https://doi.org/10.17221/235/2024-CJFS

Consumer sensory evaluation of flavour enhancers derived from snail protein hydrolysate using the Rate-All-That-Applies method

Dedin Finatsiyatull Rosida[1,2], *Dina Mustika Rini*[1]*, *Dwi Ernawati*[1]

[1]*Department of Food Technology, Faculty of Engineering, University of Pembangunan Nasional Veteran Jawa Timur, Surabaya, Indonesia*

[2]*Innovation Center of Appropriate Food Technology for Lowland and Coastal Area, University of Pembangunan Nasional Veteran Jawa Timur, Surabaya, Indonesia*

**Corresponding author: dina.mustika.tp@upnjatim.ac.id*

Citation: Rosida D.F., Rini D.M., Ernawati D. (2025): Consumer sensory evaluation of flavour enhancers derived from snail protein hydrolysate using the Rate-All-That-Applies method. Czech J. Food Sci., 43: 263–273.

Abstract: Snails, which are high in protein, have the potential to be developed as a flavour enhancer through the hydrolysis process. However, consumer acceptance of the flavour enhancer needs to be fully evaluated. The aim of this study was to determine the consumer acceptance of a snail protein hydrolysate from different snail species (golden apple, apple, and freshwater) and at different hydrolysis durations (3, 6, and 9 h), and to identify the drivers of liking of snail protein hydrolysates through descriptive profiling using Rate-All-That-Apply (RATA) method and consumer testing using Hedonic test. The RATA intensity data were subjected to analysis using analysis of variance, followed by a Tukey's post hoc test ($P < 0.05$). Furthermore, the sensory profile data were analysed using principal component analysis and preference mapping. Snail species and hydrolysis time influenced the sensory profile of snail protein hydrolysate, with the longer hydrolysis time being the most liked. The most liked flavour enhancer derived from golden apple snail with 9 h hydrolysis time had a strong savoury aroma, salty taste, umami taste, lingering mouthfeel, and yellow colour. Additionally, it exhibited a moderate intensity of seafood aroma, a garlic taste, an umami aftertaste, a liquid mouthfeel, and a salty aftertaste. However, it had a low intensity of bitter aftertaste and burnt taste, and a very low intensity of sweet aroma, sweet taste, bitter taste, and bland taste. Thus, these findings highlight the importance of evaluating the efficacy of flavour enhancers and facilitate the identification of the optimal snail species and hydrolysis time according to consumer preference.

Keywords: umami; preference mapping; food innovation; hydrolysis; sensory profiling

Flavour enhancers are food additives that are used to improve the sensory characteristics of a food thereby significantly influencing consumer acceptance and preference. A commonly used flavour enhancer in the market is monosodium glutamate, which is typically produced synthetically by microbial fermentation (Rosida et al. 2021). However, recent studies have shown that the naturalness of food is crucial for most consumers with differences in the definition and measurement of naturalness categorised by food origin, production methods and final product properties, emphasising that neglecting naturalness could be costly for the food industry (Román et al. 2017). This observation reinforces the need to replace artificial additives with natural alternatives. Currently, recent study has been dedicated to the identification and isolation of natu-

Supported by the International Collaboration Grant from University Pembangunan Nasional Veteran Jawa Timur with Grant No. SPP/42/UN.63.8/LT/V/2020.

https://doi.org/10.17221/235/2024-CJFS

rally occurring substances that improve flavour which are being explored as alternative sources of flavour enhancers (Rosida et al. 2021). In line with this trend, the development of functional foods and beverages using natural ingredients rich in bioactive compounds is gaining interest. These compounds can enhance both taste and health benefits, supporting cleaner labels and consumer well-being (Maulida et al. 2024).

Meat, rich in protein, lipids, and essential micronutrients like iron and vitamins, is highly valued, with increasing interest in snail meat from the *Gastropoda* class of *Mollusca*. Different snail species vary in protein content; for example, golden apple and apple snails contain 15.0% and 19.1% protein, respectively (Ernawati and Rosida 2022). However, certain snail species, such as golden apple and apple snails, pose a threat as invasive pests in rice fields, resulting in significant economic losses (Mokhtar et al. 2024). The use of snail protein as a flavour enhancer could help manage these pests, which require a hydrolysis process to develop savoury or umami flavours. Studies show that protein hydrolysates yield peptides with distinct flavours such as sweet, salty, sour, bitter, and umami (Yarnpakdee et al. 2014).

Developing snail-derived flavour enhancers faces consumer acceptance challenges, making sensory evaluation crucial. Many studies have assessed the sensory profile of protein hydrolysates from meat products like fish and chicken using trained panellists in generic descriptive analysis (Steinsholm et al. 2021). Highly specialised descriptive panels enable the collection of detailed, robust, consistent and reproducible sensory data that remain stable over time and within a specific sensory framework (Moussaoui and Varela 2010). Maintaining a trained sensory panel is costly, posing financial challenges for small food companies and significant expenses for larger firms managing multiple panels (Moussaoui and Varela 2010). To ensure accurate, discriminating and precise results, regular evaluation and monitoring of panel performance is essential. For food manufacturers, understanding consumer descriptions of sensory attributes in food products is critical. Increasingly, the industry is seeking alternative methods that eliminate the need for trained sensory panels and instead collect sensory insights directly from consumers (Sharif et al. 2016). As a result, a number of innovative methods have emerged that allow for efficient sensory profiling without the need for trained panels.

Recently, a faster and more flexible consumer-based sensory profiling method has been developed, such as the Rate-All-That-Apply (RATA) technique, which can be performed by semi-trained panellists. The RATA method is capable of quantifying the intensity of sensory attributes and distinguishing products with similar perceived taste. Moreover, attribute intensity testing is typically complemented by a hedonic test, which is used to correlate the sensory profile of the flavour enhancer with consumer acceptance (Jariyah et al. 2024). To the best of our knowledge, limited studies have evaluated the sensory profile of protein hydrolysates using the RATA method.

