



Consumer acceptance, sensory quality, and techno-functional behaviour of vegetable-based, inulin-enriched ice creams

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ABSTRACT

This study developed and evaluated vegetable-based, inulin-enriched ice creams. A questionnaire (n = 295) was followed by sensory testing (n = 70) of three prototypes – mint-lemon zucchini, orange-carrot, and dark chocolate-sour cherry beetroot – and texture/melting analyses. Willingness to try was high (89 %) despite low awareness (22 %); mango-carrot was the most appealing prospective flavour (63 %). In sensory tests, mint-lemon zucchini achieved the best overall impression (~75 % preference). Overrun ranged 8.7-25.7 %, indicating relatively dense, low-air products. Melting behaviour reflected fibre/solids: beetroot melted slowly with a gel-like residue, carrot melted faster, and zucchini was intermediate. Vegetable-based ice creams thus appear a realistic market alternative – especially for women aged 20-29 – provided that launch strategies emphasise tasting and clear education (inulin as a natural dietary fibre). Technologically, target mouthfeel can be achieved by tuning total solids/fibre/fat and emulsifier-stabiliser levels.

Keywords: vegetable-based ice cream; inulin; consumer acceptance; sensory evaluation; texture analysis; melting behaviour; overrun; functional foods

1. INTRODUCTION

Ice cream symbolises summer, relaxation, and fun for children, but the high sugar and fat content of traditional recipes makes it unsuitable for a health-conscious diet. Given the increasing prevalence of obesity and lifestyle-related chronic diseases, there is a growing urgency to develop innovative desserts that are enjoyable yet nutritious. A growing number of consumers are looking for products that offer added values, whether in terms of fibre intake, micronutrient content, or the more sustainable use of ingredients.

Although vegetables are traditionally used in main courses and side dishes, their use in desserts is still unusual. However, their fibre and micronutrient contents, as well as their low energy density,



make them ideal ingredients for developing health-conscious desserts. Developing vegetable-based ice cream presents technological and sensory challenges, such as ensuring the right texture, achieving a harmonious flavour profile, and gaining consumer acceptance, while also benefiting from the favourable dietary properties of vegetables.

This study focuses on three vegetables commonly found in home diets: zucchinis, carrots, and beetroot. The research aims to explore consumers' openness to vegetable-based ice creams, present the sensory perception of the developed products, and evaluate the potential of inulin as a functional fibre-enhancing ingredient. Thus, the work aims to provide a comprehensive picture of the development and consumer perception of vegetable-based ice cream, situated at the intersection of traditional ice cream concepts and health-conscious, innovative product development.

2. LITERATURE REVIEW

In the 21st century, health, special diets, and related functional foods have become a major focus of attention and a primary driver for many product developments. Plant-based ice creams manufactured using soy, almond, or coconut milk have reduced fat content, offer a lactose-free alternative, and can be fortified with probiotics or prebiotics, which have been shown to improve the balance of gut flora (Taspinar et al., 2023; Goktas et al., 2022; Kowalczyk et al., 2021). Several studies have shown that different plant-based beverages, especially soy and coconut-based systems, have favourable emulsifying and foam-stabilising properties, making them technologically suitable as ice cream bases, while consumer acceptance can reach competitive levels compared to traditional dairy ice creams (Acar et al., 2025; El-Sayed, 2025; Taspinar et al., 2023).

Furthermore, ice cream provides a favourable matrix for probiotic microorganisms. Several studies have shown that the bacterial count in ice creams enriched with different strains of *Lactobacillus* is increased (Taspinar et al., 2023; Goktas et al., 2022; Kowalczyk et al., 2021). As demonstrated in the relevant literature, *Lactobacillus*, *Bifidobacterium*, and *Saccharomyces* have been shown to reach the 10^6 - 10^7 CFU/g range that is considered to be the maximum level at which these organisms can be found in functional foods by the end of storage, without any significant deterioration in sensory quality (Elkot et al., 2022; Goktas et al., 2022; Hanafi et al., 2022; Kowalczyk et al., 2021).

As demonstrated in the relevant literature, dietary fibres, such as inulin and those derived from oats and apples, have been shown to modify the viscosity, melting properties, and texture of ice cream, while also providing nutritional benefits (Tolve et al., 2024; Arslaner & Salik, 2020; Kowalczyk et al., 2021). The incorporation of black rice powder, coconut fibre, or other plant-derived fibre fractions has been demonstrated to enhance the water retention capacity of the system, elevate viscosity, exert a favourable influence on overrun and ice crystal size, and support the viability of probiotics. Consequently, these factors contribute to a creamier, more stable texture (Tang et al., 2025; Elkot et al., 2022; Hanafi et al., 2022). Fibres fulfil dual roles, functioning both technologically (as a fat and sugar replacement, stabiliser) and nutritionally (as a prebiotic), aligning with the rising consumer demand for health-conscious yet pleasurable dessert options. Recent reviews emphasise that developing healthier or functionally enriched ice creams requires formulation and processing strategies that preserve microstructure (e.g. fat partial coalescence and air cell stability) and limit ice recrystallization to avoid iciness and weak body (Chang et al., 2025; Tang et al., 2025).

In recent years, there has been an increasing focus on plant-based desserts, which offer new flavour profiles and can contribute to two key issues of modern society: increasing vegetable consumption



and reducing food waste (Darko et al., 2024; Nur'Aqilah et al., 2023; Vijayalakshmi & Vijayavahini, 2022). The former would be particularly necessary in Hungary, which, according to the 2024 report by the Organisation for Economic Co-operation and Development (OECD), ranks last in terms of vegetable consumption in the EU. The per capita daily vegetable consumption in Hungary is approximately 165 grams, which is only ~33 % of the recommended intake according to the guidelines set by the Association of Hungarian Dietitians (MDOSZ, 2016).

Consumer studies on plant-based frozen desserts have indicated that non-traditional matrices are frequently penalised for vegetal/off-flavours and texture defects (e.g., grittiness) (Ettinger et al., 2024; Gorman et al., 2023), underscoring the necessity for meticulous ingredient selection and optimisation when introducing plant-derived components. A recent Hungarian consumer survey on plant-based and vegan substitute products indicates a comparable level of receptiveness among consumers to novel and non-traditional food applications (Németh-Torkos et al., 2023).

