven et al., 2012). Vanilla flavour, although traditionally popular among the younger population, may seem too sweet and monotonous to seniors. In addition, it can interact with the polysaccharide matrix and curcumin, changing its volatile profile. In combination with arabinogalactan, apple crush proved to be the optimal carrier. It provided a balanced profile of sweetness and freshness, while suppressing any undesirable undertones of the bioactive substance. This effect was not observed with the beta-glucan base, where the aroma was less pronounced, probably due to the different structure of the gel matrix and greater retention of volatile substances.

The presence of the bioactive substance had a dual effect. It reduced the intensity of taste and flavour, but slightly improved the perception of fluidity. This result can be explained both by the chemical properties of curcumin (mild bitterness, lipophilicity) and its interaction with the polysaccharide network. This effect was less pronounced in arabinogalactan gels because their structure better masked the bitterness. The decrease in sensory values in samples with BAS is consistent with the literature, which states that curcumin in its native form has low sensory acceptability (Gupta et al., 2013). Therefore, processes such as microencapsulation (Zhang et al., 2018), complexation with cyclodextrins or combination with fruit flavours, which reduce its bitterness and improve dispersibility, are commonly used in food applications. An interesting finding was that the addition of BAS led to a subjective increase in the fluidity of the gels. This effect can be attributed to a slight disruption of the polysaccharide network, which causes a reduction in viscosity. Such a change may be advantageous from a technological point of view, improving swallowing and facilitating consumption, which is desirable for the target group of seniors.

The Slovak panel was stricter in its evaluation of taste and flavour, while the Czech evaluators showed greater tolerance towards samples with BAS. This difference can be explained by different gastronomic experiences and slightly different taste stereotypes. In terms of fluidity, Slovak evaluators preferred thinner gels, while Czech evaluators tended to prefer thicker consistencies. This points to cultural variability in sensory perception and the need to adapt the product to a specific market. In practice, this could mean the need for slightly different formulations for different regions, especially if the product were to be marketed in both countries. A comparison of panels in Slovakia and the Czech Republic revealed similar trends, but also several differences. In both countries, fruit flavours were preferred over neutral or bitter ones. Differences were particularly evident in the evaluation of texture and fluidity. This finding points to the need to culturally adapt products when launching them in different markets. Similar findings have also been published in European comparative studies of functional foods, which showed that consumer preferences are influenced not only by age group but also by regional traditions (Verbeke, 2005).

Taste proved to be a key parameter determining the overall acceptance of the samples tested.

Arabinogalactan combined with apple crush flavouring was accepted significantly more positively than the beta-glucan variants. This result can be explained by several factors. Apple crush provided a more intense taste stimulus, which is important for seniors with reduced taste receptor sensitivity. Arabinogalactan has a neutral sensory profile and therefore allowed the fruity aroma to stand out, while beta-glucan often contributes to a feeling of "graininess" or blandness (Vetvicka and Vannucci, 2019). In contrast, the vanilla flavour was rated more neutrally to negatively. Seniors often lose the ability to perceive sweet tastes (Mojet et al., 2003), which means that the subtle sweetness of vanilla was not sufficiently stimulating. Compared to the literature, it can be concluded that fruit flavours (especially sour and fresh ones) are better accepted by older consumers than delicate aromas (Methven et al., 2012). The presence of curcumin negatively affected the sensory evaluation. Its naturally bitter taste and specific aromatic properties reduced the attractiveness of the samples. Although curcumin is being intensively studied for its anti-inflammatory and antioxidant effects (Aggarwal et al., 2003; Gupta et al., 2013), its sensory compatibility is problematic. Taste-masking technologies, such as microencapsulation or the use of natural sweeteners and acidic flavours that can suppress bitterness, appear to be a promising solution (Dai and Mumper, 2010).

Texture and fluidity are among the most critical attributes for food acceptance in older adults. Dysphagia, xerostomia and reduced sensory sensitivity are common problems in this age group (Sura et al., 2012). It is therefore essential that products are easily soluble, have a soft texture and do not require excessive effort to swallow. The results of our analysis showed that seniors preferred samples with lower viscosity and a smooth consistency that break down more quickly in the mouth. Differences between the Slovak and Czech panels were found in the assessment of fluidity. While the Slovak panel preferred thinner gels, the Czech panel showed greater tolerance for thicker forms. This difference can be attributed to dietary traditions. Czech cuisine is known for its thick sauces and soups, while Slovak cuisine tends towards thinner dishes. Similar cultural determinants of sensory perception have also been described in other studies (Shepherd, 2001).