Considering the potential of snails as a novel food source to their implementation as flavour enhancers, we hypothesised that snail species and hydrolysis time will influence consumer acceptance driven by the sensory profile of snail protein hydrolysate. Thus, the main objectives of this study were: (*i*) determine the consumer acceptance of snail protein hydrolysates prepared from different snail species and different hydrolysis time, (*ii*) determine the drivers of liking of snail protein hydrolysates through descriptive profiling using the RATA method and consumer testing using the Hedonic test. Despite their potential, snail-based flavour enhancers remain underexplored, particularly in terms of consumer sensory perception. Filling this gap is critical to the development of sustainable, culturally appropriate flavour alternatives that meet evolving consumer preferences for natural and environmentally responsible food products.

MATERIAL AND METHODS

Materials. Three snail species, including golden apple snail (*Pomacea canaliculate*), apple snail (*Pomacea maculata*), and freshwater snail (*Anentome helena*), used in current study were obtained from Jombang, East Java, Indonesia. Pineapple (*Ananas comosus*) as sources of bromelain enzyme was used for protein hydrolysis.

Preparation of crude bromelain enzyme. The crude bromelain enzyme was derived from pineapple as previously described (Ernawati and Rosida 2022). The pineapple was prepared by peeling, washing, and cutting it into little pieces. These pieces were then crushed using a blender, along with an equal amount of distilled water. The pineapple juice obtained was initially clarified using a filter cloth. The resulting filtrate was next subjected to a second filtration using filter paper to get the crude bromelain enzyme extract. The crude bromelain enzyme exhibited an activity of 5.20 $U \cdot mL^{-1}$.

Preparation of snail protein hydrolysates. Protein hydrolysate from different species of snails was prepared separately. The snail meats were thoroughly washed under running water and then mixed with distilled water at a 2 : 1 ratio. Crude bromelain enzyme (10%) was

https://doi.org/10.17221/235/2024-CJFS

added to the slurry, which was then incubated at 50 °C for 3, 6, and 9 h, as previously described (Ernawati and Rosida 2022). The enzyme was subsequently inactivated by heating the mixture to 90 °C for 10 min. The solid and supernatant phases were separated using centrifugation (3 000 rpm, 30 min). The supernatant, which had an 80% concentration, was then combined with additional ingredients, including powdered sugar (2%), garlic powder (0.5%), salt (0.5%), and filler (10%, a mixture of gum arabic and maltodextrin in a 1 : 4 ratio). The mixture was homogenised using a magnetic stirrer (6 000 rpm, 20 min) and subsequently dried in a cabinet dryer at 60 °C for 6 h. The dried product was then pulverised to produce a flavour enhancer powder.

Preparation of flavour enhancer sample. The dried snail protein hydrolysate obtained from the above steps was further prepared for sensory profiling. Each snail protein hydrolysate derived from different snail species and different hydrolysis time was dissolved in water at a concentration of 2% (Steinsholm et al. 2021) and presented in 20 mL plastic cups. Each of the nine samples was then labelled with a unique three-digit code to prevent panellist bias during testing.

Participants. 60 semi-trained panellists (18% male, 82% female, ages 18–60), who had completed sensory evaluation coursework including practical training, were selected from the students and faculty members at the University of Pembangunan Nasional Veteran Jawa Timur in Surabaya, Indonesia. To participate in the study, individuals were required to be at least 18 years old, in good health, and willing to undergo a series of sensory tests. During the tests, each panellist was asked to rate nine samples from each group using the RATA and hedonic methods.

Sensory profiling using Rate-All-That-Apply Method. The semi-trained panellists were presented with a list of sensory attributes and instructed to rate the intensity of the 17 sensory attributes of the flavour enhancer samples on a 5-point scale (1: very weak, 2: weak, 3: medium, 4: strong, 5: very strong). The duration of the test ranged from 35 to 50 min. Palate cleansers were provided in the form of drinking water and unsalted crackers, with a mandatory 5-minute interval between testing each sample. The sensory attributes are displayed in Table 1.

Hedonic test. In conjunction with the RATA testing, a hedonic rating test was also conducted to determine consumer acceptance of the flavour enhancer samples. The sensory attributes tested were colour, aroma, flavour, mouthfeel, aftertaste, and overall acceptance. Panellists

Table 1. Sensory attributes of flavour enhancer

Category	Attributes	Description
Aroma	Savoury	Rich, mouth-watering smell that is typically associated with cooked meats, broths, or other umami-rich foods
	Seafood	Reminiscent of fish, shellfish, or seaweed
	Sweet	A pleasant, sugary smell that is often associated with the smell of table sugar
Taste	Sweet	Taste like table sugars and other sweet substances
	Salty	Taste like table salt or salty foods
	Bitter	Sharp and unpleasant taste
	Umami	Has a meaty, brothy, or savoury taste that mimics that of monosodium glutamate
	Bland	A lack of strong or distinctive flavours
Mouthfeel	Clean	Sensation of a smooth, refreshing, and uncoated feeling in the mouth after consumption
	Astringent	A dry, puckering sensation in the mouth
	Lingering	A prolonged sensation or coating that remains in the mouth after the food has been swallowed
Aftertaste	Sweet	The residual sweet flavour that lingers in the mouth after the initial taste has dissipated
	Salty	A lingering sensation of saltiness that remains in the mouth after the initial salty taste has faded
	Umami	A prolonged meaty, brothy, or savoury sensation remains in the mouth after consuming the foods
Colour	Yellow	The visual appearance of the sample colour is yellowish
Flavour	Garlic	Distinctive taste and aroma of garlic
	Burnt	Taste of food that has been charred, scorched, or overcooked

https://doi.org/10.17221/235/2024-CJFS

were instructed to indicate their level of acceptance for the samples on a 5-point hedonic scale, with 1 indicating strongly dislike and 5 indicating strongly like.

Statistics. A completely randomised design with two factors was used in this study: type of snail (golden apple, apple, and freshwater snail) and hydrolysis time (3, 6, 9 h). The RATA and hedonic data were subjected to an analysis of variance (ANOVA) with a Tukey's post hoc test ($P < 0.05$). Furthermore, principal component analysis (PCA) was conducted to elucidate the differences in sensory attributes based on the data of RATA methods. PCA transforms the original variables into a new coordinate system, thus enabling the interpretation of large data sets, including sensory ratings. This was achieved by determining the means for attributes such as appearance, aroma, taste, and texture. PCA biplot and preference mapping were generated using Minitab (version 19) and XLSTAT 2019 (version 21.4).