The use of vegetables in ice cream has a double advantage in this respect. Firstly, they enrich the matrix with natural colouring and flavouring components, fibres, and phytochemicals. Secondly, they can partially replace fat and/or added sugar, which can lead to changes in viscosity, aeration, crystallisation, and melting properties of the ice cream (El-Sayed, 2025; Ateteallah et al., 2019). Conversely, they facilitate the utilisation of vegetable-derived by-products (e.g., beetroot pulp, zucchini residue) for food purposes, thereby promoting the principles of the circular economy and reducing food waste (Darko et al., 2024; Nur'Aqilah et al., 2023).

In accordance with this, recent research has demonstrated that the incorporation of fibre-rich by-products, such as oat okara, into plant-based ice cream can enhance dietary fibre levels and modify rheological and sensory characteristics. This emphasises the technological trade-offs associated with by-product valorisation (Caponio et al., 2025).

The objective of this study is to investigate consumer preferences and interest in vegetable-based ice cream through the implementation of an online questionnaire survey, and to examine the technological and organoleptic characteristics of vegetable-enriched products. A series of three innovative ice creams derived from vegetables (zucchinis, carrots, and beetroot) were developed, accompanied by a sensory evaluation in order to ascertain consumer acceptance and identify the most suitable products for production. Furthermore, physical tests were conducted, encompassing melting rate and composition analysis, to furnish an objective evaluation of the texture and quality of the ice cream. This scientific approach provides a robust foundation for the subsequent development of vegetable-based ice cream products.

3. MATERIALS AND METHODS

The objective of the present study was twofold: firstly, to develop a range of vegetable-based ice creams, and secondly, to evaluate their consumer perception in a complex manner. The primary research comprised five consecutive phases: a questionnaire survey, product development, qualitative interviews, sensory evaluation, and physical (texture and melting) tests. A selection of three vegetable raw materials (zucchinis, carrots, and beetroot) was made on the basis that they would be of use in the production of ice cream. These were then used in combination with fruit to develop inulin-enriched ice cream recipes.



3.1 Questionnaire survey

A quantitative, cross-sectional, self-completed online questionnaire survey was conducted to explore consumer attitudes and acceptance of vegetable-based ice cream. The questionnaire examined respondents' vegetable consumption habits, interest in vegetable-based ice cream, preferred vegetable and ice cream flavours, and knowledge of inulin. Furthermore, an analysis was conducted to ascertain the influence of demographic characteristics (age, gender, education, and place of residence) on consumers' propensity to adopt innovative products.

The sampling method employed was non-random, namely convenience sampling, with the questionnaire being disseminated primarily through social media platforms. The questionnaire was available on Google Forms from May 2024 to July 2024. Of the 308 completed questionnaires, 295 were found to be assessable ($n = 295$).

The questionnaire comprised 16 closed questions, 14 of which were mandatory. The survey comprised four questions pertaining to demographic data, five questions relating to ice cream consumption habits, four questions regarding attitudes towards vegetable-based ice creams, and three questions assessing knowledge about inulin. The question types encompassed single-choice, multiple-choice, and scaled (rating) formats.

3.2 Product development

Based on the questionnaire results and practical feasibility (taste harmony and anticipated consumer acceptance), three inulin-enriched vegetable ice cream prototypes were developed: (i) mint-lemon zucchini, (ii) orange-carrot, and (iii) dark chocolate-sour cherry beetroot.

The selected concepts combined a dominant vegetable ingredient with complementary flavour notes (citrus-mint, citrus-carrot, and cocoa-fruit-beetroot) in order to balance freshness, sweetness, and colour appeal.

The formulations (ingredient quantities per batch) are summarised in *Table 1*. Raw materials were prepared as follows: zucchini was washed, peeled, diced, briefly blanched, and blended to a puree together with fresh mint; orange juice was freshly squeezed, and the peel was finely grated; sour cherries were used frozen and were gently heated together with dark chocolate, then cooled and blended with beetroot juice prior to adding the remaining dry ingredients. After homogenisation (hand blender), mixes were matured for 4-5 h at 4-6 °C and frozen in a domestic ice cream machine (Ambiano IM-201/11457, Intertrading GmbH, Hamburg, Germany) with continuous agitation for 30 min; products were then stored at -18 °C. Inulin was included as a dietary fibre and partial sugar replacer; texture-supporting ingredients (a stabiliser/thickener base powder or gel mix, an emulsifier where applicable, and a whipping agent) were used according to each formulation to support aeration and structure.



Table 1: Formulations of the vegetable-based ice cream prototypes (per batch)

Ingredient (unit)	Mint-lemon zucchini	Orange-carrot	Dark chocolate-sour cherry beetroot
Lemon ice cream base powder (Tutti Ltd., Hungary) [g]	80	-	-
Zucchini puree (blanched) [g]	340	-	-
Fresh mint (chopped) [g]	50	-	-
Carrot juice [mL]	-	500	-
Orange juice (freshly squeezed) [mL]	-	200	-
Orange zest (freshly grated) [g]*	-	approx. 2	-
Beetroot juice [mL]	-	-	375
Sour cherry (frozen) [g]	-	-	300
Dark chocolate [g]	-	-	40
MEC3 Super gel mix (stabiliser/thickener) (MEC3 - OPTIMA S.P.A., Italy) [g]	-	50	37.5
MEC3 softin (emulsifier) (MEC3 - OPTIMA S.P.A., Italy) [g]	8	5	5
Sugar [g]	40	40	30
Inulin [g]	5	5	5
Citric acid [g]	2	3	3

*Orange zest was freshly grated; the amount was approximately 2 g (not weighed).

Note: MEC3 softin functions as an emulsifier; MEC3 Super Gel Mix functions as a stabiliser/thickener.

3.3 Sensory evaluation

Sensory evaluation was conducted in December 2024 at the Széchenyi István University Department of Food Science. Seventy untrained (lay) panellists (students and staff) participated voluntarily. A structured, descriptive scoring sheet was used. Panellists rated each sample for colour, smell, taste, texture (mouthfeel), and overall appearance/overall impression on a 5-point scale (1 = very poor / dislike very much; 5 = excellent / like very much). After scoring, participants answered an open-ended question to guess the main raw materials (vegetables/fruits) perceived in the product, to capture ingredient recognisability. Samples were served in transparent plastic cups at serving temperature under neutral indoor lighting; samples were coded and served in a balanced order where possible (*Figure 1*). Water was provided for palate cleansing between samples.



Figure 1: Products tasted during the organoleptic evaluation (A: Mint-lemon zucchini; B: Orange-carrot; C: Dark chocolate-sour cherry beetroot)

Source: own photo

3.4 Texture analysis

Texture analysis was performed using an FRTS Texture Analyzer (IMADA, Inc., Northbrook, USA) to follow softening during controlled melting. Ice cream was portioned into 50 mL measuring cups. Measurements were carried out at 20 ± 2 °C. Immediately after removal from frozen storage (-18 °C), samples were placed in the instrument and tested at 15-min intervals over time (eight time points per product; three replicates).

