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(RESEARCH ARTICLE)

Evaluation of morphological and physicochemical characteristics of tomato (*Lycopersicum esculentum*) produced on soilless substrates in Daloa (Haut Sassandra Region, Côte d'Ivoire)

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Abstract

The present study was carried out to set up soilless culture substrates and to evaluate the impact of these substrates on the morphological and physicochemical characteristics of tomato (Lycopersicum esculentum). Four types of agricultural by-products (cocoa, sawdust, cashew and rice husk) from which seven substrates were constructed. The sawdust and rice husk were carbonised beforehand. A tomato crop was grown on these different substrates for three months. The tomato fruits of each substrate were analysed morphologically and physicochemically. The main results of the physico-chemical properties show that the shape coefficient and density gave good results with a round shape and a density lower than 1. The physico-chemical parameters showed that water content, dry matter and ash content showed no difference between the substrates. Tomatoes from RJC621 plants had high pH and brix (4.6 and 3.77) compared to the control (4.47 and 2). Fruits from plants receiving RJC710 composition had a high reducing sugar content (8.03%). As for titratable acidity, the RJC711 substrate showed the highest value (7.5g/l).

Keywords: Tomato; Physico-chemical parameters; Ensory; Yield; Soilless culture

1. Introduction

The tomato (Lycopersicum esculentum L) originates from South America and is consumed all over the world. It has become one of the first vegetables produced in the world and is one of the most important vegetables in the diet after the potato (Doganlar et al., 2002). Traditionally classified as a vegetable, the tomato is also a fleshy fruit in the botanical sense. Intended for fresh consumption or industrial processing, tomato fruits are an important source of minerals, vitamins, antioxidants and fibre in the human diet. Indeed, it contributes to a balanced diet and prevents obesity (Chougar, 2011). It is the most cultivated vegetable in the world, occupying an important place in market gardening in terms of surface area and consumption rate for its great nutritional and organoleptic richness (Dorais and Ehret, 2008) and is considered a dietary food. Indeed, it is low in calories (20 per 100g), but rich in minerals (Abidi et al., 2017). It represents an important source of health-promoting antioxidants and vitamins (ascorbic acid and α-tocopherol) involved in the detoxification process of cells and help in the prevention of many cancers (Abidi et al., 2017). Also, these dietary bioactive compounds in tomatoes are reported to reduce the risk of chronic health problems such as cardiovascular diseases, hypertension and both types of diabetes (Surh and Na, 2008). In Africa, it is grown in all latitudes with an area of about 3 million hectares (Abir et al., 2006). Moreover, global tomato production has increased steadily in recent decades. It rose from 48 million tonnes in 1978 to 124 million in 2006 (Toufouti, 2013). According to FAO statistics, world tomato production in 2016 was 177,000 million tonnes. In Côte d'Ivoire, production varies between 22,000 and 35,000 tonnes (Sangaré et al., 2009). However, this local production only covers two-thirds of tomato needs, estimated at 100,000 tonnes (Soro et al., 2007).

The country therefore imports a very large quantity of tomatoes to meet demand.

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In view of these socio-economic challenges, it is imperative to look for other inputs that can enable sustainable agriculture because imports of agricultural products such as tomatoes are at an all-time high due to low crop yields. To increase yields, farmers resort to mineral fertilisation. However, the use of mineral fertiliser could have a financial impact that tomato growers cannot afford. Not only are these inputs very expensive, but also their misuse can represent a certain risk to human health. Consequently, they compromise the quality of tomato fruits. This explains, in part, the growing consumer interest in organic vegetables and fruits (Dorais, 2007). However, in urban areas, access to cultivable land is particularly difficult, as agriculture competes with urban land uses (housing, infrastructure) (Bakker et al., 2000; Temple & Moustier, 2004). Faced with this situation, soilless cultivation represents an important technical mutation allowing the optimisation of agricultural production factors while increasing yields (Bernier, 2015). This farming method is carried out in urban and peri-urban areas on supports other than soil. However, agricultural conditions and farmers' means favour the search for soilless substrates based on local substrates. Work by several authors has shown that agricultural waste products are a potential source of nutrients (Fondio et al., 2013). Four types of by-products were used in this study (rice husks, cocoa pods, cashew husk, and sawdust). The question is to know what are the effects of these substrates on the characteristics of tomatoes in Daloa. This work is situated in a context of improving farmers' incomes by reducing input costs on the one hand, and meeting consumer demands for food safety on the other.

