British Journal of Applied Science & Technology
4(27): 3967-3975, 2014

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Characterization of Some Physico-chemical Properties of F5 Breeding Lines of Tomatoes

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Authors' contributions

Authors JN and EKQ nursed and planted the seeds from which the fruits were obtained for analysis. Authors WTT, EKG, WSKA and BTO did the laboratory work. The other authors apart from looking at the insect pests abundance and diversity on the tomato accessions which have already been accepted for publication, made significant contributions to the editing and proofreading of the final manuscript together with the above mentioned authors.

Original Research Article

Received 26th April 2014
Accepted 3rd July 2014
Published 25th July 2014

ABSTRACT

Aims: In an effort to improve the breeding lines of tomatoes for further breeding work; this work was done to evaluate the physico-chemical properties of selected lines.
Study Area and Duration: The research was carried out between May-September 2012 at Nuclear Agriculture Research Center (NARC) farms and the laboratories of Radiation Technology Center (RTC) of Biotechnology and Nuclear Agriculture Research Institute (BNARI).
Methodology: 10 accessions of fully ripe tomato fully ripened tomatoes from ten F5 breeding lines were harvested and analyzed for their physico-chemical properties including colour, pH, Total Titratable Acidity (TTA), Total Soluble Solids (TSS) and Vitamin C.
Results: The highest pH was recorded in wosowoso variety, T19 (4.31) while the lowest

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was T14 (3.90). The Vitamin C content was observed to be high in wosowoso (78.86mg/100g) and the least being T14 (20.83mg/100g). Among the various lines, the highest TTA value was found in roma, T11 (1.18%CA) while lowest (0.55%CA) was T3 belonging to the cherry yellow variety. Among all the accessions, T9 had the most reddish colour (a*) whilst the lowest value was reported in TI5Ay. Most of the generational lines performed better than their parents and thus can be selected for further breeding work.

Conclusion: Generational lines; T3, T11 T14, T17, T9, T15Ay, T15Br and T19 obtained from the various parents were found to have more desirable traits compared to their parents.

Keywords: Wosowoso; variant lines; pH; Solanum lycopersicon.

1. INTRODUCTION

Tomato, *Solanum lycopersicon* L., is a member of the nightshade family and plays an important role in the diet of most Ghanaians [1]. It can be used as juice, ketchup, sauce, canned fruits, puree, paste, etc. They are consumed either fresh or processed. Tomato is nutritionally rich in various elements and adds colour and flavour to our diets. Moreover, tomato is a valuable source of antioxidant or chemo-protective compounds.

It is a rich source of folate, phytonutrients, beta-carotene and gamma carotene, photoene as well as several minor carotenoids [2]. Additionally, it possesses a variety of nutrients including fibre and potassium according to the USDA National Nutrient Database [3].

It is a source of vitamins A and C and contains lycopene, a powerful antioxidant which fights free radicals. Free radicals interfere with normal cell growth and activity. Antioxidants help prevent disease in plants, animals and humans. Lycopene is the pigment responsible for the characteristic deep red colour of ripe tomatoes [4,5] and their products [6]. Lycopene is used as an agent for prevention and treatment of cardiovascular diseases, skin cancer [7], eye diseases, prostate cancer [8] and lung cancers [9]. Nkondjock et al. [10] reported that the dietary intake of lycopene from tomatoes can reduce pancreatic cancer risk among men by 31%.

The physico-chemical properties of tomato such as pH, TTA, TSS, are among the important determinants of its consumer acceptability. TTA and pH are interrelated in terms of acidity, but have different impacts on food quality [11]. The total acid available to react with sodium hydroxide solution during titration is TTA whiles the pH gives a measure of the strength of the acid in food [12].

The pH of food gives an indication of its resistance to microbial attack [12]. A pH value of 2.5 - 5.5 tends to prolong the shelf life of fresh fruit and inhibit the multiplication of micro-organisms. A pH value of around 4.5 is the simplest way to ensure the stability of the product. Lower pH values have been found to give greater protection to tomato against *Bacillus coagulans* [13]. Tomato pH ranges from 4.0 - 4.5.

