Nat. Volatiles & Essent. Oils, 2021; 8(5): 12801-12815

Comparative Analysis of Nutritional Composition of 61 Varieties of Mandarins (*Citrus Reticulata* Blanco)

EL-KHLIFI Farid[1-2], EL BAKKALI Mohamed[3]. TALHA Abdelhak[1], CHETTO Ouiam[1] BENKIRANE Rachid[2], BENYAHIA Hamid[1]*

[1]Research Unit of Plant Breeding and Germplasm Conservation, National Institute for Agricultural Research (INRA), Kenitra 14000, Morocco

[2] Laboratory for Plant, Animal and Agro-Industrial Production, Department of Biology, Faculty of Science, IbnTofail University, BP 133, Kenitra, Morocco

[3]Département of Biology, Faculty of Sciences, University Ibn Tofail, Kenitra, Morocco

ABSTRACT

The fruits juice of 61 mandarins (*Citrus reticulata* Blanco) germplasm from the citrus fruits collection planted in the experimental field of National Institute for Agricultural Research (INRA) of Kenitra in Morocco were analysed. From principal component analysis, a selection based on the study of the chemical characters of sixty-one varieties allowed to characterize the following profiles of important nutritional composition: (**1**) For the mandarinette variety the beta-carotenoid content, Vitamin C, Juice yield, TSS, Maturity Index and TA was 3.25 mg·L^{-1}, 542.85 mg·L^{-1}, 49%, 12%, 4.23% and 2,84, respectively. For Honoy, average β-Carotene intakes, Vitamin C, TSS, TA, Juice yield and Maturity index were almost 3.07 mg·L^{-1}, 477.47 mg·L^{-1}, 12% 0.94, 39.79% and 13%, respectively. Chow chow tien was also characterized as an important source of β-carotene (3.04 mg·L^{-1}), Vitamin C (447.44 mg·L^{-1}) and TSS (12 %). Regarding the Forst Dancy variety, we found a high of β-Carotene content (3.23 mg·L^{-1}) but low intake of Vitamin C (355.32 mg·L^{-1}) and TA content (0.87 %). (**2**) A second profile consists of Chuika, Ananas, Suen and Cravo characterized by an average β-Carotene intake varying from 2.36 to 2.92 mg·L^{-1}, Vitamin C between 444.15 and 526,4 mg·L^{-1}, TSS greater than 11%, Juice yield greater than 45 % if we except Suen (23.12 %) and an TA around 1, but Suen was very acidic (2.73 %). (**3**) For the last profile consisting of Siamélo, Ortonique, Bergamota and Pankan varieties, the average Vitamin C content varied between 503.37 and 644 mg·L^{-1}, that of β-Carotene between 1 and 1.25 mg·L^{-1} while the Juice yield intake was greater than 46%, TSS almost 11%, TA varying between 1.25 and 3.5 % and Maturity index less than 8.4.

key words: β-Carotene, germplasm, Total Soluble Solids, titratable acidity, vitamin C

INTRODUCTION

The Mandarin (*Citrus reticulata* Blanco) is native to Southeast Asia and the Philippines and they reached Europe (England) in 1805 and Italy around 1850, while they spread to the United States and the rest of the world circa 1840 [**1**]. Mandarins constitute an important group of citrus fruits, one of the four ancestral taxa along with *C. maxima* Merr. (pummelo), *C. medica L*. (lemon) and *C. micrantha* Wester (*papeda*) from which all cultivated citrus species have been generated by reticulate evolution [**2,3**]. The mandarin group includes various natural subgroups, including common mandarin (*C. reticulata Blanco*), Satsuma mandarin (*C. unshiu Marcovitch*), king mandarin (*C. nobilis Loureiro*), Willow leaf mandarin *(C. deliciosa*), clementine (*C. Clementina* Hort.ex. Tan), hybrids such as tangor (*C. reticulata x C. sinensis*) and tangelo (*C. reticulata x C. paradisi*). Small citrus (*C. indica, C. tachibana and C. reshni*) and Clementine mandarin *(C. clementina Hort.ex* Tanaka*)* [4]. In addition, mandarin trees, there is not only an abundant diversity of species, but also very many variations between varieties within the same species genetic diversity is the raw material to create varieties adapted to different environments or with better taste qualities.

Morocco considered to be one of the main producing countries of citrus "small fruits" (mandarins, Clementines, and their hybrids) in the Mediterranean basin. Morocco is the 4th largest producer of mandarins in the world (not to be confused with clementine), according to the latest report from the US State Department of Agriculture [**5**]. The Kingdom's production is estimated at 1.07 million tonnes (t) against 1.1 million for Japan and 3.3 million for the European Union [**5**]. China remains by far the world's leading producer of this fruit with 20 million t harvested [**5**]. While Moroccan production has evolved significantly since 2011, the best season was recorded in 2013/2014 with 1.16 million t. Regarding exports, Morocco is 3rd with 460,000 t against 570,000 for Turkey and only 660,000 for China [**5**]. The Asian giant consumes most of its production (18.7 million t), as does the EU (2.8 million t), Japan (1.3 million t) and the United States (900,000 t) [**5**]. Morocco reserves a little more than half of its production (605,000 t) for the domestic market. Citrus fruits are important for human nutrition and health [**6,7,8**], citrus extracts have anti-inflammatory, anti-tumor and anti-fungal inhibitory activities [**9**]. The soluble sugars, organic acids, vitamin C which provide important nutritional benefits and also contribute to total antioxidant activity, are important constituents of all mandarin species, and their content varies markedly between varieties [**10**]. The concentration of vitamin C in the juice of different cultivars of mandarins can be very variable, but is generally between 150 and 500 $mg \cdot L^{-1}$ of juice [**11**]. Mandarins are among the most pigmented citrus species, due to their carotenoid content [**12**] and are mainly eaten in the form of fresh fruit; they are a valuable source of vitamins and fiber and also contain secondary metabolites, including antioxidants like ascorbic acid, phenolic compounds, flavonoids, carotenoids and limonoids, as well as sugars, organic acids, amino acids, pectin, minerals and volatile organic compounds important for human nutrition and health [**13,14,15,16**].

