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Development of functional foods: Consumer acceptance of resveratrol-loaded crackers and cookies

Pedro M. Silva[a,b,c,*], Miguel A. Cerqueira[c], Lorenzo Pastrana[c], Manuel A. Coimbra[d], Antonio A. Vicente[a,b], Filip Van Bockstaele[e], Daylan Tzompa-Sosa[e], Koen Dewettinck[e]

[a] Centre of Biological Engineering (CEB), Campus de Gualtar, University of Minho, 4710-057 Braga, Portugal
[b] Associate Laboratory (LABBELS), Braga, Guimarães, Portugal
[c] International Iberian Nanotechnology Laboratory, Av. Mestre José Veiga, 4715-330 Braga, Portugal
[d] LAQV/REQUIMTE, Department of Chemistry, University of Aveiro, 3810-193 Aveiro, Portugal
[e] Food Structure and Function (FS&F) Research Group, Department of Food Technology, Safety and Health, Faculty of Bioscience Engineering, Ghent University, Ghent, Belgium

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ABSTRACT

Micro-nano encapsulation can be impactful in flavour masking of bioactives, and it has the potential to be used in the development of functional food ingredients.

This work aimed to develop functional foods using emulsified resveratrol, assessing the impact of resveratrol addition and its consumer acceptance. Resveratrol-loaded emulsions were produced through high-speed homogenization/ultrasonication. Functional snacks (crackers and cookies) loading 4 mg resveratrol/g were developed using resveratrol-loaded emulsions and free resveratrol. Results showed that the incorporation of emulsified resveratrol in the dough led to an increase in its elasticity and a decrease in its consistency. Slight color differences were noticed between non-encapsulated resveratrol and reference samples. The texture of baked crackers and cookies showed a decrease in hardness for the emulsified cookies and an increase in the crackers.

Sensory analysis was conducted with over one-hundred volunteers. For both products, the reference sample was the highest-rated sample in overall liking, followed by the emulsion-loaded sample and the unencapsulated resveratrol-loaded sample. Unencapsulated resveratrol-loaded and emulsion-loaded samples displayed an increase in bitterness when compared to the reference. The sensory analysis revealed a slight positive impact of the encapsulation of resveratrol versus the unencapsulated resveratrol. Nonetheless, further progress needs to be achieved to reduce resveratrol's impact.

1. Introduction

Functional foods have been of rising interest recently and are projected to continue attracting consumer demand, as consumers search for healthier eating habits to combat the shortcomings of a modern lifestyle. Consumers are searching for products that are reduced in fat, sugar, and salt and additionally are interested in products that can add health benefits to their lives, usually through the prevention of nutrition-related diseases or by combating the stresses of a modern lifestyle (Chávarri and Villarán, 2017; Hosseini et al., 2021; Temelli, 2018).

While the value of the global specialty food ingredients market varies according to the source (from 120 to 140 billion US dollars), all seem to agree that it is rising at a compound annual growth rate (CAGR) of around 6 % over this decade (Grand View Research, 2022; Markets and Markets, 2022; The Business Research Company, 2022).

Some specialty food ingredients such as loaded encapsulation systems can provide additional health benefits through an improved nutritional profile (e.g., adding vitamins, bioactive compounds, or reducing fat) while maintaining the typical properties of a food product. (e.g., texture, stability, color). These ingredients are then used to develop functional foods, which can be defined as foods that are demonstrated to potentially aid health by adding health benefits or decreasing disease risk (Chávarri and Villarán, 2017; Pund et al., 2021).

One of the bioactives that can add value to a food product is

* Corresponding author.
E-mail address: pedro.m.silva@inl.int (P.M. Silva).

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resveratrol, a polyphenol. Like other polyphenols, it possesses several potential health-promoting benefit properties, namely antioxidant, antimicrobial, antidiabetic, weight loss, anticarcinogenic, and anti-inflammatory (Cai et al., 2020; Davoodvandi et al., 2020; Shabani et al., 2020; Torregrosa-Muñumer et al., 2021; K. Wang et al., 2020; P. Wang et al., 2020; Zhou et al., 2021). It can be found naturally in different dietary sources in the range of a few ng/g to a few µg/g (e.g., berries and grapes) (Baur and Sinclair, 2006), but presents several limitations as a functional food ingredient, given its low bioavailability, low aqueous solubility, chemical instability, and vulnerability to degradation, as well as the typical bitterness associated with polyphenols (Chávarri and Villarán, 2017; Fiod Riccio et al., 2020; Lesschaeve and Noble, 2005; Walle, 2011).

Encapsulation is a convenient process to improve some of these drawbacks. Oil-in-water emulsification processes provide a straightforward dispersion of resveratrol in the oil phase while allowing for a simple dispersion process of the developed emulsion (Hosseini et al., 2021; Marques et al., 2019), thus improving one of the major barriers to the use of resveratrol in the food industry. Resveratrol dosage can vary depending upon the application and health benefit of interest (Mukherjee et al., 2010; P.M. Silva et al., 2023). In clinical studies, resveratrol has been studied for human consumption ranging from 100 mg to 1000 mg per day (ClinicalTrials.gov, 2018, 2020, 2021) with positive results regarding potential health benefits.

As such, this study aimed to develop functional bakery products, namely crackers and cookies, given that they are highly consumed snacks that can be either salty or sweet. So far, few authors have explored the use of encapsulated resveratrol for the development of functional foods and conducted a sensory analysis on its acceptance, especially at explored beneficial dosages of resveratrol. We determine the effect of resveratrol on the organoleptic properties of bakery products, with two different flavor profiles, namely salt crackers and butter cookies where resveratrol was added either encapsulated or unencapsulated. The sensory profiling and product acceptance tests, and instrumental data of texture, rheological, and color properties were evaluated.

The effect of resveratrol addition and encapsulation on the sensorial properties of cookies and crackers was assessed via sensory analysis, and product acceptance was evaluated. A rate-all-that-apply (RATA) methodology was used to evaluate the acceptance of untrained assessors, i.e., consumers, towards the developed resveratrol-loaded products. Furthermore, the effect of the flavor profile of the food matrix (salty or sweet) on product acceptance was also assessed.

2. Materials and methods

2.1. Materials

Resveratrol (trans-resveratrol, 99 %, extracted from Japanese knotweed) was purchased from Bulk (Mirków, Poland); refined sunflower oil (100 % sunflower, Sovena, Portugal) used as the oil phase (10 % saturated lipids, 42 % monounsaturated lipids and 39 % of polyunsaturated lipids) was purchased at a local supermarket in Portugal; sodium octenyl succinic anhydride modified starch (OSA-MS) (C*EmCap 12635) was purchased from Cargill (Iowa, United States); distilled water, and ultrapure water type 1, generated by a Milli-Q system (Advantage A10, Darmstadt, Germany). Bakery ingredients (wheat flour (11 % protein), patisserie flour (9.3 % protein), yeast, sunflower oil, salt, and sugar) were purchased at local supermarkets in Ghent, Belgium.

2.2. Emulsion production

The OSA-MS emulsions were prepared according to the methodology referred elsewhere (Espinosa-Sandoval et al., 2021; P.M. Silva et al., 2024). A detailed protocol and characterization can be found in Supplementary Material. Emulsions were freeze-dried after production as described in P.M. Silva et al. (2024) and in the Supplementary Material.

2.3. Bakery products

Three formulations were tested for crackers and cookies, a control reference bakery product, a bakery product loaded with unencapsulated resveratrol, and a bakery product loaded with encapsulated resveratrol, hereby referred to as reference, resveratrol-loaded, and emulsion-loaded, respectively.