RESULTS AND DISCUSSION

Sensory profiles of flavour enhancer by RATA method. The intensity of sensory attributes of flavour enhancer samples, assessed using the RATA method with 60 *s*emi-trained panellists, is shown in Table 2 and visualised in Figure 1. The RATA test included 17 sensory attributes. The results showed that different snail species and hydrolysis time influenced the sensory attributes of the flavour enhancer. Among these sensory attributes, nine of them were significantly different among the groups: aroma (savoury and seafood), taste (salty, bitter, umami), aftertaste (salty and umami), lingering mouthfeel, and yellow colour. Therefore, the following discussion will focus on attributes significantly affected by treatment.

Snail protein hydrolysed for 9 h produced moderate to strong savoury flavour intensity (3.07–4.28) compared to the 3 h hydrolysis treatment which produced very weak to moderate savoury flavour intensity (1.87–2.82). These results showed that the longer the hydrolysis time, the higher the degree of hydrolysis produced, resulting in a savoury aroma with higher intensity in the flavour enhancer product. Previous work has demonstrated that prolonged hydrolysis enhances the degree of hydrolysis, soluble protein and glutamic acid content of snail protein hydrolysates (Ernawati and Rosida 2022). In line with the previous study, the savoury flavour was formed by the process of protein hydrolysis, which produced short-chain peptides (Yuniarti et al. 2024).

Both snail species and hydrolysis duration significantly affected the seafood aroma of snail hydrolysate. Extended hydrolysis time correlated with increased seafood aroma intensity. The Maillard reaction may contribute to the formation of volatile compounds, involving interactions between carbonyl groups of re-

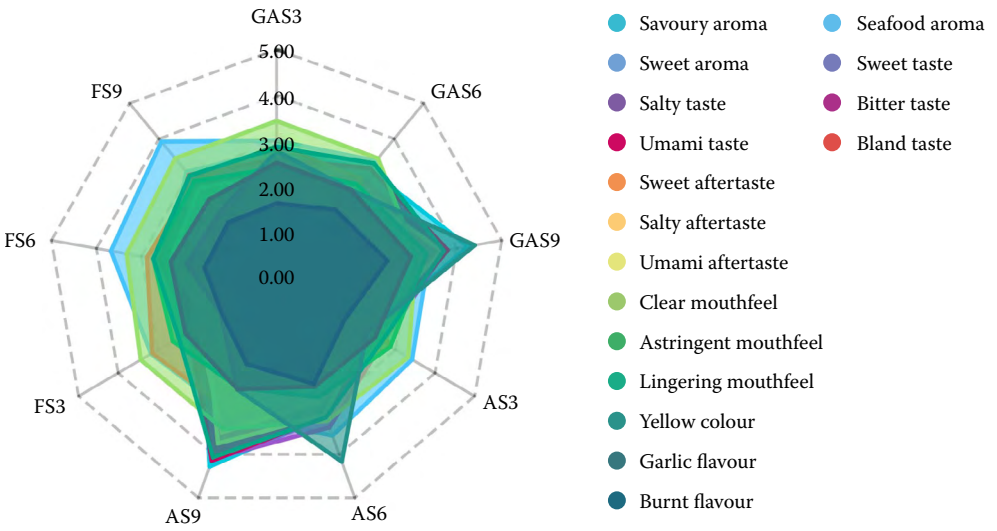

Figure 1. Radar chart of intensity of sensory attributes of flavour enhancer by RATA method. This visualization complements Table 2 by providing a comparative overview of the sensory profiles across treatments

GAS3, GAS6, GAS9 – protein hydrolysate of golden apple snail with 3, 6, and 9 h hydrolysis time, respectively; AS3, AS6, AS9 – protein hydrolysate of apple snail with 3, 6, and 9 h hydrolysis time, respectively; FW3, FW6, FW9 – protein hydrolysate of freshwater apple snail with 3, 6, and 9 h hydrolysis time, respectively

https://doi.org/10.17221/235/2024-CJFS

Table 2. Intensity of sensory attributes of flavour enhancer by RATA method

Category	Attributes	Treatment									*P*-value
		Golden apple snail			Apple snail			Fresh water snail			
		3 h (GAS3)	6 h (GAS6)	9 h (GAS9)	3 h (AS3)	6 h (AS6)	9 h (AS9)	3 h (FS3)	6 h (FS6)	9 h (FS9)	
Aroma	Savoury	2.82^{bc}	3.13^{b}	4.25^{a}	2.30^{d}	3.13^{b}	4.28^{a}	1.87^{e}	2.43^{cd}	3.07^{b}	**0.000**
	Seafood	3.02^{b}	3.38^{ab}	3.40^{ab}	3.42^{ab}	3.57^{ab}	3.05^{b}	3.17^{ab}	3.68^{ab}	3.92^{a}	**0.033**
	Sweet	0.90	0.67	0.80	0.83	0.72	0.55	0.67	0.48	0.67	0.745
Taste	Sweet	1.37	1.42	1.37	1.32	1.48	1.48	1.27	1.22	1.38	0.862
	Salty	2.30^{def}	2.87^{c}	3.75^{ab}	2.68^{cd}	3.38^{b}	4.10^{a}	2.23^{ef}	2.12^{f}	2.65^{cde}	**0.000**
	Bitter	1.70^{ab}	1.83^{ab}	2.69^{a}	2.29^{ab}	1.82^{ab}	1.50^{b}	1.84^{ab}	1.79^{ab}	1.78^{ab}	**0.016**
	Umami	2.63^{cde}	3.17^{bc}	3.80^{a}	2.48^{e}	3.13^{b}	4.15^{a}	2.18^{e}	2.58^{de}	2.98^{bcd}	**0.008**
	Bland	2.94	2.87	1.80	2.85	2.73	3.00	3.14	2.88	2.81	0.079
Aftertaste	Sweet	2.52	2.26	2.33	1.96	2.40	2.00	2.13	1.82	2.32	0.329
	Salty	2.04^{cde}	2.42^{bc}	3.30^{a}	2.23^{cd}	2.79^{b}	3.49^{a}	1.98^{de}	1.76^{e}	2.26^{cd}	**0.000**
	Umami	2.28^{c}	2.62^{c}	3.67^{a}	2.24^{c}	3.09^{b}	3.75^{a}	1.77^{d}	2.37^{c}	2.63^{c}	**0.000**
Mouthfeel	Clean	3.45	3.45	3.10	3.32	3.23	3.42	3.43	3.33	3.45	0.541
	Astringent	2.44	2.72	3.33	2.87	2.69	2.46	2.62	2.74	2.80	0.104
	Lingering	2.88^{cde}	3.31^{bc}	3.71^{ab}	2.65^{de}	3.15^{cd}	4.07^{a}	2.47^{e}	2.74^{de}	2.96^{cde}	**0.026**
Colour	Yellow	2.80^{b}	2.55^{bc}	4.40^{a}	2.27^{cd}	4.17^{a}	2.51^{bc}	1.41^{e}	2.00^{d}	1.93^{d}	**0.000**
Flavour	Garlic	2.55	2.55	2.98	2.48	2.44	2.50	2.30	2.35	2.29	0.400
	Burnt	1.67	2.00	2.46	1.71	2.38	1.92	1.39	1.60	1.64	0.278

