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Original research paper

UNVEILING ADULTERATION IN ACACIA HONEY ORIGINATED FROM TUZLA AREA BY THE PIVOT PROFILE TECHNIQUE

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Abstract: This research aimed to examine the applicability of the Pivot Profile (PP) technique in detecting adulteration in acacia honey from the Tuzla region, Bosnia and Herzegovina (B&H). The PP technique captured the relative meaning of descriptors and gathered free descriptions of differences between a target product and a pivot product (PVT), which served as a standard. Four pairs of samples were evaluated: original acacia honey (PVT) versus honey samples adulterated with 20%, 40%, 60%, and 80% fructose-glucose syrup. The sensory assessment involved 72 participants (25 women and 47 men), all acacia honey producers aged from 20 to 55 years of age. The chi-square test ($\chi^2 = 3032.37$, $p < 0.001$) revealed significant statistical differences among values, indicating that the consumer panel effectively distinguished the samples. The chi-square test per cell was used to explore variation within the data matrix, identifying descriptors significantly differing from PVT in citation frequency. A total of 48 sensory attributes were generated (5 for appearance, 14 for odours, 4 for basic tastes, 3 for aftertastes, 16 for flavours, 2 for trigeminal effects, and 4 for texture). Correspondence Analysis (CA) was employed to visually represent sensory changes in honey samples based on adulteration levels, illustrating consumer perception of samples and attributes. CA effectively explained nearly 60% of the variability observed across the initial two dimensions, thus emphasizing the connection between sensory alterations and consumer perception. The results revealed a reduction in aroma and appearance attributes, along with occurrences of sensory defects such as off-flavours, unpleasant trigeminal effects, and altered viscosity properties.
PP technique provided detailed information about each sample, assessing similarities and differences compared to PVT in a single session using multivariate techniques, contrasting with traditional trained or expert assessments. The PP technique appears promising for further exploration in vocabulary use and data analysis, not only for other honey types but also for various food products susceptible to adulteration.

Key words: *Pivot Profile technique, acacia honey, adulteration*

INTRODUCTION

Significant efforts have been made over the past decade to combat food fraud and improve food authenticity. According to Pharmacopeia's Food Fraud Database (United States Pharmacopeia, 2018), honey is ranked as the third most commonly targeted food for adulteration, trailing only behind milk and olive oil. In response, the European Commission (2016)

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initiated a coordinated monitoring plan in 2015 to investigate the occurrence of adulterated honey in the European market. The findings, released in December 2016, revealed that 15% of the samples were not compliant with the Honey Directive 110/2001 (European Honey Directive, 2021).

According to data from the Chamber of Foreign Trade of Bosnia and Herzegovina, the annual honey production in Bosnia and Herzegovina (B&H) averaged between 2,500 and 2,900 tons over the past half-decade. Approximately 20 - 50 tons were exported annually, with the remaining amount, being consumed domestically (around 250-300 grams per capita) (Foreign Trade Chambre of Bosnia and Herzegovina, personal communication, May 2023). Furthermore, an annual import of approximately 500 tons significantly boosted consumption levels. Concurrently, these statistical data could be considered incomplete due to a significant portion being produced and consumed informally, considering that 40-60% of the total domestic honey production occurred through unofficial channels. The economic sustainability of honey production in B&H is increasingly threatened by rising production costs, reduced honey yields due to industrial agriculture expansion, and declining prices, resulting in lower profits (Hodžić, 2016). Simultaneously, low prices may serve as an initial indicator of potential honey quality issues, prompting the necessity for additional research to assess its authenticity. All the above presented facts not only compromise the statistics regarding the origin of honey and honey-based products but also raise concerns about the consumption of potentially inferior or artificial honey.

In this regard, quantitative descriptive sensory techniques have emerged as initial, effective methodologies for detecting food adulteration (Juárez-Barrientos et al., 2019). During previous research, sensory analysis was utilized to detect adulterated honey, primarily involving panels of trained assessors/experts. A study by Brazilian researchers examined citrus honey adulteration with glucose syrup at 20% and 50% concentrations, comparing parameters like viscosity, aroma, sweetness, and colour (Viana et al., 2012). Guler, Bek and Kement (2008) investigated sensory attributes of honey adulterated through bee feeding with sucrose syrup, finding significant differences in odour, flavour, and taste for filtered honey, but not comb honey. Bodor et al. (2020) examined the sensory profiles of acacia and linden honey, both pure and with added sugar syrup. Their analysis revealed noticeable differences in four parameters for acacia honey and eight for linden honey between authentic and adulterated samples, emphasising the difficulty of detecting lower levels of adulteration in acacia honey.

These studies demonstrated the practical utility of sensory evaluation in identifying adulterated honey, primarily geared towards distinguishing honey sourced from diverse botanical origins (Piana et al., 2004). However, quantitative descriptive sensory techniques trained assessors contribute to increasing ana-lysis time and operating costs of the sensory panel (Dairou & Sieffermann, 2002).

