World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(RESEARCH ARTICLE)

Check for updates

Study of the geographical variability of peppers (*Piper nigrum*) products in Ivory Coast

Ramzie Kelly Dago [1,*], Djédjro Clément Akmel [2], Antoinette Yoboue [3] and Emmanuel Assidjo [2]

[1] *Department of Training and Research in Chemical and Agro-Food Engineering, Unit of Agronomic Sciences and Processing Techniques, Félix Houphouet Boigny National Polytechnic Institute (INPHB), Ivory Coast.*
[2] *Laboratory of Industrial Processes, Synthesis, Environment, and New Energies, Félix Houphouet Boigny National Polytechnic Institute (INPHB), Ivory Coast.*
[3] *Laboratory of Medical Biochemistry, Unit of Training and Medical Ressearch, Alassane Ouattara University (UAO), Ivory Coast.*

World Journal of Advanced Research and Reviews, 2025, 26(01), 4059-4066

Publication history: Received on 18 March 2025; revised on 26 April 2025; accepted on 28 April 2025

Article DOI: https://doi.org/10.30574/wjarr.2025.26.1.1487

Abstract

This study aims to analyze the sensory variability of black pepper (*Piper nigrum l*) produced in Ivory Coast according to its geographical origin. A trained sensory panel evaluated samples from seven locations using descriptive analysis. The analysis was performed by XLSTAT version 21 using the Friedman test at $p<0.05$ followed by the Conover test and hierarchical ascending classification (HAC). The results of the Friedman test revealed highly significant differences for some descriptors, notably Black (p= 3.53e-20), Punget (p=6.38e-11), Bitter (p=1.52e-15) and Salty (2.54e-08). The post-hoc test showed that the localities of Guiberoua and Niablé presented very distinct sensory profiles. The analysis by hierarchical ascending classification made it possible to group the localities into three clusters: (1) Guiberoua and Niablé; (2) Assouba and Lopou; (3) Azaguié, Maféré and Yakassémé with homogeneous sensory characteristics. These results confirm that pedoclimatic conditions and cultural practices significantly influence the organoleptic quality of pepper. They thus provide a scientific basis for valorization by geographical origin, with a view to strategies such as the protected geographical indication (PGI).

Keywords: Sensory Profile; Friedman Test; CAH; Black Pepper; Geographic Variability

1. Introduction

Black pepper (*Piper Nigrum L*) is one of the most consumed spices in the world due to its organoleptic properties and its culinary and medicinal uses [1]. Africa represents 6% of global production with Madagascar, Ghana and Ethiopia, including successively 5,282.56 tonnes; 3,737.9 tonnes; 4,431.03 tonnes of pepper produced in 2021 ([2]; [3]). With a national production of 57.46 and 45.03 tonnes of pepper respectively in 2020 and 2021, Ivory Coast is classified among the countries with low production [3]. Despite the recent boom in its cultivation in several regions of the country, few studies have been conducted to characterize its sensory qualities according to the production areas. However, the differences observed in the field suggest that the geographical origin could influence the sensory profile of pepper. It is in this context that this study is taking place, which aims to explore the sensory variability of Ivorian pepper according to its origin. This approach aims to provide scientific elements to promote local production and lay the foundations for differentiation by terroir, with a view to a more strategic positioning on the markets.

* Corresponding author: Ramzie Kelly Dago

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 [4] among pepper producers in Ivory Coast identified thirty-eight (38) pepper plantations in production. Taking into account the geographical location and the distribution of soils in Ivory Coast, 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. Preparation of samples for sensory analysis

The dry pepper samples were ground into powder in a laboratory dry grinder to obtain the ground pepper (MP) 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 [5] 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.

2.2.4. Sensory descriptive analysis procedure

The sensory profiles of peppers were developed by a trained sensory panel using the quantitative descriptive analysis method according to the standard [6]. A graduated interval scale from 0 to 9 was used. Consensus among the panelists was used for selection. and the definition of 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 (smooth, rough, crunchy, floury, round, green, black, herbaceous, mushroom, spicy, hazelnut, woody, mint, bitter, salty, pungent, refreshing, acidic, umami, warm) in a progressive order (texture, color, aroma and taste). The panelists were asked to read the definition of each attribute, evaluate the pepper samples based on the references, and indicate the perceived intensity of the attribute on the provided scale.