The objective of this study is to characterise tomatoes produced on soilless substrates and to evaluate their impact on the morphological and physicochemical characteristics of tomato fruits grown on these substrates

2. Material and methods

2.1. Study area

The study was carried out in Côte d'Ivoire in the town of Daloa. The town of Daloa is located in the Haut-Sassandra region in the centre west of Côte d'Ivoire between 6° and 7° north latitude and between 7° and 8° west longitude (Figure 1). It is characterised by four seasons: a long rainy season from April to mid-July, a short dry season from mid-July to mid-September, a short rainy season from mid-September to November and a long dry season from December to March. The average annual rainfall is over 180 mm with temperatures ranging from 24.65 °C to 27.75 °C on average (N'Guessan et al., 2014). Thus, this region is one of the major regions of intense tomato production due to the large area of lowland developed for this purpose on the one hand and its high plant richness on the other.

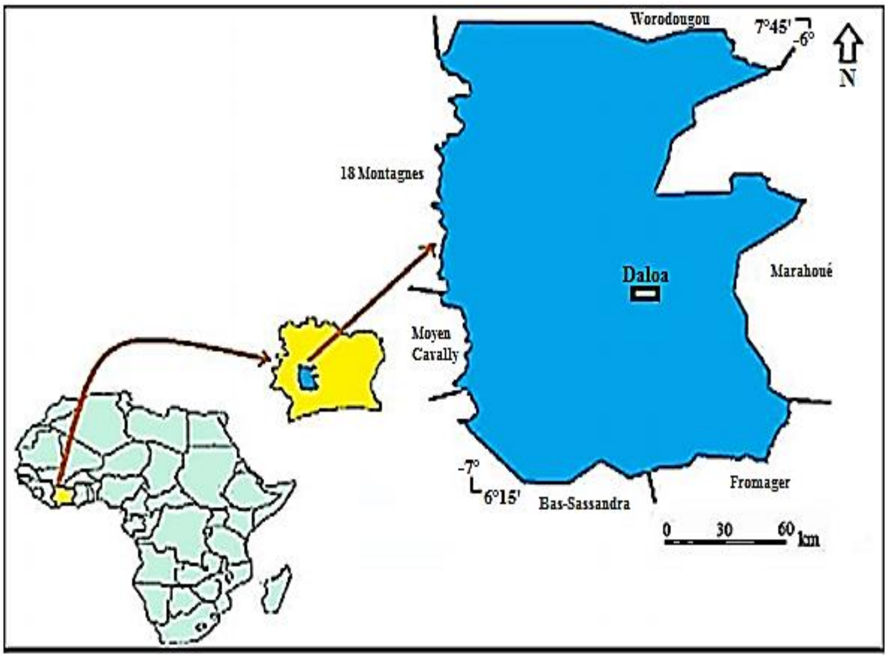


Figure 1 Location of the study area (Groga et *al.,* 2018)

2.2. Plant material and composition of growing media

The plant material used was tomato seed of the Cobra 26 variety from the local market in Daloa. The growing media consisted of sawdust, cashew husks, cocoa pods and rice husks. These four agricultural by-products were combined in varying proportions as shown in Table 1. The control was an unamended soil.

Table 1 Composition of substrates

N°	proportion of rice husk (g/100g)	proportion of cashew film (g/100g)	proportion of cocoa pods (g/100g)	proportion of sawdust (g/100g)	Substrates
1	20	60	10	10	RJC261
2	10	70	10	10	RJC171
3	10	80	0	10	RJC180
4	0	0	100	0	C100
5	25	25	25	25	RJC333
6	50	0	0	50	RB5050
7	0	0	0	100	B100
Control	0	0	0	0	Soil

B: Wood; C: Cocoa; RB: Rice-Wood; RJC: Rice-Cashew-Cocoa

2.3. Experimental design and conduct of the trials

The buckets containing the substrates were arranged in randomised Fisher blocks (three blocks) with three replicates as shown in Figure 4. Each block consisted of eight (8) elementary plots. A drip system was set up to allow watering of the plants until the appearance of flower buds. Fruit harvesting started about two months after transplanting. It was done regularly every three days. At each harvest, the fruits were sorted to remove those with irregularities and/or defects. To ensure the homogeneity of the samples, the tomato fruits of each plant were picked at the same stage of maturity and kept at room temperature. Then, a sample of three tomato fruits is taken for each substrate, thus eight samples. These samples were then sent to the laboratory where they underwent various analyses.