An ice cream puncture test was used, in which a needle probe penetrated the sample and the instrument recorded force (N) and penetration depth (mm). Hardness was defined as the peak force during puncture; penetration depth was reported as the achieved depth within the 15 mm travel limit under the test settings.

Instrument settings were: penetration speed 1.0 mm/s, return speed 5.0 mm/s, maximum displacement 15.0 mm, single test cycle; the target maximum force limit was 50 N.

3.5 Melting test

To assess melting behaviour (drip loss), three 50 g portions were weighed from each ice cream (three replicates) and placed separately into stainless-steel filters positioned above pre-weighed beakers. The test was performed at 20 ± 2 °C for 90 min; drip loss was recorded every 15 min by weighing the beakers and calculating the cumulative melted mass. Melting rate (g/min) and melting curves were derived from these data.

3.6 Statistical and visualisation methods

Statistical evaluation of the survey data was performed. This used F- and two-sample T-tests. The significance level was set at 95 %. Data processing and basic statistical analyses (calculation of means, standard deviations, and graphical representations) were performed using Microsoft Excel spreadsheet software.



4. RESULTS

4.1 Questionnaire survey

4.1.1 Demographic characteristics of the sample

A total of 295 responses to the questionnaire were assessable. The vast majority of respondents were women (84 %; 247 respondents), while men accounted for 16 % (48 respondents) (Table 2). This proportion is consistent with the observation that women tend to be more interested in health-conscious and innovative food products.

Table 2. Demographic data

Description	Frequency (persons)	Distribution (%)
By gender (n = 295)		
Female	247	84
Male	48	16
Age/year (n = 295)		
under 19	17	6
20-29	145	49
30-39	37	13
40-49	45	15
50-59	34	12
60-69	11	4
70-79	6	2
up to 80	0	0
Place of residence (n = 295)		
County seat, county-level city	75	26
City	93	32
Municipality	82	28
Capital city	45	15
School education (n = 295)		
Elementary school	16	5
Secondary school without a high school diploma, with a vocational certificate	18	6
Secondary school graduation	74	24
Secondary vocational qualification based on secondary school leaving examination	31	10
Higher vocational qualification	11	4
College (BA/BSc)	103	35
University (MA/MSc)	33	11
Doctoral degree	9	3

The largest age group was 20-29 years (49 %), followed by 40-49 years (15 %), 30-39 years (13 %), and 50-59 years (12 %). The number of responses received from participants in the 60+ age group was minimal, and this was further compounded by the scarcity of responses from the 70+ age group. The present sample is predominantly composed of young and middle-aged adults, rendering it well-suited to the investigation of openness to new, functional products.

With regard to the geographical distribution of the sample, the majority of respondents resided in urban areas (32 %) or municipalities (28 %), while 26 % lived in a county town or city with



county rights, and 15 % resided in the capital. The results of the study indicate the presence of potential consumers of vegetable-based ice cream in all types of municipalities.

The data indicate that almost half of the respondents (48 %) had a tertiary-level education, while a further 40 % had completed secondary education. The proportion of the population with a primary education was 5 %. The sample reflects a population with higher levels of education than average, which may be associated with greater receptiveness to health-conscious thinking and novel food innovations.

4.1.2 Habits and taste preferences relating to ice cream consumption

With regard to seasonality, 74 % of respondents primarily consume ice cream from May to October, while 26 % purchase it regularly throughout the year. About frequency of consumption, 47 % of respondents consume ice cream several times a week or daily, while 53 % consume it monthly or less frequently (*Figure 2*). While the data confirm the classic seasonal increase in ice cream consumption in summer, they also indicate stable demand throughout the year.

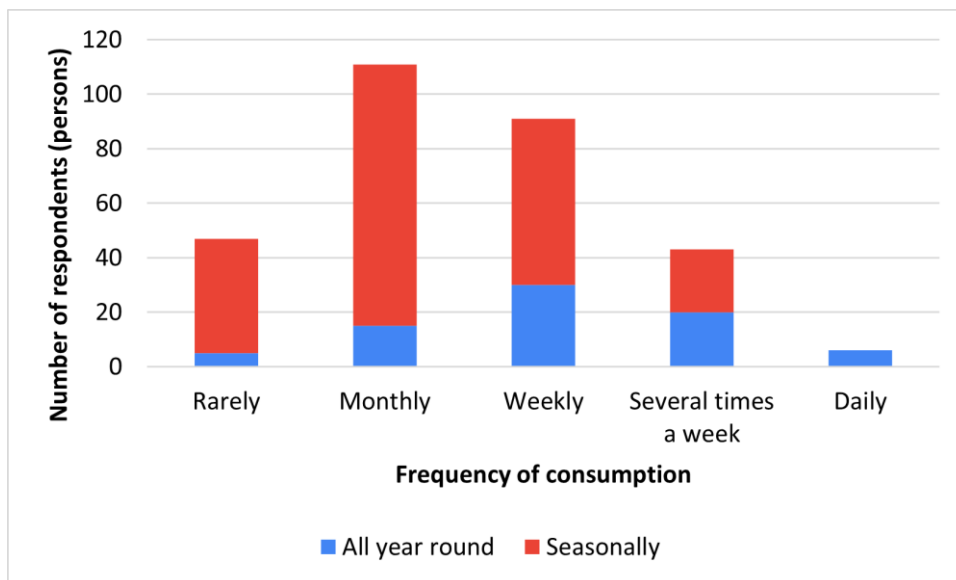


Figure 2: Ice cream consumption by seasonality and frequency (n = 295)

Concerning the preferences of respondents in relation to ice cream, the traditional dairy-based variety was the most popular (168 responses), followed by the fruit-based option (160 responses). Vegetable-based ice creams received only two responses, while sugar-free and dairy-free ice creams received 33 mentions each. This finding indicates that, despite the existence of a demand for alternative ice creams, conventional products continue to dominate the market.

Figure 3 demonstrates that vanilla and chocolate are the most popular traditional flavours, with 55 % of respondents expressing a preference for vanilla and almost 70 % for chocolate-flavoured ice cream. Lemon and orange were less popular, with respondents exhibiting more divergent preferences. The 'other fruit' category was the preferred choice of 74 % of respondents, thereby confirming the widespread popularity of fruit-based ice creams.