Currently, the food industry requires rapid generation of sensory data, emphasizing insights from the consumer perspective (Worch, Lê & Punter, 2010). Ares and Varela (2018) revealed that consumers can serve as an efficient replacement for trained panellists, providing valuable insights crucial for decision-making, as exemplified by the reference-based Pivot Profile (PP) technique for unrestricted description of sensory products. The PP technique, introduced by Thuillier, Valentin, Marchal and Dacremont (2015), has been applied across a variety of food items, including wines (Pearson, Schmidtke, Francis & Blackman, 2020), chocolate ice cream (Fonseca et al., 2016), Greek yogurt (Esmerino et al., 2017), beef burgers (Rios-Mera et al., 2019), whey-based fermented beverage (Miraballes, Hodos & Gámbaro, 2018), honeys from diverse flower sources (Deneulin, Reverdy, Rébénaque, Danthe & Mulhauser, 2018), and multiflora Mexican honey (Ramón-Canul et.al., 2023). Its versatility and simplicity make it a promising approach for detecting food adulteration. Involving consumers, easy implementation, and the ability to compare products against a reference sample are significant advantages of this sensory evaluation technique.

Considering all the aforementioned factors, there was a challenge in applying the PP technique to detect differences in monofloral honey, particularly in acacia honey, at different levels of adulteration. In light of the foregoing, this research aimed to apply the PP sensory technique and determine its suitability for sensory analysis in the case of adulterated Bosnian acacia honey.

MATERIALS AND METHODS

Ethical considerations

Consumer testing has been conducted fully in accordance with all relevant international guidelines for human research, including the World Medical Association Declaration of Helsinki (2013), the International Ethical Guidelines for Biomedical Research Involving Human Subjects (CIOMS, 2002), and the guidelines of the World Health Organization (WHO 2011).

Honey sample

Acacia honey (*Robinia pseudoacacia*), used as the *Pivot* sample (PVT) or reference, was collected from the beekeeping site Teočak – Tuzla Canton - northeastern B&H. With the support of the Beekeepers' Association of Tuzla Canton, the honey was obtained directly from beekeepers during the 2023 harvest. Subsequently, it was stored in a dark environment at room temperature (<25 °C) for less than 5 months until analysis. The botanical origin of the honey was initially determined by the respecttive beekeepers, by assessing the characteristics of the honey (flavour, odour, colour, texture) and the hive surroundings (hive location, dominant biotope, flowering). Its sensory profile matched the characterization of acacia honey as described by Persano Oddo and Piro (2004).

Sample preparation - Adulteration process

Four samples of adulterated honey were prepared following the method of Ramón-Canul et al., (2023). High fructose - glucose corn syrup was mixed with non-adulterated honey in the following proportions: 20% syrup w/w, (20%); 40% syrup w/w, (40%); 60% syrup w/w, (60%); and 80% syrup w/w, (80%). The non-adulterated sample was coded as PVT (Fig. 1).