Resveratrol and emulsion were mixed with the flour to prepare the functional bakery products. The freeze-dried emulsion was converted into powder form and added to the bakery products instead of flour, thus partially reducing the flour content (info regarding the freeze drying of emulsions can be found in the Supplementary Material) and the rest of the preparation was the same as the reference bakery products. Flour content was partially replaced by unencapsulated resveratrol and emulsified resveratrol. Unencapsulated resveratrol was added at 0.4 % (w/w) of baked cookie and cracker weight, while the emulsion was added at 3.0 % (w/w) (the equivalent of 0.4 % (w/w) of unencapsulated resveratrol). Estimated product composition is found in Supplementary Material (Table S2).

2.3.1. Crackers

Crackers were prepared using a traditional recipe (Table 1) (Tzompa-Sosa et al., 2021). The yeast was mixed with the water, while the salt, flour, and oil were added together, everything was mixed and kneaded for about 20 min. The resulting dough was left to prove for 30 min at 30 °C in a proving cabinet (Panimatic). After proving, the dough was rolled out to a thickness of 1 mm. After cutting, each cracker was pinched to produce nine holes. A mixture of one tablespoon of oil and three of water was used to brush the crackers. The crackers were then baked for 10 min at 175 °C in a pre-heated oven (MIWE aeromat FB12 (oven type 4.64), Arnstein, Germany). After cooling down to room temperature, the crackers were stored in closed zip lock bags overnight at room temperature (∼15 °C) until further evaluation.

2.3.2. Butter cookies

Butter cookies were prepared using a traditional recipe (Table 1). The butter was quickly hand-mixed with the flour until the outcome looked like breadcrumbs. Sugar was added to the resulting mixture, followed by the addition of egg, and further mixing until a homogeneous dough was formed. The resulting dough was rolled out to a thickness of 5.4 mm using a rolling pin with adjustable rings. The cookies were baked for 10 min at 185 °C in a pre-heated oven [MIWE aeromat FB12 (oven type 4.64), Arnstein, Germany]. After cooling down to room temperature, the cookies were stored in closed zip lock bags overnight at room temperature (∼15 °C) until further evaluation.

2.4. Instrumental analysis

2.4.1. Dough rheology

Creep-recovery measurements were performed on an Anton Paar rheometer (MCR 102, Anton Paar, Graz, Austria), equipped with a cross-hatched parallel plate geometry with a 25 mm diameter. The cracker or cookie doughs were prepared in the mixing chamber of a farinograph (Measuring mixer S 50, Farinograph-E, Brabender, Duisburg, Germany) to ensure a homogeneous and reproducible dough mixture, similar to the preparation method in 2.3.1 and 2.3.2. A small piece was taken from the inside part of the dough and loaded between the parallel plates. After dough compression, the excess edges of the sample were trimmed, water drops were placed around the sample and a solvent trap was placed around the sample and probe to prevent sample drying. After sample loading and resting (10 min), the creep recovery measurements were taken at 250 Pa for 300 s for the creep phase, followed by a recovery phase of 600 s at 0 Pa (Van Bockstaele et al., 2011). Maximum creep strain (MCS), maximum recovery strain (MRS), and recovery percentage

Table 1
Ingredients to produce 100 g of baked cookies and crackers of all samples.

Product	Sample	Oil (g)	Flour (g)	Salt (g)	Yeast (g)	Eggs (g)	Butter (g)	Sugar (g)	Emulsion (g)	Resveratrol (g)	Water (g)
Crackers	Reference	20.1	83.6	1.7	0.7	–	–	–	–	–	30.1
	Resveratrol-loaded	20.1	83.2	1.7	0.7	–	–	–	–	0.4	30.1
	Emulsion-loaded	20.1	80.6	1.7	0.7	–	–	–	3	–	30.1
Cookies	Reference	–	48.0	–	–	4.3	32.1	26.7	–	–	–
	Resveratrol-loaded	–	47.6	–	–	4.3	32.1	26.7	–	0.4	–
	Emulsion-loaded	–	45.0	–	–	4.3	32.1	26.7	3	–	–

were obtained from the creep-recovery measurements. The recovery percentage was calculated as the ratio between MRS and MCS, expressed in percentage. Reported values are the average of three independent replicates, each of them representing a separately made dough.

2.4.2. Texture

Cookie and cracker thickness was measured by stacking six cookies or crackers on top of one another. The mean thickness value (T) of six cookies was obtained by restacking in different orders (Manaf et al., 2019).

The texture of baked crackers and cookies was determined using a texture analyzer (TA.XTplus, Stable Micro Systems, UK). The hardness and fracturability of the crackers and cookies were measured with a three-point bend rig (HDP/3 PB). The adjustable supports of the rig base plate were placed 40 mm apart. The probe blade was lowered at a speed of 3 mm/s for a travel distance of 5 mm, sufficient to break the crackers and cookies. During analysis, the baked crackers or cookies were subjected to a cutting motion, which breaks the product into two pieces (or more in the case of brittle products, such as the crackers).

2.4.3. Color

Crackers and cookies color was measured ($n = 10$) using the CIELAB scale with a spectrophotometer (Konica Minolta spectrophotometer CM700d/600d, Tokyo, Japan) with the specular component excluded. For both products, the color was measured on the center of the surface of the crackers or cookies and was used as one replicate. The visible differences were calculated between the reference crackers or cookies and the resveratrol-loaded or emulsion-loaded samples using the Euclidian distance equation (Mokrzycki and Tatol, 2011).

$$\Delta E_{ab} = \sqrt{\Delta L^{*2} + \Delta a^{*2} \Delta b^{*2}} \tag{1}$$

The evaluated color parameters were L^* for lightness, a^* (negative a^* values indicated to the green while the positive a^* values indicated to the red, and the negative b^* values referred to the blue while the positive b^* values referred to the yellow.

2.5. Resveratrol extraction and quantification

Resveratrol was extracted from the cookies according to Guamán-Balcázar et al. (2016) to quantify the *trans*-resveratrol present at the end of the baking process. Cookie samples were ground with a mortar and weighed (1 g) into sample cups. Then, 39 mL of 90 % methanol (v/v) was added. Ultrasonic homogenization at a frequency of 20 kHz (Branson Digital Sonifier Model 450, Branson Ultrasonics Corporation, USA) was then used to extract the resveratrol using a 13 mm horn diameter probe, at a measured power of 50 W, with an extraction time of 10 min. Samples were weighed before and after extraction to account for solvent evaporation during the extraction procedure, and the evaporated solvent was re-added. Samples were then centrifuged (at 4 °C and 3000 *g* for 30 min) and the clear supernatant was recovered.

Trans-resveratrol quantification was performed by HPLC with diode-array detection (DAD) using an Agilent 1200 series system (Agilent, Waldbronn, Germany) equipped with a Kinetex C18 100 Å, LC Column (150 × 4.6 mm, 2.6 µm, Phenomenex, USA) and a column guard system at 30 °C. The mobile phase was A: 1 M Acetic Acid and B: acetonitrile/1 M Acetic Acid (80:20). The compound was eluted and monitored at 306 nm using the following gradient: 18 % B for 10 min, 18–23 % B in 7 min, 23–31.5 % B in 10 min, 31.5–100 % B in 3 min, and finally 100 % A for 3 min. A 2-minute pastime was added between injections. The flow rate was 1.0 mL/min, and the injection volume was 20 µL. For calculation, the area under the curve (AUC) was used for interpolation in resveratrol (*trans*-resveratrol, 99 %, Bulk, Mirków, Poland) standard calibration curve ($Y = 145093X + 25.612; R^2 = 1$) prepared in methanol in the range 0.001–0.5 mg/mL.

2.6. Experimental design of consumer tests

Consumer sensory testing was designed for both crackers and butter cookies. For both product types, the concentration of resveratrol in the final baked product was the same, 0.4 % (w/w) of resveratrol. The loading amount per snack was selected to ensure that resveratrol can exert its health-promoting properties without the need to consume a high number of snacks, and at the same time to prevent loss of resveratrol due to degradation or bioavailability.

