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Performance of evaluators in a descriptive analysis of black pepper (*Piper nigrum* l) from Ivory Coast

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Abstract

The objective of this study was to evaluate the performance of a panel in the sensory characterization of pepper from Ivory Coast through three criteria: discrimination, repeatability and agreement. Twelve trained panelists evaluated fresh, dry and ground pepper samples from seven localities during three sessions on twenty sensory descriptors. The analysis was performed by XLSTAT version 21 using the Friedman test at $p<0.05$ and principal component analysis (PCA). The Friedman test revealed significant discrimination for all descriptors with the highest scores for Crunchy (631.22); Floury (585.54); Smooth (683.35); Round (554.84); Rough (674.78). Repeatability was satisfactory for the majority of sensory descriptors although deviations ($p<0.05$) were noted for Hazelnut, Floury, Bitter and Green. The PCA showed a good agreement between judges explaining 63.56% of the total variance. Finally, the highest standard deviations were observed for the samples of ground pepper from Yakassémé (2.68), fresh from Maféré (2.56), Guiberoua (2.51) and Yakassémé (2.48) and dry from Yakassémé (2.40) reflecting sensory heterogeneity. These results validate the reliability of the panel for future analyses on the sensory profile of Ivorian pepper.

Keywords: Sensory Descriptors; Performance; Pepper; Discrimination; Repeatability

1. Introduction

Spices and aromatic herbs are substances of plant origin, playing a fundamental role in the seasoning of food. Among them, black pepper (*Piper Nigrum L*) known as the king of spices, is the most popular and the third most consumed food in the world [1]. Used as much for its taste qualities as for its medicinal virtues, it represents a strategic commodity for several producing countries. However, Africa contributes only 6% to the world production of pepper with countries like Madagascar, Ghana or Ethiopia in the lead [2]. Ivory Coast, although a producer of pepper, remains marginal in this market with an annual production of less than 60 tons and a market dominated by Asian imports. In a context of increased competitiveness, the valorization of Ivorian black pepper inevitably requires a better knowledge of its sensory qualities. Despite the growing interest in the sensory analysis of food products, very few studies have been devoted to the sensory characterization of black pepper produced in Ivory Coast. Furthermore, the performance of the panels used for these analyses in terms of discrimination capacity, repeatability or agreement between assessors is rarely examined in depth. This lack of data specific to the Ivorian context reveals a significant gap in the scientific literature. It is therefore necessary to conduct studies that integrate not only the sensory analysis of Ivorian pepper but also a rigorous evaluation of the performance of the panels involved. It is with this in mind that this study aims to evaluate the performance of a panel trained in the descriptive sensory analysis of black pepper from Ivory Coast. Three main criteria were taken into account: discrimination, repeatability of assessors and their agreement. The objective is to assess the reliability of the panel as a sensory analysis tool, with a view to better commercial promotion of Ivorian pepper on local and international markets.

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2. Material and methods

2.1. Material

The plant material consisted of fresh pepper (*Piper nigrum*) (PF), dry pepper (PS). The ground peppers (PM) were obtained by grinding the dry pepper. They were collected in seven (7) producing localities of the country and sampled in triplicate: Azaguié, Maféré, Guibéroua, Niablé, Yakassémé, Lopou, Assouba.

Figure 1 Fresh peppers in bunches and destemmed dried peppers

2.2. Methods

2.2.1. Selection of sampling sites

A survey previously conducted by FIRCA [3] among pepper producers in Côte d'Ivoire identified thirty-eight (38) pepper plantations in production. Taking into account the geographical location and the distribution of soils in Côte d'Ivoire, these plantations were grouped into seven (7) different localities aforementioned.

2.2.2. Sampling

Samples of fresh and dried peppers were collected from producers in the seven (7) localities of Ivory Coast. In each locality, (3) three samples of 1.5 kg of fresh pepper and (3) three samples of 1.5 kg of dried pepper were collected. After collection, the fresh pepper samples were packed in coolers.10 kg containing dry ice. The samples were transported directly to the Nutrition and Food Technology Laboratory of UMRI SAPT of the Houphouët Boigny National Polytechnic Institute (INP-HB). Knowing that a sample is made up of 1.5 kilograms, a total of twenty-one (21) samples for fresh peppers and twenty-one (21) samples for dried peppers were the subject of this study.