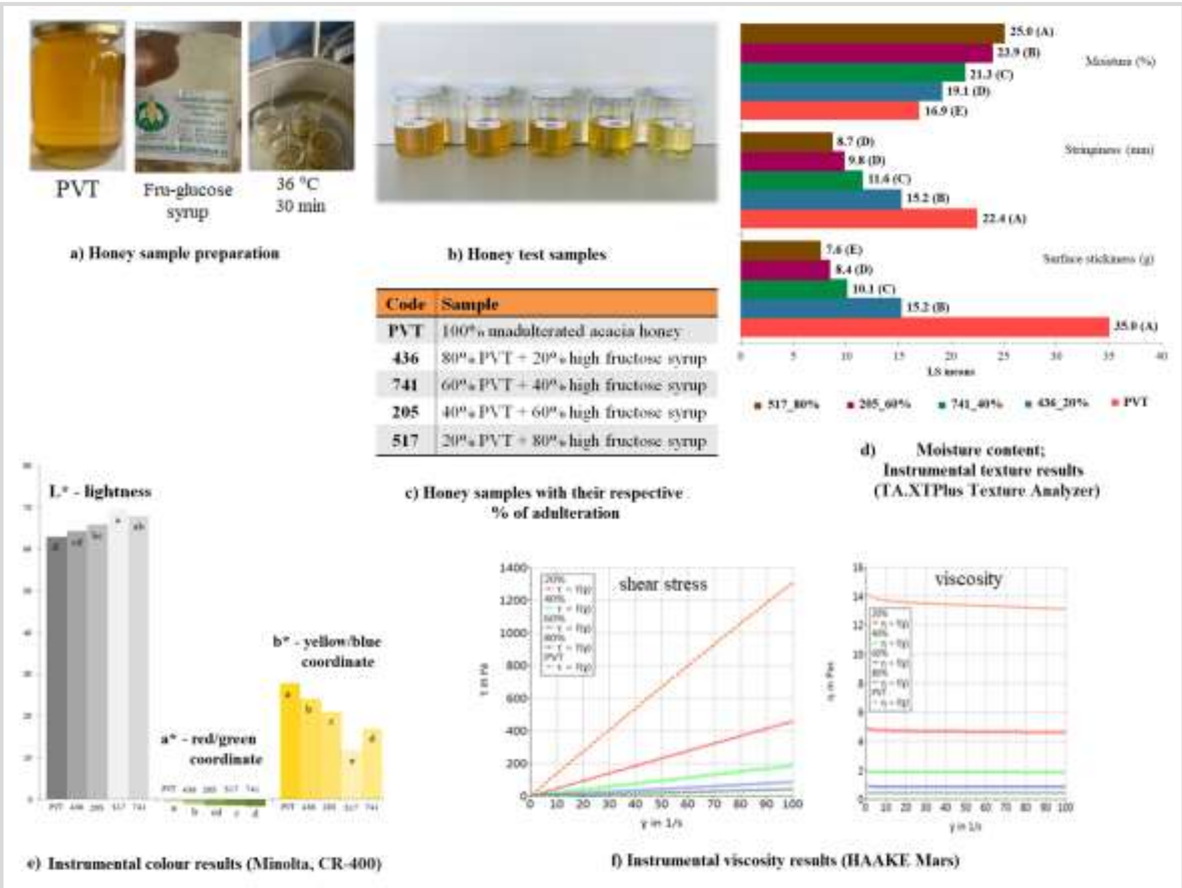

Figure 1. Preparing honey samples (a); honey test samples (b) and their codes with corresponding % of adulteration (c); verifying the adulteration process through moisture content (d), texture (d), colour (e), and viscosity parameters (f)

The mixtures were heated in a water bath at 36 °C for 30 min to ensure homogeneous adulterated honey samples. Moisture level, viscosity, texture, and colour parameters were checked to make sure the honey was adulterated correctly (Fig. 1). According to Fakhlaei et al. (2020), high fructose syrup was chosen for three primary reasons: (a) low cost of the adulterant; (b) its prevalence as the most commonly used honey adulterant in the region under study; and (c) its widespread availability (Fig. 1).

Consume panel

The consumer panel consisted of 72 people (25 women and 47 men) aged 20 to 55, who were honey producers from the area of Tuzla Canton, B&H. Participants in the consumer panel were selected based on their ability to discriminate sensory attributes, according to the guidelines indicated in the SRPS EN ISO 8586-1, (2002), SRPS EN ISO 5496, (2014), and SRPS EN ISO 13301, (2018). Participants met the following criteria: (a) regular acacia honey consumption, (b) absence of honey allergies, and (c) successful completion of discriminatory screening tests. Before participating in the sensory tests, all consumers were briefed on the research objectives, and product ingredients, and signed consent forms. They also received an introductory session on the fundamental principles of sensory evaluation and the distinctive sensory attributes of honey, with a specific focus on acacia honey. Additionally, each participant had access to a sensory atlas that included detailed descriptions of the general sensory profile of acacia honey, instructions for conducting the PP technique, visual characteristics of honey, definitions and methods of flavour perception, a flavour wheel, as well as classifications of textural properties found in food products.

Sensory procedure

The evaluation was organized in a single session at the Chamber of Economy of Tuzla Canton, B&H, during the 18th Fair event ’Honey Tuzla 2023’. The PP technique, as described by Thuillier et al. (2015), was employed to generate a sensory lexicon for the various honey samples. This technique emphasizes the use of a sensory vocabulary table (PVT) that encompasses various sensory attributes to facilitate comparison among samples. Consumers evaluated four pairs of samples, each consisting of a PVT and a well-balanced coded sample, presented sequentially. After tasting each pair, participants responded to two distinct open-ended inquiries. The first question asked about sensory attributes perceived more intensely in the coded sample compared to the PVT, while the second focused on attributes perceived less intensely. More precisely, for each pair, participants were asked to list all perceived attributes in the sample with either lower or higher intensity compared to the PVT (e.g., less honey aroma, more sweetness). Participants were informed that the mention of sensory descriptors was based on their own discretion and perception. They were encouraged to provide descriptions in response to open-ended questions regarding observed differences in attributes, whether greater or lesser in intensity, in the honey samples compared to the PVT, while avoiding hedonistic terms. To standardize the procedure, participants were instructed to first create a list of sensory attributes similar to or different from the PVT on their own paper and to record this list of identified attributes, which most accurately reflect differences in honey sensory quality, in the appropriate Excel tables as a form of evaluation sheet. They were instructed to use only descriptive words without forming sentences. After data collection, calculations were performed on the PVT to compare it with adulterated samples. Since the evaluation method involved paired comparisons (an adulterated honey sample vs. PVT), each participant first assessed the adulterated sample. They then rinsed their mouth with room temperature water (25 ± 5 °C) to remove any lingering aromas before testing the PVT. Honey samples for sensory analysis were presented in 30 g portions (for each sensory test) using 50 mL glass jars with lids.