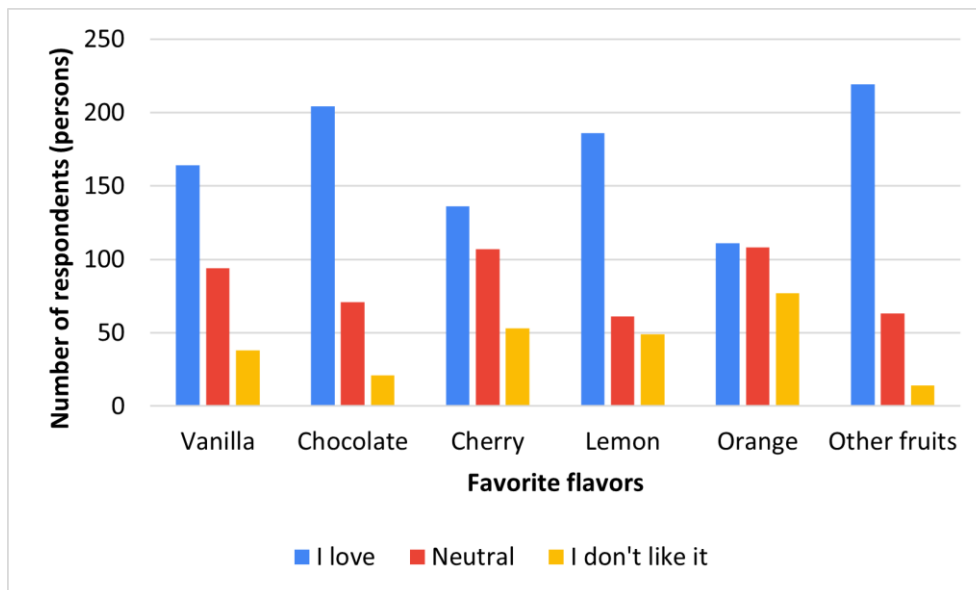


Figure 3: Popularity of ice cream flavors among respondents (n = 295)

4.1.3 Consumption of vegetables and attitudes towards vegetable-based ice creams

As demonstrated by the statistics available for consideration, the consumption of vegetables by the Hungarian population is below the recommended levels. The 2019 data from the Hungarian Central Statistical Office shows that the annual per capita consumption of vegetables is 53.5 kg, which equates to approximately 146 g per day. This is approximately 29 % of the recommended 500 g per day. In line with this, food innovations aimed at increasing vegetable consumption are of particular importance.

Of the vegetables surveyed, carrots and cucumbers proved to be the most popular, with 77 % and 79 % of respondents, respectively, strongly preferring them and only 2 % and 5 % rejecting them, respectively. The results of the survey indicate that 66 % of respondents expressed a positive preference for zucchini, while 22 % consumed it but did not regard it as a preferred choice. Conversely, 12 % of respondents indicated a dislike for zucchini. The perception of beets and pumpkin is more favourable than is generally assumed: The results of the survey indicate that 59 % of respondents expressed a positive preference for beetroot, while 54% indicated a preference for pumpkin. Conversely, 30 % of respondents expressed a dislike for pumpkin. The public's perception of pumpkin is polarised, with 34 % expressing a positive sentiment and 35 % expressing a negative sentiment. The results of the study suggest that several vegetables that could potentially be used for the development of ice creams (in particular carrots, cucumbers and zucchinis) already have an inherently favourable consumer attitude.

However, the awareness of vegetable-based ice creams remains limited, with 78 % of respondents reporting no familiarity with such products and only 22 % having encountered them. Nevertheless, the survey results indicate that 89 % of respondents expressed a willingness to sample vegetable-based ice creams: The data indicates that 46 % of respondents are categorically open to the suggestion, while 43 % are conditionally open. The type of vegetable used was identified as a significant factor in this regard. A mere 5% of respondents expressed a preference for the alternative option, while a further 5 % remained undecided. Consumer attitudes are, in general, favourable towards this practice, although these attitudes are highly dependent on the ingredient image employed.



The question regarding specific flavour combinations (*Figure 4*) indicates that the combinations of carrot and mango, and beetroot juice and forest fruits, are the most promising, with 63 % of respondents expressing a preference for the former and 55 % for the latter. Furthermore, a significant proportion of the population expressed a strong predilection for orange carrot ice cream, with 55 % of respondents indicating a definite openness to the flavour, and 29 % expressing a willingness to consider its consumption. The results of the survey indicate that 43 % of respondents expressed a desire to sample mint-lemon zucchini ice cream, while 26 % remained undecided and 31 % expressed reluctance. An even more pronounced reluctance to try chocolate zucchini ice cream was observed, with 31 % of respondents indicating acceptance, 33 % undecided, and 36 % reluctant. The combination of chocolate beetroot ice cream and cinnamon-coffee pumpkin ice cream proved to be a divisive one. The products developed (orange carrot, mint-lemon zucchini, dark chocolate beetroot) were selected on the basis of practical considerations (availability of ingredients, ease of production) as well as consumer preferences.

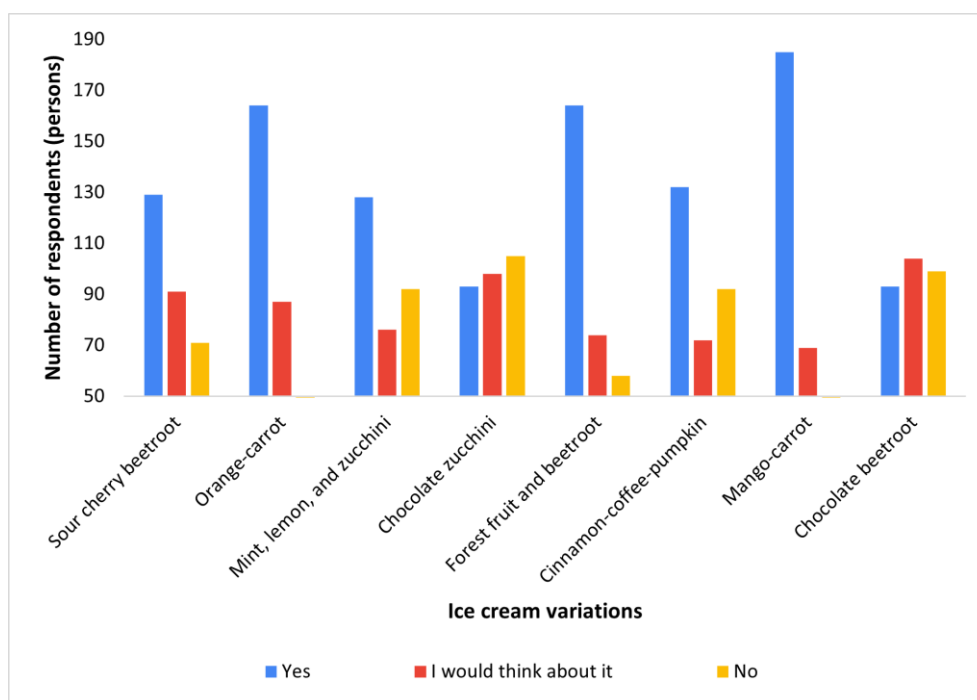


Figure 4: Consumer willingness to try different ice cream flavours (n = 295)