The objective of this work was to characterize and evaluate the physicochemical parameters and to select the best profiles, of a significant intake of vitamin C and beta-carotenoids, in 61 germplasm of mandarins from the collection of citrus fruit planted in the experimental area of the National Agronomic Research Institute (INRA) of Kenitra in Morocco, with the aim of conserving indigenous genetic material and identifying varieties with valuable traits linked to the quality of the fruits and then exploit in variety breeding programs.

MATERIAL AND METHODS

Plant Materiel

The present study was carried out on 61 Mandarins varieties, included 32 common mandarins (*C. reticulata* Blanco), six Tangerine (*C. tangerina Hort.* ex Tan), four Mediterranean mandarins (*C. deliciosa* Tenore), three King mandarin (*C. nobilis* Loureiro), four satsumas (*C. unshiu* Marcovitch) and twelve Hybrid Mandarin, derived from the collection of citruses germplasm planted in the experimental field of National Institute for Agricultural Research (INRA) of Kenitra in Morocco, were collected during the 2017-2018 season. Fruits were collected from adult trees, and were subject to the same agricultural conditions (water, fertilizers and pesticides) has an altitude of 25 m, latitude of 34°64). The climate is Mediterranean, belonging to the subhumid stage, with a temperate winter and rare frosts. Fruits were collected from adult trees, and were subject to the same agricultural conditions (water, fertilizers and pesticides). For each genotype, 30 fruits were harvested on 3 commercial mature trees (10 fruits/tree; 3 trees for each variety) harvested from different areas of the tree tops. In the laboratory, Juices were pressed and analyzed.

Juice Extraction and Analysis

The juices were squeezed the same day, filtered through a 1mm mesh sieve and placed in amber bottles and stored at -18 ° C for further analysis. the Juices were analyzed for vitamin C, β-carotene contents as well as the quality attributes such as juice yield, total soluble solids, titratable acidity and maturity index **(**table 1**)**. each measurement consisted of three replicates (including the juice from three different fruits per measurement). The juice yield was determined as follows**:**

Juice yield (%) = (JW/FW) ×100

where J*W* was the weight of extracted juice (g), F*W* was the weight of relative fruit material of each group (g).

Table 1: List of the characteristic studie

	Parameters	Abbreviation	Unit
Bioactive Compounds ;	β-carotene	β-ca	$mg \cdot L^{-1}$
	Vitamin C	VC	$mg \cdot L^{-1}$
Chemical Parameters ;	Juice yields	JY	%
	Titratable acidity	TA	%
	Total soluble solids	TSS	°Brix
	Maturity index (TSS/TTA)	MI	-

Chemical Parameters

Total Soluble Solids Content (°Brix)

The sugar content is determined using a manual refractometer (PR-1. Atago Co. Ltd., Japan), by placing a drop of juice on the prism and the reading is taken directly, the value is expressed in (° Brix). Each measurement included three replications. Each measurement consisted of three replicates (including the juice from three different fruits per measurement).

Titratable Acidity Determination (TA)%

We put a soda alkaline liquor in a Mohr burette at 6, 25 $mg \cdot L^{-1}$. We take 10 cm3 of juice decanted with a few drops of colored indicator phenolphthalein at 1%, and then we leave the soda liquor gently by shaking the beaker till the beginning of the turn. The reading of the number of cm3 elapsed soda liquor is divided by 10cm3 (volume of juice) to get the exact value of citric acidity which is expressed in % [**17**]. Each measurement consisted of three replicates (including the juice from three different fruits per measurement).

Bioactive Compounds

β-carotene content determination

The method for the determination of total carotenoids is described by Lee & Castle [**18**]. 2 ml of fruit juice of each variety has been mixed with 5 ml of extraction solvent (hexane, acetone, ethanol, 50 :25 :25, v/v/v), Shaked and centrifuged for 5 min 6500 rpm. The top layer of hexane containing Caroténoïds was recovered and transferred to a 25 ml flask. The volume of recovered hexane is then adjusted to 25 ml with hexane. White is represented by hexane. The absorbance reading is done at 450 mm using a spectrophotometer (SP-8001.Metertech Inc. 1.09), levels of Caroténoïds were calculated in mg β-carotene per liter by referring to the obtained calibration curve, using β-carotene as a calibration standard. Each measurement consisted of three replicates (including the juice from three different fruits per measurement).

Vitamin C content determination

The vitamin C content is carried out by the method described by Izuagie, Anthony & Izuagie, F. (2007) [**19**]. We dissolve 0, 2 g of KIO3 and 1, 6 KI in a bottle of 500 containing distilled water. The solution was acidified by adding 1 ml of concentrated acid of tetraoxosulphate (VI) (H3SO4). The mixture was swirled and the volume of solution raised to 500 ml with distilled water. The bottle was clogged and stirred to ensure homogeneity of content. Thus, the concentration of the iodine solution 5,6076 x 10^{-3} M. 20 ml of juice for each sample was titrated against standard iodine solution 5,6076 10-3 $mg \cdot L^{-1}$. The starch solution is used as indicator. Each measurement included three replications. Each measurement consisted of three replicates (including the juice from three different fruits per measurement).

DATA ANALYSIS

The data were analysed using Minitab version 17.0. The data analysis included descriptive statistics and the data are expressed as mean for continuous variables. Multivariate statistical approaches are very useful in attaining significant information from Physico-chemical parameters dataset in the experimental area of the National Agricultural Research Institute (INRA) of Kenitra. In this study, the multivariate statistical approaches including principal component analysis (PCA), applied to build new variables called principal components out of a set of existing original variables. The PCA is performed to reduce the large data set of variables into few factors called the principal components, which can be interpreted to reveal underlying data structure. The first principal component (PC1) absorbs and accounts for the maximum possible proportion of the total variance in the data set and the second component (PC2) absorbs the maximum of the remaining variance and so on. For interpretation, only a few numbers of PCi are retained in the analysis. The number of principal components to be retained in the analysis is based on Kaiser criterion. In order to reduce a data set to a more manageable size while retaining as much of the original information as possible and identifying clusters of variables to understand the structure of a set of variables, 6 chemical parameters were used in PCA. The pattern of the data reduces the dimension of the data without much loss of data.