2.2.3. Selection of tasters

The selection of subjects was carried out in accordance with the ISO 8586-1 standard [4]. A questionnaire was carried out according to the method of [5] and consisted of collecting a certain amount of information from people (about a hundred) made up of students from the Polytechnic Doctoral School (EDP) and the School of Agronomy (ESA) as well as from the staff of the ESA of the INP-HB. In this questionnaire, it was necessary to specify the preferences regarding tastes, flavors, textures, aspects and colors of food. Also, these different people interviewed had to give the constraints to which they were subjected in terms of food or allergies that they may have and their level of interest in the project. Also, these respondents had to indicate their availability in terms of days and times when they could carry out a taste test. Questionnaires were distributed to 100 individuals and 78 people were able to provide feedback, i.e. 78% of respondents due to 56 men (71.79%) and 22 women (28.20%). Then, taking into account the eligibility conditions, i.e. food preferences, allergies, availability and interest in the project but especially any previous participation of the individual in at least one panel, 12 people were selected.

2.2.4. Panel training

This training was carried out according to the method of [5] and the definitions described by [6]. It took place from 02-13-2021 to 02-27-2021 and was carried out in two stages. The first theoretical training was carried out on the basis of a physical document containing information on the definitions of sensory analysis, the importance of sensory analysis in the food industry, neurophysiological aspects, the constitution of a sensory group, the layout of a sensory evaluation laboratory and the different categories of test in sensory analysis distributed to the 12 people. The second part of this theoretical training was dedicated to the general definition of descriptors (complex and simple) and to generate

together (selected tasters and facilitator) a probable list of complex descriptors and simple descriptors specific to pepper. The list of complex descriptors retained has been: color, texture, aroma and taste. The simple descriptors assigned to each complex descriptor have been defined as follows: Texture: smooth, rough, crunchy, floury and round; Color: green, black; Aroma: herbaceous, mushroom, spicy, hazelnut, woody and mint; Taste: bitter, salty, pungent, refreshing, acidic, umami, warm. Thus, the rest of the training was carried out using this established list of complex and simple descriptors. The twelve (12) people who agreed to participate in the taste tests were subjected to an examination to determine whether they had "normal" sensory acuity. This phase was carried out by asking them to identify basic flavors, odors as well as common textures, aspects and colors. A sample of the different common products listed according to the method of [7] with a three-digit code was presented to each member of the panel. In total, 24 common products in the form of a sample were presented to each member of the panel. The results obtained at this stage indicated that more than 50% of the tasters had normal sensory acuity, which would mean that these tasters can move on to the stage of testing their ability to distinguish between different levels (different concentrations) of a sensory characteristic.

2.2.5. Preparation of samples for sensory analysis

The dry pepper samples were ground into powder in a laboratory dry grinder to obtain the ground pepper (PM) samples. The dry and ground pepper samples were stored in dyed bottles wrapped on the outside with aluminum foil and then placed in a cupboard away from light. As for the fresh samples, they were packaged in food-grade plastic bags and then stored at a temperature of 4°C. About 30 g [8] of the different forms of pepper were weighed in three (3) separate glasses and then covered with plastic film to prevent the evaporation of some essential characteristics of the pepper. The samples were made in the preparation room and then placed in the tasting room.

2.2.6. Sensory descriptive analysis procedure

The sensory profiles of peppers were developed by the panel using the quantitative descriptive analysis method according to the standard [9]. A graduated interval scale from 0 to 9 was used. Consensus among the panelists was used for the selection and definition of the sensory vocabulary. In our case, there were three (3) sessions in which the sensory attributes of pepper samples were evaluated by the twelve (12) panelists. During the sessions, each panelist evaluated the sensory attributes in a progressive order (aroma, taste, texture, and color). The panelists were asked to read the definition of each attribute, evaluate the pepper samples according to the references, and indicate the perceived intensity of the attribute on the scale provided.

2.2.7. Analysis of panel performance

The panel's performance was assessed using three criteria:

- Discrimination: judges' ability to differentiate between samples
- Repeatability: stability of the same judge's responses over several sessions
- Inter-judge agreement: consistency of assessments between panelists

2.3. Statistical analysis

The data obtained were analyzed with XLSTAT version 21. The statistical tests applied are: Friedman test (discrimination and repeatability) with p-value of 5% and PCA (agreement).

