MANAS Journal of Engineering
ISSN 1694-7398 | e-ISSN 1694-7398

Volume 8 (Issue 1) (2020) Pages 11-16

The concentration distribution of components and particles in the system: tomato-water-sodium nitrate and assessment of the oxidation-reduction potential at different temperatures

Damira Sambaeva[1], Timur Maimekov[2], Nurzat Shaykieva[3], Janarbek Izakov[3], Zarlyk Maimekov[3,*]

[1]Kyrgyz State University of Geology, Mining and Natural Resources Development, Bishkek, Kyrgyz Republic

[2]Moscow Institute of Physics and Technology, Dolgoprudny, Russia

[3]Kyrgyz-Turkish Manas University, Engineering Faculty, Department of Environmental Engineering, Bishkek, Kyrgyz Republic, zarlyk.maymekov@manas.edu.kg, ORCID 10000-0002-9117-262X

ABSTRACT

The paper considers a triple complex system of tomato, water and sodium nitrate. Taking into account the average macronutrient composition and moisture content of field and greenhouse tomatoes, physicochemical modeling of the system was carried out tomato-water-sodium nitrate. The hydrogen index of tomato was determined at various temperatures and it was noted that tomato medium was acidic. It is shown that with an increase in the content of sodium nitrate in the system: tomato - water - sodium nitrate within the temperature range from 278 to 293 K, the hydrogen index of tomato increases, i.e. the process of neutralizing the acidic medium based on sodium hydroxide proceeds. The calculated hydrogen value of tomato corresponds to the experimental values of pH = 3.3-4.38. The obtained results made it possible to determine the distribution of individual simple and complex cations and anions in water-salt solution, as well as to establish the values of redox potential, and thereby revealed the antioxidant nature of tomato.

ARTICLE INFO

Research article

Received: 25.12.2019
Accepted: 13.04.2020

Keywords:
Tomato,
sodium nitrate,
redox potential,
solution,
ions,
complex system

*Corresponding author

1. Introduction

Currently, the study of oxidation process in biological systems, specifically deceleration aging process of human body are relevant task. Accordingly, an active search for antioxidants based on plant materials with the highest content of lycopene in order to limit the oxidation of biogenic elements carried out [1; 2; 3]. It should be noted here that lycopene is most often found in vegetables of red color (tomato, watermelon etc.) [4; 5]. Noted, that tomato (tomato from lat.) is a thermophilic plant and in tomato the amount of water is more than 90%., which grows well in fertile soils, using nitrogen, phosphorus, potassium, i.e. stimulating the process of bioremediation of technogenic soil [6; 7]. For example, the toxic effect of nitrate and sodium nitrite on germinating seeds and nitrogen in relation to tomatoes was considered and the chemical composition of the tomato [8; 9] was also given in studies [10; 11]. In the study [12; 13] the influence of various plant growth regulators and micronutrients on the content of micronutrients in tomatoes was studied; the effect of various soil pH on the growth of a tomato was considered in the

studies [14; 15]; in [16; 17; 18] the effect of nitrogen fertilizers on the content of nitrates in salad was indicated; the role of macronutrients and micronutrients in improving the quality of tomatoes was noted in [19]; influence of temperature, pH and food additives on the content of volatile products of tomatoes was given in [20; 21]; nutrients in tomato based on the use of vermicompost and chemical fertilizers are indicated in [22; 23]; the influence of potassium on the quality of tomato fruit was considered in [24; 25], and in [26; 27] the influence of fertilizers on the yield of some minerals in tomato were shown, and the efficiency of biohumus in the quantitative and qualitative growth of tomato plants; the reaction of foliar application of boron to vegetative growth, the quality of tomato yield were studied in [28], and in [29] the influence of zinc and boron on the growth, flowering and fruiting of tomatoes, as well as the effect of foliar application of ferrous sulfate and citric acid, and quality tomato plants; the composition of tomato fruit were studied in [30]; the influence of boron, calcium and surface moisture on the quality of fresh tomatoes was considered in [31].

The brief review of the literature shows that the study of the influence of temperature, pH, concentration of mineral salts, including sodium nitrate [32; 33] on the activity of the bioremediation process of the soil-tomato-fertilizer system, is a very useful research.

2. Materials and methods

Physicochemical modeling of the system tomato-water-sodium nitrate was carried out by searching for potentially possible phases in equilibrium, distributing components and particles, and also the composition of the system by chemical elements while minimizing the isobaric-isothermal potential [34; 35; 36; 37]. The calculation included the use of macronutrient composition and the moisture content of the tomato, as well as the calculation of the thermodynamic characteristics of the system at various temperatures (278-298 K) and sodium nitrate concentrations (29.3-50 mg). The verification and comparison of various basic sources, as well as the processing, correction and visualization of the thermodynamic parameters of the system studied above, were carried out taking into account the molar ratio of all components over a wide range of temperature changes (P = 0.1 MPa). The thermodynamic parameters of the system (ΔG, ΔH, ΔS, ΔU), equilibrium compositions, pH, Eh, ionic strength (I) of the aqueous tomato solution were calculated. The concentration distribution of individual components and particles (cations and anions) in aqueous solution of tomato (Table 1-5). The humidity of the tomato (W_{H2O} = 935 g/kg) was determined by the express method based on the drying using humidity (OHAUS MB200) analyzer. The hydrogen value of the tomato was determined on the basis of the pH-meter (Denver Instruments) and was equal to pH = 3.64-4.38, and the content of the gluten in the field tomato ranged from 5.6 to 5.68 %, in the green house tomato from 5.76 to 6.03 %.