Data analysis

Data analysis included generating a sensory vocabulary using the PP technique and conducting an initial analysis of adulteration, followed by creating a map illustrating sensory adulteration in honey. Results from the PP technique were derived by counting the number of times each sensory attribute was identified as *'the sample is **less** than the Pivot'* (negative frequency) and *'the sample is **more** than the Pivot*' (positive frequency). Positive values in the contingency table were constructed following Thuillier et al. (2015). Attributes were initially categorized by sensory dimensions - appearance, odour, taste, flavour, and texture, according the criteria of Deneulin et al. (2018), who suggested that attributes mentioned at least five times may be considered more significant. Accordingly, the PP technique was used to characterize honey and assess sensory attributes for various levels of adulteration compared to PVT. Frequencies were adjusted by subtracting negatives from positives, and this difference was added to the smallest achieved value from the attribute table (Table 2). After establishing the sensory terms, initial results were visualized using Correspondence Analysis (CA). To confirm the results obtained from the previous step, Discriminant Analysis (DA) was preformed to deter mine if the panel could differentiate the original sample from the adulterated samples. The analysis was conducted using XLSTAT software, version 2020 (XLSTAT, 2021).

RESULTS AND DISCUSSION

Generation of the contigence table

A contingency table with positive values was constructed following the methods of Thuillier et al. (2015), Fonseca et al. (2016), and Ameca-Veneroso et al. (2021). The attributes were categorized into sensory dimensions: 'appearance', 'odour', 'taste', 'flavour', and 'texture' to enhance clarity in the graphs and reflect natural evaluation processes.

Table 1.
Selected attributes and their corresponding frequency

No.	Attribute*	Frequency	No.	Attribute	Frequency
1	Clarity_AP	109	27	Intesity_F	117
2	Colour_AP	120	28	Persistence_F	21
3	Brightness_AP*	221	29	Fullness_F	5
4	Liquid/thin_AP	22	30	Acacia_F	55
5	Stickiness_AP	13	31	Honey_F	18
6	Intesity_O	201	32	Honeycomb/wax _F	9
7	Persistence_O	7	33	Floral_F	12
8	Acacia_O	30	34	Smoky_F	4
9	Honey_O	7	35	Fermented_F	5
10	Honeycomb/wax _O	10	36	Chemical/plastic_F	17
11	Floral_O	11	37	Caramelized_F*	12
12	Smoky_O	3	38	Acidity_F*	16
13	Chemical_O*	7	39	Fruity/apple_F	12
14	Acidity_O*	10	40	Sugar syrup/sweetener_F	25
15	Sweetness_O	3	41	Vanilla/sweet_F*	10
16	Fruity/apple_O	6	42	Unpleasant_F*	4
17	Caramelized_O*	5	43	Burning_TG	26
18	Unpleasant_O*	17	44	Astringency_TG*	5
19	Uncharaceristic_O	7	45	Texture_TE*	7
20	Intesity_T*	11	46	Liquid/thin_TE*	33
21	Sweetness_T*	26	47	Stringiness_TE	5
22	Acidity_T	56	48	Mouthfeel_TE	13
23	Bitterness_T	28			
24	Stale_AT*	3			
25	Sweetness_AT*	8			
26	Bitterenss_AT*	6			

*AP - appearance; O - odour; T - taste ; AT – aftertaste; F – flavour; TR – trigeminal sensation; TE – texture; *- stands for attributes which discriminated the test samples*

Each assessor evaluated samples based on 5-7 attributes related to the PVT, consistent with findings by Lelièvre-Desmas, Valentin & Chollet (2017), who reported that consumers typically identify around seven sensory attributes per sample. After categorization, a final list of 48 sensory attributes was compiled, including 5 appearance attributes, 14 odours, 4 basic tastes, 3 aftertastes, 16 flavours, 2 trigeminal sensations, and 4 mouth textures. This list was used to construct a contingency table representing five honey samples across these 48 sensory attributes. The number of attributes on the final list (Table 1) is comparable to findings by Pearson et al. (2020), who identified 53 sensory attributes in wines using the PP technique, and to Ramón-Canul et al. (2023), who also identified 53 attributes in multiflora honey. Moreover, Ameca-Veneroso et al. (2021) reported that Mexican consumers identified 52 sensory terms using the PP technique for adulterated coffee samples.

After data standardization, the frequency with which each sensory attribute was cited above or below the PVT (positive and negative occurrences) was depicted in Table 2.

The visualization of positive (+) and negative (-) frequencies, along with the translated frequency provided insight into the intensity of the attributes mentioned relative to those of the PVT.