3. Results and discussion

3.1. Panel Discrimination

The results of the Friedman test (**Table 1**) highlight that all the descriptors significantly discriminate ($p<0.05$) the samples. The descriptors Smooth (683.35), Rough (674.78), Crunchy (631.22), Floury (585.54) and Round (554.84) are the most discriminating with a high variability in the texture of the pepper studied. The descriptors Acid (41.8) and Umami (66.44) are discriminating but weakly perceived by the panel. Our results are similar to those of [10] who found significant differences between the varieties of Vietnamese pepper according to spiciness, menthol and woodiness.

Table 1 Results of the Friedman test (panel discrimination)

Descriptors	Statistical	Degrees of freedom	p-value	Interpretation
Herbaceous	411.8	20	7.28E-75	Significant (p<0.05)
Mushroom	**507.04**	20	9.78E-95	Significant (p<0.05)
Hazelnut	**474.17**	20	7.34E-88	Significant (p<0.05)
Spicy	**481.49**	20	2.17E-89	Significant (p<0.05)
Mint	410.52	20	1.34E-74	Significant (p<0.05)
Woody	370.47	20	2.66E-66	Significant (p<0.05)
Bitter	139.99	20	5.08E-20	Significant (p<0.05)
Salty	102.69	20	4.14E-13	Significant (p<0.05)
Punget	**434.61**	20	1.31E-79	Significant (p<0.05)
Refreshing	372.13	20	1.21E-66	Significant (p<0.05)
Acidic	41.8	20	2.94E-03	Significant (p<0.05)
Umami	66.44	20	6.88E-07	Significant (p<0.05)
Warm	**488.43**	20	7.67E-91	Significant (p<0.05)
Crunchy	631.22	20	7.53e-12	Significant (p<0.05)
Mealy	585.54	20	3.20E-111	Significant (p<0.05)
Smooth	683.35	20	7.34E-132	Significant (p<0.05)
Round	554.84	20	9.16E-105	Significant (p<0.05)
Rough	674.78	20	4.76E-130	Significant (p<0.05)
Green	**536.75**	20	5.74E-101	Significant (p<0.05)
Black	356.65	20	1.90E-63	Significant (p<0.05)

3.2. Panel repeatability

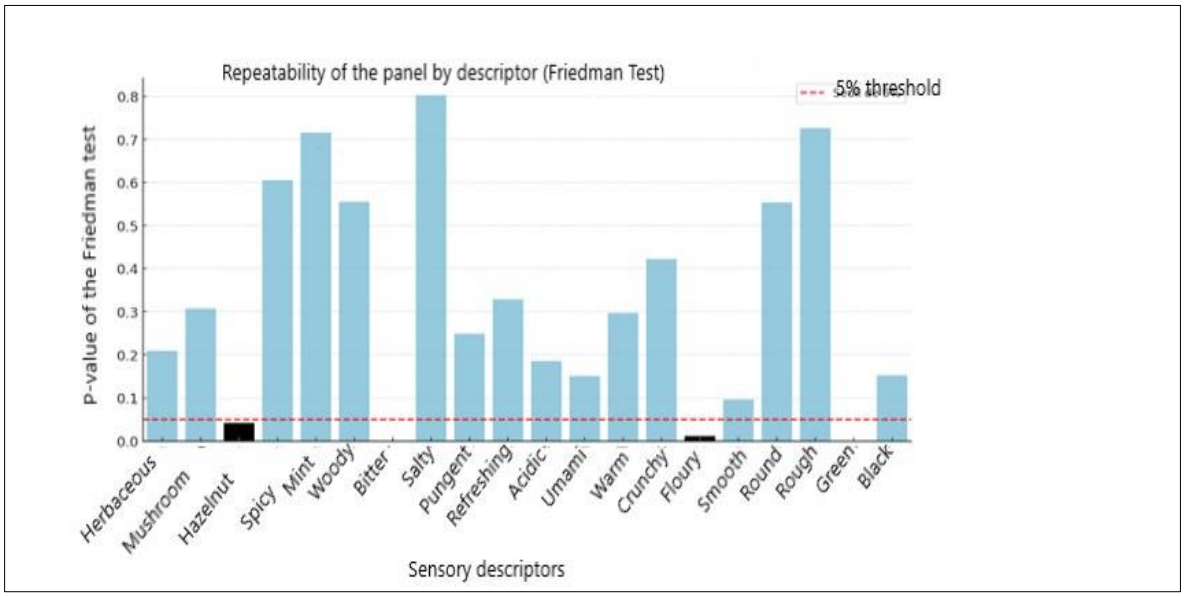

Figure 2 Repeatability of the panel by descriptor (Friedman test)