2.2.5. Statistical analysis

The statistical analysis was carried out using XLSTAT version 21 software using an approach adapted to non-parametric sensory data. Four main tools were used to explore the sensory variability of pepper according to its geographical origin:

- Friedman test to see if descriptors vary significantly by origin.
- Conover's test for determining distinct localities.
- CAH to identify groups of localities with distinct sensory profiles.
- Heatmap to illustrate the intensity of pepper sensory descriptors across locations.

3. Results and discussion

3.1. Variability of sensory descriptors according to origin

The Table I shows that some sensory descriptors vary significantly depending on the geographical origin of the pepper, the most significant of which are: Bitter (p=1.52e-15), Punget (6.38e-11), Black (3.53e-20) and Salty (2.54e-08). This suggests that these characteristics are influenced by environmental factors specific to each location (climate, soil, cultivation techniques).

Table 1 Friedman test for all sensory descriptors according to origin

Level of significance	Sensory descriptors
Highly significant (p<0.001)	Bitter, Punget, Black, Salty
Moderately significant (p<0.01)	Herbaceous, Mushroom, Hazelnut, Refreshing, Warm, Green, Round, Crunchy, Rough
Less significant (p<0.05)	Spicy, Mint, Woody, Floury, Umami
Not significant (p>0.05)	Acidic, Smooth

3.2. Differentiation of localities

The Table II presents the localities with the most significant differences with the others: Guiberoua: 10 significant comparisons, Niablé: 9 significant comparisons, Azaguié: 7 significant comparisons, Yakassémé: 7 significant comparisons, Assouba: 6 significant comparisons, Lopou: 3 significant comparisons, Maféré: 5 comparisons. We note that Guiberoua and Niablé clearly stand out from the other localities in terms of the sensory profile of pepper. This indicates that these regions probably have specific agroecological conditions that strongly influence the sensory profile of pepper. Regarding spiciness, some localities produce significantly hotter peppers than others, suggesting a piperine content influenced by climate and soil [1]. Previous studies on Penja pepper (Cameroon) have also shown that pedoclimatic conditions strongly influence this sensory characteristic [7]. The difference between localities for black color may be related to post-harvest practices, including drying and sun exposure [8]. The perception of salty and bitter flavors varies depending on the distribution of secondary compounds such as alkaloids and flavonoids, influenced by the growing environment [9]. [10] showed that the mineral salt content of the soil could influence the perception of the salty taste of spices including pepper. Our results are in agreement with those of [11], who demonstrated that the chemical and sensory composition of pepper varies according to the terroir. In addition, [12] highlighted the impact of environmental factors on the biosynthesis of aromatic compounds in spices. The sensory differentiation of Ivorian peppers could therefore be valued as a marketing asset, similar to what has been observed for other spices and local agri-food products [13].

Table 2 post-hoc test (Conover) followed by the Friedman test

Descriptors	Location 1	Location 2	p-Value	Significant
Bitter	Assouba	Guiberoua	3.41E-06	Yes
Bitter	Assouba	Yakassémé	0.000505	Yes
Bitter	Assouba	Maféré	6.89E-05	Yes
Bitter	Azaguié	Guiberoua	0.001984	Yes
Bitter	Azaguié	Niablé	0.001447	Yes
Bitter	Guiberoua	Niablé	1.08E-09	Yes
Bitter	Lopou	Niablé	2.31E-05	Yes
Bitter	Niablé	Yakassémé	1.02E-06	Yes
Bitter	Niablé	Maféré	7E-08	Yes
Salty	Azaguié	Yakassémé	6.09E-05	Yes
Salty	Azaguié	Maféré	0.000409	Yes
Salty	Lopou	Yakassémé	0.000543	Yes
Salty	Niablé	Yakassémé	2.07E-05	Yes
Salty	Niablé	Maféré	0.000131	Yes
Punget	Assouba	Azaguié	0.000167	Yes
Punget	Assouba	Guiberoua	0.001202	Yes
Punget	Azaguié	Lopou	0.002089	Yes
Black	Assouba	Guiberoua	1.96E-07	Yes
Black	Azaguié	Guiberoua	7.29E-07	Yes
Black	Guiberoua	Lopou	2.76E-08	Yes
Black	Guiberoua	Niablé	0.000567	Yes
Black	Guiberoua	Yakassémé	2.28E-11	Yes
Black	Guiberoua	Maféré	5.43E-09	Yes
Black	Niablé	Yakassémé	0.002333	Yes