Table 2.
Example of obtained frequencies for some attributes of the observed sample

Sample	Attribute*	Positive frequency	Negative frequency	Difference	Translated frequency
20%	Clarity_AP	21	-1	20	83
20%	Colour_AP	0	38	-38	25
20%	Brightness_AP	57	0	57	120
20%	Intesity_O	12	41	-29	34
20%	Honey_O	2	7	-5	58
20%	Acidity_T	13	0	13	76
20%	Sweetness_T	53	13	40	103
20%	Bitterness_T	9	0	9	72
20%	Intesity_F	10	20	-10	53
20%	Burning_TG	8	0	8	71
20%	Liquid/thin_TE	69	12	57	120
...	**...**	**...**	**...**	**...**	**...**
40%	Clarity_AP	30	2	28	91
40%	Colour_AP	0	27	-27	36
40%	Brightness_AP	55	0	55	118
40%	Intesity_O	11	37	-26	37
40%	Acidity_T	17	0	17	80
40%	Sweetness_T	53	11	42	105
40%	Bitterness_T	7	0	7	70
40%	Intesity_F	4	25	-21	42
40%	Honey_F	0	17	-17	46
40%	Burning_TG	5	0	5	68
40%	Liquid/thin_TE	72	13	59	122
...	**...**	**...**	**...**	**...**	**...**
60%	Clarity_AP	21	1	20	83
60%	Colour_AP	0	22	-22	41
60%	Brightness_AP	59	1	58	121
60%	Intesity_O	7	40	-33	30
60%	Unpleasant_O	7	0	7	70

Sample	**Attribute***	**Positive frequency**	**Negative frequency**	**Difference**	**Translated frequency**
60%	Acidity_T	10	0	10	73
60%	Sweetness_T	57	7	50	113
60%	Bitterness_T	6	0	6	69
60%	Intesity_F	7	19	-12	51
60%	Honey_F	1	14	-13	50
60%	Chemical/plastic_F	4	0	4	57
60%	Burning_TG	11	0	11	74
60%	Liquid/thin_TE	78	7	71	134
60%	Melting_TE	5	0	5	68
...	...	...	...	...	...
80%	Clarity_AP	33	0	33	96
80%	Colour_AP	0	33	-33	30
80%	Brightness_AP	49	0	49	112
80%	Liquid/thin_AP	9	0	9	72
80%	Intesity_O	8	45	-37	26
80%	Honey_O	0	6	-6	57
80%	Acidity_T	15	1	14	77
80%	Sweetness_T	58	9	49	112
80%	Intesity_F	6	26	-20	43
80%	Honey_F	0	10	-10	53
80%	Sugar syrup/sweetener_F	13	0	13	76
80%	Liquid/thin_TE	73	8	65	128
...	...	...	...	...	...

* *For each attribute, the negative frequency and the positive frequency indicate the number of participants who reported that the sample 20% (80% PVT +20% fructose - glucose syrup) was 'less…' or 'more…' than the PVT. Abbreviations: PVT - unadulterated sample; AP - appearance; O - odour; T - taste ; AT – aftertaste; F – flavour; TR – trigeminal sensation; TE – texture*

Generation of the honey sensory adulteration map

After transforming data into positive values (i.e., frequency translated), a contingency table (Table 2) was created for the pivot profile. Correspondence Analysis (CA) was then employed to visualize the spatial arrangement of samples according to their characteristics, as illustrated in Fig. 2.

Furthermore, the chi-square test ($\chi2 = 3032.37$, $p < 0.001$) revealed significant statistical differences among values, indicating that consumers effectively distinguished the samples.

By applying chi-square per cell, we investigated sources of variation within the data matrix to identify descriptors that significantly differed from the PVT in terms of citation frequency.

Figure 2 shows the representation of the samples and attributes generated by consumers in describing the samples using the PP technique across the first two factors of the CA. The first two factors explained almost 60% of the variability of the experimental data obtained. These variance percentages closely match those reported by Lelièvre-Desmas et al. (2017), who identified 57.68% of the total variance in PP-based beer evaluation.

Additionally, PP-based sensory evaluation explained 56.67% of the total variance in coffee adulteration samples (Ameca-Veneroso et al., 2021), and 72% in monofloral honey adulteration samples (Ramón-Canul et al., 2023).

The attributes that explained differences in the appearance of samples were colour, clarity, and brightness. Odour primarily differed in overall intensity and notes of acacia and honey, which were also observed in aromatic components of flavour. Variations in taste attributes included acidity, sweetness, and bitterness. As the content of the adulterant increased, adultered samples expressed more clarity, while odour intensity and notes of acacia and honey were weaker and acidic, sweet, and bitter tastes were more prominent. Regarding texture variations, they were primarily influenced by changes in viscosity (liquid/thin) whereas the level of adulterant increased, and adultered honey was less viscous. Clear differences can be evidenced among the evaluated samples, dispersed across the four quadrants of the sensory map derived from the CA (Fig. 1), showing a distinct separation between the PVT sample and the adulterated samples.