Correlations between the evaluated attributes suggest that the perception of taste and flavour intensity is closely related to the textural properties of gels. A smoother and less viscous structure facilitates the release of aromatic substances and improves their perception. This relationship is also known from previous sensory studies of gel products (Clegg et al., 2023), which confirmed that optimal texture enhances both aroma and taste perception. In the case of beta-glucan gels, this synergistic effect was not observed. The thicker consistency probably limited the release of aromatic molecules, leading to a weaker taste experience. Conversely, the arabinogalactan base allowed for a harmonious interaction between texture and aroma, which explains its higher overall acceptance.

The overall impression, which combined taste, texture, appearance and flavour, best reflected the acceptability of the individual samples. The highest scores were obtained by arabinogalactan samples without the addition of curcumin, confirming that although bioactive substances have health benefits, they must be applied in a form that does not compromise sensory acceptability. The beta-glucan samples with vanilla received the lowest ratings, indicating a cumulative effect of bland taste and less favourable texture. These results correspond with the findings of other authors who have confirmed that sensory compatibility is crucial when launching new functional products on the market (Kaur et al., 2019). At the same time, they indicate the need to find a balance between health benefits and sensory acceptance.

The results confirm the great application potential of gel matrices as carriers of bioactive substances. Compared to tablets or capsules, gels are more suitable for seniors with reduced swallowing ability and offer the possibility of individualised dosing. This group of consumers has specific sensory needs, reduced taste sensitivity, weakened swallowing and often altered salivary secretion. It is therefore essential to create products that are not only nutritionally valuable but also sensorially attractive and easy to consume. The most promising combination appears to be arabinogalactan with fruit flavours. Edible gels appear to be a suitable platform in this context. They allow the incorporation of bioactive substances, customised dosing and texture adjustment as needed. The combination of arabinogalactan as a base and fruit flavours (e.g. apple crush) is an optimal solution that combines good sensory properties with high application potential. From a technological point of view, it is recommended to pay attention to masking the bitterness of bioactive substances and optimising viscosity, for example by using modified polysaccharides or adding pectin. Such modifications could improve the sensory profile without losing functional properties. Another recommendation is to link sensory studies with clinical trials of bioactive effects to ensure not only acceptance but also the effectiveness of the product. Such an approach could support the development of personalised gel supplements for seniors, tailored to individual needs and preferences.

The limitations of this study include the relatively small number of evaluators and the short-term nature

of the testing. In the future, it would be advisable to expand the panel to include greater age and geographical variability, supplement the rheological and physicochemical analyses of gels, and monitor the long-term acceptance of products. An interesting direction for research would also be to test new types of bioactive substances (e.g. resveratrol, quercetin) and new flavours (e.g. citrus or herbal) that could increase sensory appeal. The sensory preferences of seniors may change over time and be influenced by health changes, drug therapy or psychological factors.

Our findings underscore the importance of a multidisciplinary approach that combines nutrition, food technology, sensory science and medicine. The successful development of functional foods requires not only scientific evidence of efficacy, but also technological solutions that ensure acceptance by the target population.

4 Conclusions

The study confirmed that edible gels represent a promising platform for the application of geroprotective substances for seniors. Arabinogalactan combined with fruit flavours proved to be the most acceptable matrix, while beta-glucan and curcumin require technological interventions to improve their sensory profile. The differences found between Slovakia and the Czech Republic highlight the importance of cultural adaptation of products and the need to take regional preferences into account. From a practical point of view, these results are important for the development of new functional foods for the ageing population. When creating recipes, it is essential to balance health benefits with high sensory acceptability to ensure regular consumption and long-term health benefits for seniors. Future research should focus on optimising technologies for masking undesirable tastes, testing larger panels of respondents, and linking sensory analyses with clinical efficacy trials. Products designed in this way can significantly contribute to improving the quality of life of the elderly population and support the trend towards personalised nutrition in Europe.

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Conflict of Interest

The authors declare no conflict of interest.

Authors' Contributions

Žemberyová – conceptualisation, methodology, software, validation, formal analysis, data curation, writing – preparation of the original draft, writing. Gažarová – review and editing. Vietoris – visualisation, project administration, research supervision, fundraising. All authors have read and agreed to the published version of the manuscript.

AI and AI-Assisted Technologies use Declaration

No generative AI tools/AI-assisted technologies were used during the preparation of the manuscript.

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