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Effects of Different Beer Compounds on Biometrically Assessed Emotional Responses in Consumers

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Abstract: The study of emotional responses from consumers toward beer products is an important digital tool to obtain novel information about the acceptability of beers and their optimal physicochemical composition. This research proposed the use of biometrics to assess emotional responses from Mexican beer consumers while tasting top- and bottom-fermented samples. Furthermore, a novel emotional validation assessment using proven evoking images for neutral, negative, and positive emotions was proposed. The results showed that emotional responses obtained from self-reported emoticons and biometrics are correlated to the specific emotions evoked by the visual, aroma, and taste aspects of beers. Consumers preferred bottom-fermentation beers and disliked the wheat-based and higher-bitterness samples. Chemical compounds and concentrations were in accordance to previously reported research for similar beer styles. However, the levels of hordenine were not high enough to evoke positive emotions in the biometric assessment, which opens additional research opportunities to assess higher concentrations of this alkaloid to increase the happiness perception of low or non-alcoholic beers.

Keywords: hordenine; alcohol content; elicited emotions; Geneva images; emoticons; biometrics

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1. Introduction

Emotional responses among beer consumers can be elicited by a combination of different compounds that can produce physiological and positive, neutral, and negative emotional reactions in consumers. The complexity of beer production, from raw material farming; through yeast, grain, and hops selection; to the water composition, fermentation, and brewing process, contributes to the complexity of visual characteristics, such as color, bubble formation, size, and lifetime, as well as the aroma profile, flavor composition, and mouthfeel [1,2]. Furthermore, beer is comprised of complex physicochemical compounds developed from the raw material and brewing process, such as volatile aromatic compounds [3,4], proteins [5,6], sugars, alpha and beta acids, tannins, alcohol [2,7], and alkaloids [8,9], among others.

Previous research has shown that the first visual impression of beer is paramount in the physiological and emotional responses of participants, specifically through parameters related to beer color, foamability, and bubble size [7,10]. The latter has prompted researchers to investigate the effect of the manipulated bubble size of beer through sonication, which showed that stabilizing foamability through bubble size can be achieved and, in this way, change beer's acceptability to consumers [11]. Other studies have been conducted in sparkling mineral water with similar results [7,12]. Hence, these effects add an extra layer of complexity to the interpretation of the effects of aroma profiles and flavor composition. These can be avoided using dark glasses, so tasters in sensory sessions can concentrate only on aroma and flavor profiles [13,14].

There is an increasing amount of commercial software to assess emotional responses from consumers while they are tasting different food and beverage products, such as FaceReader™ (Noldus Information Technology, Wageningen, The Netherlands), iMotions (iMotions, Inc., Boston, MA, USA), Affectiva (Affectiva, Boston, MA, USA) [15], and MorphCast (MorphCast, Florence, Italy). However, many researchers apply these computer applications and rely on the results at face value. Some software, such as FaceReader™, also offers physiological responses, such as heart rate. However, early tests showed no correlation (r = 0.01) with the real heart rate measured from consumers with Oscillometric monitors and finger sensors [16]. There have been advances from commercial companies to improve their models compared to early deployments. Hence, researchers are urged to test this software against ground-truth data with enough participants.

In the case of emotional responses, quick tests can be performed using the Geneva Affective Picture Database (GAPED), which has proven to evoke general emotional responses in the negative, neutral, and positive emotions [17]. This simple test can also confirm the reliability of data obtained from the same consumers previously doing the sensory sessions with products. Other simpler emotional proxies have been used to capture responses from consumers, such as emojis, which may reflect, in part, the emotional state of consumers by association with simple figures through the engagement of mirror neurons as one of the multiple components of more complex underlying processes of emotional empathy [12,18–20].