Consumer tests were carried out back-to-back for consumers who evaluated both products, evaluating first the crackers and then the butter cookies, given the higher fat content in the cookies (25.1 %) compared to the crackers (14.3 %) EyeQuestion v. 4.9.4 (Logic8Bv, Netherlands) was used to collect the data. Participants evaluated three formulations for each product, a reference, a resveratrol-loaded, and an emulsion-loaded cookie/cracker, respectively. Between samples and products, apple slices were provided to participants for palate cleansing, in particular regarding bitterness (González et al., 2010; Sokolowsky and Fischer, 2012). Each evaluated sample was randomly coded and presented to the participants. Sample order was randomized for each participant and the samples were evaluated blindly. The participants were aware that the goal of the study was to determine the acceptance and likeness of resveratrol-loaded crackers and cookies and as such they knew and consented to consuming products that might contain resveratrol and data publication.

2.7. Participants

Volunteer participants were recruited at Ghent University, campus Coupure through flyers. The sensory analysis was conducted in the sensory facility of Ghent University, in individual booths with a computer, white light, and temperature control (20 °C). Participants were able to select if they wanted to evaluate crackers, cookies, or both. People who had allergies to wheat were not able to participate in the sensory analysis, while people with egg allergies were not able to participate in the cookie's sensory analysis. In total 214 participants completed the study of which 104 (57.7 % female, 43.3 % male, 0 % non-binary, mean age = 26.8 years old (S.D. = 8.80)) assessed the cookies and 110 (59.1 % female, 41.9 % male, 0 % non-binary, mean age = 26.6 years old (S.D. = 8.15)) assessed the crackers.

2.8. Questionnaire design

The sensory questionnaire was similarly structured for both products, with slight changes in the rate-all-that-apply (RATA) attributes, and was conducted using EyeQuestion software (Logic8 B.V., The Netherlands) (EyeQuestion v4.9.4). Analysis of each sample was conducted in a three-step process. Participants were asked to first conduct the sensory analysis of the crackers, followed by the sensory analysis of the butter cookies. Firstly, participants were asked to sensory profile the sample through the RATA method, followed by the overall liking assessment of the sample with a 9-point hedonic scale, and lastly, the participants were asked about their willingness-to-pay (WTP). The attributes for the sensory profiling were selected based on prior research, pilot work, and using a focus group with a generally trained panel (n = 6) with sensory analysis of the products, followed by a group discussion of the most appropriate attributes for each of the products as described elsewhere (Delicato et al., 2020; Tzompa-Sosa et al., 2021).

The final list of sensory attributes contained 13 attributes for the crackers and 15 for the butter cookies. RATA sensory attributes were separated into categories (e.g., appearance, aroma, flavor and mouthfeel, and texture). Two of the main attributes mentioned by the focus group were the bitterness and spiciness of the samples that contained resveratrol, either in pure form or in emulsion. Before the sensory analysis, participants were asked a series of questions regarding their knowledge and consumption of functional food products, with "yes", "no", and "I am not sure" as answer options. The questions, and further details, can be found in the cookie and cracker questionnaire in supplementary material. Participants were then asked to first assess the appearance and aroma of the samples, followed by the flavor and mouthfeel, and finally the texture of the samples.

The attributes within these categories were randomized between participants. WTP was evaluated with an open-ended question; no reference price was included. Participants were asked for their WTP regarding 100 g of crackers and butter cookies and were indicated the weight of the samples they were tasting (~2 g for the crackers, and ~6 g for the butter cookies). After evaluating all three samples for each product, participants were asked to select their preferred sample.

Following the sensory analysis of the samples, participants were asked questions regarding their eating habits, willingness to purchase and pay extra for functional foods, and sociodemographic information. Participants were then asked six questions on the food neophobia scale (FNS) (Pliner and Hobden, 1992), three questions related to their general health interest (GHI) (Roininen et al., 1999) and four questions to assess their interest and willingness to purchase functional food products with antioxidant properties, which can be found in the supplementary materials. These consumer attitudes were measured on five-point Likert-type agreement scales with endpoints 1 = 'strongly disagree' to 5 = 'strongly agree'.

A food neophobia score was calculated for the participants using an assessment of their answers to the FNS (Chronbach's α = 0.74 for crackers and 0.79 for cookies) section of the questionnaire, and the same logic was applied to the GHI section (Chronbach's α = 0.61 for crackers and 0.66 for cookies). The higher the scores the higher the food neophobia and the importance of health characteristics of food for the participants. Lastly, age, gender, education, and profession were recorded as socio-demographic variables.

2.9. Data analysis

Repeated measures analysis of variance (ANOVA) was carried out on all the RATA attributes, as well as with the overall liking and WTP data. When differences among samples were found, Tukey's test was used for post-hoc comparison of means.

Statistical analyses regarding the sensory analysis were performed using EyeOpenR® (v5.0.6.5, EyeQuestion, Netherlands), IBM SPSS Statistics (v28.0.1.0, Armonk, NY), and GraphPad (v 9.2.0, California, USA). Significance levels of 10 %, 5 %, and 1 % were considered, when appropriate, in the statistical tests.

3. Results and discussion

3.1. Functional food product instrumental analysis

The viscoelastic properties of the cookie and cracker dough were studied. After baking, the weight loss was determined to calculate the exact flour replacement needed. After baking, the texture and color of the produced cookies and crackers were analyzed, results can be seen in Table 2.

3.1.1. Dough rheology

The MCS can be used to gather information related to dough consistency, with softer doughs having higher MCS values, while firmer doughs displaying lower MCS values. On the other hand, MRS results provide info on the elastic properties (springiness and resilience) of the dough: the higher the recovery, the more elastic the dough is (Sanz et al., 2017; F.C. Wang and Sun, 2002;Van Bockstaele et al., 2008).

The results of the creep-recovery measurements are presented in Table 2. Cookie doughs presented lower values, indicating that these doughs are more consistent and less elastic than the cracker doughs, likely due to differences in formulations, such as the higher water content, but also due to a more developed gluten network typically associated with crackers, which can enhance dough deformability. Statistically significant differences were found between the different samples in the MCS and MRS parameters. Supplementary Figure 1 shows the creep-recovery curves of the cracker and cookie doughs. For both the cracker and cookie doughs the MCS and MRS parameters of the emulsion-loaded dough presented statistically significant differences when compared to the reference dough.

The emulsion-loaded doughs, both for cracker and cookie dough, displayed higher MCS and MRS values than the reference and resveratrol-loaded dough, indicating it was less consistent and elastic when compared to the reference and resveratrol-loaded dough. In the crackers, the addition of emulsion led to an increase in elasticity and cracker thickness, while for the cookies the thickness of the baked cookies decreased for the emulsion-loaded sample.

The creep-recovery tests indicate that the viscoelastic characteristics of the doughs were affected by the addition of freeze-dried emulsion, and subsequent increase in flour replacement. The freeze-dried emulsions consist of resveratrol, oil, and OSA-modified starch which has binding, thickening, and gelling properties, and as such can physically and chemically interact with the cookie and cracker ingredients. This will lead to different water absorption and gelatinization behaviors, which in turn can influence dough elasticity and viscosity, as previously reported in other works (Korus et al., 2021; Pojić et al., 2016). The increase in the compliance values results in a lower resistance to deformation, resulting in weaker structural matrices, most prominently seen in the cookie dough. This might be explained by a decreased amount of gluten, as samples that had flour replaced by resveratrol and particularly emulsion have a lower amount of protein, resulting in a weaker gluten network. Additionally, the addition of oil, present in freeze-dried emulsions, to baking products has also been previously reported to influence the dough's properties, namely its elasticity and thus also needs to be considered (Mamat and Hill, 2014; Pareyt et al., 2011). Our observations are in agreement with Pulatsu et al. (2021) and Herranz et al. (2017) who reported that changes in protein content can lead to this behavior when analyzing cookies made from flour with different protein contents. Pulatsu et al. (2021) reported higher compliance values, indicative of a weaker structure due to a less developed gluten network, when comparing formulations with rice (7.5 % protein) and wheat (9.68 % protein) flour. Similarly, Herranz et al. (2017) evaluated the creep-recovery compliances for gluten-free muffin formulations. They reported that replacing wheat flour with chickpea flour (gluten-free) resulted in higher compliance values, indicative of lower gluten connectivity, leading to a less dense and more flexible batter.

