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Study of organoleptic and physico-chemical qualities of three strawberry varieties, case of the Gharb and Loukkos, Morocco

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Abstract

Known for their sweet and tangy taste, strawberries are highly appreciated in Morocco, which ranks among the first producers of these small fruits. In fact, many efforts have been undertaken by those in charge of the sector to achieve desired positions. Among these efforts is the integration of new varieties that possess certain privileged agronomic characteristics, such as precocity, taste, and resistance to biotic and abiotic diseases. The present study focuses on three varieties: "Fortuna", "Sabrina", and "Victoria", cultivated in the Gharb and Loukkos regions in northern Morocco. The aim is to highlight their organoleptic and physicochemical qualities by analyzing various parameters. The results demonstrate that, on average, the Brix levels of Fortuna and Sabrina are 6.99±0.87 and 7.93±1.3, respectively, and the pH for both genotypes is approximately 3.4. This indicates strong compliance with international recommendations for improved marketing. Furthermore, significant quantities of these strawberries are obtained during the period from February to May, suggesting that the studied strawberries are short-day cultivars. In conclusion, strawberries are very sensitive fruits that require careful handling to prevent damage and maintain their high value.

Keywords: Strawberry, Organoleptic Quality, Physico-chemical Quality, Brix, Gharb-Loukkos, Morocco.

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1. Introduction

The strawberry belongs to the Rosaceae family, and the genus Fragaria includes wild species with varying ploidy levels. Worldwide, strawberry production has been steadily increasing over the past several years, with the primary producing countries being China, the United States, and Mexico. Together, these three countries account for 63% of global strawberry consumption [1]. In Europe, major strawberry-producing countries include Spain, Poland, the United Kingdom, France, and Belgium [2]. Strawberries have a relatively short shelf life, requiring special attention at every stage of the distribution chain, including harvesting, storage, and transportation. In 2008, Morocco adopted a proactive agricultural development strategy known as the Plan Maroc Vert (PMV) with the goal of transforming agriculture into a significant driver of economic growth and socio-economic development within the country [3-4]. Morocco has since diversified and expanded its agricultural production for export, particularly in the case of citrus fruits, strawberries, raspberries, tomatoes, green beans, table olives, and olive oil. The cultivation of red fruits such as strawberries, raspberries, and blueberries has proven to be especially profitable, with continuously growing international demand [4]. In Morocco, strawberry production is primarily concentrated in the Loukkos basin area, accounting for 80% of the country's total production. This sector generated a turnover of more than 3 billion Moroccan Dirhams in 2016/2017, providing employment for over 6 million working days over nine months, involving farms and packing stations. It also contributed to 23% of agricultural employment in the Tangier-Tetouan-Al Hoceima region [5]. According to data from the 2017-2018 campaign, only 49% of Morocco's total strawberry production was exported (14% in fresh form and 35% frozen). Despite its origins as an agricultural export sector, it's noteworthy that over half of Morocco's strawberry production is now consumed within the domestic market, including both fresh consumption and processing [6].

On the other hand, the crop is highly susceptible to various diseases and pests throughout their production cycle, necessitating increased use of phyto-sanitary treatments. This escalation in chemical treatments poses risks to both public health and the environment. While modern crop protection methods have predominantly relied on chemical plant protection products, this approach presents significant challenges in terms of health and environmental impacts [7-9]. Despite the efforts made by the Moroccan government, several constraints persist, including: i) Limited availability of water resources and often degraded soil; ii) insufficient provision of basic socioeconomic infrastructure such as roads, water, and electricity; iii) inadequate technical supervision; iv) high levels of illiteracy and inadequate health coverage; and v) communities characterized by high levels of poverty and vulnerability. The objective of this study is to evaluate the organoleptic and physico-chemical properties of three strawberry varieties, namely, "Fortuna", "Sabrina", and "Victoria", in the Gharb and Loukkos regions of Morocco.

2. Materials and Methods

2.1. Environment of the study

The study was conducted at the industrial unit "Frulact" located in Larache, Morocco (35.1744° N, 6.1474° W). This unit primarily focuses on the second stage of fruit processing and serves both the domestic market and exports to the Middle East and North Africa (MOAN) markets. Frulact's mission is to handle the initial processing of fruits from the region, with a primary emphasis on strawberries and apricot.

2.2. Collection of samples

The quantities of strawberries, measured in kilograms (Kg), were supplied to the unit by seven producers during the period from February to May 2022. Below is the distribution of the quantities supplied by these producers (Table 1).