Happiness has been one of the most researched emotions elicited by food and beverages, and much research has been conducted to elucidate specific compounds that can be related to this emotion [8,21–23]. One of the most promising compounds in beer is hordenine, an alkaloid produced in the barley grain and retained in the beer through the brewing process. This compound is partly responsible for the diuretic effect in beer and, to a lower extent, the bitter taste. Some researchers have claimed that hordenine acts as a stimulant to release dopamine, which contributes to the happy emotion [24–26]; as a result of these publications, it has been published in the media that beer can potentially make consumers happy due to the hordenine content [27,28]. However, prior studies on bioactivity have been conducted using the pure compound in radioligand assays [24,25] by standardizing a volume of beer consumption in humans, further analyzing their blood levels of hordenine and its precursor N-methylthyramine [29], and spiking millet beer to different concentrations of pure hordenine and measuring the correlation of neurotransmitters with hordenine [25]. Nevertheless, previous research analyzed hordenine concentration in six beers obtained naturally from barley grains and showed hordenine to have higher correlations with sad and disgusted self-reported emoticons. These emotions were also correlated to alcohol concentration, alpha acids, and bitterness [8]. These results seem contradictory but may be explained by the lower hordenine concentrations found naturally in commercial beers relative to those required to generate a direct effect at the dopamine D2 receptor [29]. Higher correlations between hordenine and alcohol content [8,9] in prior studies have been attributed to an increased solubility and extraction of this alkaloid in the fermentation process at higher ethanol concentrations [30]. On the other hand, alcohol has been shown to be a depressive compound due to a reduction in serotonin levels [8,31]; however, the action of these negative emotional states may be delayed and not appear for hours or until the next day after beer consumption.

Contradictory results on emotional response and hordenine may also be related to the reliability of the emotional response software/tools used for different studies. Hence, there is a need to implement validation points within sensory trials to confirm outputs from emotional response software. Furthermore, these procedures could benefit significantly from artificial intelligence (AI) modeling to obtain emotional and physiological responses calibrated at the person-by-person scale. Currently, most AI software to extract physiological or emotional responses from consumers has general models or specific cultural-based models, such as for Westerners, Asians, and south-east Asians, among others.

Therefore, this paper proposed incorporating validation points at the beginning of sensory sessions involving beers by using the Geneva image-based database to assess the effects of different beer compounds on the biometric emotional responses of Mexican consumers.

2. Materials and Methods

2.1. Samples Description

Six different Mexican beer samples (Table 1; three bottom and three top fermentation) from different styles were used for this study. The samples were selected from a pool of 32 beers produced in Mexico based on their chemical composition according to the hordenine and alcohol content and international bitterness units (IBU).

Table 1. Beer samples used for the study, including the information used for their selection.

Beer Style	Label	Fermentation	Hordenine ($mg\ L^{-1}$)	Alcohol (%)	IBU *	Best-by Date
Pale Lager	H	Bottom	3.82	5.00	17.65	Jan-23
Pale Lager	H0	Bottom	3.19	0.00	12.60	Jan-23
Pilsner	Ch	Bottom	7.02	4.50	10.90	Jan-23
Pale Ale	MPA	Top	9.66	6.00	29.15	May-23
Pale American Ale	P	Top	7.56	5.20	45.30	Sep-22
American Wheat Ale	MW	Top	3.09	4.30	31.18	Sep-22

* IBU: International bitterness units.

2.2. Sensory Session Description

A sensory session was conducted with N = 73 Mexican beer consumers (49% females; 51% males; age: 18–38 years old; mean age: 22; age standard deviation: 3.11) at the sensory laboratory from Tecnologico de Monterrey, Mexico, on the 7 June 2022 and 8 June 2022. All participants were regular beer consumers, with 82% consuming at least once a week and 18% at least twice a month. The sensory laboratory consisted of five individual booths with uniform lighting and equipped with Android (Googleplex, Mountain View, CA, USA) tablets and the Bio-Sensory application (App) developed by the Digital Agriculture, Food, and Wine group from The University of Melbourne (DAFW-UoM) [32]. Recruitment was conducted through email invitations among the staff and students from Tecnologico de Monterrey. All protocols were approved by the ethics committee from Tecnologico de Monterrey (Ethics ID: CSERDBT-0002), and participants signed a consent form prior to the sensory session.

Samples were stored at refrigeration temperature (~4 °C) for 24 h prior to the sensory session and served at that temperature. For safety reasons, due to the COVID-19 pandemic risks, the beers were served in clear 1 oz disposable plastic cups. Samples were labeled with three-digit random codes and evaluated monadically in random order; furthermore, water crackers and plain water were provided as palate cleansers between samples.

The questionnaire was displayed in the Bio-Sensory App on the tablets. At the start of each sample, three Geneva Affective Picture Database (GAPED) [17,33] images (Figure 1) were displayed one at a time with a question (Table 2) to calibrate participants' emotions. Following the three images, the App showed the sample code to test and questions, as specified in Table 2. Videos of each participant's face were recorded while the participant was evaluating the images and tasting the beer samples to assess their physiological and emotional responses. Figure S1 in supplementary material depicts the sensory session process.

(**a**) (**b**) (**c**)

Figure 1. Geneva Affective Picture Database (GAPED) images used in the study. (**a**) negative; (**b**) neutral; (**c**) positive.

Table 2. Attributes used for the sensory acceptance test of the Geneva Affective Picture Database images and six beer samples.