Additionally, water is essential for dough development as it

Table 2
All results analysis for cookies and crackers. Different letters within a variable and in the same sample (cracker or cookie) represent statistically significant differences ($p < 0.05$). MCS (%), MRS (%), and Recovery (%) are analyzed using cookie or cracker dough, while Thickness, Hardness, Hardness/Thickness, Fracturability, *L**, *a**, *b**, and *ΔEab*, are characterized using baked cookies and crackers.

Analysis	Cookies			Crackers		
	Reference	Resveratrol-loaded	Emulsion-loaded	Reference	Resveratrol-loaded	Emulsion-loaded
Thickness	7.07±0.29	7.24±0.28	6.12±0.10	3.45±0.16	3.65±0.93	4.96±0.61
MCS (%)	$0.70{\pm}0.05^{a}$	$0.79{\pm}0.08^{a}$	$1.84{\pm}0.10^{b}$	$26.40{\pm}2.62^{a}$	$34.93{\pm}1.07^{ab}$	43.90 ± 6.53^{b}
MRS (%)	$0.37{\pm}0.03^{a}$	$0.45{\pm}0.02^{a}$	$0.93{\pm}0.05^{b}$	$12.67{\pm}0.85^{a}$	$15.83{\pm}0.64^{b}$	$18.80{\pm}1.74^{c}$
Recovery (%)	$47.13{\pm}2.28^{a}$	$44.86{\pm}3.08^{a}$	$49.37{\pm}0.27^{a}$	$51.91{\pm}1.68^{a}$	$54.63{\pm}2.72^{a}$	$57.18{\pm}4.75^{a}$
Hardness (N)	$55.36{\pm}13.66^{a}$	$54.32{\pm}10.31^{a}$	$41.12{\pm}6.85^{b}$	$10.86{\pm}3.49^{a}$	$11.67{\pm}3.61^{a}$	$13.71{\pm}3.15^{b}$
Hardness/Thickness (N/mm)	7.83±1.93	7.50±1.42	6.72±1.12	3.15±0.91	3.20±0.93	3.61±0.73
Fracturability (mm)	$38.51{\pm}0.65^{a}$	$38.28{\pm}0.42^{a}$	$38.03{\pm}0.33^{a}$	$9.81{\pm}3.93^{a}$	$7.04{\pm}3.53^{a}$	$16.28{\pm}5.89^{b}$
*L**	71.2 ± 2.0^{a}	70.5 ± 1.0^{a}	70.5 ± 0.9^{a}	70.1 ± 3.8^{a}	69.1 ± 4.5^{a}	69.9 ± 3.7^{a}
*a**	4.2 ± 1.5^{ab}	5.3 ± 1.0^{a}	4.0 ± 0.7^{b}	6.9 ± 3.3^{a}	7.0 ± 3.4^{a}	7.2 ± 3.0^{a}
*b**	29.9 ± 1.6^{a}	32.2 ± 1.2^{b}	30.0 ± 1.0^{a}	30.6 ± 2.8^{a}	$31.1 + 2.9^{a}$	30.7 ± 2.9^{a}
ΔEab	–	2.7	0.7	–	1.1	0.3

contributes to forming a gluten network, thus providing the correct dough consistency. Hydrophilic groups in proteins absorb most of the water added to the dough. Given the reduction in the amount of gluten present in the resveratrol-loaded and emulsion-loaded doughs, there might exist an excess of free water which can result in an increased dough viscous component (Edwards et al., 1999a; Sanz et al., 2017).

It seems that the gluten content, and the water-to-gluten ratio, can heavily influence the viscoelastic properties of the dough, as well as their structure and creep-recovery measurements (Edwards et al., 1999b; Sanz et al., 2017; Van Bockstaele et al., 2008; Pulatsu et al., 2021). This is similar to what was seen in the presented data, as the increasing flour replacement led to softer and more elastic doughs being produced.

3.1.2. Texture

Crackers displayed a higher weight loss after baking (26.68 %) when compared to cookies (9.95 %).

Table 2 shows the texture analysis and thickness results for the baked crackers and cookies.

There were statistically significant texture differences between the emulsion-loaded crackers and the other crackers, possibly due to the reduced flour content of the emulsion cracker dough, as some of the flour was substituted for dried emulsion, which also resulted in a different water-to-gluten ratio of the different crackers. This leads to a more elastic cracker dough that results in thicker emulsion-loaded crackers after the cutting of the dough, as the spread ratio might be reduced due to the higher elasticity of the dough, while also enhancing lift throughout the baking process. The thickness of the crackers did increase with an average thickness of 4.98±0.61 mm, vs 3.45±0.16 and 3.65±0.93 mm for the reference and resveratrol crackers ($n = 2$), respectively, and as such results in higher hardness and lower fracturability values being obtained for this sample. Nevertheless, when calculating hardness/thickness differences between samples are still seen, indicating that the properties of the emulsion crackers were modified due to the addition of emulsion (Sciarini et al., 2013).

The emulsion-loaded cookie displayed lower values, statistically significant ($p < 0.05$) when compared to reference and resveratrol-loaded cookies. Emulsion-loaded cookies registered a 25.73 % (w/w) reduction in hardness when compared to the reference cookies and a 24.29 % (w/w) reduction when compared to the resveratrol-loaded cookies. Similarly to the crackers, this might be due to the influence of the substitution of flour for dried emulsion, as the dried emulsion does not possess the same functional properties as flour, as well as the resulting modification of the water-to-gluten ratio, leading to changes in the gluten network and resulting in a dough with lower consistency that can lead to a lower cookie height due to a higher spread ratio. A lower cookie height was noticed for the emulsion cookie, with a height of 6.12 ±10 mm vs a height of 7.07± 0.29 and 7.24±0.28 mm for reference and resveratrol cookies ($n = 2$), respectively. Nevertheless, differences in the hardness/thickness are seen between cookie samples, namely reference, and emulsion, indicating the influence of adding emulsion to the cookie dough.

Similar impacts regarding the effect of changing the composition of crackers and cookies in dough properties and, as a result, the thickness of crackers and cookies, were reported in other works (En Tay et al., 2022; Lauková et al., 2019; Ren et al., 2021; Waheed et al., 2022; Xu et al., 2020). When calculating hardness/thickness (Table 2) it is also seen that the addition of emulsion led to a reduction of this value for the cookies, while for the crackers it led to an increase, likely due to the different behavior of the flour and emulsion that was added and partially replaced flour. Additionally, as mentioned previously, the modification of the water-to-gluten ratio, as a consequence of the flour replacement by emulsion, has also likely played a part in the differences seen between the reference and the emulsion cookies and crackers (Ren et al., 2021; En Tay et al., 2022;Lauková et al., 2019). Typically, when substituting flour for other ingredients with a lower content of gluten, cookie thickness might decrease and as such hardness will be reduced, and fracturability can increase (Lauková et al., 2019; Waheed et al., 2022; D. Xu et al., 2020).

The emulsion crackers had higher fracturability values when compared to the other crackers, possibly due to higher hardness values, while for cookies the fracturability of the samples was identical for all analyzed samples.