4.1.4 Awareness and perception of inulin

The study revealed a lack of awareness regarding inulin among the study population, with 69 % of respondents expressing a lack of awareness, 28 % indicating awareness but no utilisation, and a mere 3 % reporting both awareness and regular usage.

In the question regarding the properties of inulin, the following statements were identified as accurate: the presence of a sweet taste, the capacity to facilitate digestion, the alleviation of constipation, and the potential for bloating (*Figure 5*). In the survey, 78 % of respondents who used inulin provided at least one correct answer, while 76 % of those who were not familiar with inulin provided only incorrect statements. For example, one statement was, "The group who know but do not use inulin is in an intermediate position: 64 % of respondents who were aware of inulin but did not use it provided correct answers, while 36 % provided incorrect answers.

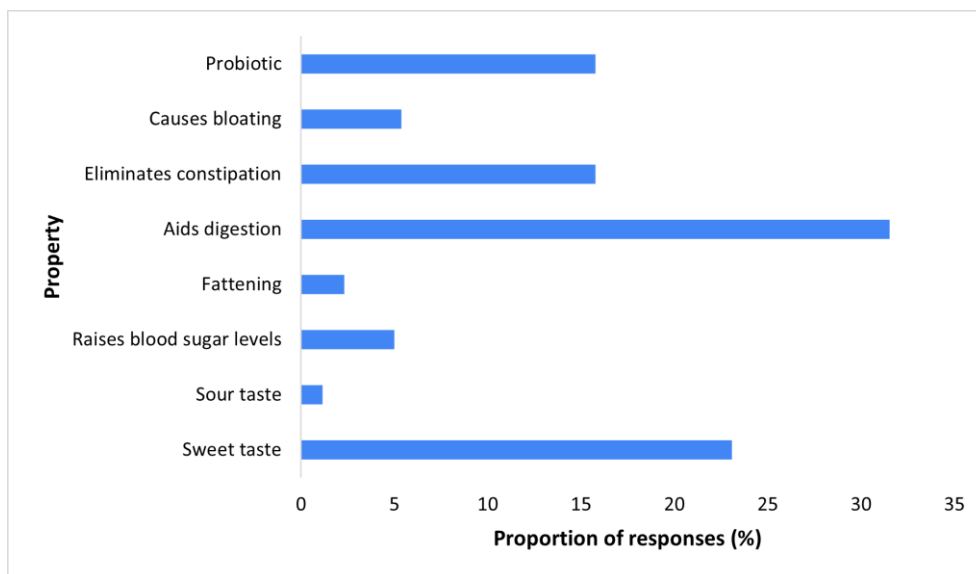


Figure 5: Distribution of responses regarding the properties of inulin (n = 260)

In response to the query regarding the sources of inulin, Jerusalem artichokes, chicory, and onions were identified as the correct responses. However, it is noteworthy that a relatively small proportion of respondents selected these options, with only 50, 3, and 4 respondents, respectively, opting for them. Consumers have limited awareness of inulin, both in terms of its functional properties and its natural sources. This represents a significant opportunity for communication and education in the development of products containing this ingredient.

The results of the study indicate that inulin is generally an 'invisible' functional ingredient in the sample under study: most consumers lack sufficient knowledge of it, yet do not associate it with a particularly negative image. This situation may provide a favourable starting point for communication strategies that link inulin to the 'natural fibre' message, emphasising both its physiological benefits (e.g., aiding digestion, increasing fibre intake) and its sensory benefits (creamier texture, pleasant, sweet sensation).

The responses indicate that the assessment of functional ingredients is predominantly information-driven. Participants with prior knowledge of inulin exhibited a higher propensity to select correct statements, while insufficient knowledge frequently resulted in erroneous categorisation. For instance, one participant stated, "This suggests that consumer education, in the form of straightforward, easily comprehensible messages on labels and online, can be a pivotal component for successful product positioning when launching vegetable-based inulin-enriched ice cream."

4.2 Sensory evaluation

The sensory test was completed by 70 participants (60 % of whom were female and 40 % of whom were male), with an average age of 24.3 years. The demographic composition of the sample was dominated by participants in the 19-30 age group, with a proportion of 84 %. This observation is indicative of the fact that the results obtained primarily reflect the consumer perception of young adults.

The results of the five-point rating scale are summarised in *Table 3*. The highest and lowest scores were attributed to dark chocolate and beetroot ice cream, respectively. In terms of aroma and flavour, however, the mint-lemon zucchini ice cream scored the highest, while the other



two samples scored lower. The texture scores exhibited minimal variation among the three products, indicating comparable properties.

Table 3: Overall results of sensory evaluation

Name of ice cream	Sensory characteristics score (average / mode)				
	Colour	Smell	Taste	Texture	Overall impression
Mint-lemon zucchini	3.83 / 4	4.04 / 5	4.56 / 5	4.59 / 5	4.39 / 5
Orange carrots	4.53 / 5	3.41 / 4	3.31 / 4	4.46 / 5	3.74 / 4
Dark chocolate-sour cherry beetroot	4.76 / 5	3.37 / 3	3.10 / 3	4.50 / 5	3.71 / 3

The colour of the mint-lemon zucchini ice cream was subject to a lower level of approval than that of the orange-carrot and dark chocolate-sour cherry beetroot ice creams. In contrast, the mint-lemon zucchini variant demonstrated superior performance in terms of aroma and flavour compared to the other two products. However, no significant differences were observed between the orange carrot and dark chocolate-sour cherry beetroot ice cream in these attributes.

The overrun values for the vegetable-based ice creams produced during the product development process were as follows: the mint-lemon zucchini ice cream had an overrun value of 25.7 %, the orange carrot had an overrun value of 8.7 %, and the dark chocolate-sour cherry beetroot had an overrun value of 17.4 %. In consideration of the results obtained, it can be concluded that the ice creams were of a high density and low air content. No statistically significant differences were observed in the texture scores.