RESULTS AND DISCUSSION

Characteristics of Mandarin Fruit Juice

Total Soluble Solids (°Brix)

The Total soluble solids (°Brix) content is used as an indirect measure of the sugar content and is an important quality factor, related to the taste of the final product. Variations in TSS are triggered by several factors such as cultivar, soil, climate and field practices [**20**]. The average analysis of the TSS is presented in (figure 1). The Afourer genotype had a higher average TSS (14.3 ° Brix) than the other genotypes. Also, the genotypes Oneco (13.9 °Brix), Meun Sui Chang (13.7 °Brix), Indochine (13.5 °Brix) and Houany yeny mi (13.3 °Brix) are similar and much higher than the other genotypes. The average total soluble solids extract of Murcott honey (7.00 °Brix) satsuma Saigon (7.0 °Brix) and Beauty de glen (7.5 °Brix) genotypes are comparable. In a similar study on the mandarin group, Kinley and Chinawat [**21**] reported high TSS in the Trongsa Adhesions (12.90 °Brix), Zhemgang (12.10 °Brix) and Dagana genotypes (11.20 °Brix) but low in the Sarpang (10.90 °Brix), Tsirang (10.60 °Brix) and Samtsé genotypes (10.30 °Brix). Dorji and Yapwattanaphun [**22**] Performed diversity studies among 39 Mandarins and reported that TSS ranged from 9.90 to 10.81 °Brix for Shumar and Narang Mandarins. Evaluation of Mandarin fruits in other work has shown mean TSS values of around 10.9 °Brix [**23**], and between 9.6 to 15.8 °Brix [**24**]. In another study, carried out by Goldenberg et al (2015) [**25**] on 42 varieties of Mandarins, found that the most preferred varieties of Mandarins contained TSS between 12.0 and 15.0 °Brix.

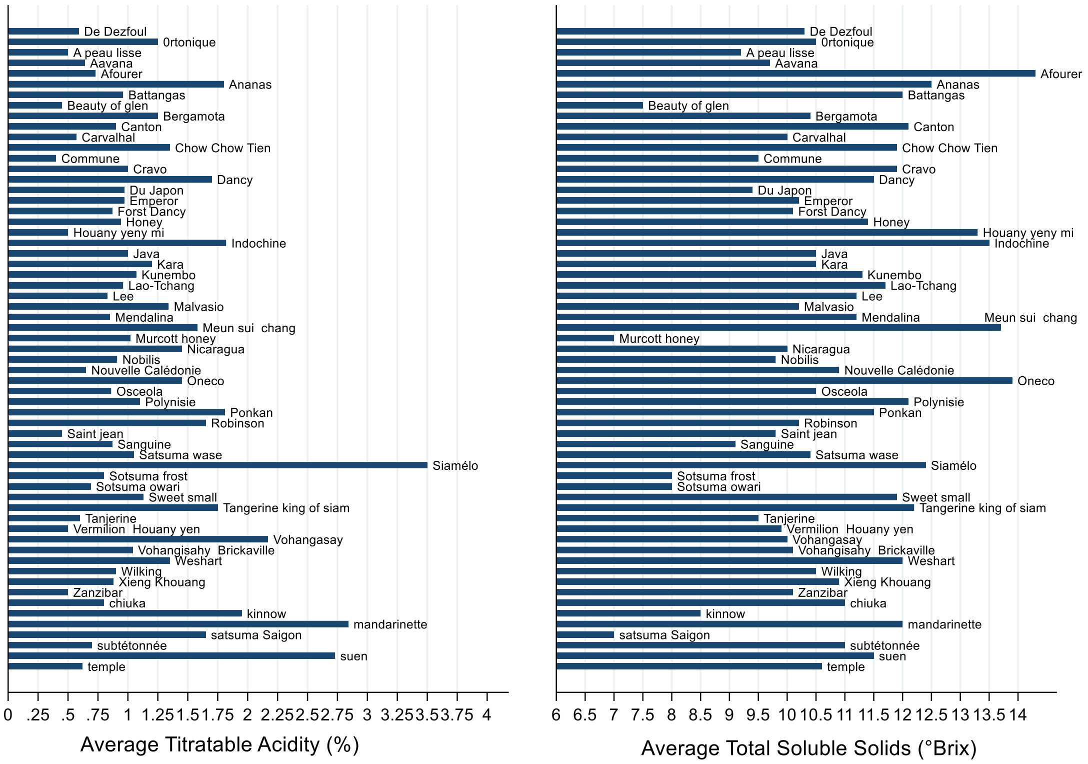

Figure 1: Diversity among mandarin varieties in total soluble solid and titratable acidity contents. Data are means of three replications.

Titratable Acidity (%)

Mean analysis of the average titratable acidity (TA %) of the fruits is presented in (figure 1). The data revealed that the average percentage of fruit acidity ranged from 0.4 to 3.5 %. The Siamelo (3.5 %), Mandarinette (2.84 %), Suen (2.73 %) and Vohangasay (2.17 %) genotypes are higher than Commune (0.4 %), Beauty of Glen (0,45 %), Saint John (0.45 %). In other works, by [**26, 27, 28, 22**], the average titratable acidity (TA %) of the fruits varies from 0.61 % in Mandarin Shumar to 1.17 % in the Dagana variety. also, the average titratable acidity (TA%) is between 0.52 and 2.19 % (Belo et al., 2018). while the average titratable acidity (TA %) varied from 0.29 to 2.04 % according to Garcia et al (2018) [**29**]. Similarly, for Goldenberg et al (2014) [**24**], the average titratable acidity in a group of Mandarin Common “Odem” and “Vered” Temple Tangor was 0.5 % and 2 %, same author found that the most preferred varieties of Mandarins contained acids of 0.7 % to 1.4 % [**25**].