Results from Ren et al. (2021) and Lauková et al. (2019) seem to substantiate the correlation between hardness and fracturability, with increases in hardness resulting in a higher travel distance in the fracturability assessment, possibly due to the increased thickness of the crackers. Additionally, it also indicates that the higher the substitution of flour for other components is, the lower the strength of the gluten dough network will be.

En Tay et al. (2022) evaluated whey protein isolate (WPI) wheat-based crackers regarding the impact of the WPI replacement (5 to 20 %), and reported that the addition of WPI influenced the properties of the crackers, decreasing their thickness, which led to a decrease in hardness.

Similarly, Lauková et al. (2019) reported a decrease in both the thickness and hardness for cookies and crackers when replacing wheat flour with sweet potato powder. These decreases in thickness are due to a less developed gluten network, leading to higher spread ratios, thus lowering the cookie and cracker height, inherently affecting the hardness values.

Similarly, the results in this work are also in accordance with these trends resulting in the emulsion-loaded crackers and cookies displaying larger changes in their textural parameters when compared to the resveratrol-loaded crackers and cookies, which maintain similar properties to the reference crackers. In our case, the increase in the thickness of the crackers led to an increase in hardness values.

3.1.3. Color

Food appearance plays a significant role in product acceptance, and as such it is intended that any changes made to the cookies and crackers due to the addition of resveratrol can be minimized through encapsulation (Clydesdale, 1993; Spence, 2019; Spence et al., 2010). Color data of the produced cookies and crackers is presented in Table 2. No significant statistical differences were seen for any of the CIELAB parameters (L^*, a^*, b^*) between the different samples (reference versus loaded with resveratrol versus loaded with emulsion) for the crackers, while for the cookies there were some differences, namely in the a^* parameter between the resveratrol-loaded cookies and the emulsion-loaded cookies, and in the b^* parameter between the resveratrol-loaded cookies and the other two cookies.

The slight increase of the a^* and b^* parameters indicates that resveratrol-loaded cookies were slightly yellower and redder, while lightness parameters were similar. Previous research has stated that the addition of phenolic compounds to bakery products may influence their color, typically when added at higher concentrations (Ou et al., 2018). Cookies with a higher content of phenolic extracts display higher color parameter values (Ou et al., 2018). Other works have reported a similar trend, in which the addition of phenolic compounds can affect the color outcome of the food products in question (Oladunjoye et al., 2021; Sarabandi and Mohammadi, 2022; Szpicer et al., 2021).

In this work, the crackers did not present significant differences in color parameters, which might be explained by the higher variations between samples, as evidenced by the higher standard deviations. The cookie's results are similar to what was determined by Ou et al. (2018), as there was a statistically significant difference in some of the color parameters for the resveratrol-loaded cookies. For the emulsion-loaded cookies, there were no differences from the reference cookies, which can be explained due to encapsulation, helping to prevent color changes in food products, as demonstrated in previous research regarding encapsulation of bioactive in different food matrices, such as cake (Alifakı et al., 2022; Jansen-Alves et al., 2019) and yogurt (El-Messery et al., 2021; Tavakoli et al., 2018). The differences in the resveratrol-loaded cookies were small, and barely above the ΔE_{ab} limit for visible differences for untrained observers ($\Delta E_{ab} > 2$) (Mokrzycki Cardinal Stefan and Tatol, 2014), indicating that the addition of unencapsulated or encapsulated resveratrol to crackers and cookies should not have a significant impact on their appearance.

3.2. Resveratrol quantification

The percentage of resveratrol present in the final products was similar ($p < 0.05$) between the resveratrol-loaded (81.91±0.69 % (w/v)) and the emulsion-loaded (79.67±2.34 % (w/v)), indicating that no additional protection from heat degradation was offered by the encapsulation, similar to results by other authors (A. F. R. Silva et al., 2022). These values are within the reported results as previous studies have reported between 10 and 50 % degradation of resveratrol after baking. For example, Guamán-Balcázar et al. (2016) reported a heat degradation of 10.3 % and Ou et al. (2018) reported between 50 and 25 % of resveratrol being recovered after baking between 170 and 190 °C. Ahmad and Gani (2021) reported that encapsulated resveratrol was able to retain between 43 and 53 % of its content when encapsulated in different starch nanoparticles, while unencapsulated resveratrol had a retention of only 5.43 %. It seems different encapsulation techniques and baking conditions can influence the degradation of resveratrol. While a 20 % degradation might not be extremely high, improvements might be possible using polymeric materials/structures with higher melting points, temperature stability, or improved encapsulation (e.g., nanostructured lipid carriers, stabilized Pickering emulsions, and cyclodextrins), that can better withstand the high temperatures of the baking process. Additionally, other processing conditions and interactions between ingredients can lead to the degradation of resveratrol (e.g., pH, ionic force, among others), and should be taken into consideration to ensure maximum protection during processing. The release rate of resveratrol from the encapsulating systems can also play a role, as it will lead to more resveratrol being exposed to external environmental conditions, and thus promoting lower release rates which might result in lower degradation of resveratrol (Choi et al., 2022; Wani et al., 2016; W. Xu et al., 2023).

3.3. Consumer tests

3.3.1. Consumer behavior

In the questionnaire, around half of the participants declared they knew what functional foods are (around 52 %). Of the 110 participants for the sensory analysis, 45 % of them said they had previously consumed functional food products, while another 45 % were not sure whether they had, and 10 % claimed they had not previously consumed a functional food product. Regarding the frequency of consumption, 16 % of the participants claimed to regularly consume functional food products, while 38 % were not sure, and 46 % responded that they did not consume functional food products regularly. The average food neophobia scores were low (crackers mean = 2.30 ± 1.08; cookies mean = 2.31 ± 1.03, 0–5 scale). Regarding the importance of the healthiness of the food products they consume, participants displayed a quite neutral attitude (crackers GHI score, mean = 3.33 S.D. = 1.04; cookies GHI score, mean = 3.33, S.D. = 0.97; 0–5 scale). Regarding the specific interest in functional foods with antioxidant properties, 80 % of participants replied they would have interest in them, while only 3 % replied they would not be interested. When it comes to purchasing functional foods with antioxidant properties if the price was the same as current products, for the crackers 85 % responded they would be interested or very interested. When asked if they would be willing to pay extra for these products, most participants in the study replied neutrally (nor agree or disagree, 48 %), with 30 % willing to pay more, and 22 % would not pay more for the products.

When it came to quantifying how much participants would pay for the products, 16 % answered they would not pay extra, 70 % answered they would pay 10 % more, and 14 % answered they would pay 20 % more.

Functional foods do not have a long history of consumption, despite the increased usage in recent years, which can lead to skepticism and reluctance to adopt by consumers. The fact that the tangible effects of functional foods are hard to quantify, as some are designed to mitigate health risks, can lead to consumers' distrust in the efficacy of functional foods and result in food neophobia (Baker et al., 2022; Frewer et al., 2003).

In the present study, the food neophobia results were low, indicating an increased openness of the participants to try novel foods, in this case, functional foods. Several demographic factors can affect food neophobia, including age, education, and exposure to information, with older age being linked to higher food neophobia scores (Baker et al., 2022; Predieri et al., 2020). Indeed, the majority of the panelists were young people (mean age = 26.6 years, S.D. = 8.5 years), pursuing (or have completed) higher education (BSc, MSc, PhD) and typically exposed to novel foods, as sensory analysis often occurs in this setting.

Despite the typical lower consumption interest of younger demographics in functional food products, the participants in this study claimed to be interested in the purchase of potential functional food products, even if it meant paying more for these products.