3.3. Grouping of localities according to sensory profile

Analysis of the geographical variability of peppers produced in Ivory Coast using the Ascending Hierarchical Classification (AHC) has made it possible to identify several groups of localities with distinct sensory profiles.

3.3.1. Structure of sensory groups

The Figure 2 present the formation of three main groups following the hierarchical ascending classification:

the first group composed of peppers from Guiberoua and Niablé presents marked similarities, suggesting that they share sensory characteristics common. This could be due to similar agro-climatic factors, similar cultivation practices or genetic proximity of cultivated varieties.

The second group consists of Assouba and Lopou peppers. The proximity between these localities in the classification tree indicates a relative homogeneity of sensory descriptors. This result can be attributed to similar growing conditions or identical post-harvest processing.

The third group consists of peppers from Azaguié, Maféré, and Yakassémé. This group includes Yakassémé and Maféré, which are the closest sensory-wise, followed by Azaguié. This grouping suggests that peppers from these locations share sensory notes distinct from the other groups.

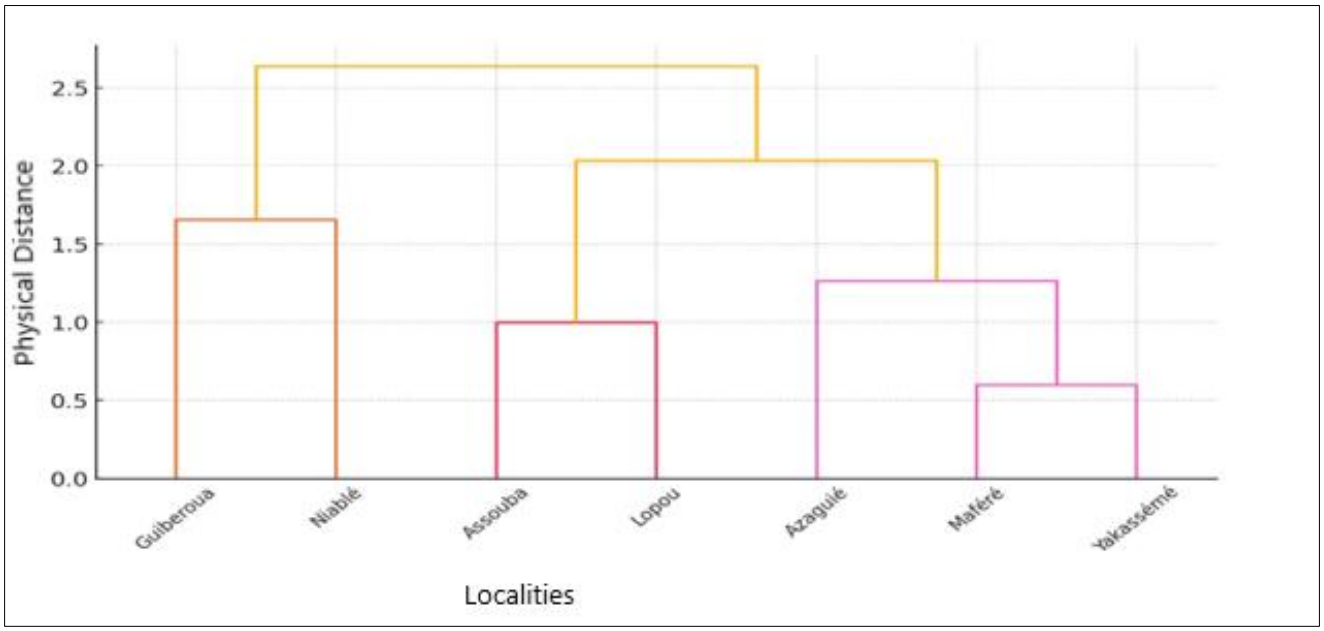

Figure 2 Dendrogram of classification of localities according to sensory descriptors

3.3.2. Differences and proximities between localities

The distance between the different groups indicates notable differences in the sensory profiles of peppers depending on the locality. This differentiation can be explained by:

-pedoclimatic conditions (soil type, humidity, temperature) which influence the chemical composition of peppercorns.