TSS / TA ratio

The TSS/TA ratio is used as an indicator of the stage of fruit ripening and determines the balance between sugars and organic acids; This ratio is directly related to the quality of the bait and is an important parameter for breeding programs. All cultivars showed sufficient TSS/TA ratios for fruit harvest (figure 2). The highest proportions were observed for the cultivars Afourer, Vermilion Houany yen, Zanzibar, Saint Jean, Commune and Houany yeny mi (19.59, 19.8, 20.2, 21.78, 23.75 and 26, 6, respectively; figure 2). In contrast, cultivars Siamélo, Suen, Mandarinette, Satsuma Saigon, Kinnow and Vohangasay showed the lowest TSS/TTA ratios (3.54, 4.21, 4.23, 4.24, 4.36 and 4, 6, respectively; figure 2), indicating that these cultivars fruit must remain in the tree longer to reach the correct physiological maturity before harvest. The other varieties had intermediate ratios (6.18-18.4), most of which are listed in classes 8-18 [**29**]. Different ratio TSS/TA results were observed for the Ortanique (28.9) and Nova (23.7) varieties compared to our work [**30**].

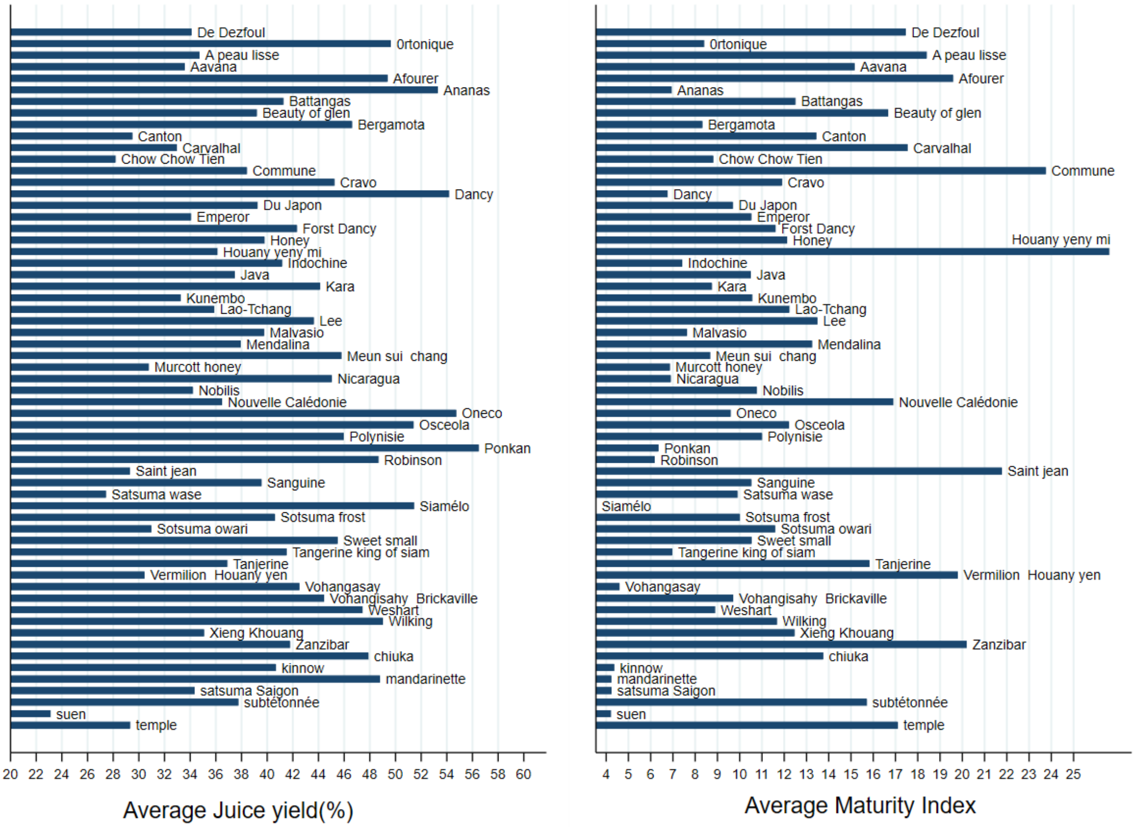

Figure 2: Diversity among mandarin varieties in maturity index and juice yield contents. Data are means of three replications.

The Juice Content in The Endocarp (%)

Mean analysis showed that the average percentages of fruit juice Ponkan (56.48%), Oneco (54.73 %), Dancy (54.17 %), Ananas (53.3 %), Siamélo (51, 44 %), Osceola (51.41 %), Ortonique (49.64 %), Afourer (49.38%), Wilking (49.02%) are higher than the other genotypes. Other genotypes like Suen, Satsuma wase, Chow Walking Tien, Saint jean, temple and Canton, Vermilion Houany yen, Murcott honey and Sotsuma owari had average juice contents of 27.43 %, 28.18 %, 29, 31 %, 29.32 %, 29.49%, 30.44 %, 30, 77 % and 30.97 % ($p > 0.05$), respectively. In a similar study on the mandarin group, Belo et al (2018) [**31**] reported high percentages of juice in the Ortonique (56.29 %), Miyauti (52.51 %) and Tangerina Cravo (50.20 %) genotypes but low in the Tangor Ellendale (22.61 %), Tangor Nova (22.81 %) and Clementina (28.09 %) genotypes.

Bioactive Compounds

β-carotene content determination

The peel and pulp of citrus fruits are an important source of carotenoids, and therefore of natural pigments; in juices, the most abundant are β-carotene, β-cryptoxanthin, lutein and zeaxanthin, all of which have antioxidant activity [**30**]. Dhuique-Mayer et al (2005) [**32**] found that the bioaccessibility of β-carotene was greater than that of β-cryptoxanthin in all citrus fruits, with the exception of Meyer lemon. Dhuique-Mayer et al (2007) [**33**]. In our study, the mean β-carotene content of the Juice varied from 0.5668 to 3.255 mg·L^{-1}. The average β-carotene content of the Mandarinette Mandarins (3.255 mg·L^{-1}), Forst Dancy (3.2355 mg·L^{-1}), honey (3.068 mg·L^{-1}) and chow micellization tien (3.0454 mg·L^{-1}) genotypes is similar. Also, the Chuika (2.9233 mg·L^{-1}), Vohangasay (2.7087 mg·L^{-1}), temple (2.5378 mg·L^{-1}), Dancy (2.5291 mg·L^{-1}) and blood (2.4855 mg·L^{-1}) genotypes are also shown to be good sources of β-carotene and higher than the other genotypes while

Carvalhal (0.5668 mg·L^{-1}), Sotsuma owari (0.7534 mg·L^{-1}), Saint jean (0.7918 mg·L^{-1}) and Sweet Small (0.8982 mg·L^{-1}) had similar and lowest β-carotene contents (figure 3). In another work, the β-carotene content varied from 0.082 to 0.377 mg·L^{-1} [**27**].