The mint-lemon zucchini ice cream sample obtained the highest overall score, while the remaining two samples obtained similar but lower overall scores.

The responses to the open-ended questions provide a valuable complement to the quantitative results. In the case of the mint-lemon zucchini ice cream, the tart flavour was noted by several reviewers as being refreshing, while the colour and texture were considered misleading or less homogeneous by some reviewers. Furthermore, the intensity of the sweet flavour was criticised by some. The orange carrot ice cream was judged by the majority of tasters to be a harmonious and interesting combination, with a clearly identifiable carrot flavour, although the intensity of the aroma was considered low by some. In the case of the dark chocolate-sour cherry beetroot ice cream, the chocolate flavour and texture were generally favourable, although the dominant taste of beetroot was mentioned by several reviewers, while the presence of sour cherries was less clear.

The sensory analysis revealed that the incorporation of the vegetable did not necessarily result in a decline in enjoyment; the mint-lemon zucchini ice cream was comparable to, and in some cases superior to, the other two products tested in terms of overall taste. This suggests that, when selected with care and combined in a harmonious manner (for example, a refreshing citrus-mint profile), the vegetable element can be perceived as an enhancement rather than a concession.

The lower score for colour, however, highlights the potential tension between consumers' visual expectations and the objectives of health-conscious product development. An 'unconventional' ice cream colour (e.g., pale green, yellowish-green) may initially appear unappealing or out of place, despite a positive taste profile. This finding indicates that for vegetable-based ice creams, colour design (e.g., natural colour enhancement, visually appealing decoration) and targeted communication ("green colour = more vegetables") can be important tools to increase consumer acceptance.

The variances observed among the various designs indicate that consumer acceptance is not solely contingent on the vegetable itself but is also influenced by its "culinary context". The combination of carrots with citrus flavours is a more familiar and well-accepted practice in the context of domestic culinary traditions. Conversely, the pairing of beetroot with chocolate or zucchini in the form of ice cream represents a more novel concept, necessitating a higher level of innovative acceptance.

4.3 Texture analysis

The outcomes of the texture (firmness) test demonstrated that, for all products, there was a decrease in firmness with time, whilst there was an increase in penetration depth (*Figure 6*). As demonstrated in *Figure 1*, the probe achieved maximum penetration depth (15 mm) after 30 minutes for the orange carrot ice cream sample. For the dark chocolate-sour cherry beetroot ice cream sample, this was achieved after 45 minutes, and for the mint-lemon zucchini ice cream sample, it was reached after 60 minutes. Consequently, the orange carrot ice cream experienced a more rapid loss of structural firmness, while the dark chocolate-sour cherry beetroot ice cream sample, after 45 minutes, and the mint-lemon zucchini ice cream demonstrated a prolonged retention of their firmer consistency.

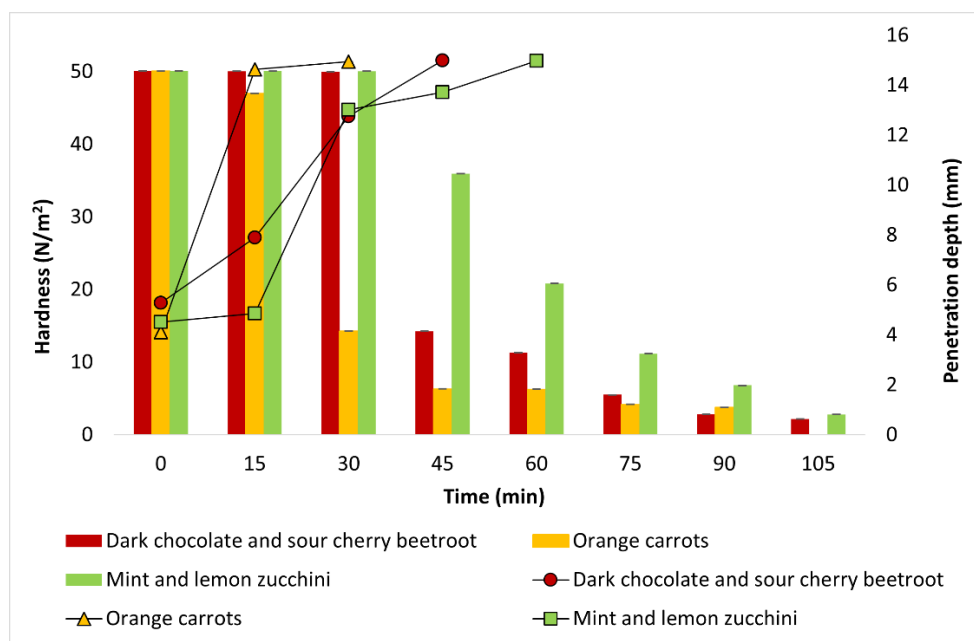


Figure 6: Changes over time in the textural parameters of vegetable-based ice creams



The slopes of the fitted lines for the change in hardness and penetration depth over time are summarised in *Table 6*. The negative slope values indicate the rate of decrease in hardness over time, while the positive slope values express the rate of increase in penetration depth. A statistically significant ($p < 0.05$) variation was observed in both hardness and penetration depth among the three products.

Table 6: Changes in hardness ($N \pm SD$) and penetration depth ($mm \pm SD$) over time

Name of ice cream	Parameter	
	Hardness (N)	Penetration depth (mm)
Dark chocolate- sour cherry beetroot	-0.562 ± 0.003^a	0.222 ± 0.003^a
Orange carrots	-0.471 ± 0.001^b	0.361 ± 0.002^b
Zucchini with lemon and mint	-0.538 ± 0.003^c	0.202 ± 0.003^c

^{abc} Different letters within a column indicate a significant ($p < 0.05$) difference.

The findings of the study indicated that the orange carrot ice cream structure was the least stable, while the mint-lemon zucchini and dark chocolate-sour cherry beetroot ice cream structures demonstrated slower decomposition rates under the test conditions.

The findings from the mechanical tests are consistent with the sensory evaluation, indicating that distinct combinations of vegetable, fruit, and inulin result in varied structural stability. The accelerated structural degradation of the orange carrot ice cream is likely associated with its elevated water content and the comparatively weaker inter-phase network bonding. Conversely, the enhanced dry matter and fibre content, in addition to the presence of cocoa/chocolate components, in dark chocolate-sour cherry beetroot ice creams may have facilitated the maintenance of a more stable structure.