TTA and pH are two important quality attributes of processing tomatoes. In California, industrial processors of tomatoes specify a pH of 4.2 or 4.3 in their processed products. The pH of tomatoes is determined primarily by the acid content of the fruit.

The colour of tomato is due to the presence of diverse carotenoid pigment system with appearance conditioned by pigment types and concentrations [14,15]. The colour is mostly used to determine the stage of ripening.

a* is the measure of redness of the fruit, L* indicates lightness (ranging from 0 to 100), with 0 being black and 100 being white. The coordinates a* measures red (+) and green (-), and b* is for yellow (+) and blue (-) [16].

Tomato production in Ghana is constrained by a myriad of challenges which has relegated the industry to the point of suffocation. Aside biotic factors such as pest and disease incidences that pose serious challenges, fruit quality issues is another headache for most farmers. While most exotic breeds have been touted as a panacea for these problems, most end up succumbing to a number of viral diseases. Local landraces that are tolerant to these viruses however have poor fruit quality characteristics, shorter shelf lives and poor storage qualities. There is therefore the need to improve these traits by breeding new varieties that have high quality fruits and a measure of tolerance to diseases such as the Tomato Yellow Leaf Curl Virus (TYLCV). Hybridization and other plant breeding techniques such as mutation breeding have been proved to be effective methods of generating variability for selection for improved plant traits. Quartey [17], through mutation induction, generated variants of *Solanum pimpinellifolium* L. (whose disease tolerance traits and excellent fruit qualities - but small fruit shape and high number of seeds - have been well documented) with improved fruit sizes. Nunoo [18], hybridized these variants with some landraces and exotic genotypes that needed amendments in their fruit quality. Subsequent generations showed remarkable quality traits in terms of shape, fruit colour and plant architecture. There is the need to analyse fruits of some screened breeding lines to evaluate their physico-chemical properties in the course of the breeding work to aid in choosing appropriate and promising lines for further breeding work. The objective of the study was therefore to evaluate the physico-chemical properties of ten (10) selected breeding lines of tomato.

2. MATERIALS AND METHODS

2.1 Study Area

The study area was the Research Farm of Nuclear Agricultural Research Centre (NARC) and Laboratories of the Radiation Technology Centre (RTC) of the Biotechnology and Nuclear Agriculture Research Institute (BNARI) of the Ghana Atomic Energy Commission (GAEC). The work was carried out between May-September 2012. The variants lines were planted and nursed in trays and after 21 days transplanted onto the field. All agronomic practices were observed.

2.2 Sample Collection

At maturity, fully ripe fruits were harvested by hand-picking, stored in zipper-locks and sent to the laboratory for analysis. The selected samples were round in shape, free from pest infestation and without cracks. The fruits were grown under the same climatic conditions and harvested at the same time of maturity. 200 g of each breeding line were sent for analysis of which only 100 g of the fruit was used. The breeding lines were T1, T3, T11 T14, T17, T5, T9, T15Ay, T15Br and T19 which represent wosowoso parent variety, cherry yellow, roma variant (a prolific trait), wosowoso variant (stripped, prolific and big fruit), roma variant (bi-coloured fruit), *S. pimpinellifolium* parent, roma variant (hardened and big fruit), roma variant (yellow skin), roma variant (red skin) and wosowoso variant (big fruit, and deep red colour) respectively. The parental progeny lines are the offspring (T11, T17, T5, T9, T15Ay, T15Br and T19) of the parents (T1, T3 and T17) have been grown to the fifth generation.

2.3 Colour Determination

The colour of the fruits was determined in triplicates using a Minolta Camera (CR-300 with a D65 light source; Minolta Camera Co., Osaka Japan) which had its bases on the CIELAB {1976 CIE L*a*b* Space} colour parameters. These are; L*, a* and b*, where L* defines the lightness, a* relates to redness and degree of ripening in tomato while b* relates to yellowness.