Attribute	Scale	Anchors/Options	Assessment
Valence	15 cm non-structured	Unpleasant—Pleasant	Images/Beers
Arousal1	15 cm non-structured	Calm—Excited	Images/Beers
Arousal2	15 cm non-structured	Relaxed—Stimulated	Images
FaceScale	100 cm non-structured	😢😟😟🙁😐🙂🙂😊😊	Images/Beers (aroma, taste)
Check all that apply (CATA)	Multiple choice	😀😐🤔😋🙄😖😱😊🙁 😏😍😮😷😕😠😟😵😁	Images/Beers (visual, aroma, taste)
Aroma	15 cm non-structured	Dislike extremely—Like extremely	Beers
Bitter	15 cm non-structured	Dislike extremely—Like extremely	Beers
Sweetness	15 cm non-structured	Dislike extremely—Like extremely	Beers
Acidic	15 cm non-structured	Dislike extremely—Like extremely	Beers
Overall liking	15 cm non-structured	Dislike extremely—Like extremely	Beers

2.3. Computer Vision Analysis—Biometrics

Videos of participants recorded during the sensory session while they were evaluating the GAPED images and beers were automatically analyzed in batches to assess facial expressions translated into emotional responses using software developed by the DAFW-UoM based on the histogram-oriented gradient and support vector machine algorithms from the Affectiva software development kit (SDK; Affectiva, Boston, MA, USA). The variables that were obtained from this software and that were used for this study consisted of head orientation: (i) jaw , (ii) pitch , (iii) roll , and emotions: (iv) joy, (v) fear, (vi) disgust, (vii) sadness, (viii) anger, (ix) surprise, (x) contempt, (xi) valence, (xii) engagement, and (xiii) relaxation. On the other hand, videos of participants that were recorded while they were evaluating the beer samples were analyzed in Matlab® 2021a (Mathworks, Inc., Natick, MA, USA) to assess heart rate using the computer vision algorithm developed by the DAFW-UoM [16], which is based on the photoplethysmography method that evaluates the luminosity changes in the green channel from the RGB color code.

2.4. Physicochemical Analyses

For physicochemical analyses, each sample was degassed in two steps: (i) each beer bottle was agitated for 10 min, and (ii) samples were transferred to a 500 mL flask to be degassed for 90 min by using an ultrasonic sonicator (5800, Bransonic® CPX, Emerson Electric Co., St. Louis, MO, USA). Degassed samples for chromatographic and IBU determinations were stored at −80 °C until further analysis.

2.4.1. Hordenine

Hordenine content was measured using the method described by Sommer et al. [25] and with modifications described by Gonzalez Viejo et al. [8]. Sample preparation included centrifugation and a two-step dilution. Final dilutions were filtered through a Polyvinylidene difluoride (PVDF) syringe filter (0.22 µm, ThermoFisher Scientific™, Waltham, MA, USA). All samples were analyzed in triplicate. A calibration curve (0.001–0.025 ppm) was built using a hordenine commercial standard (Sigma-Aldrich, St. Louis, MO, USA) prepared in acidified water (formic acid 0.1%).

Chemical separation was performed in an Acquity Ultra-High-Performance Liquid (UPLC) Chromatography system (Waters, Milford, MA, USA) coupled with a Quattro Premier XE Micromass UPLC-MS/MS system (Waters, Milford, MA, USA) equipped with a triple quadrupole mass spectrometer (QQQ) and an electrospray ionization (ESI) source in positive mode. The mass spectrometer and UPLC were set in the same conditions stated by Gonzalez Viejo et al. [8] using high-strength silica (HSS) T3 C-18 column (2.1 mm × 100 mm, 1.8 µm particle size) coupled with a VanGuard HSS T3 C-18 column (2.1 mm × 5 mm, 1.8 µm particle) at 50 °C; mobile phases included acidified water (0.1% formic acid) and 0.1% formic acid in acetonitrile/ethanol (70:30 *v*/*v*) delivered in a 6.6 min gradient.