2.3. Plant material

This study was carried out on three varieties of strawberries:

- ***Fortuna*:** This cultivar is selected for its precocity between winter and spring. It is well adapted to hot climates like that of Morocco; a fruit with a big size of conical form and exceptional brightness characterized by a high productivity (1Kg/plant).
- ***Sabrina*:** It is very attractive, characterized by its bright red color, medium-large size, elongated conical shape, fungus resistance, and a high productivity.
- ***Victoria*:** Performs well in the Mediterranean region thanks to its hardiness resistance to high temperatures, and adapts to all types of soils.

2.4. Measured parameters

The three studied strawberry varieties were analysed for the following parameters:

- Degrees Brix (symbol °Bx): This measurement quantifies the dissolved solids in a liquid and is commonly used to gauge the dissolved sugar content in an aqueous solution. Higher °Brix values indicate sweeter samples, with one Brix degree equivalent to 1 gram of sucrose per 100 grams of solution. Sugar content (°Brix) was measured using a digital refractometer (HI, 96801 from Hanna Instruments, USA).
- Fruit acidity: This was determined through titration with NaOH (OEDC, 2009).
- Quantity of mature and green fruits in Kg: Calculated as the quantity received in Kg multiplied by the percentage of mature and green fruits.
- Quantity of damaged (rotten) fruits in Kg: Calculated as the quantity received in Kg multiplied by the percentage of damaged (rotten) fruits.
- Quantity of damaged fruits in Kg: Calculated as the quantity received in Kg multiplied by the percentage of damaged fruits.
- Quantity of foreign bodies in Kg: Calculated as the quantity received in Kg multiplied by the percentage of foreign bodies.
- Quantity of defective fruits in Kg: Calculated as the quantity received in Kg multiplied by the percentage of defective fruits.
- Percentage of conforming fruits: Calculated as 100% of defective fruits.
- Quantity in conformity in Kg: Calculated as the percentage of conformity multiplied by the quantity received in Kg.

2.5. Statistical tools

The data were entered into Excel, categorized, and then transferred to SPSS for analysis. Quantitative variables were expressed as mean ± SD (Standard Deviation). Combined analysis included the use of a one-way ANOVA (analysis of variance), Tukey's comparison test, and Pearson correlation test. Principal Component Analysis (PCA) was also explored, with the significance level set at 5%.

3. Results

Table 2 presents the results regarding the quantity (Kg) of strawberries received each month during the studied period. The average quantity is approximately 3146.84±63.28 Kg, with the highest quantity observed in March (3453.11 Kg), followed by February (3377.59 Kg), April (3253.30 Kg), and May (2743.04 Kg). The lowest average quantity was recorded in June (1951.88 Kg). Fisher's test reveals a significant difference in the average quantities supplied by producers each month (Fisher=6.22; $p<0.000$). Table 3 presents the results of the ANOVA for the 'Genotype effect' on the distribution of Brix and pH. Fisher's test reveals significant differences among the three varieties for both Brix (F=68.53; $p<0.000$) and pH (F=17.30; $p<0.000$). Furthermore, when comparing the means using Tukey's test, it becomes evident that the Fortuna variety has the lowest Brix and pH, with means of 6.99±0.87 and 3.42±0.17, respectively. In contrast, the Victoria variety exhibits the highest Brix (8.57±0.93) and pH (3.46±0.15). It's worth noting that despite these differences among the three varieties, all measurements fall within the intervals [6-14] for Brix and [3.1-3.8] for pH.

However, there is no significant correlation between these two factors (r=0.049; $p<0.159$). Table 4 presents the results of strawberry compliance by variety. Fisher's test indicates a significant difference in the average values of compliance indicators among the three varieties ($p<0.05$).