2.4 Ascorbic Acid (Vitamin C) Measurement

A 0.005M of iodine solution was prepared by weighing 2 g of potassium iodide and 1.3 g of iodine into a beaker. Few drops of distilled water was added and swirled until all the iodine had dissolved. The solution formed was made up to 1 litre in a volumetric flask. A 1 % (w/v) starch solution was prepared by weighing 1 g of powdered starch and dissolving it in 100 ml of distilled water to serve as an indicator. Ten millilitres (10 ml) of the sample was titrated with iodine solution with an indicator until a blue black colouration was observed at the end point.

2.5 pH Determination

About 100 g of previously washed and dried tomato fruits were weighed into high density polypropylene sealed bags and crushed for 3 minutes in a stomacher (Seward medical, UK). The fruit juice was then filtered through a sieve of l mm pore size facilitating the removal of fruit coats and seeds. The pH determined using Association of Official Analytical Chemists (AOAC, 2000) [19] method with pH meter (Mettler Toledo Model) after it had been calibrated. This was done in triplicates.

2.6 Total Titratable Acidity (TTA)

The TTAs of the fruits were determined using the AOAC (2000) [19]. Ten (10 ml) millilitres of the fruit juice was taken and 50 ml of distilled water was added to it. This was titrated with 0.1 M (NaOH) with phenolphthalein as an indicator. Titration continued until a pH of 8.1 was recorded on the pH meter (Mettler Toledo Model). This was done in triplicates.

2.7 Total Soluble Solids (TSS)

The TSS of the fruits was obtained using the hand refractometer. The juice from the fruits was obtained by crushing them in the stomacher and the juice transferred into 50 ml beakers. With the help of a teat pipette, 1 ml of the juice was placed on the hand refractometer after it had been calibrated. This was done in triplicates.

2.8 Data Analysis

The completely randomized design (CRD) was used with three replicates. The results were evaluated for statistical significance with one-way analysis of variance (ANOVA) and means separated by the multiple range test (STATGRAPHICS Centurion XVI.VI) and expressed as the mean upon three independent analyses. A p-value of 0.05 or less was considered as statistically significant.

3. RESULTS AND DISCUSSION

3.1 Colour of the Fruits

The highest L-value (brightness) was observed in T3 (60.36), whiles the lowest (darkest) was observed in T11 (35.99). The highest brightness observed in this sample may be due to high lutein content in this sample as compared with the other samples. Gowda and Huddar, 2000, [20] reported that breeding lines of the same crop may differ in terms of physical and chemical characteristics. Hence the observed phenomenon in this sample may be due to its varietal characteristics. There was no significant differences ($P > 0.05$) among T1, T 14, T 5, and T9; T5, T9 and T19. Also there were no significant difference ($P > 0.05$) between T11 and T19 (Table 1).

Table 1. The colour parameters of the various breeding lines of tomato (*Solanum lycopersicon* L.) in Ghana

Breeding line	L* – values (lightness)	a* – values (redness)	b*– values (yellowness)
T1	$37.02{\pm}0.38^{e}$	$16.67{\pm}0.25^{f}$	$11.65{\pm}0.15^{g}$
T3	$60.36{\pm}0.36^{a}$	$6.73{\pm}0.03^{g}$	$56.05{\pm}0.68^{a}$
T11	$35.99{\pm}0.37^{g}$	$17.12{\pm}0.24^{f}$	$10.31{\pm}0.08^{h}$
T14	$36.99{\pm}0.49^{e}$	$24.93{\pm}0.79^{ab}$	$14.82{\pm}0.98^{de}$
T17	$38.09{\pm}0.14^{d}$	$20.31{\pm}0.06^{e}$	$14.13{\pm}0.33^{e}$
T5	$36.59{\pm}0.14^{ef}$	$22.23{\pm}0.40^{d}$	$12.80{\pm}0.32^{f}$
T9	$36.77{\pm}0.17^{ef}$	25.14±0.13a	$16.16{\pm}0.28^{c}$
T15Ay	$59.48{\pm}0.08^{b}$	$-1.41{\pm}0.04^{h}$	$40.03{\pm}0.09^{b}$
T15Br	$40.49{\pm}0.10^{c}$	$22.85{\pm}0.09^{c}$	$16.49{\pm}0.22^{c}$
T19	$36.24{\pm}0.51^{fg}$	$24.59{\pm}0.26^{b}$	$15.16{\pm}0.38^{d}$