2.4.2. Iso-Alpha Acids

The characterization of iso-α-acids was conducted according to Gonzalez Viejo et al. [8] by triplicates with slight modifications. Samples were filtered through a polytetrafluoroethylene (PTFE) syringe filter (0.2 µm) into a chromatographic 2 mL vial and were then injected into an Acquity H-Class Ultra-Performance Liquid Chromatography (UPLC, Waters, Milford, MA, USA) coupled with a Photodiode Array Detector (PDA), with monitoring at 270 nm and 330 nm. These compounds were separated using a Zorbax Extend C-18 column (100 × 3 mm, 3.5 µm particle size, Agilent, Santa Clara, SA, USA) with a constant temperature of 35 °C. Mobile phases consisted of 5 mM ammonium acetate in 20% ethanol (pH 9.95) and acetonitrile/ethanol (60:40 *v*/*v*), and the solvent flow rate as stated by Gonzalez Viejo et al. [8] with 20 min recalibration following each injection. The iso-alpha-acids were identified using different methods: (i) comparison with ultra-violet/visible (UV/Vis) spectral characteristics from the literature [34], (ii) with retention times and UV/Vis spectra from the standards of the American Society of Brewing Chemists (ASBC), and (iii) elution order or retention times based on the literature with a similar method [34,35].

2.4.3. Sugar and Alcohol Determination

Fermentable sugars (mg L^{-1}) and ethanol (%ABV) were analyzed in triplicate using HPLC (Prominance i LC-2030C-Plus, Shimadzu, Columbia, MD, USA) with Refractive Index Detector (RID-20A, Shimadzu, Columbia, MD, USA), as stated by Chuck-Hernandez et al. [36]. Samples were filtered through PTFE syringe membranes with a 0.22 µm pore size. The column that included an ionic exchange RezexTM ROA-Organic Acid H+ (8%) (250 × 4.6 mm, particle size of 3.5 µm, Phenomenex, Torrance, CA, USA) with Phenomenex SecurityGuard at 60 °C was used for the chromatographic separation, and the mobile phase was acidified water with sulfuric acid (5 mM H_2SO_4) (96–98%; Desarrollo de Especialidades Químicas, San Nicolas de los Garza, N.L., Mexico) and was delivered by isocratic flow at 0.4 mL min^{-1}. Calibration curves were developed with 0.71–10 mg·mL^{-1} for maltotriose, 10–140 mg·mL^{-1} for maltose, and 3.57–50 mg·mL^{-1} for glucose.

2.4.4. Other Physicochemical Analyses

The pH of the samples was measured by using a potentiometer (Orion Star Series, Thermo Scientific, Waltham, MA, USA), and acidity was measured via titration with NaOH. Bitterness was assessed in international bitterness units (IBU) by isooctane extraction using a spectrometer (Genesys 10SUV, Thermoelectron) with absorbances recorded at 275 nm. All measurements were conducted in triplicate, as described by the ASBC [37] and Gonzalez

Viejo et al. [8]. Soluble solids (Brix) were measured in triplicate using a digital refractometer (AT-PAL-3, Atago, Saitama, Japan).

2.5. Statistical Analysis

Sensory data were analyzed using multivariate analysis of variance (MANOVA) with Wilks' lambda test, univariate analysis of variance (ANOVA), and Fisher's least significant difference (LSD) post hoc test ($\alpha = 0.05$) to assess significant differences between studied beer samples. Additionally, the check-all-that-apply (CATA) tests from the GAPED images and visual, aroma, and taste evaluations of the beer samples were analyzed using correspondence analysis (CA) to assess the associations between samples and emojis. On the other hand, two multiple-factor analyses (MFA) were conducted for (i) the GAPED images using the self-reported responses, biometrics, and CATA, and (ii) the beer-tasting sensory results from CATA from beer taste, self-reported and biometric responses, and the physicochemical parameters to assess relationships among variables and associations between samples and variables. All data were analyzed using XLSTAT 2020.3.1 (Addinsoft, New York, NY, USA).

3. Results and Discussion

3.1. Multivariate and Univariate Analysis of Variance (MANOVA and ANOVA)

Results from MANOVA showed that the interaction between samples and the self-reported and biometric responses was significant (Wilks' lambda $p < 0.05$; Table S1) when considering all variables simultaneously.

Figure 2 shows results from the univariate ANOVA with only the variables with significant differences ($p < 0.05$) between samples for eight self-reported responses for acceptability. The full details of the ANOVA can be found in the supplementary material (Table S2). It can be observed that beers Ch and H, which are from bottom fermentation and with alcohol content (4.50% and 5.00%, respectively), were the most acceptable for bitterness (9.61 and 9.53, respectively) and had similar scores for sweetness (Ch = 9.58; H = 9.00), acidic taste (Ch = 8.63; H = 9.14), and overall liking (Ch = 9.75; H = 10.09). Similarly, H had the highest score for FaceScale (positive emotion; 10.07), followed by Ch (9.71). On the other hand, P was the least accepted for bitterness (6.72), sweetness (7.14), and acidity (6.99), and the lowest in FaceScale scores (negative emotions; 7.93). In general, it can be observed that top-fermentation beers (P, MW, and MPA) were less accepted than those from bottom fermentation (Ch, H, and H0).