These values are within the range that has been previously reported for willingness to buy and pay for functional food products, especially if consumers are aware of the potential health benefits of these functional foods (Menrad, 2003; Mirosa and Mangan-Walker, 2018; Pappalardo and Lusk, 2016), and also tracks well with the increased market of functional food ingredients and products (Hosseini et al., 2021; Market Data Forecast, 2020).

3.3.2. Product selection, acceptance, and willingness-to-pay

The data for the product selection, acceptance, and willingness to pay is shown in Table 3.

When it came to sample choice in the sensory analysis of crackers, the reference crackers were predominantly chosen, with 75 % of participants choosing that sample, while for the sensory analysis of the cookies, 80 % of the participants selected the reference cookie.

The reference sample, in both the crackers and cookies study, obtained the better overall liking results, indicating that consumers would prefer this option as it had the best overall score and flavor profile. After the reference sample, the second-best rated products were the crackers and cookies that had emulsified resveratrol, and lastly the crackers and cookies with unencapsulated resveratrol. There was a statistically significant difference between the overall liking of all samples for both the crackers samples ($p < 0.01$ between the reference crackers and the remaining samples, $p < 0.10$ between the unencapsulated and encapsulated samples) and the cookies samples ($p < 0.01$ between the reference crackers and the remaining samples, $p < 0.01$ between the unencapsulated and encapsulated samples).

Willingness-to-pay data follows the same trend as the overall liking, with the reference samples obtaining the highest value in euros for willingness-to-pay (consumers were asked to consider a 100 g package), as consumers would tend to be willing to pay more for products they consider to be of superior quality (Caswell and Siny, 2011; Lancaster, 1966), followed by the emulsion sample and the resveratrol sample, indicating that the encapsulation of resveratrol did have a positive influence in the overall liking of the different samples.

The addition of resveratrol led to a decrease in acceptance, and it seems that the incorporation into a sweet or salty product did not produce a significant change in acceptance, as drop-offs from reference to emulsion-loaded samples are similar, although that drop-off is slightly higher for the sweet product.

Additionally, it is also seen that while the encapsulation of resveratrol into emulsions led to a slight increase in acceptance, both the cookies and crackers loaded with emulsion still had a lower acceptance than the reference products.

The next section covers a more detailed analysis of the attributes that contribute to the differences seen between the different samples.

3.4. Sensory profiling

3.4.1. Overview

The sensory profiling aimed at analyzing the impact of the addition of resveratrol to baked products, assessing the impact of the use of emulsification to encapsulate resveratrol, while additionally evaluating the impact of the type of food product used, sweet or salty, in product acceptance and impact of resveratrol addition.

Fig. 1 displays the overview of the sensory profiling of the cracker's sensory analysis, while Fig. 2 displays the cookie's sensory profile. In both products, the addition of resveratrol either unencapsulated or in an emulsion had an impact on the sensory profiling, namely when compared to the reference products. The more impactful differences between the reference products and the resveratrol-loaded and emulsion-loaded products were seen in the bitterness and spiciness attributes as well as in the overall liking. For both products, the reference crackers or cookies had a low rating in bitterness and spiciness, and a higher overall liking rating, compared to the resveratrol-loaded and emulsion-loaded crackers and cookies, indicating it was the preferred choice. The negative impact of *bitter* and spicy attributes seems to be caused by the addition of resveratrol. Between the resveratrol-loaded and the emulsion-loaded products, the unencapsulated resveratrol-loaded products had higher ratings in bitterness and spiciness, while having a lower rating in the overall liking.

This trend, seen across two different products seems to indicate that the use of starch emulsions can help to slightly mask the impact of resveratrol, nevertheless, the effect of the addition of emulsified resveratrol is still felt and led to a decrease in acceptance of both products.

The attribute *thin* also displayed some changes in the crackers, with the reference crackers rating more highly in this attribute, followed by the resveratrol-loaded and emulsion-loaded crackers. This is supported by the thickness measurements of the crackers in which the emulsion-loaded samples were thicker than the reference and resveratrol-loaded crackers. This is possibly due to differences in dough elasticity, leading to an increase in thickness after dough cutting as higher elasticities may reduce spread and also enhance lift (oven rise) during baking by better gas holding capacity.

As for the cookies, the sweetness attribute also seems to have been affected, both by the addition of free resveratrol and by using resveratrol in its encapsulated form. The reference cookies had the highest rating of all cookies followed by the emulsion-loaded cookies and the resveratrol-loaded cookies, possibly as the result of the contrasting sensations between sweetness and bitterness.

Table 3 shows that for both crackers and cookies, the reference and emulsion-loaded cookies displayed higher overall liking ratings (7.10 and 5.18, respectively) than the equivalent crackers formulations (6.37 and 4.95, respectively). The resveratrol-loaded cookies and crackers obtained similar results (4.56 and 4.57, respectively), indicating that consumers preferred the cookies over the crackers, namely when the resveratrol was absent or encapsulated.

The effect of the addition of resveratrol was more prevalent in the cookies than in the crackers, as the differences between the reference samples and the resveratrol-loaded and emulsion-loaded samples are higher in the cookies than in the crackers, with an overall rating drop-off of 1.92 for the cookies and 1.42 for the crackers.

It seems that the presence of resveratrol had a more adverse sensorial influence in the cookies, when compared to the crackers, indicating that perceived changes in familiar attributes (such as *sweet* and *salty*) influence the perception and liking of the products. The presence of attributes such as bitterness and spiciness can feel more contrasting, or more out of place, in a sweet product than in a salty product. As such, it is possible that a greater reduction of a key and familiar attribute in the cookies (sweetness), versus a smaller reduction in one of the more familiar attributes in the crackers (saltiness), can explain the higher drop in overall liking between the reference cookies and the remaining cookies when compared to the crackers. Familiarity regarding color, texture, aroma, and flavor has been linked to consumer preference as one of the main drivers of consumer preference and can even affect the consumer's willingness to buy products (Borgogno et al., 2015; Clydesdale, 1993; Labbe et al., 2006; Lyly et al., 2007; Muñoz and Vance Civille, 1987; Spence, 2019; Spence et al., 2010; Tan et al., 2016; Torrico et al., 2019).

It has also been reported that salt can reduce the bitterness perception of certain compounds in the human palate, as its use is linked to flavor enhancement through selective suppression of bitterness (Breslin and Beauchamp, 1997; Keast et al., 2004; Kroeze and Bartoshuk, 1985).

Table 3
Average (S.D.) overall liking scores (1–9 hedonic scale), average (S.D.) WTP (in €) and choice (number of participants) for the cookies and crackers. Different letters in the same line represent statistically significant differences ($p < 0.1$).

Product	Attribute	Reference	Resveratrol-loaded	Emulsion-loaded
Crackers	Liking	6.37 (1.20)^{a}	4.57 (1.67)^{b}	4.95 b (1.46)^{c}
	Willingness-to-pay	1.57 (0.96)^{a}	1.01 (0.87)^{b}	1.12 (0.90)^{b}
	Choice	83	16	11
Cookies	Liking	7.10 (1.16)^{a}	4.56 (1.87)^{b}	5.18 (1.68)^{c}
	Willingness-to-pay	2.07 (1.28)^{a}	1.34 (1.19)^{b}	1.43 (1.16)^{b}
	Choice	83	13	8