From a technological standpoint, it is imperative to observe that the structural evolution over time and the rate of decrease in hardness exhibited congruence with the outcomes of the melting test. The specimen that exhibited the most rapid 'loosening' also demonstrated the swiftest melting, a factor that is pertinent to practical applications, such as serving time and the anticipated consistency at the time of consumption. The optimization of the texture must incorporate not only sensory parameters but also rheological and melting parameters.

4.4 Melting rate

In the melting test, the orange carrot ice cream was completely melted by the 75th minute, while the mint-lemon zucchini and dark chocolate-sour cherry beetroot ice cream melted by the 90th minute (*Figure 7*). It is noteworthy that the beet ice cream did not fully melt after 90 minutes, with more than half of the sample remaining on the filter and failing to drip off afterwards.

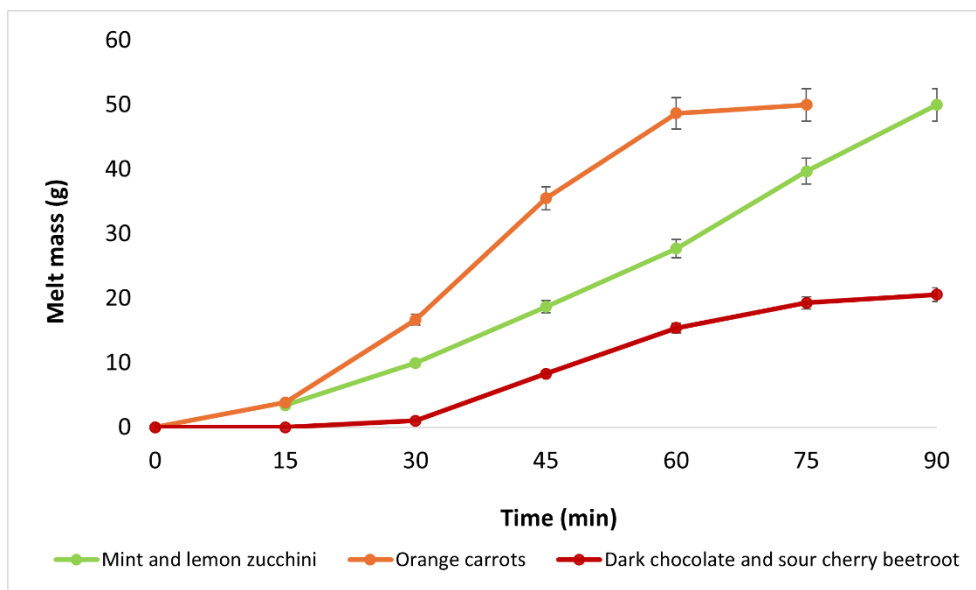


Figure 7: Examination of drip loss in vegetable-based ice creams at 20 ± 2 °C

The mean rate of melting was 0.67 g/min for orange carrot ice cream, 0.55 g/min for mint-lemon zucchini ice cream, and 0.23 g/min for dark chocolate-sour cherry beetroot ice cream. In all cases, the results of the paired comparisons indicated a significant difference ($p < 0.05$) between the melting rates of the three products.

The results demonstrated that orange carrot ice cream exhibited the most rapid melting dynamics, while dark chocolate-sour cherry beetroot ice cream demonstrated the greatest stability in terms of melting resistance. This finding aligns with the observations made in the herd study, suggesting that diverse combinations of vegetables, fruits, and inulin result in varied profiles, manifesting not only in sensory characteristics but also in physico-technological properties.

As demonstrated by the melting profiles, the three ice creams exhibited distinctly divergent technological behaviours. In practice, the rapid melting of orange carrot ice cream results in a reduced time window for aesthetic presentation, thereby increasing the likelihood of consumers encountering a product that has already begun to melt slightly. Conversely, the slower thawing of beet and zucchini varieties is indicative of enhanced heat stability, a trait that may prove particularly advantageous in hotter environments or for extended serving chains, such as in buffet settings or event contexts.

The partially solid phase that remains on the filter after 90 minutes in the case of beetroot pulp indicates that the sample does not melt homogeneously but forms a denser, gel-like residue. This phenomenon can be explained by the higher fibre and dry matter content on the one hand and by the interaction between the chocolate and the vegetable component on the other. In the subsequent phase of product development, it may be advantageous to identify a compromise through the refinement of the recipe (e.g., by adjusting the proportions of inulin, fat, or emulsifiers) to ensure both adequate serveability and a positive sensory experience.

The above results served as the basis for the integrated assessment and further interpretation presented in the Discussion section.



5. DISCUSSION

5.1 Integrated assessment of results

Taken together, the questionnaire data, sensory ratings, and instrumental measurements of texture and melting behaviour suggest that vegetable-based, inulin-enriched ice creams have realistic market potential, particularly among young, health-conscious consumer groups. A substantial proportion of respondents (89 %) expressed a willingness to sample vegetable-based ice creams, while only 22 % were familiar with such products. This indicates that the main barrier to market expansion is not consumer rejection but limited awareness and availability. Among the proposed flavours, mango–carrot ice cream was the most attractive (63 % preference), confirming that carrot fits well into fruit-forward ice cream concepts. The demographic profile of the sample further suggests that young women (20-29 years) may constitute a key target segment, as they showed high openness to innovative, health-oriented products.

In a broader context, the incorporation of vegetable-derived ingredients into dairy matrices is an area of increasing exploration with a view to enhancing nutritional or functional value. However, the success of the product is dependent on achieving a balance between added bioactive components, sensory acceptance and textural stability (El-Sayed et al., 2025). In related frozen dessert applications, beetroot-based formulations have demonstrated that solids composition and acid-sweetness balance can materially affect colour, melting behaviour, and consumer preference, thereby supporting the importance of formulation-driven optimisation when using pigmented vegetable raw materials (Putradamni & Pramitasari, 2024).

The findings related to inulin point to an information-driven pattern of knowledge. Respondents who had already used inulin demonstrated a clearer understanding of its properties, whereas miscategorisation was more common among those unfamiliar with it. This underlines the importance of targeted consumer education in communicating the functional value of inulin-enriched vegetable-based ice creams (MDOSZ, 2021; Vijayalakshmi & Vijayavahini, 2022). The sensory evaluation showed that all three developed ice creams were generally well received, with most panellists assigning positive ratings. The mint–lemon zucchini ice cream emerged as the most preferred variant, with approximately 75 % of the judges favouring it based on taste, texture, smell, colour, and overall impression. The mint-lemon zucchini and orange-carrot variants were the most popular in the interviews, while the dark chocolate–sour cherry–beetroot ice cream was sometimes perceived as having an overly dominant beetroot flavour. Nevertheless, the consistency of all products was typically described as creamy and pleasant, reflecting the success of the product development process.