Acceptability results were in agreement with Brazilian consumers' preferences, which presented higher acceptability for bottom-fermentation beers, such as American pilsener, with lower bitterness [38]. Bottom-fermented beers were not as popular in craft breweries in the first half of the twentieth century since they require artificial cooling during fermentation and a longer maturation time, which increased production costs. Only larger companies started producing them and popularized them through aggressive marketing strategies in media and television [38], which may have influenced the perception of consumers. Furthermore, lager (bottom-fermented) beers dominate the Mexican market with 71% representation for the beer category [39].

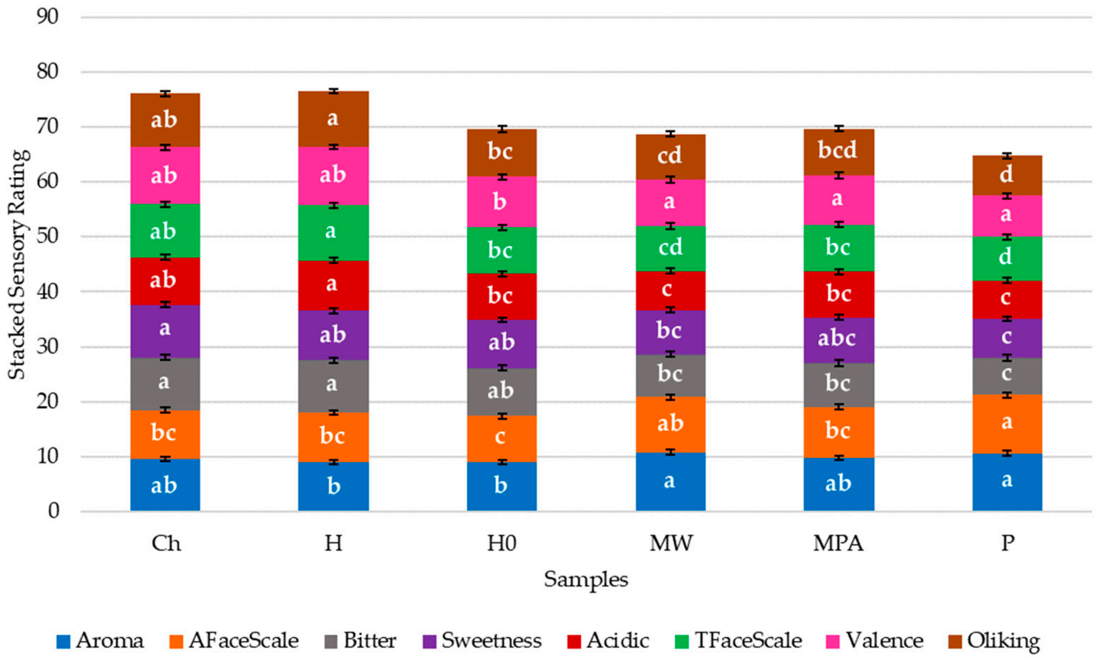

Figure 2. Stacked graph showing the means and standard error bars of the statistically significant self-reported consumer sensory responses. Different letters a–d denote significant differences according to the ANOVA and Fisher's least significant difference (LSD) post hoc test (α = 0.05). Abbreviations: AFaceScale: FaceScale from aroma; TFaceScale: FaceScale from taste; Oliking: overall liking. Sample abbreviations are shown in Table 1.

3.2. Multivariate Data Analysis

3.2.1. Correspondence Analysis

Figure 3a shows the correspondence analysis of the GAPED images and the self-reported responses for the CATA of emojis. Factors one and two (F1 and F2) represented a total of 100% data variability. It can be observed that consumers were able to accurately discriminate the three images according to positive, neutral, and negative emotions. This is usually used as a baseline to assess any possible bias in consumers' self-reported responses. Figure 3b explains a total of 60.89% data variability (F1 = 40.32%; F2 = 20.57%) and shows that for visual attributes, the samples H, H0, P, and MW elicited more positive emotions (😁, 😃, 😋, 😊) than Ch and MPA. Conversely, when smelling the samples, Ch, MW, and MPA produced the most positive emotions (😃, 😁, 😊, 😍, while P had the most negative responses (😖, 😟, 😲, 😠, 😷); these results are represented in Figure 3c, with a total of 69.75% data variability (F1 = 50.48%; F2 = 19.27%). Furthermore, once the samples are tasted, as observed in Figure 3d with a total of 76.93% data variability (F1 = 59.94%; F2 = 16.99%), consumers were more able to discriminate the beers in terms of emotions, with H, Ch, and H0 (bottom fermentation) generating the most positive responses (😊, 😍, 😋, 😁, 😃) and MPA, P, and MW (top fermentation) being the samples associated with negative emotions (😖, 😷, 😠, 😵, 😟). The latter results coincide with the ANOVA, as bottom-fermentation beers were significantly ($p < 0.05$) more accepted than those from top fermentation.