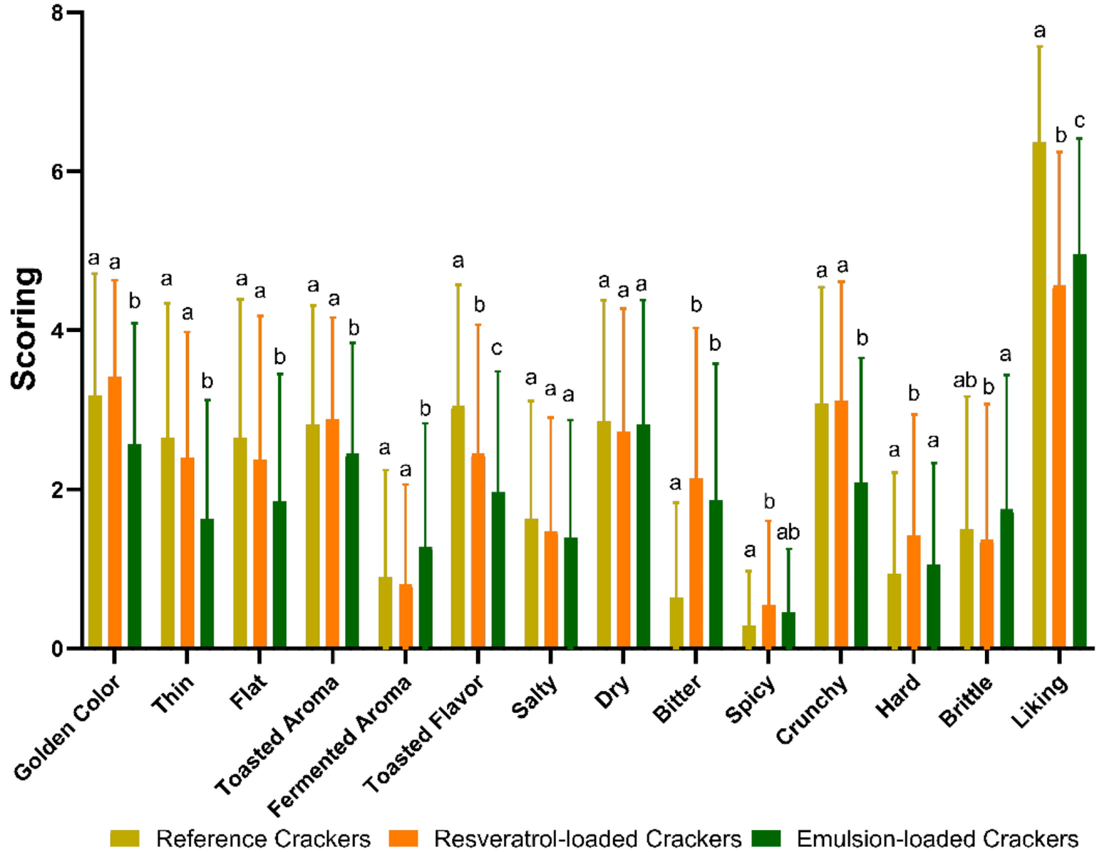

Fig. 1. Overview of the sensory profiling for cracker samples. Different letters in the same attribute represent statistically significant differences ($p < 0.1$).

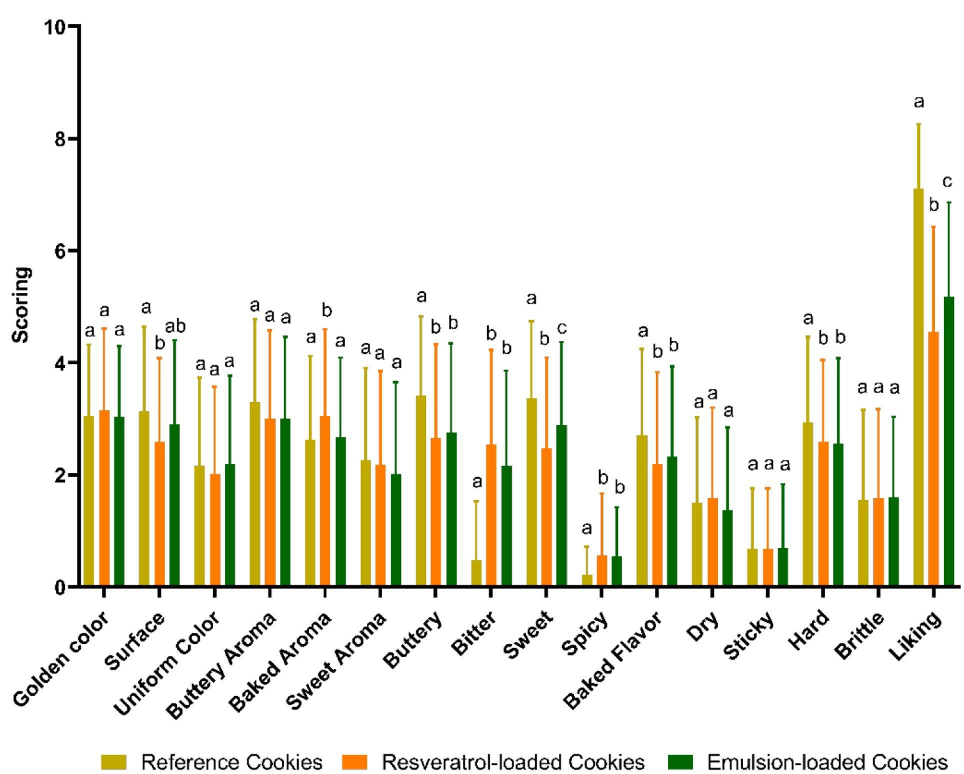

Fig. 2. Overview of the sensory profiling for cookie samples. Different letters in the same attribute represent statistically significant differences ($p < 0.1$).

As such, the presence of salt in the crackers would lead to a decreased sensation of bitterness when compared to cookies, resulting in the bitterness ratings seen in Figs. 1 and 2.

The penalty-lift analysis (Fig. 3), allowed to determine which attributes have the highest positive or negative impact on the hedonic liking of consumers, as it links the frequency of attribute selection with the overall liking of the samples (Torri and Salini, 2016; Tzompa-Sosa et al., 2021).

When it came to the crackers samples (Fig. 3), the penalty-lift analysis showed that attributes such as *crunchy, toasted flavor, toasted aroma,* and *flat* were among the main drivers for liking, while attributes such as *spicy, bitter, dry, hard,* and *brittle* were the main drivers for dislike. Both the resveratrol and emulsion-loaded crackers were negatively influenced by the attribute *bitter* (mean impact = −1.01 and −0.40, respectively). Additionally, resveratrol-loaded crackers were negatively influenced by the attribute *spicy* (mean impact = −1.07). Drivers of liking were attributes that were familiar to the consumer and expected in crackers (e.g., *crunchy, toasted flavor*), while the dislike drivers were mostly linked to unfamiliar or unexpected attributes (e.g., *spicy, bitter, hard*). The impact of the increased hardness measured in the texture results is also noticed here, as *hard* was one of the attributes that had a negative connotation for the emulsion crackers.

For the cookies (Fig. 3), the penalty-lift analysis showed that attributes such as *bitter, spicy*, and *baked aroma* had a negative influence.

All samples had a negative influence from the attribute *bitter* (mean impact = −0.39, −1.57, −1.25, respectively for reference, resveratrol, and emulsion loaded).

Overall, it is noticeable the high negative impact that the *bitter* and *spicy* attributes had on both products and that this impact is higher in the resveratrol-loaded crackers and cookies, followed by the emulsion-loaded crackers and cookies.

Additionally, as explored in the sensory profiling, it seems that the addition of resveratrol had a higher impact on the cookies than on the crackers, as the negative influence of bitterness is higher in the cookies (mean impact of −1.57) than in the crackers (mean impact of −1.01). As seen in Fig. 3, the drivers of liking are the attributes that consumers would expect and be familiar with in butter cookies (e.g., *golden color, sweet, buttery*), while the drivers of disliking with the highest negative impact are the attributes whose presence or absence would be unexpected (e.g., *bitter, spicy, baked aroma*).