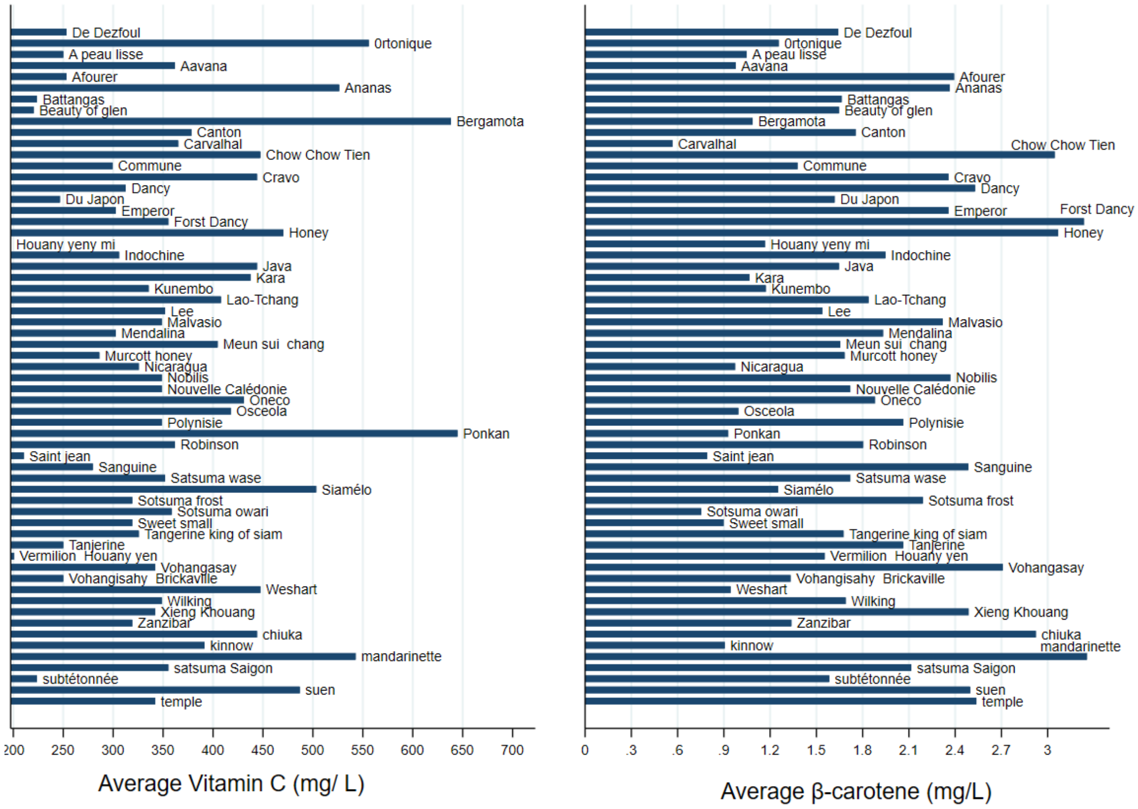

Figure 3: Diversity among mandarin varieties in vitamin C and β-carotene contents. Data are means of three replications.

Vitamin C content determination

The nutritional quality of citrus fruits is mainly related to the content of Vitamin C, it is the main antioxidant compound present in these fruits [**34, 35, 36**]. The content of Vitamin C in fruits and vegetales can be influenced by various factors such as genotypic differences, climatic conditions and cultural [**37**] In the present study (figure 3) the average Vitamin C content ranged from 197.40 to 644.80 mg·L^{-1}. The average vitamin C intakes of the Ponkan (644.84 mg·L^{-1}), Bergamota (638.26 mg·L^{-1}), Ortonique (556.01 mg·L^{-1}) and Mandarinette (542.85 mg·L^{-1}) genotypes were the most important, followed by Ananas (526.4 mg·L^{-1}) and Siamélo (503.37 mg·L^{-1}), while Houany yeny mi, Vermilion houany yen, Beauty of Glen, Subtétonnée and Battangas had the lowest average values below (197.40 mg·L^{-1}), (200.69 mg·L^{-1}), (210.56 mg·L^{-1},) (220.43 mg·L^{-1}), (223.72 mg·L^{-1}) and (223.72 mg·L^{-1}), respectively, which is in agreement with the work reported in the literature for different citrus varieties whose total vitamin C levels ranged from 195.7 to 593 mg·L^{-1} for different cultivars of Mandarins [**27**]. Carballo et al (2014) [**28**] found a vitamin C content ranging from 194 to 590 mg·L^{-1} for the juice of twenty-eight citrus varieties analysed in Spain in (2011). This content was within the range of reported levels, previously by Xu et al (2008) [**38**] in seven varieties of mandarins which was recorded between 218.83 ± 4.00 and 631.25 ± 5.51 mg·L^{-1} [**39**]. The ascorbic acid content in different cultivars of mandarins varied from 150 to 600 mg·L^{-1} of vitamin C [**39,40**].

Multivariate analysis of Mandarin germplasm on the basis of characteristics and juice fruit Principal component analysis (PCA)

Bartlett's test of Sphericity [**41**] χ^2 (15) = 393,049, p <0,001, indicated that correlations between samples were sufficiently large for PCA. An initial analysis was run to obtain eigenvalues for each factor in the data.

three principal components (PCs) had eigenvalues over Kaiser's criterion [**42**] of 1 and in combination explained 81,32% of the variance. We retained three factors because of the convergence of the scree plot and Kaiser's criterion on this value figure. Table 2 shows the factor loadings after rotation. PC1 explains 44,830% of total variance whereas; PC2 and PC3 explain 18,661% and 16,882% of total variance respectively.