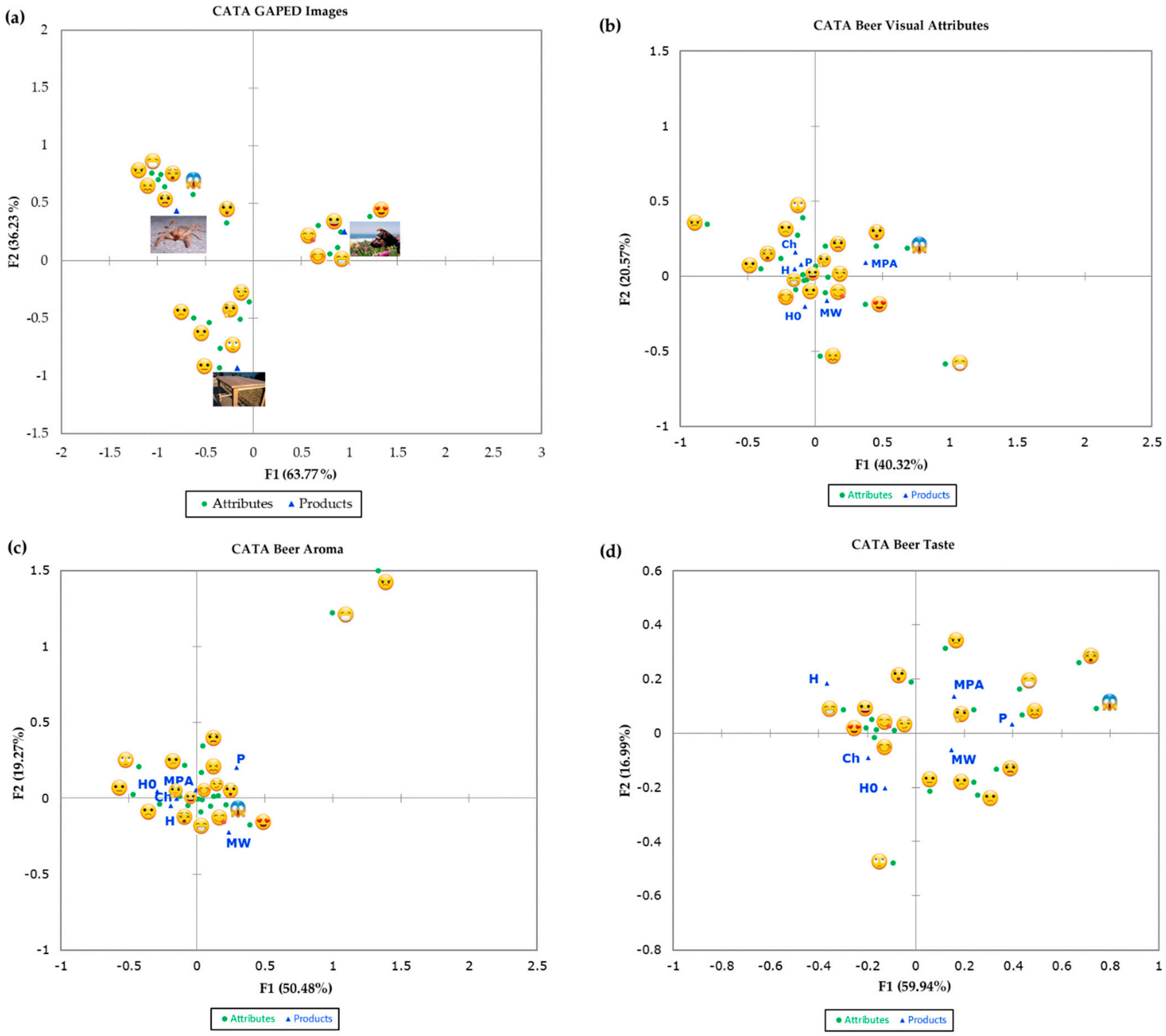

Figure 3. Correspondence analysis using the check-all-that-apply (CATA) with emojis from (**a**) the Geneva Affective Picture Database (GAPED) images, (**b**) visual attribute, (**c**) aroma attribute, and (**d**) taste attribute evaluation of the beer samples. Abbreviations of the beer samples are found in Table 1. Other abbreviations: F1 and F2: factors 1 and 2.