**LSD: Means in the same column with the same letters are not significantly different (P > 0.05) from each other. [T1 – wosowoso parent variety), T3 – cherry yellow, T11 – roma variant, T14 – wosowoso variant, T17 – roma variant (bi-coloured), T5 – S. pimpinellifolium parent, T9 – roma variant (bigger and harder), T15Ay – roma variant (with yellow skin), T15Br – roma variant (red skin) and T19 – wosowoso variant (big and deep red in colour)].*

The highest a* -value (redness) occurred in T9 [24.14], whiles the lowest value (greenness) was observed in T15Ay.The observed value in terms of redness in the sample T9 may be an indication of the high lycopene content (high carotenoid content) of this breeding line.

The sample T15Ay which had a low a*-value is an indication of low lycopene content (low carotenoid content) as compared with the other samples. There was no significant difference ($P > 0.05$) in terms of the a*-value between T14 and T9, this might be due to similarities between these two breeding lines. There was no significant difference ($P > 0.05$) between the fruits of T14 and T19. Thus the non-significance ($P > 0.05$) difference observed in these samples is an indication of the same amount of lycopene content.

The highest b*– value in terms of yellowness was observed in T3 (56.05) and the lowest (bluish) was observed in T11 [10.31]. The observed highest yellowness in T3 depicts the presence of other carotenoids [21] in this sample which is not so much abundant in the other lines of the tomato bred. This may be attributed to varietal differences [20]. There was no significant difference ($P > 0.05$) between T14 and T17 on one hand and T14 and T17 on the other hand. The observed pattern between T14 and T17, and then T14 and T19 may be due to some similarities in these breeding lines since there could be varietal similarities. The values obtained for yellowness ranged between 10.31 and 56.05 (Table 1). The lowest value of yellowness was less than what was observed in breeding lines reported by Albano et al. [22] and the highest was greater than what was observed by Albano et al. [22]. This may be due to varietal differences [20].This might be due to the transfers of characteristics (genes) for brightness to these from the same parents [20].

3.2 pH and Total Titratable Acidity (TTA)

The lowest pH value for the samples analysed was 3.90 (wosowoso variant), which was smaller than the pH of the tomato fruits analysed by Alenazi et al., (2009) [23], however the highest value was 4.31 which was higher than the values observed by Alenazi et al., (2009) [23]. This is an indication of stronger acidity in the samples worked on than the samples worked on by Alenazi et al., (2009) [23]. The highest pH value recorded in wosowoso was significantly different ($P < 0.05$) from the other hybrids, however, this gave rise to the second least TTA, a higher pH is expected to give rise to a lower TTA value, but this was not the case in the wosowoso, and this might be due to other factors. A higher pH should give rise to a lower TTA. This was due to the lower percentage of citric acid present in this line. The highest TTA value was recorded in roma 1.18% but was not significantly different ($P > 0.05$) from the wosowoso hybrid (1.16%) this was due to the non-significance ($P > 0.05$) in the pH values of these two hybrids (Table 2.). However, a significant difference ($P < 0.05$) between wosowoso red and wosowoso did not lead to any significant difference ($P > 0.05$) in the TTA values of these lines (Table 2). A non-significant difference ($P > 0.05$) between roma and wosowoso red at pH values, led to significant differences ($P < 0.05$) in the TTA values of these lines (Table 2). This might be due to varietal differences which are expected to occur in terms of TTA. Different lines or hybrids of a particular crop are expected to have different characteristics. This was confirmed in these two lines.