Figure 2 shows that there is poor repeatability (p<0.05) of the panel for the descriptors Hazelnut, Bitter, Floury and Green. This can be explained by a difficulty in distinguishing the notes or sensory fatigue of the panelists according to [11]. On the other hand, the panel showed good repeatability for other descriptors such as Mushroom, Herbaceous, Spicy. Our results are consistent with those of [12] on complex aromas where he suggests that descriptors strongly associated with sensory references (mint, spicy) are more repeatable while descriptors with subtle perceptions (hazelnut) have greater variability.

3.3. Panel Agreement

Principal axes analysis shows that 63.56% of the total variance is explained by the first two axes, indicating good overall consistency. **Figure 3** shows that subjects A, L, J, H, F, and D disagree with the rest of the panel. This disagreement can be explained by a different perception of certain sensory descriptors. [13] confirms this by pointing out that evaluations diverge by certain judges due to different sensitivity to stimuli or a lack of training.

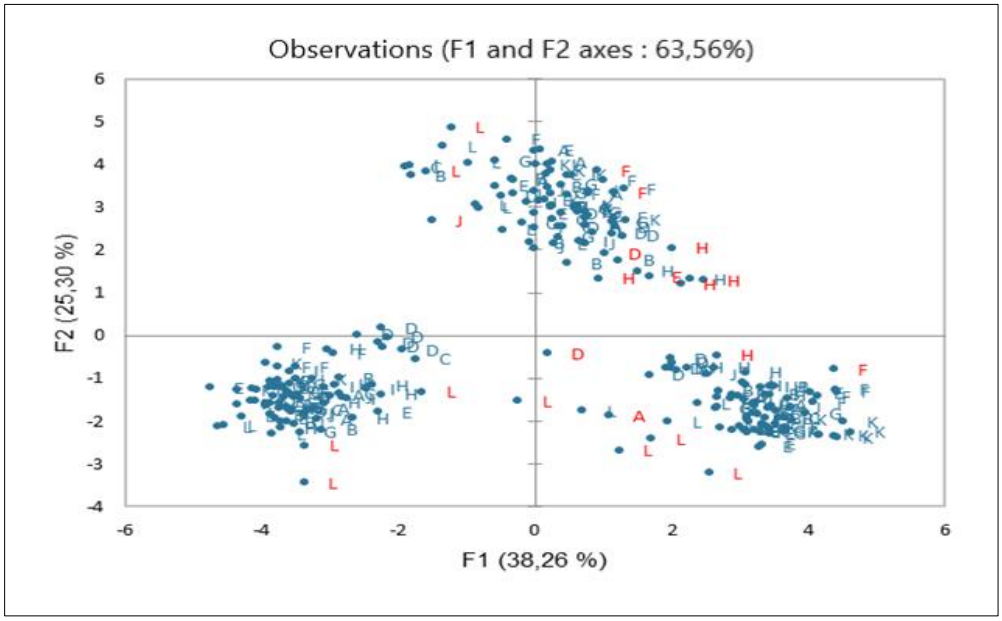

Figure 3 Contribution of the panelists to the consensus

3.3. Variability of judges by descriptor

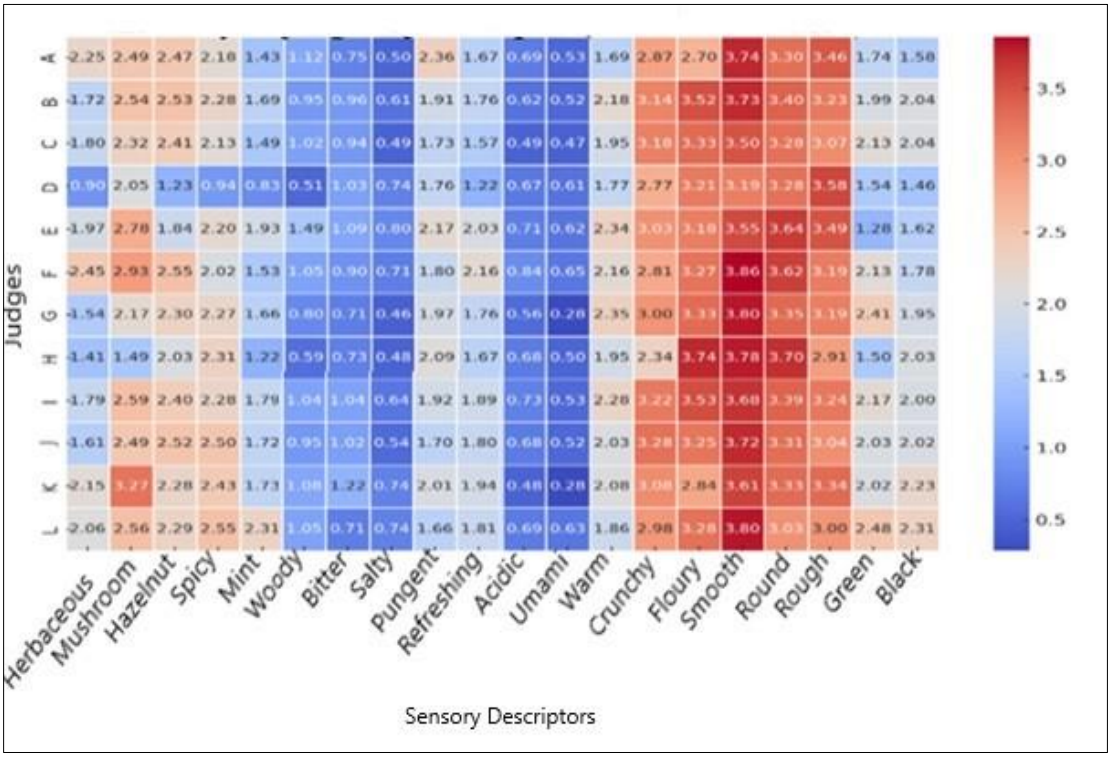

Figure 4 Variability of judges by descriptor (standard deviation)

Figure 4 shows the variability of the judges by each descriptor. Some attributes show strong heterogeneity, notably Herbaceous, Mushroom, Hazelnut and Spicy due to the deviations-relatively unstable types (sometimes high, sometimes low). Other attributes such as Crunchy, Floury, Smooth, Round and Rough record relatively high variabilities, certainly reflecting an inability of the judges to differentiate the intensity of these descriptors. A better agreement between judges is observed for the descriptors Acid, Salty, Woody, Bitter and Umami with relatively lower variability. According to [14] this is a difficult evaluation of multisensory descriptors or complex descriptors, hence a presentation of greater inter-judge variability.

3.4. Variability of ratings by product

Figures 5, 6 and **7** present the variability of ratings by product. Yakassémé M (2.68), Maféré F (2.56), Guiberoua F (2.51), Yakassémé F (2.48) and Yakassémé S (2.40) are the products presenting the most divergences between judges. This is explained by a great heterogeneity of grains from the regions, more advanced extraction of volatile aromas making the evaluation more subjective or difficulty of evaluation by the panel. These results confirming the importance of extensive judge training and calibration tests to reduce discrepancies.