Specifically, the Victoria variety exhibits an exceptional value in the green and mature state, with a mean of 132.68±22.4 Kg, surpassing the other two varieties, "Fortuna" (60.28±5.47 Kg) and "Sabrina" (94.93±5.34 Kg). Conversely, the variety "Victoria" has the lowest quantity of damaged fruits, with an average of 5.66±1.53 Kg, compared to more than 17 Kg of damaged fruits in both Fortuna (18.44±1.08 Kg) and Sabrina (17.53±0.94 Kg) varieties. The percentage of defective fruits was less than 4% in Fortuna and less than 5% in Sabrina, while Victoria had a slightly higher percentage at 6.70%. This corresponds to compliance rates of over 95% for Fortuna and Sabrina, and 93% for Victoria. As for the average quantity of foreign bodies, all three varieties showed almost negligible percentages. Table 5 presents the results of multiple correlations among the indicators. From this table, it is evident that Brix is positively correlated with the mature and green state of the fruit and negatively correlated with damaged fruit ($r=-0.129$; $p<0.000$) and the compliant quantity. On the other hand, pH exhibits an increasing trend with the mature and green state of the fruit as well as with the damage of the fruit. Consequently, the quantity in conformity shows an increasing trend with the damage. Table 6 presents the results of strawberry compliance by month. Fisher's test indicates highly significant differences ($p<0.05$) among the monthly averages of all the indicators. Specifically, the quantities of mature and green strawberries are most abundant during the months of May and June, with averages of 144.22±11.2 Kg and 190.04±33.1 Kg, respectively. The Brix content is at its peak in May (8.48±0.05), while the pH reaches its maximum in February (3.54±0.02). The highest quantities of damaged strawberries are recorded in March (31.95±1.75 Kg). Furthermore, the percentage of conformity for strawberry fruits is notably high in the months of February and April, with values of 96.98±0.10% and 96.70±0.12%, respectively. This corresponds to conforming quantities of 3269.84±194 Kg and 2987.07±113 Kg, respectively. Figure 1 depicts the results of the projection of the indicators using Principal Component Analysis (PCA). From this graph, two new factorial variables emerge: factor 1 is defined positively by indicators related to the mature and green state of the fruits and negatively by conformity indicators; and factor 2 is defined positively by the fruit damage status and sugar levels but negatively by other factors. The projection of the studied varieties reveals interesting characteristics:

- The variety "Sabrina" is characterized by a mature and green state, opposite to the variety "Fortuna," which is characterized by conformity.
- The variety "Victoria" is characterized by high Brix levels.

4. Discussion

The objective of the present study was to establish the organoleptic and physico-chemical profiles of three strawberry cultivars, namely, 'Fortuna', 'Sabrina', and 'Victoria', grown in the Gharb and Loukkos regions of Morocco. In the context of global strawberry production, China ranks as the largest producer, yielding approximately 2,964,263 tons annually, followed by the United States with an annual production of 1,296,272 tons. Mexico occupies the third position with an annual production of 653,639 tons. Morocco, on the other hand, holds the 11th position globally in strawberry production, with an annual output of 148,554 tons and a cultivated area of 3,537 hectares as of the 2018-19 season [10-11]. According to the Regional Office for Agricultural Development of Loukkos (ORMVAL), the cultivated area for strawberries in the crop year 2022-2023 amounts to 2,822 hectares. This means that the volume of red fruits exported represents approximately 85% of the total strawberry production.

Table 1: The distribution of the quantities supplied by seven producers.

Producer	Total quantity (Kg) received from February to May 2022
1	353671.59
2	464183.26
3	376888.21
4	195264.88
5	458648.20
6	34539.80
7	691562.15
Total	**2574758.09**

Table 2: Descriptive of the quantities of strawberries supplied by the producers per month.

Month	N	Total amount (Kg) received per month	Mean	Standard Error	Minimum	Maximum	Fisher (P-value)
February	87	293850.67	3377.5939 (b)	202.84821	514.00	8368.00	6.22 (p<0.000)
March	197	680264.14	3453.1175 (b)	125.99801	714.00	7485.00	
April	275	894658.16	3253.3024 (b)	114.20212	2.48	9425.50	
May	245	672045.12	2743.0413 (ab)	104.47824	1.19	8182.00	
June	9	17567.00	1951.8889 (a)	341.96858	891.00	4315.50	
Total	813	2558385.09	3146.8451	63.28074	1.19	9425.50	

Table 3: Analysis of variance with a single classification criterion "Genotype effect" on Brix and pH.

Parameters	Variety	N	**Mean**±SD	95% confidence interval for the mean		Khi2 (p-value)
				Lower terminal	Upper terminal	
Brix (6-14)	***Fortuna***	249.00	6.99±0.87 (a) (6.01; 9.91)	6.88	7.10	68.53 (p<0.000)
	Sabrina	520.00	7.93±1.3 (b) (6.01; 11.71)	7.82	8.04	
	Victoria	44.00	8.57±0.93 (c) (6.64; 11.31)	8.28	8.85	
	Total	813.00	7.68±1.26 (6.01; 11.71)	7.59	7.76	
pH (3.1-3.8)	***Fortuna***	249.00	3.42±0.17 (a) (3.11; 3.83)	3.40	3.44	17.30 (p<0.000)
	Sabrina	520.00	3.49±0.15 (b) (3.10; 3.93)	3.48	3.51	
	Victoria	44.00	3.46±0.15 (ab) (3.11; 3.71)	3.41	3.50	
	Total	813.00	3.47±0.16 (3.10; 3.93)	3.46	3.48	

Table 4: Descriptive analysis of the compliance characteristics of the quantities received according to the varieties.