Values are presented as mean values on a sensory attribute scale from 1 (very weak) to 5 (very strong); $^{a–e}$different letters indicate statistically significant differences ($P < 0.05$), as determined by Tukey's post hoc test; bold numbers indicate significant differences between flavour enhancer samples; GAS3, GAS6, GAS9 – protein hydrolysate of golden apple snail with 3, 6, and 9 h hydrolysis time, respectively; AS3, AS6, AS9 – protein hydrolysate of apple snail with 3, 6, and 9 h hydrolysis time, respectively; FW3, FW6, FW9 – protein hydrolysate of freshwater apple snail with 3, 6, and 9 h hydrolysis time, respectively

ducing sugars and amine groups of amino acids, peptides, and proteins (Liu et al. 2022). These reactions are likely enhanced by the increase in soluble protein due to prolonged hydrolysis, which allows greater interaction between protein amine groups and reducing sugars (Ernawati and Rosida 2022).

In addition, the aroma intensity of protein hydrolysates from different snail species showed significant variability. Previous studies have shown that the aroma of fish-derived protein hydrolysates was influenced by species as well as postharvest, storage, and processing conditions (Ali et al. 2022). Proteolysis induced by external stimuli releases volatile compounds bound to proteins, enhancing the savoury aroma without altering the volatile properties (Hashempour-Baltork and Farshi 2022). Thus, differences in snail habitat and biochemical composition may contribute to the variation in hydrolysate flavour.

As for the salty taste, hydrolysis of snail protein for 9 h produced a stronger salty taste intensity compared to shorter hydrolysis times across in all snail species (Table 2). Previous studies have shown that longer hydrolysis times increased the solubility of small molecules, such as salts, by fragmenting protein molecules and releasing salt (Sukkhown et al. 2018). There was a clear correlation between the intensity of perceived saltiness and the number of sodium ions accessing ion channels on the tongue, with salt perception being en-

https://doi.org/10.17221/235/2024-CJFS

hanced by both NaCl concentration and mobility (Yucel and Peterson 2015).

On the other hand, the intensity of the bitter taste of the flavour enhancer was relatively weak (Table 2). Factors such as hydrophobic amino acids, degree of hydrolysis, molecular weight, protease type, and peptide sequence contribute to the bitterness of hydrolysates (Yarnpakdee et al. 2014; Liu et al. 2022). However, NaCl may have suppressed bitterness by binding to hydrophobic amino acids and reducing overall hydrophobicity (Xu et al. 2019). The persistent low bitterness intensity of snail protein hydrolysate may be due to the addition of salt in the flavour enhancer formulation, which suppressed bitterness from the hydrolysis process. Importantly, the consistently low bitterness, even after prolonged hydrolysis, suggests effective modulation of hydrophobic peptides by NaCl and enzyme selectivity, providing insight into the development of milder, more palatable protein hydrolysate seasonings.

In terms of umami taste, hydrolysis of snail protein for 9 h produced higher umami flavour intensity compared to hydrolysis for 3 and 6 h. Short-chain peptides and free amino acids are responsible for the umami flavour in protein hydrolysate (Rosida et al. 2021). Umami peptides contain glutamic acid or aspartic acid residues (Yoshida and Ninomiya 2024). The peptide sequence Trp-Asp-Asp-Met-Glu-Lys was identified as a significant contributor to the umami flavour in *Trachinotus ovatus* fish protein hydrolysate (Deng et al. 2021). Although the present study did not identify specific peptides responsible for umami, our previous results showed increased glutamic acid levels with longer hydrolysis treatments (Ernawati and Rosida 2022), suggesting a potential for umami enhancement. Further research is needed to isolate specific umami peptides.

In terms of aftertaste, aftertaste refers to the lingering sensations and flavours in the mouth after consumption. This study found that the salty aftertaste intensity of snail hydrolysate flavour enhancers was significantly affected by snail type and hydrolysis duration (Table 2). Apple snail protein hydrolysate with 9 h hydrolysis had the highest salty aftertaste, probably due to its high NaCl content (approximately 3.73%, unpublished data). The intensity of the saltiness occurs when sodium ions enter the tongue ion channels and remain in the receptors, contributing to the aftertaste. In addition, protein-salt interactions affect the sodium transport properties in solution, which influences the perception of salty aftertaste (Yucel and Peterson 2015; Sood et al. 2024).

Similarly, the highest intensity of umami aftertaste was observed in the apple snail protein hydrolysate with a hydrolysis time of 9 h. This umami aftertaste is attributed to the presence of umami compounds in the hydrolysates, which produce a mild, long-lasting aftertaste and a furry sensation on the tongue (Yoshida and Ninomiya 2024). The umami aftertaste tended to be similar to the umami taste, salty taste, and salty aftertaste, suggesting that umami compounds may enhance salt perception (Sood et al. 2024).