From a technological perspective, the overrun values indicated relatively dense products with low air incorporation (25.7 % for mint–lemon zucchini, 8.7 % for orange-carrot and 17.4 % for dark chocolate–sour cherry beetroot). In light of the literature, which associates higher overrun with lighter, airier textures (Voronin et al., 2021), the developed products can be positioned as ice creams with a more “dense”, rustic texture. The particularly low overrun of the orange–carrot variant is consistent with the composition of the carrot and orange juices, while dark chocolate and sour cherry likely contributed to the thicker texture of the beetroot sample.

Texture measurements revealed a decrease in firmness over time, with the dark chocolate–sour cherry beetroot and orange–carrot ice creams softening more rapidly than the mint–lemon zucchini variant, which retained its firmness for longer. This time-dependent change in consistency has direct implications for serveability and mouthfeel. The melting behaviour was strongly influenced



by the fibre and water content of the vegetable components. The low fibre content of zucchini (0.8-2.4 g/100 g; Rödler, 2005) resulted in moderate melting, whereas the higher fibre content of beetroot juice (1.2 g/100 ml) likely explains the incomplete melting and fibre residue on the filter (Ceclu & Nistor, 2020; Rödler, 2005). In contrast, the very low fibre content of carrot juice (0.1 g/100 ml) is consistent with the faster melting of the orange–carrot ice cream and reduced water retention. These observations align with previous findings that vegetable fibres substantially influence the texture and melting properties of frozen desserts (Ceclu & Nistor, 2020; Voronin et al., 2021).

5.2 Limitations of the study

However, it is imperative to acknowledge the study's limitations when interpreting the results. The questionnaire survey was not based on random sampling, but rather utilised a convenience sample in which younger female respondents were over-represented. Consequently, the results cannot be considered representative of the population as a whole. The perceptual survey was conducted with a relatively limited number of mostly lay raters at a single location, so the generalisability of the perceptual results is also limited. The product development was constrained to three vegetable species (zucchini, carrot, beetroot) and specific recipe variations; consequently, the conclusions cannot be extrapolated to all vegetable-based ice cream concepts. The physical measurements (stock, melting behaviour) were made for a specific storage period; the effect of longer-term storage or possible technological variations (different dry matter, fat content, or fibre type) was not investigated. Furthermore, the utilisation of rudimentary statistical tests led to the exploratory investigation of relationships, which necessitates the execution of additional, more intricate statistical analyses encompassing a more substantial number of cases.

6. CONCLUSIONS

89 % of respondents expressed a desire to sample vegetable-based ice creams, while only 22 % had previously encountered them; this suggests a considerable propensity to trial them, coupled with a paucity of awareness. The primary target group for this study is women aged 20-29, characterised by high levels of openness.

The consumer screening and sensory judgement results indicated that the mint-lemon zucchini sample was the most preferred option, with an approximate overall impression of 75 %. In contrast, the mango carrot sample demonstrated a higher level of prior interest, with 63 % of respondents expressing a preference. The flavour profile, characterised by the simultaneous presence of chocolate, sour cherry, and beetroot, requires refinement to mitigate the predominance of the latter.

The fibre and dry matter content of the beetroot sample was found to be associated with a slower rate of melting and greater structural stability. In contrast, the low-fibre variants of the carrot sample were found to soften and melt more rapidly. The overrun values (25.7 %, 8.7 %, 17.4 %) indicate a denser, less airy character of the prototypes. It can be posited that the desired mouthfeel can be achieved by targeted tuning of dry matter/fibre/liquid and emulsifier/stabiliser ratios.

The combination of vegetables and pleasure does not constitute a compromise; rather, it is an exciting dessert. Inulin, a natural dietary fibre, has been shown to contribute to fibre intake. The integration of sensory experiences, such as sampling pastries and organizing events, has been identified as a pivotal strategy to enhance acceptance. The explicit communication of the symbolic



significance of colours, with green signifying a greater emphasis on vegetables, has been shown to mitigate visual resistance.

Potential avenues for future research include: A comparison of more representative samples and a control (classic lemon/chocolate) was conducted, in addition to detailed rheological and microstructural studies. Monitoring of frozen storage stability, as well as nutrient profile and consumer intervention tests (satiety, acceptance after repeated consumption) was also undertaken.

A növényi alapú, inulinnal dúsított jégkrémek fogyasztói elfogadottsága, érzékszervi minősége és technológiai-funkcionális viselkedése

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ÖSSZEFOGLALÁS

A vizsgálat célja zöldségalapú, inulinnal dúsított fagyaltok fejlesztése és fogyasztói/technológiai értékelése volt. Kvantitatív kérdőíves felmérést végeztünk (n = 295), majd három receptúrát (mentás–citromos cukkini; narancsos sárgarépa; étcsokoládés–meggyes cékla) érzékszervileg teszteltünk (n = 70), továbbá állomány- és olvadásvizsgálatokat folytattunk. A válaszadók 89 %-a megkóstolná a zöldségfagyaltokat, ugyanakkor csupán 22 % hallott róluk; a legígéretesebb előzetes ízvariáns a mangós sárgarépa (63 %). Az érzékszervi bírálatban a mentás–citromos cukkini adta a legkedvezőbb összbenyomást (~75 % preferencia). Az overrun értékek 8,7-25,7 % között mozogtak, a prototípusok inkább sűrű, kevésbé levegős profilját jelezve. Az olvadási viselkedést a rost- és szárazanyag-tartalom határozta meg: a céklás minta lassabban olvadt és részben gél-szerű maradékot adott, míg a sárgarépás gyorsabban olvadt; a cukkini köztes profilt mutatott. Következtetésünk szerint a zöldségfagyaltok reális piaci alternatívát jelenthetnek – különöse a 20-29 éves nők körében –, ám a bevezetés kulcsa a kóstoltatás és a célzott edukáció (inulin mint természetes élelmi rost). Technológiailag a kívánt szájéretet a szárazanyag/rost/zsírfázis és az emulgeátor–stabilizátor arány hangolásával optimalizálható.

Kulcsszavak zöldségalapú fagyalt; inulin; fogyasztói elfogadás; érzékszervi bírálat; állományvizsgálat; olvadási viselkedés; overrun; funkcionális élelmiszerek



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