Variety	Mg	Da. Ro	Da	% Def.	% Conforme	Aw/Fr	Q.conf. (kg)
Fortuna	60.28±5.47 (a)	35.07±2.77 (ab)	18.44±1.08 (b)	3.78±0.17 (a)	96.2±0.17 (b)	28.84±0.14 (a)	2594.24±113. (b)
Sabrina	94.93±5.34 (a)	45.429±2.69 (b)	17.53±0.94 (b)	4.61±0.15 (a)	95.38±0.15 (b)	29.00±0.12 (a)	2198.60±93.7 (b)
Victoria	132.68±22.4 (b)	17.57±2.7 (a)	5.66±1.53 (a)	6.70±0.56 (b)	93.29±0.56 (a)	28.96±0.30 (a)	250.29±66.65 (a)
Total	86.428±4.04	40.752±1.11	1±0.69	4.47±0.11	95.52±0.11	28.953±0.0	2213.40±71.5
Fisher	11.61*** (p<0.000)	7.11*** (p<0.001)	8.08*** (p<0.000)	17.4*** (p<0.000)	17.23*** (p<0.000)	0.29 (p<0.75)	26.29*** (p<0.000)

Mg: mature and green; Da.Ro: damaged and rotten; Da: damaged; % Def: defective in %, Aw/Fr: average weights; Qconf: conforming quantity; "means having the same letter are not significantly different".

Table 5: Multiple correlations among the indicators.

Indicators	Brix	pH	Mature and green	Damaged	Conforming quantity (Kg)
Brix	1	0.049	.105**	-.129**	-.315**
		0.159	0.003	0.000	0.000
pH	0.049	1	.084*	.169**	-0.016
	0.159		0.017	0.000	0.642
Mature and green	.105**	.084*	1	.267**	-0.025
	0.003	0.017		0.000	0.471
Damaged	-.129**	.169**	.267**	1	.382**
	0.000	0.000	0.000		0.000
Conforming quantity	-.315**	-0.016	-0.025	.382**	1
	0.000	0.642	0.471	0.000	
**. The correlation is significant at the 0.01 level (two-tailed). *. The correlation is significant at the 0.05 level (two-tailed).					

Table 6: Descriptive analysis of the conformity characteristics of the quantities received according to the months.

Months	Mg	Brix	Da	pH	% Conforme	Aw/Fr	Q.conf. (Kg)
February	41.48±3.2 (a)	6.44±0.04 (a)	12.87±1.43 (b)	3.54±0.02 (b)	96.98±0.10 (c)	31.08±0.48 (b)	3269.84±194 (b)
March	71.08±3.6 (a)	6.55±0.03 (a)	31.95±1.75 (c)	3.45±0.01 (a)	95.48±0.13 (bc)	28.81±0.19 (a)	3285.31±121 (b)
April	57.06±3.7 (a)	8.11±0.08 (bc)	16.10±0.98 (b)	3.45±0.01 (a)	96.70±0.12 (c)	28.60±0.12 (a)	2987.07±113 (b)
May	144.22±11.2 (b)	8.48±0.05 (c)	8.50±0.89 (ab)	3.47±0.01 (ab)	93.91±0.27 (b)	28.73±0.12 (a)	184.27±12.68 (a)
June	190.04±33.1 (b)	7.86±0.17 (b)	.00±0.00 (a)	3.47±0.02 (ab)	88.04±2.19 (a)	27.95±0.13 (a)	190.14±33.09 (a)
Total	87.32±4.04	7.67±0.04	17.00±0.69	3.47±0.05	95.45±0.12	28.94±0.09	2192.56±71.1
Fisher	30.44 (p<0.000) ***	173.20 (p<0.000) ***	53.59 (p<0.000) ***	6.63 (p<0.000) ***	52.82 (p<0.000) ***	17.93 (p<0.000) ***	173.94 (p<0.000) ***

Mg: mature and green; Da: damaged; Aw/Fr: average weights; Q.conf: conforming quantity; months with the same letter are not significantly different; ***: very highly significant difference.