Table 2: Varimax orthogonal rotation factor loadings from the PCA dataset of chemical and bioactive parameters of 61 varieties

	Principal components		
	PC1	PC2	PC3
Maturity index	**-0,940**	0,068	-0,124
Titratable Acidity (%)	**0,867**	0,194	0,159
Vitamin C (mg·L^{-1})	**0,733**	0,307	-0,066
Total Soluble Solids (°Brix) %	0,003	**0,901**	0,217
Juice yield (%)	0,401	**0,684**	-0,231
β-Carotene (mg·L^{-1})	0,125	0,053	**0,954**
Eigenvalues	2,69	1,12	1,013
% Of variance	44,830	18,661	16,882
% Total variance	44,830	63,492	80,373

The factor loadings include both positive and negative loadings. Loadings close to ±1 indicate a strong correlation between a variable and the factor. Loadings higher than ±0,75 are considered strong correlation, loadings between ±0,5 and ±0,74 are considered moderately correlated and loadings approaching 0 indicate weak correlations [**43**]. Based on the significant factor loadings (greater than ±0,5), each factor is assigned a process which the significant variables are likely to be associated within the factor. The processes which have been interpreted from the factor loadings are also provided in (Table 2). Positive loading scores are classified on an ad hoc basis into three types to rank nutrient intakes in order of importance of the varieties studied. They are with (a) low positive (<1,00); (b) medium positive (1,00-2,00); and (c) high positive (>2,000) PC loadings scores. The high positive PC loadings of TA% (0,867), Maturity index (-0,940) and vitamin C (0,733) are observed for the PC1. The high positive PC2 loadings are observed for TSS (°Brix) (0,901) while the juice shows medium positive PC2 loadings. The high positive PC3 loadings are observed for β-Carotene (0,954) (table 2). The varieties (Caochony and Chuika) with negative loadings had average contents of 407.96 and 444.15 mg·L^{-1}in vitamin C, almost 13% in maturity and less than 1% in acidity respectively. For low loadings scores, the Honoy, Cravo and M, Java varieties had an average intake of 444 and 470 mg·L^{-1}in vitamin C, almost 1% in acidity and between 10.5 and 12.3% in maturity. However, the varieties, Chow chow tien, Weshart and Oneco37 the acidity, maturity and average vitamin C content were> 1.2%, <9.50% and almost 440 mg·L^{-1} respectively. while, the cultivars with medium and high positive scores, Suen, Ananas, Ortonique, Bergomata, Pankan, Siamélo and Mandarinette had average contents of 486.92, 526.4, 556.01 638.26, 644.84, 503, 37 and 542.85 mg·L^{-1} in Vitamin C, 2.37, 1.8, 1.25, 3.5, 1.25, 1.81, 2.84 and 3.5% in acidity and 4, 21, 6.94, 8.4, 3.5, 8.32, 6.35, and 4.23 at Maturity index, respectively (figure 4). Moreover, the analysis of the second component loading scores showed that an average content between 45 and 50 mg·L^{-1} was observed in Kara, Cravo, Swett small smalle, Polynesia, Bergomata, Whshart, Chuika, Robinson, Mandarinette, Wilkong and Ortonique cultivar and an average percentage in °Brix between 10 and 12%. For varieties with medium and high socores, Osceola, Dancy, Sciamélo, Ananas, Pankan, Afourer and Oneco37 had average Vitamin C and TSS contents above 50 mg·L^{-1} and 12% respectively (figure 5).

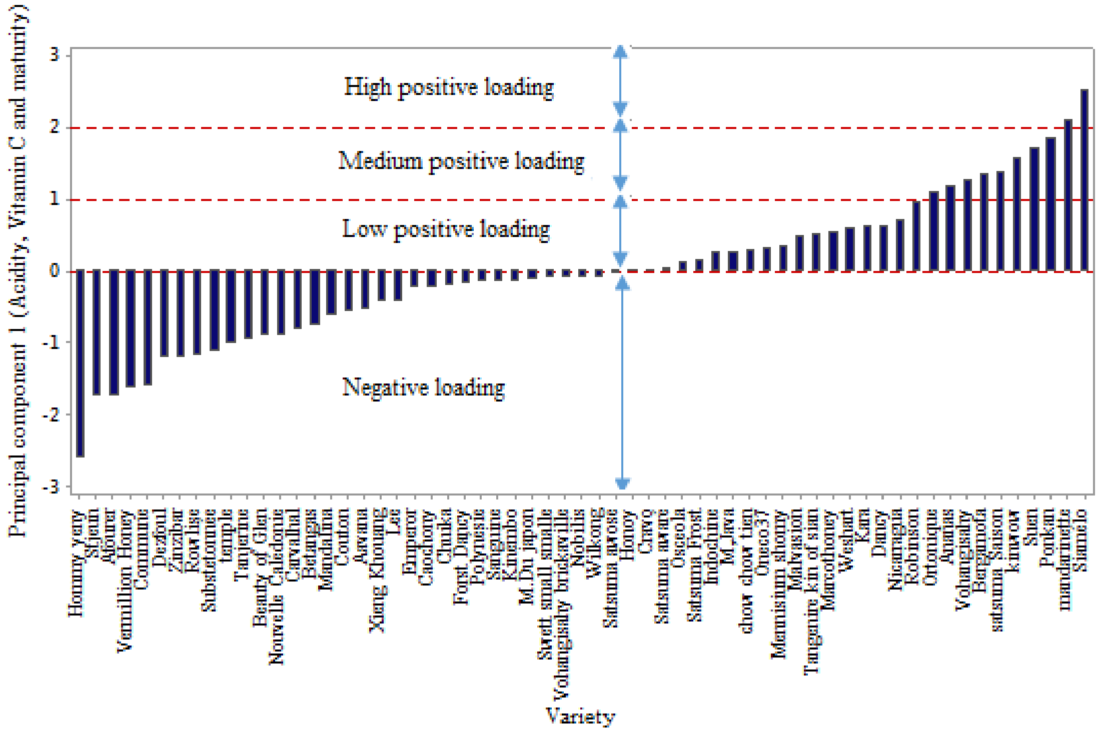

Figure 4: Principal component 1 (TA, vitamin C and Maturity index) analysis loading plot of mandarin group in sixty-one samples.