Table 2. Some physico chemical parameters of the various lines of tomato (*Solanum lycopersicon*) in Ghana

Breeding line	pH	Vitamin C (mg/100g)	TSS (%)	TTA (%CA)
T1	3.99±0.01[d]	78.86±2.04[a]	8.20±0.00[b]	0.97±0.00[d]
T3	4.20±0.00[b]	31.64±0.56[f]	6.30±0.00[g]	0.55±0.04[i]
T11	3.93±0.01[e]	29.72±0.82[g]	7.00±0.00[e]	1.18±0.03[a]
T14	3.90±0.00[e]	18.83±0.36[i]	7.00±0.00[e]	1.16±0.01[b]
T17	3.91±0.00[e]	37.21±0.74[e]	7.20±0.00[d]	1.06±0.02[c]
T5	4.18±0.01[c]	50.34±0.94[b]	6.20±0.00[h]	0.94±0.00[e]
T9	4.20±0.01[b]	24.35±0.82[h]	8.30±0.10[a]	0.76±0.02[g]
T15A	4.20±0.07[b]	28.48±0.85[g]	7.00±0.00[e]	0.64±0.01[h]
T15B	4.01±0.07[d]	48.19±0.63[c]	7.37±0.06[c]	0.88±0.03[f]
T19	4.31±0.01[a]	43.60±1.06[d]	6.87±0.06[f]	0.64±0.00[h]

LSD: Means in the same column with the same letters are not significantly different (P > 0.05) from each other. [T1 – wosowoso parent variety), T3 – cherry yellow, T11 – roma variant, T14 – wosowoso variant, T17 – roma variant (bi-coloured), T5 – S. pimpinellifolium parent, T9 – roma variant (bigger and harder), T15Ay – roma variant (with yellow skin), T15Br – roma variant (red skin) and T19 – wosowoso variant (big and deep red in colour)].

3.3 Ascorbic Acid (Vitamin C) Levels

It was observed that the highest vitamin C content was found in the parental lines (wosowoso) as compared with the other breeding lines. However wosowoso red had the highest value among all the breeding lines. The least amount of vitamin C was found in the T14 (18.83mg/100g), whiles the highest was found in the control (wosowoso (78.86mg/100g), which was higher than what was observed in lines obtained by Palop et al. [24], in five lines of tomato fruits cultivated in Turkey and smaller than tomato fruit samples analysed by Cantwell et al. [25]. There were significant ($P < 0.05$) varietal differences detected in the vitamin C content of the juice extracts from the fruits of the various lines. The vitamin C level of the juice extract from each breeding line was significantly different ($P < 0.05$) from one another.

3.4 Total Soluble Solids (TSS)

The highest TSS (8.30%) was observed in roma, whilst the lowest was observed in T5 wild. The highest TSS observed in roma might be due to the high carbohydrate (sugars and non-sugars) content. Significant differences ($P < 0.05$) were detected in the TSS values among the various breeding lines (Table 2). However no significant differences ($P > 0.05$) were detected among the total soluble solid values of roma, wosowoso and wosowoso red, which might be due to similar carbohydrate content in these samples [26]. The lowest observed TSS was in T5 wild (6.20%), which implies low carbohydrate content and the conversion of acids to sugars in the glycolytic pathway [26].

4. CONCLUSION

The line with the lightest coloured fruits was T3. This line had the highest yellowness, an indication of its use as a food garnish. In terms of redness in colour, T9 was superior as compared with others. This is an indication that T9 had high lycopene content which can meet the daily uptake of lycopene by man. Wosowoso parent (control) had the highest content of vitamin C and TSS as compared with all the others. The fruits with the highest content of acid were the lines of T11 and T17, an indication of high levels of organic acids as compared to that of the other lines, which was also seen in the TTA for the lines. The offspring performed better than their parents and possessed traits which can be used in further breeding works.

ACKNOWLEDGEMENTS

We are grateful to the technologists at both the NARC and RTC for their immense support during this work.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history.php?iid=613&id=5&aid=5475