Additionally, the hydrolysis duration significantly increased the intensity of the lingering mouthfeel of the flavour enhancer. This lingering mouthfeel of snail protein hydrolysate may be due to the umami taste of free glutamic acid, which spreads and coats the entire tongue, unlike the sweet and salty flavours, which were more intense at the tip of the tongue (Yoshida and Ninomiya 2024).

Dissolution of snail hydrolysate flavour enhancers in water produced a yellow colour of varying intensity. This might be influenced by the colour of the snail protein hydrolysate. Longer hydrolysis was associated with decreased brightness and more intense yellow coloration, as noted in the previous finding (Ernawati and Rosida 2022). In this study, the apple snail with hydrolysis for 9 h produces a strong yellow colour intensity with a value of 4.47. Consistent with this, previous studies have shown that the longer the hydrolysis, the more Maillard products occur, resulting in the darker colour of the protein hydrolysate (Xiao et al. 2021).

Principal component analysis. PCA was performed to elucidate the differences in sensory attributes among various samples of snail protein hydrolysate. This analysis considered the positions of attribute and product points within the quadrants, the proximity of vector angles between attributes and products, and the distances from these points to the central axis of the graph (Jariyah et al. 2024). Specifically, three types of plots were generated using PCA: loading plots, score plots, and bi-plots (Figure 2), which together illustrate positive or negative correlations between sensory attributes, as presented in Figure 3.

Initially, the loading plot graph illustrated the relationships between the sensory attributes of the flavour enhancer (Figure 2A). The savoury and umami attributes, for instance, were positioned closely within the same quadrant, indicating a strong positive correlation (Figure 3). In accordance with previous findings that aroma and flavour development in the protein hydrolysate was mostly related to the presence of additional sugars, free amino acids, peptides, nucleotides,

https://doi.org/10.17221/235/2024-CJFS

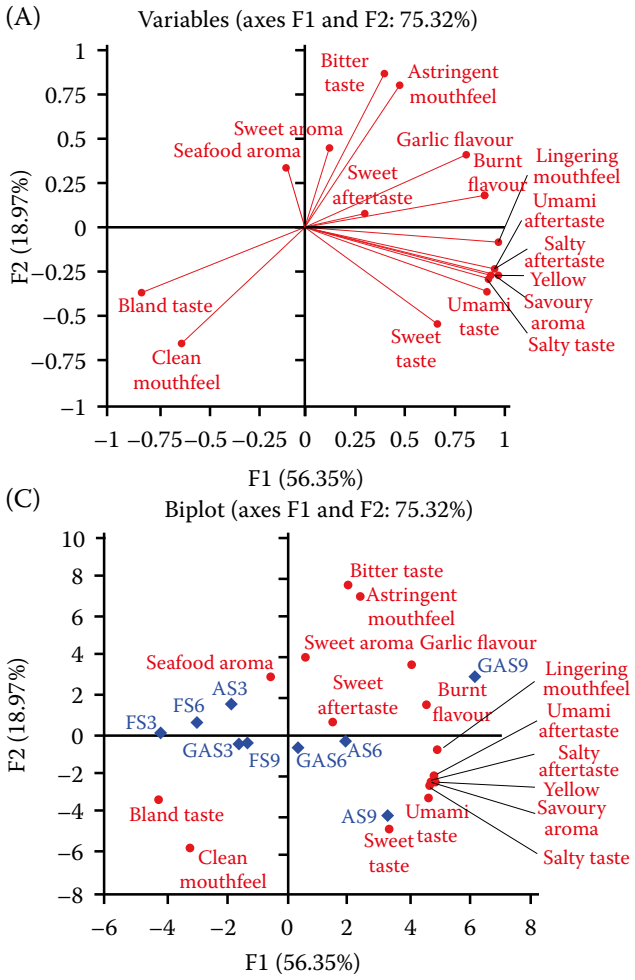

Figure 2. Principal component analysis of flavour enhancer derived from snail hydrolysate. (A) Loading plot (B) Score plot and (C) Bi-plot graph

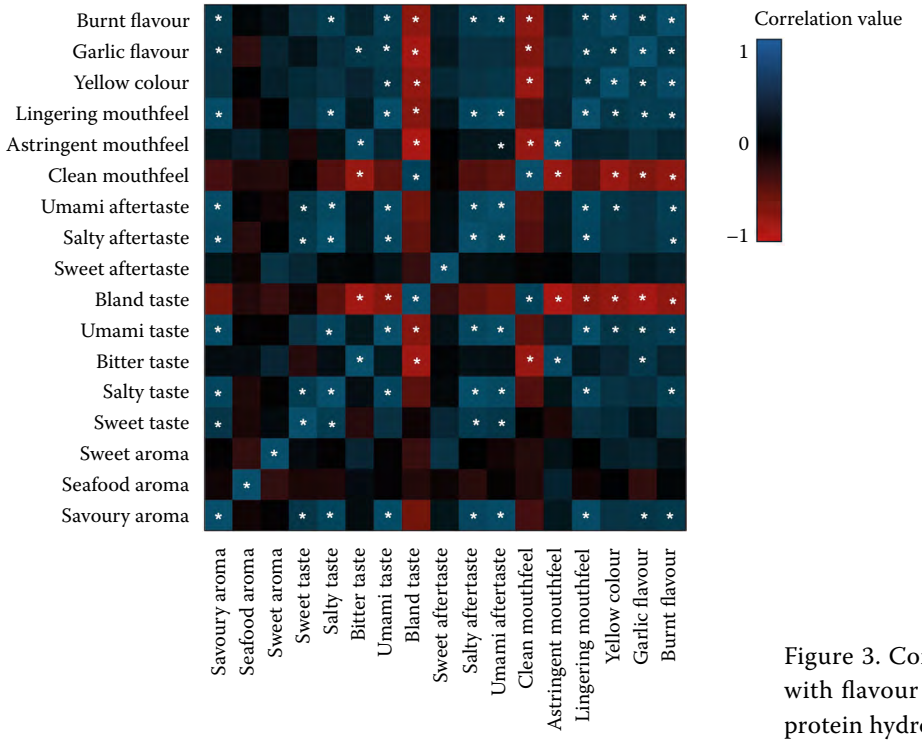

Figure 3. Correlation of sensory attributes with flavour enhancers derived from snail protein hydrolysates

https://doi.org/10.17221/235/2024-CJFS

and organic acids that act as primary precursors (Ali et al. 2022). In contrast, some sensory attributes exhibit distant relationships, such as the aroma of seafood and the salty taste, as well as the sweet aftertaste and the clean mouthfeel.