According to Fig. 2 and Table 2, sample 20% (20% adulteration) was perceived as almost as bright as the PVT. It had a faint yellow colour and a weaker overall odour intensity, including acacia odour. The sample was also perceived as more acidic, sweeter, and slightly bitter. Its flavour intensity, especially the acacia notes, was noticeably lower compared to the PVT. For the other evaluated samples, the perception trend remained consistent, showing significantly increased intensity of the mentioned attributes, both positive and negative, compared to the PVT. This was particularly evident in the increased expression of negative characteristics associated with acacia honey, such as unpleasant odour or flavour, aftertaste, trigeminal effects, and inappropriate appearance and viscosity (Fig. 1; Table 2). Although influenced by factor axis F2 (28.58%), sample 20% could primarily be characterized by attributes such as brightness (Brightenes_AP), sweetness (Sweetness_T), and liquid/thinness (Liquid/thin_TE), exhibiting higher intensity in these characteristics compared to the PVT sample.

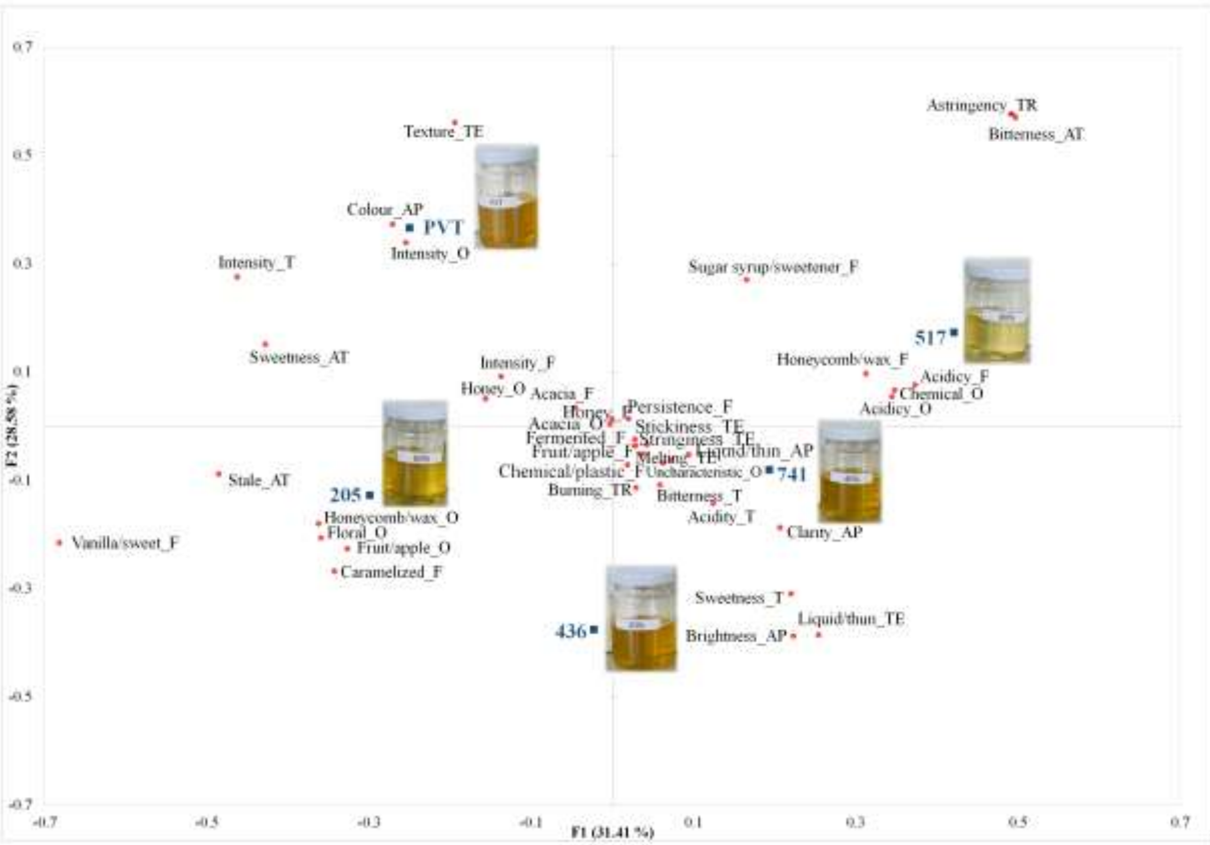

Figure 2. Correspondence analysis biplot of adulterated honey samples using the PP techniques
PVT - unadulterated sample; 20% - 80% PVT +20% fructose - glucose syrup; 40% - 60% PVT +40% fructose - glucose syrup; 60% - 40% PVT +60% fructose - glucose syrup; 80% - 20% PVT +80% fructose - glucose syrup.
Abbreviations: AP - appearance; O - odour; T - taste; AT – aftertaste; F – flavour; TR – trigeminal sensation; TE – texture