2.4. Morphological, physical and chemical characterisation of tomatoes

2.4.1. Morphological characteristics

The height and diameter of the tomato are measured with a caliper and the shape coefficient (Cf) is calculated according to the following formula:

$$\text{Shape coefficient} = \frac{\text{tomato height}}{\text{tomato diameter}}$$

2.4.2. Physical characteristics

The physical characteristics are the mass of the fruit, the percentage of seeds determined by measurement with an electronic balance and the density which was determined by taking a volume (V) of ten millilitres (10 mL) of each tomato sample and weighed on a digital balance. The density (d) of the tomato was calculated according to the following formula:

$$\text{density} = \frac{\text{mass of the tomato}}{\text{volume of the tomato}e}$$

The seed's proprtion was calculated according to the following formula:

$$\text{seed proportion} = \frac{\text{seed mass x 100}}{\text{seed volume}}$$

2.4.3. Chemical characteristics

The chemical characteristics are moisture content, dry matter, pH, total acidity, refractive index (degree brix), ash content, reducing sugars. The moisture content was determined by the AOAC method (1995), which is based on the loss of mass of the sample to a constant mass at 105 °C. The dry matter content is obtained as the difference between 100 and the water content. The pH was determined using a pH meter. The total acid content was determined by dosing with a strong base (NaOH 0.1N). The refractive index (degree brix) was assessed by means of a refractometer. The ash is determined by incineration. The determination of tomato sugars was carried out by the Fehling's liquor method.

2.5. Statistical analysis of the data

The collected data were processed using EXCEL 2013 spreadsheet software (the spreadsheet was used to draw the graphs or figures). STATISTICA 7.1 software was then used for statistical analyses and multiple comparison tests (Tukey HSD) were conducted when the difference was found to be significant ($p < 0.05$). In addition, a principal component analysis (PCA) was performed with a correlation circle. Also, the factorial design of the PCA shows the discrimination of the different treatments. The significance level is 5%.

3. Results

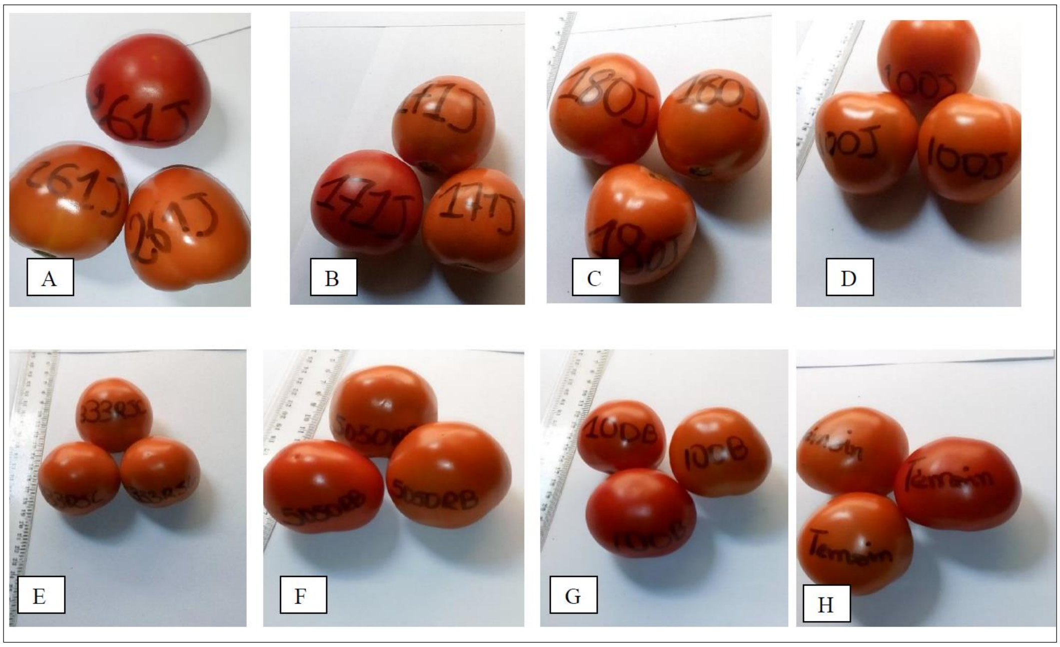
3.1. Morphological characteristics of tomatoes