-the cultivation and processing methods (drying, fermentation) specific to each region.

-the influence of local genotypes, as some pepper varieties may be better adapted to certain areas.

Previous research on the sensory variability of spices has shown that the production region strongly influences organoleptic descriptors [14]. In particular, work on Kampot pepper (Cambodia) has demonstrated a correlation between geographical origin and spicy, floral or woody notes of the pepper [10]. In the case of Ivorian pepper, our results suggest a clear sensory segmentation according to localities, which opens interesting perspectives for valorization by protected geographical indication (PGI), as has been done for Penja pepper (Cameroon) [7]. These results highlight the importance of better characterizing and promoting Ivorian pepper by highlighting regional specificities. They can be used to:

- promote certain producing regions by highlighting their unique sensory qualities.
- develop quality labels and geographical certifications.
- improve varietal selection and cultivation practices to strengthen the product's typicality.

3.4. Sensory trends by location

The Figure 3 illustrates the intensity of sensory descriptors of pepper depending on the locality.

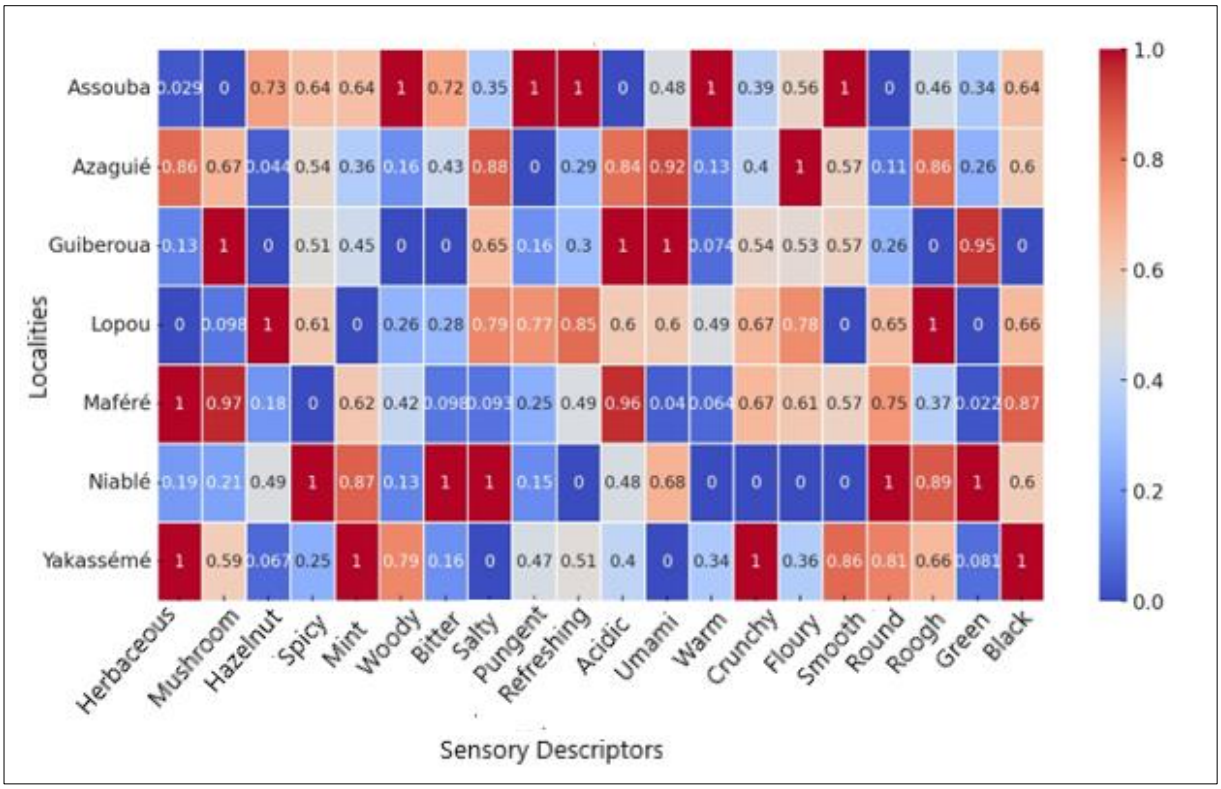

Figure 3 Heat map of sensory descriptors by location

3.4.1. Analysis by location

- Assouba: Assouba pepper is characterized by a woody aroma, a spicy, refreshing and warm taste and a smooth texture.
- Azaguié: Azaguié pepper is characterized by a herbaceous aroma, a salty, acidic and umami taste and a floury texture.
- Guiberoua: Guiberoua pepper has a mushroom aroma, an acidic, umami and hot taste and a green color.
- Lopou: Lopou pepper has a nutty aroma, a refreshing taste and a rough texture.
- Maféré: Maféré pepper has a herbaceous and mushroom aroma, an acidic taste and a black color.
- Niablé: a spicy and minty aroma, a bitter and salty taste, a round texture and a green color.
- Yakassémé: a herbaceous, woody and minty aroma, a crunchy texture and a black color.

These results indicate that the intensities of sensory descriptors vary by region and these variations can be attributed to several factors, including pedoclimatic conditions, cultural practices and interactions between the chemical composition of the pepper and its environment. [15] demonstrated that black pepper grown in different regions of Brazil presents notable differences in terms of aromas and flavors, influenced by variations in temperature and relative humidity. Similarly, [16] observed a correlation between the cultivation altitude and the intensity of aromatic compounds in Vietnamese pepper, suggesting that specific climatic conditions may intensify certain sensory descriptors.