Next, the score plot showed the relationships between samples, indicating that samples with similar characteristics were positioned closely together, while those with distinct differences were positioned in the opposite quadrants (Figure 4B). In particular, the hydrolysates of golden apple and freshwater snail, with hydrolysis times of 3 and 9 h, respectively, exhibit similar characteristics, as evidenced by their placement in quadrant III. Conversely, the golden apple and apple snail hydrolysates with hydrolysis times of 6 and 3 h, respectively, display differing characteristics as evidenced by their location in opposite quadrants (quadrant II and IV, respectively).

Furthermore, the PCA bi-plot graph effectively illustrated and explained the correlation between the samples and their sensory qualities by combining the loading plot and the score plot (Figure 2C). PCA bi-plots highlight which sensory attributes contribute most to the differences between samples. This is useful for identifying dominant sensory characteristics and understanding how different attributes correlate with each other.

For example, the golden apple snail protein hydrolysed for 9 h was positioned in quadrant I, where sensory attributes such as bitter taste, astringent mouthfeel, sweet aroma and aftertaste, and garlic and burnt flavour were observed. This result suggests that the sample has these dominant sensory attributes. In contrast, the freshwater snail protein hydrolysed for 3 and 6 h and the apple snail protein hydrolysed for 3 h were located in quadrant II with the sensory quality of seafood aroma. Quadrant III of the biplot showed golden apple snail protein hydrolysed for 3 h and freshwater snail protein hydrolysed for 9 h with sensory quality of bland taste and clean mouthfeel. Furthermore, in quadrant IV, apple snail protein hydrolysed for 6 and 9 h and golden apple snail protein hydrolysed for 6 h had sensory qualities of lingering mouthfeel, umami taste and aftertaste, salty taste and aftertaste, savoury aroma, yellow colour and sweet taste.

Overall, the PCA results indicated that each flavour enhancer sample possessed distinct dominant sensory attributes. The PCA method effectively interprets the sensory profile using the RATA method, in accordance with previous reports (Jariyah et al. 2024). Thus, the PCA bi-plots are further combined with consumer preference data to correlate sensory attributes with consumer preference.

Preference mapping. Preference mapping, derived from sensory analysis, identifies attributes that are consistent with panellists' preferences for a flavour enhancer (Bowen et al. 2019). Using agglomerative hierarchical clustering (AHC) and PCA, preference mapping results were overlaid on a contour plot, with colours indicating preference levels: red (80–100%), yellow (60–80%), green (40–60%), light blue (20–40%), and dark blue (0–20%) (Jariyah et al. 2024).

Specifically, the AHC analysis divided consumer panellists into eight clusters based on hedonic scores. Cluster 2 (C2) had the most panellists (21.67%), while cluster 7 (C7) had the fewest (6.67%) (Figure 4A). The contour plot (Figure 4B) showed a high preference for apple snail hydrolysates with 6 and 9 h of hydrolysis (80–100%). Golden apple snail hydrolysates with 6 and 9 h of hydrolysis were moderately preferred (60–80%). Freshwater and golden apple snail hydrolysates with 9 and 3 h of hydrolysis, respectively, were moderately preferred (40–60%). Flavour enhancers in the light blue range, including apple snail hydrolysate at 3 h and freshwater snail hydrolysates at 3 and 6 h, had lower preference scores (20–40%).

Furthermore, the red region of the preference map indicated sensory attributes highly rated by panellists, such as savoury aroma, salty taste, umami taste, sweet taste, different aftertastes (umami, salty, sweet), lingering mouthfeel, yellow colour, and burnt taste. Moderately preferred attributes in the yellow range included clean mouthfeel and garlic flavour. Less preferred attributes in the green region were sweet aroma, bland flavour, and astringent mouthfeel, while bitter flavour (blue region) and seafood flavour (dark blue region) were disliked.

Among the samples, apple snail hydrolysate with 9 h hydrolysis was the most preferred, with attributes such as sweet aftertaste, burnt flavour, lingering mouthfeel, savoury aroma, yellow colour, umami aftertaste, salty aftertaste, salty taste, umami taste, and sweet taste. This flavour enhancer may be well-liked by minimised the disliked attribute, such as bitter taste. Conversely, golden apple and freshwater snail hydrolysates with 3 and 9 h of hydrolysis, respectively, lacked preferred attributes and were characterised by bland taste and clean mouthfeel. Minimising the highly disliked seafood aroma could increase preference for freshwater snail hydrolysates at 3 and 6 h and apple snail hydrolysate at 3 h.

Importantly, integrating sensory attributes with consumer preference data can guide product improvements. Previous studies identified different sensory