The morphological characteristics of the fruits of the different substrates are presented in Table II. The height of the fruits varied from 3.1 to 4.9 cm and the diameter from 3.7 to 5.5 cm. These results show a significant difference in these different parameters with three homogeneous groups (a, b and c) and intermediate groups (ab, abc, bc) indicated by the Turkey test. The comparison of heights and diameters shows that tomatoes from the C100 substrate and the control have the highest values of 4.9 cm and 5.17 cm in height and 5.5 and 5.73 cm in diameter respectively. Tomatoes from the RJC180 substrate have the lowest height and diameter values (3.1 and 3.7 cm). Regarding the shape coefficient of the different tomato fruits, the values varied from 0.82±0.03 to 0.96±0.08. This coefficient is similar for all fruits. The statistical study shows that there is no significant difference ($P>0.05$), this is confirmed by Tukey's test which shows only one group of homogeneous mean A. It is noted that the fruits produced by the different plants are all round in shape with a Cf between 0.8 and 1 (Figure 2).

Table 2 Morphological characteristics of tomatoes

Substrates	Height (cm)	Diameter (cm)	Shape coefficient	Fruit shape
RJC261	$3.77±0.32^{bc}$	$4.1±0.26^{bc}$	$0.91±0.03^{a}$	round
RJC171	$3.5±0.00^{bc}$	$3.9±0.00^{bc}$	$0.89±0.00^{a}$	round
RJC180	$3.1±0.35^{c}$	$3.7±0.26^{c}$	$0.83±0.07^{a}$	round
C100	$4.9±0.00^{a}$	$5.5±0.00^{a}$	$0.89±0.00^{a}$	round
RJC333	$3.87±0.23^{b}$	$4.73±0.46^{abc}$	$0.82±0.03^{a}$	round
RJC5050	$3.43±0.12^{bc}$	$4.13±0.64^{bc}$	$0.84±0.16^{a}$	round
B100	$4.63±0.50^{a}$	$4.87±0.76^{ab}$	$0.96±0.08^{a}$	round
Control	$5.17±0.21^{a}$	$5.73±0.12^{a}$	$0.90±0.06^{a}$	round

B: Wood; C: Cocoa; RB: Rice-Wood; RJC: Rice-Cashew-Cocoa, Means ± standard deviation followed by the same letters (a, b, c) are not significantly different at the 5% level, according to the tukey test.



A: Tomato fruit of the RJC261 plant; B: Tomato fruit of the RJC171 plant; C: Tomato fruit of the RJC180 plant; D: Tomato fruit of the C100 plant; E: Tomato fruit of the RJC333 plant; F: Tomato fruit of the RJC5050 plant; G: Tomato fruit of the B100 plant; H: Tomato fruit of the control plant

Figure 2 Fruit of different substrate plants

3.2. Physical characteristics of tomatoes

The analysis of the results of the different physical characteristics are recorded in Table 3. The mass of the tomatoes ranged from 24.73 ± 5.73 g to 90.55 ±0.00 g. These results submitted to the statistical study revealed a significant difference (P< 0.05) and therefore, Tukey's test shows us five groups of homogeneous mean (a, b, c, d, e), the highest mass (99.55 g) of the first group is represented by the fruits of the control, with intermediates (ab, bc, cd, cde) that are located in an interval from the first to the fifth group (a to e), the last group shows the smallest (24.73 g) in the fruits of the substrate RJC180. The seed content varied from 1.37 ± 0.00% to 6.52± 0.94%. The analysis of variance for this parameter shows that there is a significant difference (P<0.05) between the fruits, the Tukey test shows two groups of homogeneous means (a, ab, b), the highest value of the first group is represented by the fruits of the substrate RJC5050, i.e. 6, 52%, there is an intermediate group located in a group interval of the first and second, the third group is constituted by the fruits of the substrates RJC180, and RJC171, the latter has the lowest percentage of seeds i.e. 1.37%. The density of the fruits varied from 0.88±0.26 to 0.93±0.02. There was a significant difference in fruit density between the different substrates (P <0.05) with three groups (a, b and c) indicated by the Turkey test. The highest density was observed in the fruits of the substrate RJC5050 (0.93±0.02) while the lowest density was obtained in the fruits of the substrates RJC261, RJC171 and RJC180 (0.88).