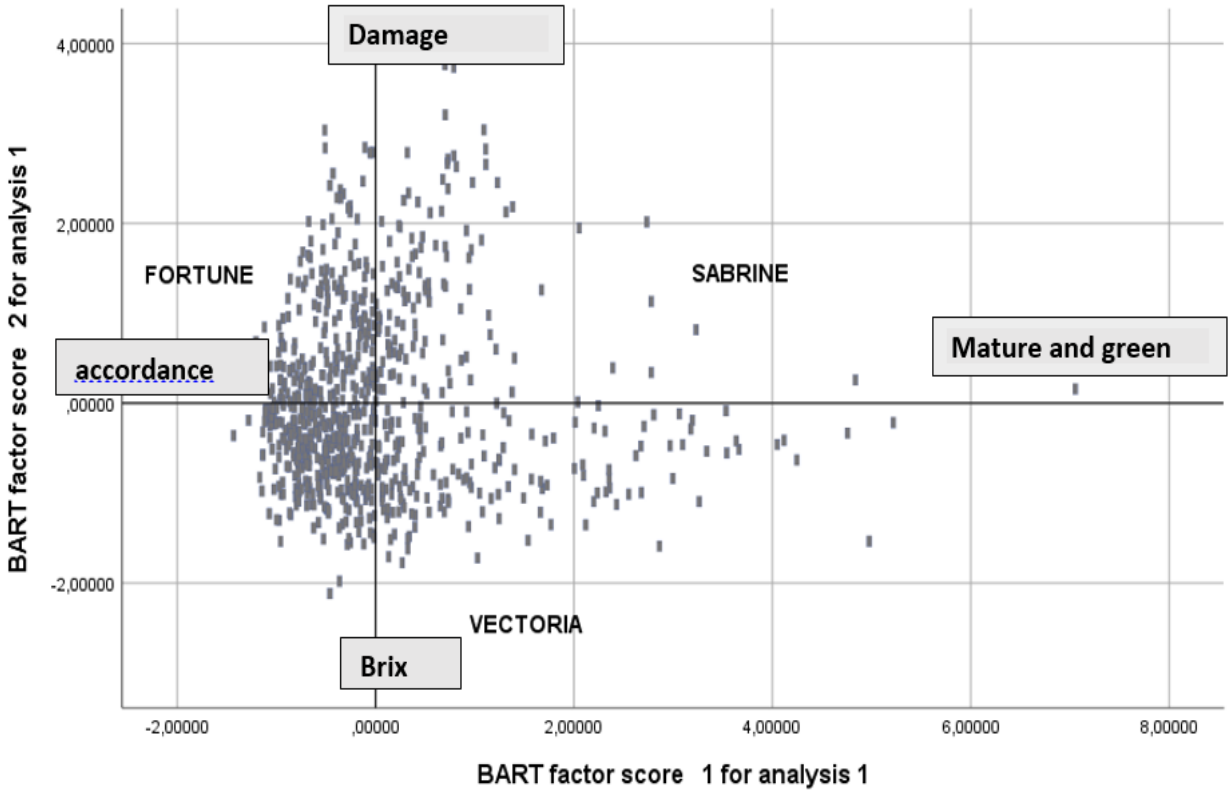

Figure 1: Principal component analysis of the indicators and the three genotypes.

In response to market demands and to enhance crop performance in terms of earliness, organoleptic quality, disease resistance, and conservation, Moroccan farmers initiated a program of varietal diversification in 2010. As part of this effort, two strawberry varieties, namely, 'Fortuna' and 'Sabrina,' were chosen by producers in the Loukkos area. Our study has confirmed the suitability of these varieties due to their valuable characteristics, including: Precocity; Productivity: High; Fruit shape: Conical; Color: Red both inside and outside; Taste and Brix (minimum rate of 8), and Tolerance to diseases and pests. For our two varieties, the Brix level above 7° until April 30 and 8° after April 30 is one of the physicochemical criteria that ensures that the fruit has good maturity [12]. Additionally, our fertigation program, characterized by a high K2O/N ratio during the vegetative period and low levels during fruit production, has significantly increased the sugar content of strawberries. In our field trial, we observed a 12% increase, while the above-ground trial showed a 6% improvement compared to the farmer's traditional practice [13].