https://doi.org/10.17221/235/2024-CJFS

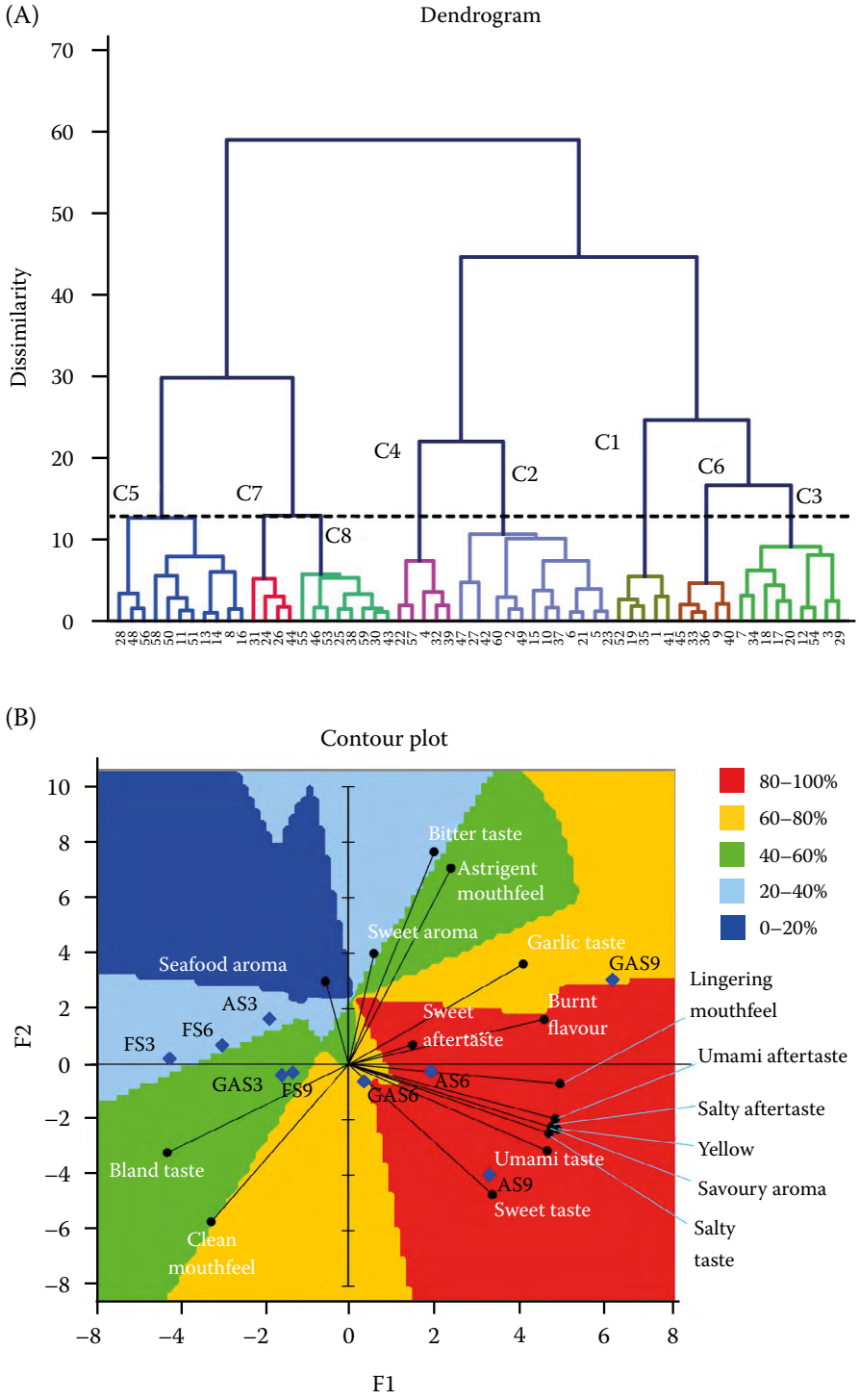

Figure 4. (A) Dendrogram of customer clusters using AHC analysis and (B) panellist preference map for a flavour enhancer derived from snail hydrolysate

profiles in flavour enhancers from different protein sources, such as salmon, herring, and mackerel, which exhibited attributes such as sea flavour, umami, bitterness, and others (Steinsholm et al. 2021). In contrast, protein hydrolysates from defatted peanuts showed different sensory attributes such as astringency, bitterness, and umami flavours depending on the enzyme used (Zhang et al. 2022). The degree of hydrolysis also influences the sensory profile of chicken protein hydrolysate (Steinsholm et al. 2021). These findings confirm that both the protein source and the duration of hydrolysis play a significant role in shaping the sensory profile of protein hydrolysates. In addition, the dominant sensory attributes of protein hydrolysates vary depend-

https://doi.org/10.17221/235/2024-CJFS

ing on their source, which may also be due to the types of sensory attributes evaluated in different studies.

It is also important to note that the sensory panel in this study consisted of 60 semi-trained participants, predominantly female (82%), recruited from a single academic institution. This demographic homogeneity may limit the generalisability of the results. Additionally, no formal calibration or validation procedures were performed prior to the RATA and hedonic assessments. This lack of validation is recognised as a limitation of the study and may affect the reliability and reproducibility of the sensory data. Future studies are encouraged to include a more diverse and representative consumer population to increase the external validity of the sensory data. In addition, although the sensory characteristics of the snail protein hydrolysate samples were thoroughly evaluated, this study did not include direct comparisons with commercial flavour enhancers such as monosodium glutamate or fish hydrolysate. Addressing this limitation in future research would provide a more comprehensive understanding of the sensory performance and practical applications of snail-derived flavour enhancers in food formulations.

Despite these limitations, the results underscore the potential of snail-derived hydrolysates as alternative natural flavour enhancers for use in food applications. The findings contribute to flavour science by demonstrating how specific enzymatic processing parameters can tailor the sensory profiles of protein sources such as snails. From an application perspective, this opens new avenues for the development of regionally inspired, clean-label flavour enhancers that align with sustainable and circular food production strategies.

CONCLUSION

The RATA method was used to investigate the sensory profile of flavour enhancers derived from different snail protein hydrolysates and hydrolysis times. Significant differences were observed in 17 sensory attributes including savoury and seafood aroma, salty, bitter and umami taste, salty and umami aftertaste, lingering mouthfeel and yellow colour. The study showed that snail species and hydrolysis time significantly affected the sensory profile of protein hydrolysates. Despite these differences, consumers liked flavour enhancers with savoury aroma, salty and umami taste, sweet taste, umami and salty aftertaste, lingering mouthfeel, yellow colour and burnt flavour. Apple snail hydrolysate with a hydrolysis time of 9 h emerged as the optimal treatment with high intensities of savoury aroma, salty taste, umami taste, and lingering mouthfeel with preference ratings from 80 to 100% of panellists. However, the small panel size may introduce bias; therefore, future research should include a broader sensory panel to mitigate this and compare the hydrolysate with other natural products in different food applications. These findings can inform the development of snail-based flavour enhancers that are tailored to consumer preferences, thereby increasing product differentiation.