Table 3 Physical characteristics of the tomatoes

Substrates	Mass (g)	Seed content (%)	Density
RJC261	42.18 ± 7.00^{cde}	2.92 ± 0.40^{ab}	0.88 ± 0.00^{b}
RJC171	36.36 ± 0.00^{de}	1.37 ± 0.00^{b}	0.88 ± 0.26^{b}
RJC180	24.73 ± 5.73^{e}	1.90 ± 0.88^{b}	0.88 ± 0.00^{b}
C100	90.55 ± 0.00^{ab}	2.74 ± 0.00^{ab}	0.90 ± 0.00^{c}
RJC333	56.48 ± 0.68^{cd}	4.77 ± 0.00^{ab}	0.91 ± 0.00^{c}
RJC5050	41.93 ± 2.56^{cde}	6.52 ± 0.94^{a}	0.93 ± 0.02^{a}
B100	66.84 ± 24.00^{bc}	4.97 ± 2.16^{ab}	0.9 ± 0.00^{c}
Control	99.23 ± 4.25^{a}	2.62 ± 2.38^{ab}	0.9 ± 0.08^{c}

B: Wood; C: Cocoa; RB: Rice-Wood; RJC: Rice-Cashew-Cocoa, Means ± standard deviation followed by the same letters (a, b, c) are not significantly different at the 5% level, according to the tukey test.

3.3. Chemical characteristics of tomatoes

Table 4 shows the physicochemical parameters of the analysed fruits. The analysis of variance showed a significant effect ($P < 0.05$).

For the tomato samples the levels varied from 1.5±0.00° Brix to 3.3±0.26° Brix. The analysis of variance showed a significant difference at $P<0.05$ and the Tukey test revealed five groups with homogeneous means (a, b, c, d, e). The first group represents the highest mean of 3.3±0.26 with the fruits of the RJC171 plant and the lowest mean is observed in the last group of 1.5±0.00 for the fruits of the C100 plant.

The pH of the tomatoes varied between 4.4±0.00% and 4.8±0.00%. The pH of the control was also 4.4. However, it can be said that the pH values of the tomato samples are within the norms (4 and 4.5), since they mostly range from 4.4 to 4.8. Indeed, the analysis of variance showed a significant difference ($P<0.05$). There were five groups of homogeneous means (a, ab, bc, cd, de, e) identified by Tukey's test from the highest mean (4.8) in fruit from the RJC171 substrate to the lowest (4.4) in fruit from the RJC444, B100 and control substrates.

The acidity values obtained for the fruits ranged from 4.33±0.58% to 6.17±0.76%. A significant difference ($P < 0.05$) was observed after analysis of variance, which showed two homogeneous groups (a, ab, b) by Tukey's test. Group (a) represents the highest average (6.17%) observed in the fruits of the B100 and RJC171 plants, ab is intermediate between a and b and the lowest averages (3.83 and 4.33%) respectively in the control and RJC5050 fruits.

The moisture content allows us to relate the results of the biochemical constituents to the dry matter. The moisture content found in the different tomato samples was very high, ranging from 94.33 ±0.58% to 96.37 ± 0.40% in the cashew skin tomatoes. The statistical study for this parameter shows that there is a significant difference ($P<0.05$), this is confirmed by Tukey's test which shows three groups with homogeneous means (a, ab, abc, bc, c). The first group has the maximum mean (96.37%) with the fruits of the substrate RJC5050, intermediates between a, b and c that follow successively and the last group with a minimum mean of 94.33% with the fruits of the substrate C100.

The values recorded in tomatoes ranged from 0.15±0.03% to 0.53±0.06%. Statistical analysis for this parameter showed that there was a significant difference ($P<0.05$) between the samples. The Tukey test identified three groups of homogeneous means (a, ab, b) by order. The group of major mean (0.53%) constituted by the fruits of the C100 plant, followed by an intermediate group and finally the last group concerning the low mean (0.15%) and presented by the fruits of the RJC261 plant.