Results showed that self-reported emotional responses from participants through emoticons could represent the separation between emojis related to neutral, positive, and negative emotion-based images. Hence, the emojis used by consumers for the different beers tested visually, for aroma, and for taste were an accurate representation of consumer responses. Emojis have been used for different food and beverage products, such as coffee labels [19], beer [8], insect-based food [40], carbonated water [12], fermented milk [41], and kefir [42], among others.

3.2.2. Multiple Factor Analysis

Factors one and two in Figure 4a represented a total of 100% data variability, which shows that consumers were able to discriminate the GAPED images through multiple factors from the self-reported liking responses and CATA of emojis, along with the subconscious responses (biometrics). Figure 4b represented a total of 66.14% data variability

(F1 = 45.46%; F2 = 20.68%). In terms of correlations between the factors and variables, it can be observed that F1 was represented mainly by IBU (r = 0.98), 😖 (r = 0.97), and AFaceScale (r = 0.93) on the positive side of the axis, and by bitter (r = −0.96), sweetness (r = −0.95), and valence (r = −0.90). On the other hand, F2 was characterized mainly by sadness (r = 0.96),  (r = 0.88), and 😲 (r = 0.82) on the positive side of the axis, and pH (r = −0.79) and Adhumulone (r = 0.73) on the negative side. Bottom fermentation samples were grouped and associated with variables such as surprise, maltotriose, acidity liking, TFaceScale, valence, and overall liking, along with positive emotions 😋,😁, 😃. On the other hand, MPA sample was mainly associated with disgust, hordenine, sadness, and 😲, while P was related to physicochemical parameters such as Brix, ethanol, and most iso-alpha acids, as well as the angry emoji 😠. Sample MW was associated with pH and adhumulone, as well as fear and .