REFERENCES

Ali A., Wei S., Ali A., Khan I., Sun Q., Xia Q., Wang Z., Han Z., Liu Y., Liu S. (2022): Research progress on nutritional value, preservation and processing of fish—A review. Foods, 11: 3669.

Bowen A.J., Blake A., Tureček J., Amyotte B. (2019): External preference mapping: A guide for a consumer-driven approach to apple breeding. Journal of Sensory Studies, 34: e12472.

Deng X., Lin H., Ahmed I., Sui J. (2021): Isolation and identification of the umami peptides from *Trachinotus ovatus* hydrolysate by consecutive chromatography and Nano-HPLC-MS/MS. LWT-Food Science and Technology, 141: 110887.

Ernawati D., Rosida D.F. (2022): The physicochemical properties of flavor enhancer made from different types of snail protein hydrolysates. International Journal on Food, Agriculture and Natural Resources, 3: 1–7.

Hashempour-Baltork F., Farshi P. (2022): Enzymes in flavor development and food preservation. In: Tripathi A.D., Darani K.K., Srivastava S.K. (eds.): Novel Food Grade Enzymes: Applications in Food Processing and Preservation Industries. Singapore, Springer Nature Singapore: 317–356.

Jariyah, Hidayat A.W., Munarko H. (2024): Sensory profile characterization of non-wheat flour biscuits using Rate-All That-Apply (RATA) and emotional sensory mapping (ESM) method. Future Foods, 9: 100281.

Liu B., Li N., Chen F., Zhang J., Sun X., Xu L., Fang F. (2022a): Review on the release mechanism and debittering technology of bitter peptides from protein hydrolysates. Comprehensive Reviews in Food Science and Food Safety, 21: 5153–5170.

Liu S., Sun H., Ma G., Zhang T., Wang L., Pei H., Li X., Gao L. (2022b): Insights into flavor and key influencing factors of Maillard reaction products: A recent update. Frontiers in Nutrition, 9: 973677.

Maulida I.D., Al Marsam M.R., Purnama I., Mutamima A. (2024): A novel beverage with functional potential incorporating cascara (*Coffea arabica*), roselle (*Hibiscus sabdar-*

https://doi.org/10.17221/235/2024-CJFS

iffa), and red ginger (*Zingiber officinale* Rosc. var. *rubrum*) extracts: Chemical properties and sensory evaluation. Discover Food, 4: 94.

Mokhtar A.S., Gilal A.A., Muhamad R. (2024): Invasive apple snails (Ampullariidae): threats and management. In: Wong. M.Y. (ed.): Advances in Tropical Crop Protection. Cham, Springer Nature Switzerland: 263–284.

Moussaoui K.A., Varela P. (2010): Exploring consumer product profiling techniques and their linkage to a quantitative descriptive analysis. Food Quality and Preference, 21: 1088–1099.

Nkansah M.A., Agyei E.A., Opoku F. (2021): Mineral and proximate composition of the meat and shell of three snail species. Heliyon, 7: e08149.

Román S., Sánchez-Siles L.M., Siegrist M. (2017): The importance of food naturalness for consumers: Results of a systematic review. Trends in Food Science & Technology, 67: 44–57.

Rosida D.F., Priyanto A.D., Putra A.Y.T. (2021): Effects of papain concentration and hydrolysis time on degree of hydrolysis and glutamic acid content of apple snail hydrolysate. Nusantara Science and Technology Proceedings, 2021: 17–21.

Sharif M.K., Butt M.S., Sharif H.R., Nasir M. (2016): Sensory evaluation and consumer acceptability. In: Jeantet R., Croguennec T., Schuck P., Brulé G.: Handbook of Food Science and Technology. London, Wiley: 376–378.

Sood S., Methven L., Cheng Q. (2024): Role of taste receptors in salty taste perception of minerals and amino acids and developments in salt reduction strategies: A review. Critical Reviews in Food Science and Nutrition, 65: 3444–3458.

Steinsholm S., Oterhals Å., Thoresen L., Underhaug J., Kousoulaki K., Aspevik T. (2021): Reduction in flavor-intense components in fish protein hydrolysates by membrane filtration. Journal of Food Science, 86: 3855–3867.

Sukkhown P., Jangchud K., Lorjaroenphon Y., Pirak T. (2018): Flavored-functional protein hydrolysates from enzymatic hydrolysis of dried squid by-products: Effect of drying method. Food Hydrocolloids, 76: 103–112.

Xiao Q., Woo M.W., Hu J., Xiong H., Zhao Q. (2021): The role of heating time on the characteristics, functional properties and antioxidant activity of enzyme-hydrolyzed rice proteins-glucose Maillard reaction products. Food Bioscience, 43: 101225.

Xu Q., Hong H., Yu W., Jiang X., Yan X., Wu J. (2019): Sodium chloride suppresses the bitterness of protein hydrolysates by decreasing hydrophobic interactions. Journal of Food Science, 84: 86–91.

Yarnpakdee S., Benjakul S., Kristinsson H.G., Kishimura H. (2014): Antioxidant and sensory properties of protein hydrolysate derived from Nile tilapia (*Oreochromis niloticus*) by one- and two-step hydrolysis. Journal of Food Science and Technology, 52: 3336–3349.

Yoshida R., Ninomiya Y. (2024): Umami and MSG. In: San Gabriel A., Rains T.M., Beauchamp G. (eds): Umami: Taste for Health. Cham, Springer Nature Switzerland: 7–42.

Yucel U., Peterson D.G. (2015): Effect of protein–lipid–salt interactions on sodium availability in the mouth and consequent perception of saltiness: In solutions. Journal of Agricultural and Food Chemistry, 63: 7487–7493.

Yuniarti T., Prayudi A., Setiarto R.H.B., Martosuyono P., Supenti L., Suhrawardan H., Maulani A. (2024): Formulation and organoleptic characteristics of flavor enhancer from shrimp head protein hydrolysate. Food Research, 8: 148–159.

Zhang L., Song C., Chang J., Wang Z., Meng X. (2022): Optimization of protein hydrolysates production from defatted peanut meal based on physicochemical characteristics and sensory analysis. LWT-Food Science and Technology, 163: 113572.

Received: November 20, 2024
Accepted: May 21, 2025
Published online: August 11, 2025