The amounts of reducing sugars in the tomato ranged from 4.27 ± 0.53% to 6.27% ± 0.00 and from 6.39 ± 0.24% to 6.67% ± 0.00. The analysis of variance revealed no significant differences. The Turkey test showed only one homogeneous group.

Table 4 Chemical characteristics of tomatoes

Substrates	Brix	pH	Acidity (Meq/100g)	Water content (%)	Dry matter (%)	Ash content (%)	Reducing sugars (%)
RJC171	3.3±0.26^{a}	4.8±0.00^{a}	6.17±0.76^{a}	95.1±0.46^{abc}	4.9±0.46^{abc}	0.43±0.07^{ab}	4.55±0.00^{a}
RJC180	2.37±0.15^{d}	4.6±0.00^{cd}	4.67±0.76^{ab}	95.47±0.34^{abc}	4.53±0.34^{abc}	0.49±0.02^{ab}	6.27±0.40^{a}
C100	1.5±0.00^{c}	4.6±0.06^{bc}	4.67±0.58^{ab}	94.33±0.58^{c}	5.67±0.58^{a}	0.52±0.06^{a}	5.56±1.57^{a}
RJC333	2.27±0.06^{de}	4.4±0.00^{e}	5.00±0.00^{ab}	95.30±0.60^{abc}	4.7±0.6^{abc}	0.46±0.06^{ab}	6.39±0.24^{a}
RJC5050	2.87±0.06^{b}	4.5±0.00^{de}	4.33±0.58^{ab}	96.37±0.40^{a}	3.63±0.40^{c}	0.35±0.07^{b}	6.41±0.45^{a}
B100	2.00±0.00^{e}	4.4±0.06^{e}	6.17±0.76^{a}	95.2±0.40^{abc}	4.8±0.4^{abc}	0.47±0.04^{ab}	6.67±0.00^{a}
Control	2.00±0.00^{e}	4.4±0.06^{e}	3.83±1.04^{b}	95.99±0.53^{ab}	4.00±0.53^{ab}	0.45±0.5^{ab}	6.07±2.17^{a}

B: Wood; C: Cocoa; RB: Rice-Wood; RJC: Rice-Cashew-Cocoa, Means ± standard deviation followed by the same letters (a, b, c) are not significantly different at the 5% level, according to the tukey test.

4. Discussion

The analysis of the results shows no influence on the shape coefficient, which is 0.8 < Cf < 1. The tomatoes all have a round shape. The difference in mass is significant. The highest mass (90.55 g) is observed in tomatoes of the C100 substrate and the lowest (24.73 g) in tomatoes of the RJC180 substrate. These values are different from those obtained by Fagbohoun & Kiki (1999) and Dossou et al. Their values were respectively between 28.4 and 41.77 g and between 23.4 and 74.35 g for two tomato varieties studied in Benin. For the seed content of tomatoes, the value ranged from 1.37 to 6.52%. These differ from the values of Fagbohoun & Kiki (1999) who found for two tomato varieties 1.6 to 2.07% for one and 1.6 to 2.46% for the other. The analysis showed a difference between these parameters. They can therefore be used to distinguish the different fruits obtained. The mass of the tomato fruit and its seed content are specific to each variety. According to Fan-Ungue et al (1969), three weight groups can be distinguished: weights above 100 g correspond to large fruits; weights between 70 g and 100 g correspond to medium fruits; weights below 70 g correspond to small fruit varieties.

These standards, compared to our results, indicate that tomato fruits produced on soilless substrates, except for the fruits of the C100 plant, all belong to the group of small-fruited tomato varieties and therefore cannot be recommended for industrial processing.

According to Fan-Ungue (1969) & Verxhivker (1973), varieties intended for industrial processing have a seed content of less than 1%. The difference between this value and those obtained during the study is very marked. Indeed, the fruits produced by the different substrates are an illustration of this with a higher average seed content (3.59%). This seems to predispose these tomatoes to a low yield, since the higher the seed content of a tomato variety, the lower its processing yield. The density varied between 0.88 and 0.93. These results are close to the values found by Zidanie (2009) which is 1.010 and 1.049.