Sample 40% (40% adulteration) was perceived as having clarity (Clarity_AP) and being less viscous (Liquid/thin_AP), with noticeable taste differences such as bitterness (Bitterness_T) and acidity (Acidity_T), compared to both the PVT and sample 20%. It was also perceived as having stringiness (Stringiness_AP) and a melting texture (Melting_TE), deviating from the typical sensory characteristics of acacia honey (PVT sample). Atypical odour and chemical flavour notes, considered defects, aligned with the composition of sample 40% as shown in Fig. 2. Sample 60% (60% adulteration) was perceived with attributes such as honeycomb/wax (Honeycomb/wax_O), floral (Floral_O), fruit/apple (Fruit/apple_O), caramelized (Caramelized_F), vanilla/sweet (Vanilla/sweet_F), and stale aftertaste (Stale_AT). Sample 80% (80% adulteration) was perceived with attributes including acidity (Acidity_O), chemical notes (Chemical_O), acidity in flavour (Acidity_F), honeycomb flavour (Honeycomb_F), sugar syrup/swee-tener flavour (Sugar syrup/sweetener_F), astringency (Astringency_TR), and bitterness in aftertaste (Bitterness_AT).

The PVT sample exhibited attributes specific to acacia honey, including a yellow hue (Colour_AP), strong intensity of odour (Intensity_O), taste (Intensity_T), flavour (Intensity_F), and comprehensive viscosity characteristics (Texture_TE). Distinct notes of acacia odour and flavour were perceived, accompanied by a noticeable sweetness in the aftertaste (Fig. 2).

The obtained results can be highly beneficial for understanding consumers' initial sensory experiences with acacia honey and for identifying adulterated samples, consistent with findings by Kreuml, Majchrzak, Ploederl & Koenig (2013). The fact that the 80% adulterated sample was perceived as entirely different honey underscores this understanding. Additionally, employing the PP tech-nique allowed consumer panels to effectively distinguish a wide range of adulterated samples, confirming its utility in analyzing adulte-rated food. These findings align with the conclusions of Lelièvre-Desmas et al. (2017), who highlighted the PP technique's effectiveness in identifying similarities and differrences among samples in their research. Consumer panels using the PP generated sensory descriptors that effectively distinguished ($p < 0.05$) between the PVT sample and the adul-terated honey samples (Fig. 3). This discrimination aligns with findings by Ameca-Veneroso et al. (2021), suggesting that the PP performs best when assessing sample complexity. Confidence ellipses further confirmed differentiation between the PVT (unadulterated sample) and the adulterated honey samples (Fig.3),

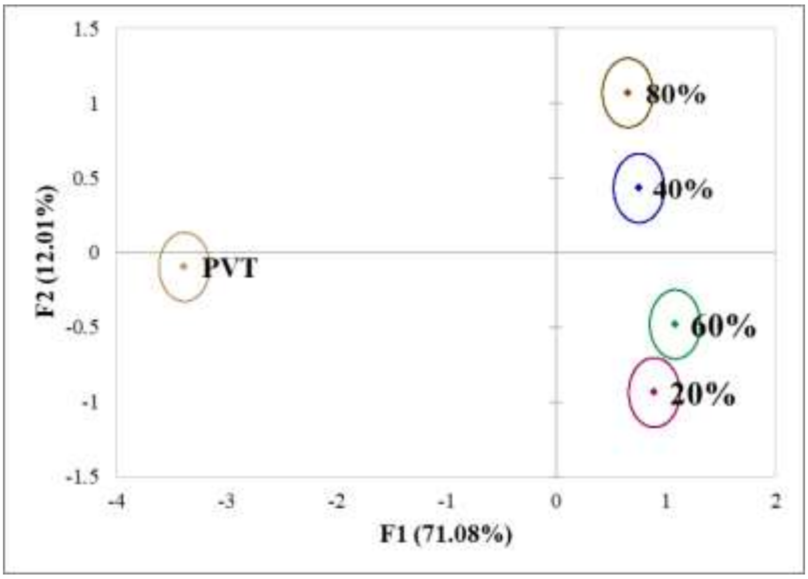

Figure 3. Confidence ellipses (95%) with 500 resamples. Dimension matrix (J * I * K), where J = five honey samples, I = 72 consumers, and K = 48 attributes, totaling 40,280 data points
- unadulterated sample; 20% - 80% PVT +20% fructose - glucose syrup; 40% - 60% PVT +40% fructose - glucose syrup; 60% - 40% PVT +60% fructose - glucose syrup; 80% - 20% PVT +80% fructose - glucose syrup

achieving a 71% classification accuracy. The first factor (F1) was associated with attributes related to appearance and texture, including colour, and brightness, as well as sensory characteristics such as odour intensity, honeycomb/wax-like odour, sweetness in taste, and liquid/thin texture. These associations suggest that the visual and textural properties of the samples were significant contributors to this component. In contrast, the second factor (F2) was primarily associated with attributes linked to flavour, odour, and trigeminal sensations, such as liquid/thin appearance, smoky odour, acidity in odour, flavour intensity, acidity in flavour, sugar syrup/sweetener flavour, burning sensation, and astringency. Moreover, the observed differences among the adulterated samples were indicative of the percentages of added fructose-glucose syrup used for adulteration purposes. Additionally, it was observed that as a consequence of adulteration presence, there was a decrease in the generation of aroma attributes and the generation of sensory attributes considered as defects, which contributed to the clear distinguishing of the honey samples. To confirm the appropriateness of this method, it would be useful to consider the correlation of the PP technique with instrumental data (e.g., colour, texture, chromategraphy, among others).