3.4.2. General trends

In our study, some localities such as Niablé and Azaguié are distinguished by a high intensity of the salty descriptor, which may be related to a specific mineral composition of the soil, similar to the observations made by [17] on Malabar pepper in India. On the other hand, the pungent, hot and refreshing characters dominant in the localities of Guiberoua, Lopou and Assouba may be associated with high piperine contents, as reported by [18] in their analysis of the chemical variability of pepper from Madagascar. The trends observed in this study are not unique to pepper. Research on other agricultural products such as coffee [19] and cocoa [20] has shown that geographical origin significantly influences the sensory profile due to the complex interactions between genetics, environment and post-harvest practices. For example, high-altitude coffees are often described as more acidic and fruitier, while those from the lowlands are more chocolatey and earthy, a phenomenon that could be transposed to pepper depending on its growing terroir.

4. Conclusion

This study highlights significant sensory variability in black pepper produced in Ivory Coast depending on its region of origin. The differences observed between localities, particularly for key descriptors such as bitterness, spiciness, black color, and salty taste, confirm the influence of geographical and agroecological factors on product quality. These results reinforce the idea that origin constitutes a strategic lever for the promotion of Ivorian pepper both economically and in terms of heritage. By paving the way for recognition by terroir, this work makes a useful contribution to the structuring of the sector and the promotion of a sensory identity specific to Ivory Coast pepper.

Compliance with ethical standards

Acknowledgments

This study was carried out with the financial support of the Interprofessional Fund for Agricultural Research and Advice (FIRCA) and the technical support of the Department of Training and Research in Chemical and Agri-Food Engineering (DFR GCAA) of the Félix Houphouët Boigny National Polytechnic Institute (INPHB).

Disclosure of conflict of interest

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

References

[1] Nair KP. The Agronomy end Economy of Black Pepper (*Piper nigrum L.*): the King of Spices." Elsevier. 2021,doi.org/10.1016/C2018-0-04166-3.

[2] IPC (International Pepper Community). Pepper Statistical Yearbook-2017; p.152.

[3] FAOSTAT. Pepper (*Piper nigrum L*) production. Italy: FAO Statistics Division, Food, and Agriculture Organization. 2023 [Accessed: June 16, 2023]. Available at: URL:http://www.fao.org/faostat/en/#compare.