One of the main drawbacks of using resveratrol and other polyphenolic compounds in food products is their influence on the organoleptic profile (Bucalossi et al., 2020; Drewnowski and Gomez-Carneros, 2000). Several studies have been conducted in the past that have assessed the addition of resveratrol, alone or in conjunction with other polyphenols, for the development of functional food products. Most of these works reported that attributes such as bitterness, sourness, astringency, and spiciness, increase as resveratrol is added to a product, while attributes such as sweetness decrease (Abreu et al., 2019; Bucalossi et al., 2020; Koga et al., 2015).

Shruthi et al. (2020) and Seethu et al. (2020) reported a slight decrease in the sensory properties of milk upon the incorporation of resveratrol-loaded proniosomes and electrospun nanofibers, respectively, while Lee et al. (2013) reported an overall liking decrease upon the incorporation of resveratrol-rich peanut sprout extract, encapsulated in double emulsions, in yogurt. Using dry extruded snacks, Ahmad and Gani (2021) reported no differences in sensory properties after resveratrol addition, although a low amount of resveratrol (0.1 mg g^{-1}) was used, 40 times lower than the amount used in our work.

Koga et al. (2016) reported a dose-dependent negative effect in the organoleptic impact of the addition of spray-dried encapsulated resveratrol in snack bars (at a loading of 0.3 mg g^{-1} no differences were reported, while a loading of 1.3 mg g^{-1} led to noticeable differences), while for gummies even a low-level addition (0.4 mg g^{-1}) led to a negative organoleptic impact. One possibility is that the attributes that are expected in a gummy bar versus a snack bar are different and as such the impact of resveratrol in the gummy bar might be more noticeable than the impact in a snack bar, similar to what was seen here, in which the addition of resveratrol in cookies led to a higher impact in overall liking when compared to the crackers (Figs. 1 and 2).

As such, it seems clear the negative impact that the addition of resveratrol can have on the organoleptic properties of crackers cookies, and other food matrices, and that encapsulation can decrease this impact, even if slightly. As such further testing should be conducted to explore further improvements in resveratrol encapsulation for flavor masking. Additionally, other food matrices where the presence of resveratrol might be less noticeable should be explored (e.g., dark chocolate).

4. Conclusions

Functional crackers and cookies were successfully developed through the incorporation of resveratrol. While color parameters were generally not affected by the addition of resveratrol, either encapsulated

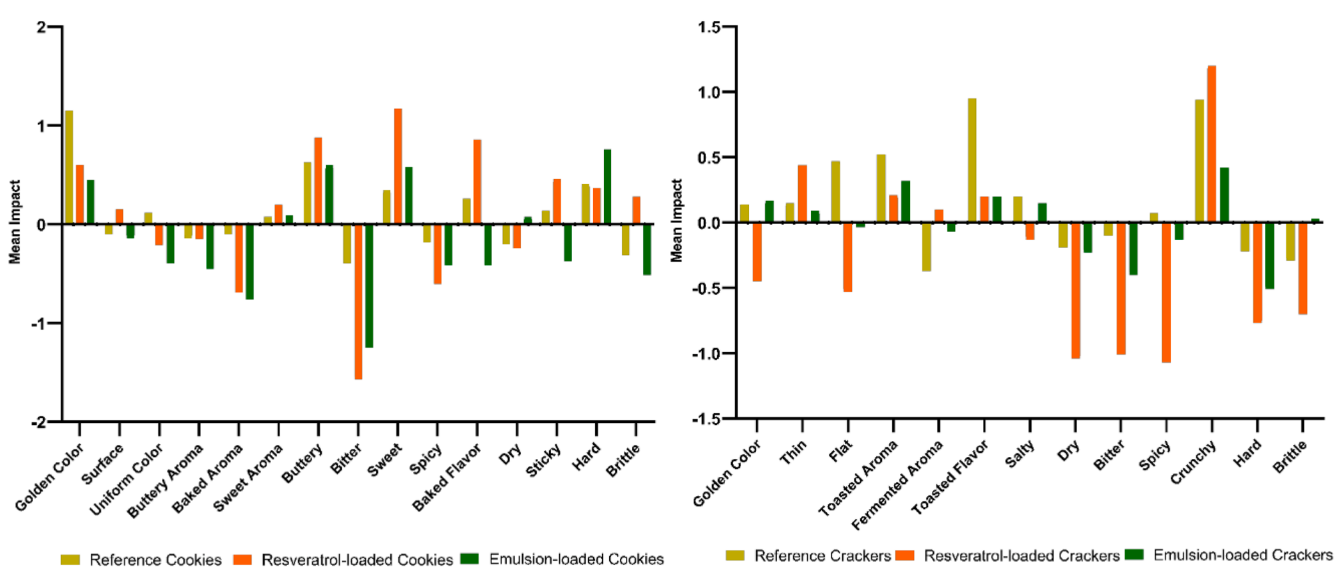

Fig. 3. The outcome of the penalty-lift analysis for the sensory attributes for the cookies' (left) and crackers' (right) samples. The mean impact score indicates the change in liking in instances in which the attributes were checked when compared to instances in which those attributes were not checked.

or not, dough and baked crackers and cookies properties were affected. The addition of encapsulated resveratrol led to a decrease in dough consistency and an increase in dough elasticity for both the cracker and cookie dough. Baked crackers and cookies displayed significant differences in their hardness, suffering an increase and decrease, respectively.

The consumer test showed the interest of consumers to try novel foods, namely foods with potential health claims associated, and their willingness to pay for those products.

The sensory analysis demonstrated the impact of the addition of resveratrol to the crackers and cookies, which can influence the organoleptic properties of the food products it is added to, modifying its texture and flavor profile, as the addition of resveratrol, both in the encapsulated and unencapsulated form leads to significant decreases in acceptance, when compared to the reference products The textural changes were also noticed by sensory analysis. For both the fortified crackers and cookies, higher ratings in bitterness, spiciness, and a decrease in overall liking were obtained, while the sensation of salty and sweet decreased for crackers and cookies, respectively. The incorporation of resveratrol was noticed in both the sweet and salty products, nevertheless, its addition seemed to have a higher impact on the cookies than in the crackers, as it led to a higher drop-off in ratings.

The encapsulation of resveratrol revealed a slight impact regarding the decrease of the bitterness and spiciness sensations, while slightly improving the overall ratings of the crackers and cookies versus the unencapsulated resveratrol-loaded samples. Nevertheless, improvements to the encapsulation need to be made to reduce the impact of the addition of resveratrol. Additionally, other food matrices can be explored for the addition of resveratrol.

Ethical statement - Studies in humans and animals

No human ethics committee or formal documentation process is available, the appropriate protocols for protecting the rights and privacy of all participants were utilized during the execution of the research, meaning no coercion to participate, full disclosure of study requirements and risks, written or verbal consent of participants, no release of participant data without their knowledge, ability to withdraw from the study at any time

Participants gave their informed consent via the statement "I am aware that my responses are confidential, and I agree to participate in this survey" where an affirmative reply was required to enter the survey. They were able to withdraw from the survey at any time without giving a reason. The products tested were safe for consumption.

CRediT authorship contribution statement

Pedro M. Silva: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Miguel A. Cerqueira:** Writing – review & editing, Supervision, Funding acquisition, Conceptualization. **Lorenzo Pastrana:** Writing – review & editing, Supervision, Funding acquisition, Conceptualization. **Manuel A. Coimbra:** Writing – review & editing, Supervision, Funding acquisition, Conceptualization. **Antonio A. Vicente:** Writing – review & editing, Supervision, Funding acquisition, Conceptualization. **Filip Van Bockstaele:** Writing – review & editing, Supervision, Methodology, Investigation, Funding acquisition, Formal analysis. **Daylan Tzompa-Sosa:** Writing – review & editing, Supervision, Methodology, Investigation, Formal analysis, Conceptualization. **Koen Dewettinck:** Writing – review & editing, Supervision, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

Data will be made available on request.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.fufo.2024.100459.

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