CONCLUSIONS

This study aimed to evaluate the effectiveness of the Pivot Profile (PP) method in consistently detecting adulteration in acacia honey. Data obtained from this technique and presented via a highly interpretable map of samples and attributes demonstrated its effectiveness in identifying adulterated acacia honey samples and assessing their sensory changes from the perspective of end-users. This technique provided comprehensive information about each sample, assessing similarities and differences compared to a reference sample in a single session using multivariate techniques, unlike the costly and time-consuming approach of trained or expert assessors. With the 48 attributes derived from this PP evaluation procedure, differentiation between PVT (unadulterated) and adulterated samples was enabled, further confirmed by the confidence ellipse technique and precise classification percentages in samples of acacia honey.

The PP technique and the qualification of the reference sample have proven useful and user-friendly for analyzing adulterated foods such as acacia honey. Further PP research should explore its correlation with modern instrumental data to enhance its capabilities in detecting honey adulteration in the market. Additionally, the PP technique appears to be a promising approach that requires further investigation into the use of vocabulary and data analysis, not only concerning other types of honey but also various food products susceptible to adulteration.

AUTHOR CONTRIBUTIONS

Conceptualization, M.V.P.; Formal analysis, N.R.M. and J.M.T.; Investigation, J.M.T., M.J.M. and S.S.H.; Methodology, D.J.Š. and M.V.P.; Supervision, M.V.P.; Writing – original draft, M.V.P. and J.M.T.; Writing – review & editing, D.N.U.S.

DATA AVAILABILITY STATEMENT

The authors confirm that the data supporting the findings of this study are available within the article.

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CONFLICT OF INTEREST

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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OTKRIVANJE PREVARE U BAGREMOVOM MEDU SA PODRUČJA TUZLE PRIMENOM PIVOT PROFILE TEHNIKE

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Sažetak: Cilj ovog istraživanja bio je da se ispita primenljivost Pivota Profile (PP) tehnike u otkrivanju falsivikovanja bagremovog meda sa područja Tuzle, Bosna i Hercegovina (BiH). PP tehnikom zabeleženo je relativno značenje deskriptora i prikupljeni su slobodnin opisi razlika između ciljnog proizvoda i pivota (PVT), koji je služio kao standard. Ocenjena su četiri para uzoraka: originalni bagremov med (PVT) nasuprot četiri uzorka meda falsifikovana sa dodatkom 20%, 40%, 60% i 80% fruktozno-glukoznog sirupa. Senzorska ocena obuhvatila je 72 učesnika (25 žena i 47 muškaraca), proizvođača bagremovog meda, starosti između 20 i 55 godina.
Hi-kvadrat test ($\chi^2 = 3032.37$, $p < 0,001$) je pokazao značajne statističke razlike među dobijenim vrednostima, što je ukazalo na efikasno razlikovanje uzoraka od strane potrošača. Primenjen je hi-kvadrat test po svakoj ćeliji u matrici podataka, identifikujući deskriptore, koji značajno odstupaju od PVT-a po učestalosti citiranja. Generisano je ukupno 48 senzorskih atributa (5 za izgled, 14 za mirise, 4 za osnovne ukuse, 3 za naknadne ukuse, 16 za arome, 2 za trigeminalne efekte i 4 za teksturu). Analiza povezanosti (CA) korišćena je za vizualno predstavljanje senzorskih promena u uzorcima meda na osnovu nivoa falsifikovanja, ilustrujući percepciju potrošačkog panela o uzorcima i atributima. Na osnovu CA dimenzije uspešno je objašnjeno skoro 60% varijabilnosti, ističući vezu između senzorskih promena i percepcije potrošača.
Studija je otkrila smanjenje mirisnih i vizuelnih atributa, kao i pojavu senzorskih nedostataka poput neželjenih aroma, neprijatnih trigeminalnih efekata i promenjenih svojstava viskoznosti. PP tehnika je pružila detaljne informacije o svakom uzorku, procenjujući sličnosti i razlike u odnosu na referentni uzorak u jednoj sesiji korišćenjem multivarijantnih tehnika, za razliku od tradicionalnih ocena obučenih ili ekspertskih ocenjivača. PP tehnika pokazuje značajan potencijal za dalje istraživanje u korišćenju rečnika i analizi podataka, ne samo za druge vrste meda, već i za razne prehrambene proizvode podložne falsifikovanju.

Ključne reči: *Pivot Profile tehnika, bagremov med, falsifikovanje hrane*

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