The physico-chemical characteristics are refractive index, PH, acidity, water content, dry matter, ash content and reducing sugars. Indeed, the refractive index or Brix degree is an important quality parameter in the acceptance of fruits and vegetables. For these tomato fruits, it was found that the substrates significantly influenced the refractive index, whose values were between 1.5 and 3.3°Brix. These values were lower than those observed by Sutharsan et al. (2014), Abidi et al. (2017) and Oboulbiga et al. (2017) which ranged from 3.10% to 5.93%. Also, Garcia & Barrett (2006) reported Brix levels between 4.5% and 6.25% for tomato for processing approximating the values obtained in this experiment.

The pH of tomatoes from the RJC333 (4.4), RJC5050 (4.5) and B100 (4.3) substrates is the same as the control (4.4). Tomato fruits are generally considered to be acidic, but their pH can vary according to their degree of ripeness and the variety (Dossou et al., 2007). Furthermore, the pH of tomato fruits obtained with these substrates is less than or equal to 4.5; these fruits are therefore acidic (Giordano et al., 2000). These results are similar to those of Campos et al. (2006) and Oboulbiga et al. According to these authors, tomato fruits generally have a pH between 3.70 and 4.50. This relatively low pH of tomato fruits is an advantage from a microbiological point of view. Indeed, this pH level could considerably reduce the nature of microorganisms that can develop on tomato fruits (Agassounon et al., 2012).

The total acidity of the fruits was different at ($p<0.05$). Indeed, it is a good estimator of the organic acid content of tomato fruits (Granges et al., 2000). Our work showed that the total acidity according to the recorded substrate composition was between 3.83 and 6.17%. These values are higher than those reported by (Granges et al. 2006; Abreu et al. 2011 and Agassounon et al. 2012). Their values ranged from 2.60 to 5.8 g/l. This difference could be explained by the fact that during tomato ripening, the acid content (mainly citric and malic) decreases in favour of the increase in sugar content, thus harvested ripe tomatoes have a low acid content. It could also be attributed to genotypic characteristics and ecological parameters.

The water composition of the fruit ranged from 94.33 ± 0.58% to 96.37 ± 0.46%. These results differ from those of Pinela et al. (2012). This difference is due to the different substrates used. Indeed, these authors showed tomato water contents ranging from 90.63 to 93.70%. These water contents are also different from those reported by Sulbarán et al. (2011); FAO (2012). These authors found water contents between 93.50% and 94.60%. The high water content of tomato fruits would explain their perishable nature. This could limit its conservation at room temperature for a long period (Agassounon et al., 2012.).

The dry matter contents less than or equal to 5% (from 3.63 to 5.67%) for all fruits are below the theoretical value of more than 5%, retained by Fagbohoun & Kiki (1999). However, these dry matter contents obtained for these fruits are similar to the results of Dossou et al (2007) who obtained 4 to 5% dry matter in their study in Benin.

The ash levels of 0.15 to 0.53% in our work are also in line with the results reported by the same authors who found 0.27 to 0.54% and are largely inferior to those found by Navarro et al. (2011) and Botsoglou et al. This difference could be due to the fact that the mineral content is a function of the variety or could be mainly related to the influence of the composition of the substrates. It should be noted that tomatoes are a source of many minerals, particularly potassium and phosphorus.

With regard to reducing sugars, our recorded values were 5.16% and 6.49%, which differs from the work done by Sherman et al (1977) who reported values of 4.97% and 5.08%. The results obtained show that the fruits studied have a high sugar content compared to the data of these authors. Indeed, a high sugar content in tomatoes is a sign of good taste and flavour.

5. Conclusion

The present study was carried out in order to characterise tomatoes produced on soilless substrates and to evaluate their impact on the characteristics (morphological, physicochemical and organoleptic) of the tomato. Thus, this study shows that all tomatoes have a round shape. The substrates made of 100% cocoa shell (90.55 g) and 100% sawdust (66.84 g) gave a high mass after the control (99.23 g). Concerning the chemical parameters the analysis of the results showed that the reducing sugar content did not differ between the substrates. The tomatoes of the different substrates had an average pH below 4.7 (acidic) and a high water content (94.83 to 96.37%) including the control.

Compliance with ethical standards

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Disclosure of conflict of interest

All The author declare no conflict of interest.

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