Analysis of average beta-carotene contents scores of four cultivars groups were found to be quite distinct. Group of varieties with negative loadings scores classified into three subgroups, the first of which (Carvalhal, Satsuma awaré, Stejeun, Swett small smalle, Kinwow, Ponkan, Weshart, Nicarragua, Aavana and Osceola) with average contents between 0.56 and 0.99 mg·L^{-1}, the second (Rowlise, Kara, Bergamota, Hommy yeny, Kinembo, Ortonique, Siamelo, Vohangisahy brickaville, Zinzibar and commune) between 1.05 and 1.38 mg·L^{-1}and the third (Lee, Substetonnée, Du Japon , java, Beauty of Glen, Marcothoney, Wilkong, Robinson and Oneco37) between 1.53 and 1.88 mg·L^{-1}. Group of low loadings scores classified into two subgroups of which 11 varieties had an average content between 1.55 and 1.95 mg·L^{-1} (Vermillion Honey, Dezfoul, Mennisium shomy, Betangas, Tangenire kin of sian, New Caledonia, Satsuma awose, Couton, Caochony, Mandalina and Indochine) and eleven varieties with an intake between 2.06 and 2.53 mg·L^{-1} (Polynesia, Tanjerine, Satsuma Saison, Satsuma Frost, Malvasion, Cravon, Ananas, Nobilis, Afourer, Sanguine and Dancy). In the medium and high loadings scores group we found an average content between 2.54 and 2.92 mg·L^{-1} for the varieties (Temple, Vohangisahy and Chuika) and a teneur between 3.05 and 3.25 mg·L^{-1}for the varieties (Chow Siamélo tien, Honoy, Forst Dansy and Mandarinette) (figure 6).

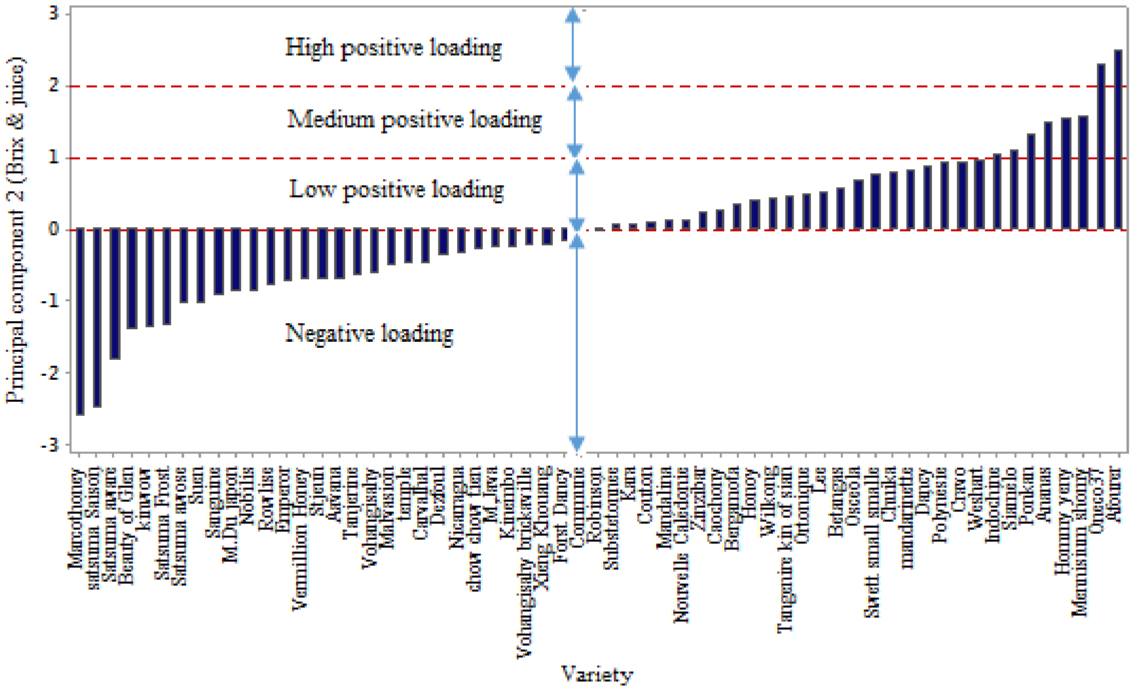

Figure 5: Principal component 2 (TSS and Juice yield) analysis loading plot of mandarin group in sixty-one samples.

From principal component analysis, a selection based on the study of the chemical characters of sixty-one varieties allowed to characterize the following profiles:

1) For the mandarinette variety the beta-carotenoid content, Vitamin C, juice, TSS, Maturity index and TA was 3.25 mg·L^{-1}, 542.85 mg·L^{-1}, 49%, 12%, 4.23 and 2,84, respectively. For Honoy, average β-Carotene intakes, Vitamin C, TSS, TA, Juice yield and Maturity index were almost 3.07 mg·L^{-1}, 477.47 mg·L^{-1}, 12 % 0.94, 39.79 % and 13, respectively. Chow Siamélo tien was also characterized as an important source of β-carotene (3.04 mg·L^{-1}), vitamin C (447.44 mg·L^{-1}) and TTS (12 %). Regarding the Forst Dancy variety, we found a high intake of β-Carotene content (3.23 mg·L^{-1}) but low intake of Vitamin C (355.32 mg·L^{-1}) and TA content (0.87%).

2) A second profile consists of Chuika, Ananas, Suen and Cravo characterized by an average β-Carotene intake varying from 2.36 to 2.92 mg·L^{-1}, vitamin C between 444.15 and 526, 4 mg·L^{-1}, TSS greater than 11 %, Juice yield greater than 45% if we except Suen (23.12 %) and an acidity around 1, but Suen was very acidic (2.73).

3) For the third profile, the Siamélo, Ortonique, Bergamota and Pankan varieties, the average vitamin C content varied between 503.37 and 644 mg·L^{-1}, that of β-Carotene between 1 and 1.25 mg·L^{-1} while the Juice yield intake was greater than 46 %, TSS almost 11 %, acidity varying between 1.25 and 3.5% and Maturity index less than 8.4.

4) The chemical character analysis of Oneco37, Caochony, Mennisium shomy and java, showed that the beta-carotenoid, Vitamin C and TSS contents varied from 1.64 to 1.88 mg·L^{-1}, 404.67 to 444.15 mg·L^{-1}and from 10.5 to 13.9 % respectively. However, the acidity was less than 1.58% and the juice yield greater than 45 % if we except M, java and Caochony. The other varieties were characterized by an antioxidant content (β-Carotene and vitamin C) of less than 1 mg·L^{-1} and 400 mg·L^{-1}, respectively.