5. Conclusions

In Morocco, the area dedicated to the cultivation of red fruits, especially in the Gharb and Loukkos regions, has experienced remarkable growth. This has contributed to job creation in these areas, particularly through the export of red fruits to the European Union market, which has seen a 96% improvement in the case of strawberries. This surge has prompted stakeholders in the sector to intensify their efforts and seek new modern cultivation technologies to achieve significant yields with desirable qualities. The primary aim of this study was to investigate the organoleptic and physicochemical profiles of three strawberry cultivars: 'Fortuna,' 'Sabrina,' and 'Victoria,' grown in the Gharb and Loukkos regions of Morocco. 'Fortuna' and 'Sabrina' were the two varieties chosen by producers in the Loukkos area, and our research confirmed that these varieties are excellent choices due to their early maturation, high productivity, conical shape, red color, appealing taste, and Brix levels, with a minimum rate of 8. They also exhibit tolerance to diseases and pests, aligning well with international recommendations for enhanced marketing. For both of our selected varieties, maintaining a Brix level above 7° until April 30 and 8° after April 30 is one of the critical physicochemical criteria ensuring that the fruit reaches optimal maturity. In terms of the quantities received, they are substantial from February to May, indicating that the studied strawberries are short-day cultivars. In conclusion, strawberries are highly delicate fruits that require meticulous handling to prevent damage and maintain their market value.

References

[1] J. B. Samtani, C. R. Rom, H. Friedrich, S. A. Fennimore, C. E. Finn, A. Petran, R. W. Wallace, M. P. Pritts, G. Fernandez, C. A. Chase. (2019). The status and future of the strawberry industry in the United States. Hort. Technology. 29 (1): 11-24.

[2] Allmanhall. (2020). Overview of the UK strawberry industry. https://allmanhall.co.uk/blog/overview-of-thestrawberry-industry-in-the-uk.

[3] M. Sadiki. (2017). La Rareté de l'eau: Défis et Opportunités: cas du secteur agricole au MAroc. Séminaire de haut niveau "Rareté de l'eau: Défis et Opportunités" (Rome).

[4] R. Harbouze, J. P. Pellissier, J. P. Rolland, W. Khechimi. (2019). Rapport de synthèse sur l'agriculture au Maroc (Doctoral dissertation, CIHEAM-IAMM).

[5] M. Arhazzal. (2018). Filière des petits fruits rouges au Nord du Maroc. AgriMaroc.ma. https://www.agrimaroc.ma/filiere-petits-fruits-rouges-nord-maroc.

[6] M. Faure. (2019). La sécurité sanitaire du consommateur de fraises marocaines: deux poids, deux mesures?. Confluences Méditerranée. (1): 149-165.

[7] L. Rissouli, M. Benicha, T. Chafik, M. Chabbi. (2017). Decontamination of water polluted with pesticide using biopolymers: Adsorption of glyphosate by chitin and chitosan. Journal of Materials and Environmental Science. 8 (12): 4544-4549.

[8] M. Benicha, S. Maadani, M. Chabbi. (2016). Conséquence d'utilisation des pesticides dans le fraisier sur la contamination des sols et des eaux souterraines du périmètre du Loukkos. Le premier congrès International des Etudes sur l'Eau et l'Environnement. ENSA, Al-Hoceima. 66.

[9] L. Zhao, Y. Li, W. Ren, Y. Huang, X. Wang, Z. Fu, W. Ma, Y. Teng, Y. Luo. (2020). Pesticide residues in soils planted with Panax notogins eng in south China, and their relationships in Panax notogin seng and soil. Ecotoxicology and Environmental Safety. 201: 110783.

[10] IPBM Maroc. (2019). Note sur la filière des fruits rouges. 1-14.

[11] M. Abbou, M. Chabbi, M. Benicha. (2021). Evaluation de la pression d'utilisation phytosanitaire sur l'environnement: Cas du fraisier de Loukkos nord-ouest du Maroc. Agricultural Journal. (130): 54-72.

[12] Cahier des charges présenté au Comité national IGP-LR-STG de l'INAO des 1er et 2 février 2017.

[13] A. Nakro, C. Khoulali, A. Bamouh. (2020). Effet de l'équilibre potassium-azote en fertigation sur la productivité et la qualité de trois variétés de fraise. Revue Marocaine des Sciences Agronomiques et Vétérinaires. 8 (3).

[14] N. Boubrahimi. (2020). Exigences liées aux mesures SPS à l'export.

[15] P. P. Vaysse, A. Devillepoix, M. Causse, M. Pitrat. (2016). Les saveurs au potager. Jardins de France. 640: 1-6.