[4] FIRCA. Presentation of the Pepper Sector: FIRCA and the Pepper Sector. Pepper Journal. 2020; p.60.

[5] ASTM Committee E-18. Manual on sensory testing methods (STP 434) American Society for Testing and Materials. 1968.

[6] ISO 11035.Sensory analysis-Research and selection of descriptors for the development of a sensory profile, using a multidimensional approach. 1994.

[7] Ngomo HM, Tchatchouang, JC and Mefire, PL. Sensory characterization and geographical indication of Penja pepper (*Piper Nigrum L*) from Cameroon. Afr Jou of Fd Sci. 2021; vol15(3), p.89-97. doi.org/105897/AJFS2020.2036.

[8] Mallet JF and Guedon D. Peppers: origin, cultivation, marketing and organoleptic qualities. Agriculture Notebooks. 2005; vol 14 (4), p.321-328.

[9] Krist S, Stuebiger,G, Bail, S and Unterweger H. Analysis of volatile compounds and triglycerides of seed oils extracted from different poppy varieties (*Papaver somniferum L.*). Jou of Agri and Fo Chem. 2006; vol54 (3), p.707-713. https://doi.org/10.1021/jf0522945.

[10] Pham TH, Le NQ and Tran DM. Geographical origin effects on the aromatic profile of Kampot pepper *(Piper nigrum L.*). Jou of Agri and Fo Chem, 2019; vol67(14), p.3984-3992. https://doi.org/10.1021/acs.jafc.8b06728.

[11] Ravidran PN and Kallupurackal JA. Black Pepper: *Piper Nigrum L*. CRC Press. 2012.

[12] Bourgaud F, Gravot A, Milesi S and Gontier E. Production of plant secondary metabolites: A historical perspective. Pla Scie, 2001; vol 161 (5), p.839-851. https://doi.org/10.1016/S0168-9452(01)00490-3.

[13] Muthukumarasamy M and Holley RA. Microbiological and sensory quality of dry fermented sausages containing alginate-microencapsulated mustard essential oil. Jou of Fo Sci, 2006; vol 71 (3), p.76-81. https://doi.org/10.1111/j.1750-3841.2006.00074.x.

[14] Du X, Song M, Zhou H and Wang Y. Influence of geographical origin on the sensory and chemical characteristics of spices: A review. Food Chemistry, 2020; vol 320, p.126-594. https://www.fao.org/faostat/en/#compare.

[15] Souza LM, Mendes, NS, Silva FL and Costa LC. Sensory profile and chemical composition of black pepper (*Piper nigrum L.*) from different regions of Brazil. Jou of Fo Sci and Tec, 2020; vol57(12), p.4281-4290. https://doi.org/10.1007/s13197-020-04518-y.

[16] Tran TT, Vu HT and Le TM. Chemical composition and sensory characteristics of Vietnamese black pepper (*Piper nigrum L.*) cultivated at different altitudes. Fo Res Inter, 2018; vol 108, p.162-170. https://doi.org/10.1016/j.foodres.2018.03040.

[17] Nair KP. The agronomy and economy of black pepper (*Piper nigrum L.*) -The King of Spices. Elsevier. 2019; https://doi.org/10.1016/C2020-0-02633-6.

[18] Jiang Y, Zhang Z, Zhao W, Wang J and Zhang Y. Variability in piperine content and volatile compounds of black pepper (*Piper nigrum L.*) from different geographic origins. Journal of Food Composition and Analysis, 2021; vol 97, p.103-759. https://doi.org/10.1016/jfca.2020.103759.

[19] Bicho NC, Leitao AE, Ramalho JC, Alvarenga NB and Lidon FC. Impact of roasting time on the sensory profile of arabica and robusta coffee. Eco and Env Saf, 2014; vol111, p.188-197. https://doi.org/10.1016/j.ecoenv.2014.09.003.

[20] Afoakwa EO, Paterson A, Fowler M and Ryan A. Flavor formation and character in cocoa and chocolate: A critical review. Critical Review in Fo Sci and Nut, 2008; vol 48(9), p.840-857. https://doi.org/10.1080/10408390701719272.