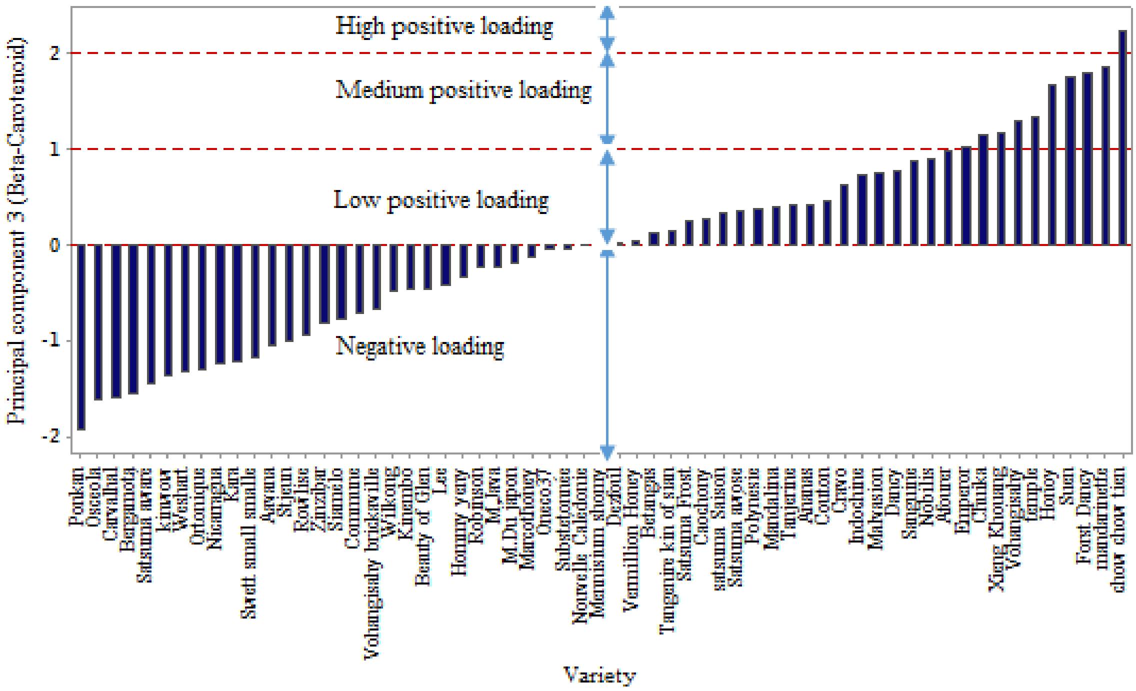

Figure 6: Principal component 3 (β-Carotene) analysis loading plot of mandarin group in sixty-one samples.

Given the nutritional quality and importance of β-Carotene and vitamin C for human health, the first three profiles constitute important sources of antioxidants. Indeed, in a comparative study of bioactive components and juice quality carried out by Bermejo et al (2016) [**27**] on the Mardarin group, the β-Carotene contents were less than 0.14 mg·L^{-1} in Arrufatina, Fina, Loretina, Moncada, Fortune and Moncalina and between 0.284 and 0.377 mg·L^{-1} for Murta and Murcott, respectively. Regarding the Vitamin C intake, the varieties Murta, Murcott, Moncalina, Moncada and Fortune had low contents varying between 195.7 and 230.51 mg·L^{-1}. In another work carried out by Xu et al (2008) [**38**] on the mandarin group, the average content of the Satsuma, Ponkan, Bendizao, Manju and Zhuhong varieties did not exceed 338 mg·L^{-1} if we except Hybrid 439 (631.25 mg·L^{-1}). Moreover, this intake remains low and less than 300 mg·L^{-1} for Garb, Fortune, Kara and Murcott [**44**].

CONCLUSION

From this work we characterized four profiles as important nutritional sources: **(1)** The mandarinette variety with high β-Carotene (3,25 mg·L^{-1}), vitamin C (542,85 mg·L^{-1}), Juice yield (49 %) and TSS (12%) content but with high TA (2,84). Honoy is also characterized by high levels of β-Carotene (3,07 mg·L^{-1}), Vitamin C (477,47 mg·L^{-1}) and TSS (12 %) but low TA (0,94 %) and Juice yield (39,79 %) intake. Chow Siamélo tien has also been characterized as an interesting source of β-Carotene (3,04 mg·L^{-1}), Vitamin C (447,44 mg·L^{-1}) and TSS (12 %). As mandarinette Forst Dancy had the highest content of β-Carotene (3,23 mg·L^{-1}) but low other chemical parameters. **(2)** In a second rank of importance in terms of intake of β-Carotene (2.36-2.92 mg·L^{-1}), Vitamin C (444.15-526.4 mg·L^{-1}) and TSS (>11%) and Juice yield (>45%), we have characterized the varieties Chuika, Ananas, Suen and Cravo. **(3)** In third rank of nutritional importance, Chuika, Ananas, Suen and Cravo were also another importants sources of β-Carotene (1-1.25 mg·L^{-1}), Vitamin C (503,37- 644 mg·L^{-1}), Juice yield (>46%) and TSS (11%). **(4)** For the last profile consisting of Oneco37, Caochony, Mennisium shomy and java, the content of β-Carotene (1.64-1.88 mg·L^{-1}), TSS (10.5-13.9 %) and Vitamin C (404.67-444.15 mg·L^{-1}) is slightly elevated while the Juice yield intake is high (> 45%) except for M, java and Caochony. For the other varieties in this study, the β-Carotene and vitamin C contents are less than 1mg·L^{-1} and 400mg·L^{-1} respectively.

Acknowledgements

We would like to express our deepest appreciation to all those who provided us the possibility to complete this paper. The authors wish to thank very much to Dr. ELMOUZRATI Abdelouahid for their help.

Conflicts of Interest

The authors declare that they have no competing interests.

Funding Statement

The authors declare that there is no conflict of interest regarding the publication of this paper.

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