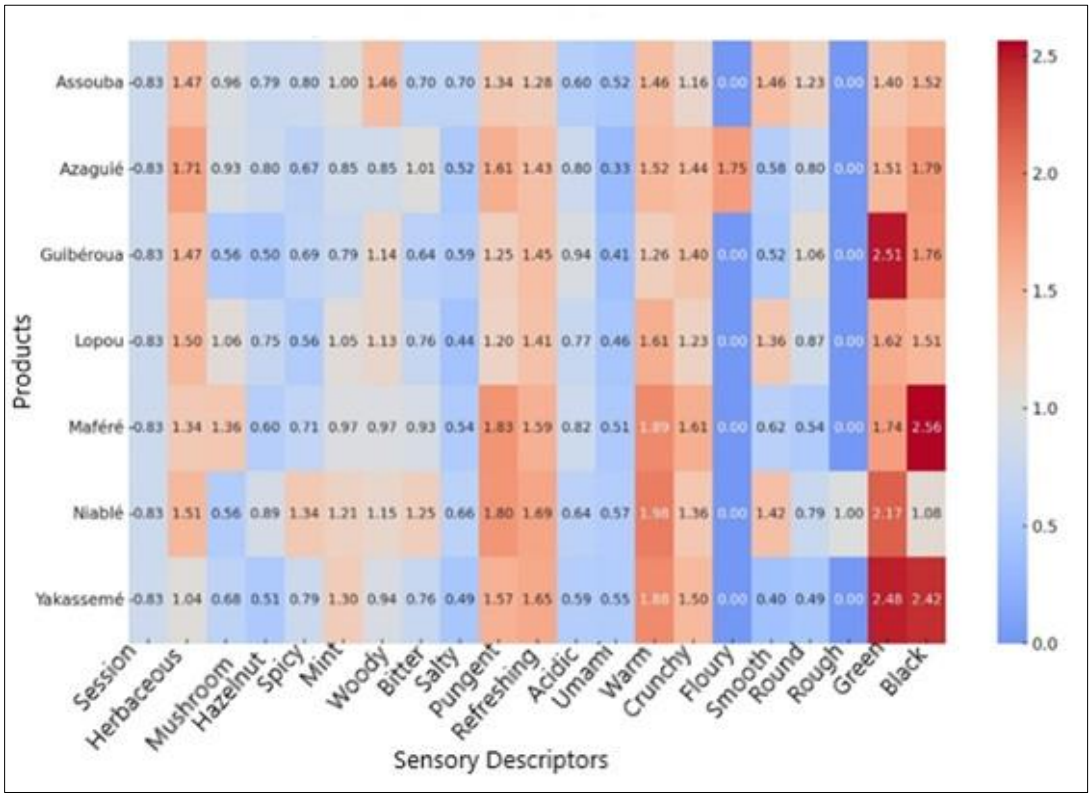

Figure 5 Variability of notes by product Fees (standard deviation)

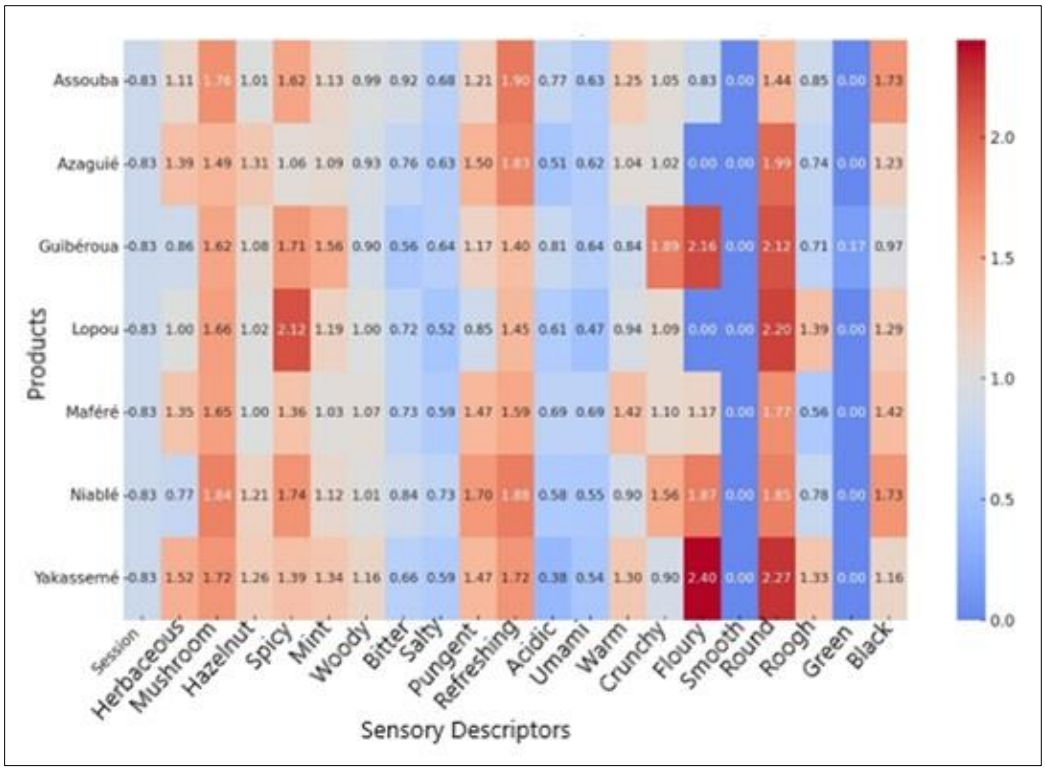

Figure 6 Variability of notes by Dry product (standard deviation)