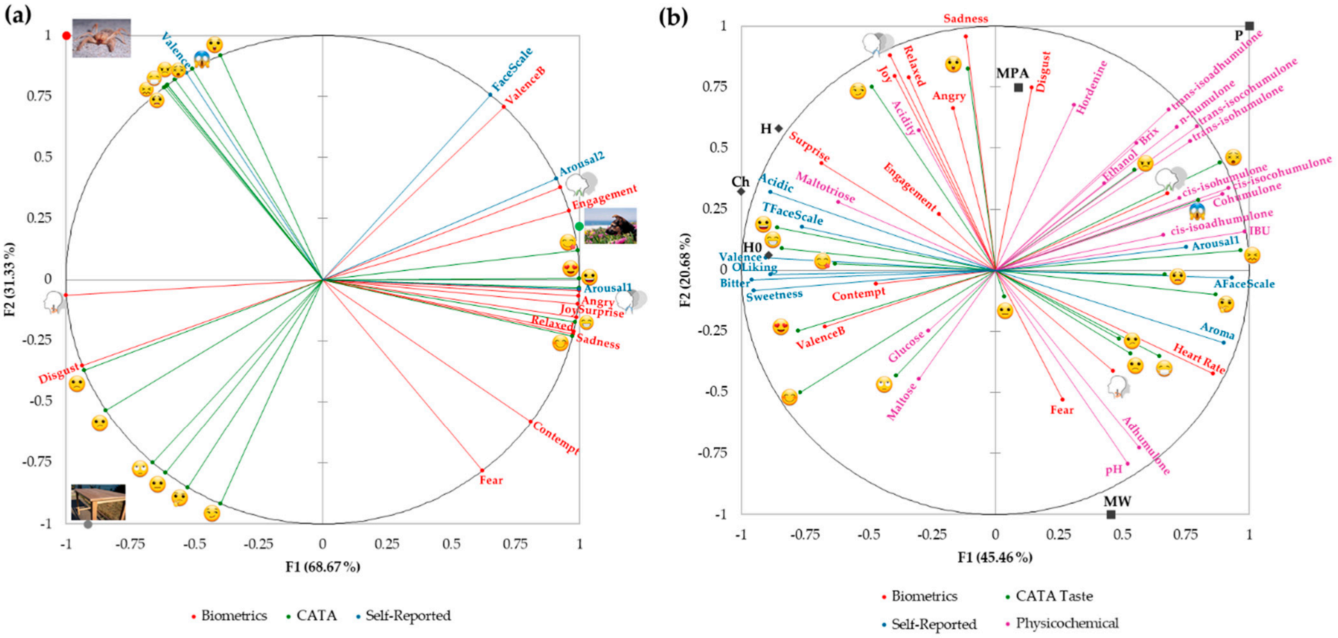

Figure 4. Multiple factor analysis (MFA) using the (**a**) check-all-that-apply (CATA) with emojis, self-reported and biometric responses from the Geneva Affective Picture Database (GAPED) images, and (**b**) physicochemical parameters, self-reported and biometric responses, and check-all-that-apply (CATA) with emojis from taste attribute evaluation of the beer samples. Abbreviations of the beer samples are found in Table 1. Other abbreviations: F1 and F2: factors 1 and 2; ValenceB: valence biometrics; AFaceScale: FaceScale from aroma; TFaceScale: FaceScale from taste; IBU: international bitterness units.

The largest separation of MW from the other top-fermentation samples may be due to two main reasons which are related to each other: (i) MW is produced from wheat, while the others are produced from barley, and (ii) MW had the lowest hordenine content (3.09 mg L^{-1}), while samples P and MPA had the highest values (7.56 and 9.66 mg L^{-1}, respectively). It can be observed that bottom fermentation samples, which were positively associated with sugars such as maltotriose and negatively associated with hordenine, iso-alpha acids, and IBU elicited more positive self-reported and subconscious responses, regardless of the alcohol content (Table 1). However, samples with the highest direct associations with hordenine, iso-alpha acids, and IBU were more related to negative emotions from both self-reported and biometric responses.

Very few studies have presented validation points when interpreting data from either emojis or biometrics using facial expression analysis of participants. Nevertheless, this study was able to show a logical correspondence between the evoked emotional response, self-reported emojis, and digitally obtained emotional responses from participants. These methodologies can be used to calibrate AI models at the person-to-person scale using initial imagery, such as the ones from the GAPED database. The latter will broaden applications beyond the general classification, and based on cultural background, it can also be applied to track changes in preference evoked by different packaging, labels, promotional material, or peer pressure in social environments.

The acceptability by beer consumers mostly agrees with published research [8] in terms of physicochemical compounds and levels of preference for each or a combination of both. This shows that there are no major limitations in using disposable plastic cups compared with glass cups. Furthermore, hordenine concentration and relation to happiness were not found in this study (Figure 4), which is in accordance with previous studies using natural hordenine concentrations on beers from grains and through the specific fermentation process [8]. A higher concentration of hordenine was found in top-fermented beers, with the exception of the wheat-based beer (Table 1), which is in accordance with the higher concentrations in barley compared to wheat, which acts as an allelopathic compound to deter predatory insects after germination [43]. However, these hordenine concentrations were not high enough to elicit positive emotions compared to early studies which used pure or spiked hordenine [24,25]. This is supported by Sommer et al. [29], who concluded that the hordenine concentration in beer is not enough to produce dopamine release; however, cumulative effects and interactions with other components may elicit responses. This would require further testing with a larger amount of beer consumption; however, experiments need to be carefully designed to avoid possible ethics concerns due to the cumulative level of alcohol intake.

4. Conclusions

It is important to have validation points for tools that are used to assess emotional responses of consumers in the evaluation of food and beverage products. These validation points can be used for AI modeling at the person-by-person scale to obtain more insights into food and beverage acceptability. Validation points can also be used to calibrate neuromarketing strategies focused on the modifications of promotional material, packaging, and labeling. Chemical profiles and concentrations were consistent with prior studies for similar beer styles. Consumer acceptability responses were also confirmed as a marked preference for bottom-fermentation beers, with less affection for the wheat-based and more bitter samples. However, hordenine content in the evaluated samples did not correlate to positive emotional responses, possibly due to its lower concentrations. More studies are needed with experimental designs focused on studying the effects of hordenine at higher concentrations and the interaction of the alkaloid with ethanol and other precursors reported to influence human well-being emotions. Further research may produce novel opportunities within the brewing industries to explore product development focused on happiness through beer consumption and the reduction or elimination of alcohol content.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/fermentation9030269/s1, Figure S1: Diagram showing the flow of the sensory session from the previous day for sample storage, along with samples and descriptors assessed. Specific beer samples used are shown in Table 1 in the manuscript; Table S1: Results from multivariate analysis of variance using sensory self-reported responses and biometrics; Table S2: Details of the ANOVA of the self-reported responses from the sensory session. Abbreviations: AFaceScale: FaceScale from aroma; TFaceScale: FaceScale from taste.

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