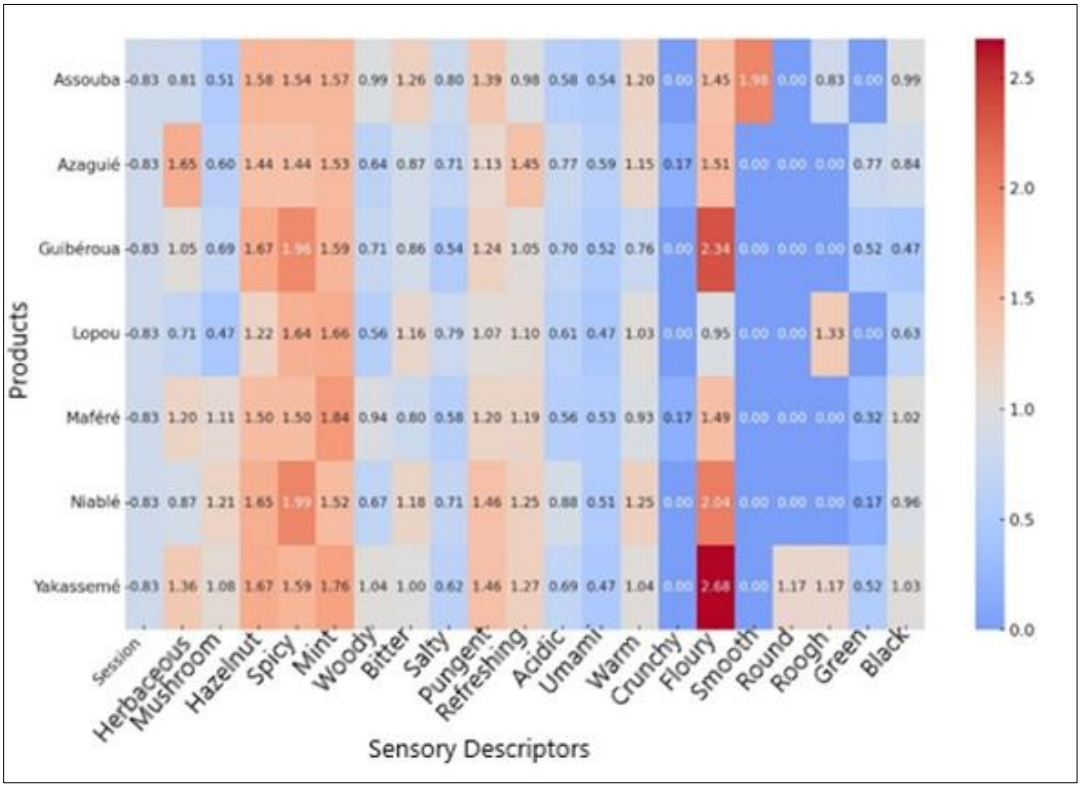

Figure 7 Variability of notes by Ground product (standard deviation)

4. Conclusion

The objective of this study was to evaluate the performance of a panel in the sensory characterization of pepper from Côte d'Ivoire. Analysis of the panel's performance demonstrated its ability to effectively discriminate pepper samples, its stability in repeating judgments, and satisfactory overall agreement between panelists. These results confirm that the panel is sufficiently trained and reliable to conduct rigorous descriptive analyses on pepper from Ivory Coast. This methodological validation is an essential step in the establishment of a quality sensory evaluation system, thus contributing to the promotion of local pepper. By strengthening the credibility of the sensory data produced, this work supports efforts to structure the pepper industry and paves the way for concrete applications in terms of varietal selection, labeling of origins, and market positioning.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

The authors declare no conflict of interest regarding the publication of this article.

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