3. Results and discussion

It was noted that the tomato was a thermophilic plant; therefore, the physico-chemical modeling was carried out within the temperature range from 278 to 293 K and atmospheric air pressure. In the model calculations, only macronutrients of tomato (mg/kg) were taken into consideration: calcium-140, magnesium-200, sodium-400, potassium-2900, phosphorus-260, chlorine-570, sulfur-120; water content in tomato H_2O = 935 g/kg; the content of sodium nitrate in the system varied from 29.3 to 50 mg/l. The chemical composition of the tomato (per 100 g/g) was given according to the data of [38]: proteins-0.6, fats-0.2, carbohydrates-4.2, starch-0.3, ash-0.7, organic acids-0.5, mono- and disaccharides-3.5; microelements (per 100g/mg): iron-0.9, zinc-0.2, iodine-2μg, copper-110μg, manganese-0.14, selenium-0.4 μg, fluorine-20 μg, molybdenum-7 μg, boron-115 μg, cobalt-6 μg. Table 1 shows the data obtained at the optimal temperature of growth of a tomato equal to 20 °C.

Table 1. *Physicochemical and thermodynamic parameters of the system: tomato-water-sodium nitrate.*

Temperature, K	*Pressure, MPa*	*Volume, m^3*	*Mass, kg*	*Density, kg/m^3*
293.15	0.1	0.0293	0.98	33.58
G, MJ	*H, MJ*	*S, kJ/K*	*U, MJ*	*Cp, kJ*
-12.92	-15.44	4.01	-15.44	1.78
C_{NaNO3}, mg/l	*Eh, B*	*pH*	*Ion strength*	*TDS, mg/kg sol*
29.3	-0.53	3.36	10	1092.73

Table 2. *Phase parameters of the system: tomato-water-sodium nitrate.*

Name phase	*Volume, m^3*	*Mole quantity*	*Mass, kg*	*Density, kg/m^3*	*Weight %*
AqueousSol.	$3.79 \cdot 10^{-6}$	$2.38 \cdot 10^{-4}$	$7.61 \cdot 10^{-3}$	$2.01 \cdot 10^{3}$	0.77283
Liquid	$2.93 \cdot 10^{-2}$	$5.27 \cdot 10^{-2}$	$9.74 \cdot 10^{-1}$	33.2	98.90978
Sulfur (S)	$5.84 \cdot 10^{-8}$	$3.74 \cdot 10^{-6}$	$1.20 \cdot 10^{-4}$	$2.05 \cdot 10^{3}$	0.01218
KCl	0	$4.03 \cdot 10^{-5}$	$3.00 \cdot 10^{-3}$	0	0.30519

Table 3. *Distribution of chemical elements of the system: tomato-water-sodium nitrate.*

Chemical elements	*Chemical component*	*Molality*	*mg/kg sol*	*Chemical potential*
Ca	0.003493	1.28	$5.13 \cdot 10^{4}$	-105505
Mg	0.008229	3.01	$7.32 \cdot 10^{4}$	-79752
Na	0.017744	6.50	$1.49 \cdot 10^{5}$	-48403
K	0.074172	12.4	$4.85 \cdot 10^{5}$	-53759
P	0.008394	3.07	$9.52 \cdot 10^{4}$	-3488
Cl	0.046658	2.32	$8.23 \cdot 10^{4}$	-43934
S	0.003742	0	0	38
N	0.000345	0.126	$1.77 \cdot 10^{3}$	-40802
C	1	22.2	$2.67 \cdot 10^{5}$	51310
H	103.8314	28.9	$2.91 \cdot 10^{4}$	8173
O	53.90142	53.7	$8.58 \cdot 10^{5}$	-73828

Table 4. *Distribution of components and particles of the system: tomato-water-sodium nitrate.*

Components and particles	*Molality*	*Mole quantity*	*mg/kg sol*	*Coeff. activity*
AqueousSol				
CO_2	$4.01\cdot10^{-5}$	$1.10\cdot10^{-7}$	$1.77\cdot10^{-3}$	6.8897
Ca^{+2}	0.589	$1.61\cdot10^{-3}$	23.6	19.322
$CaCl^{+}$	0.69	$1.88\cdot10^{-3}$	52.1	5.1448
$CaOH^{+}$	$7.79\cdot10^{-11}$	$2.13\cdot10^{-13}$	$4.45\cdot10^{-9}$	3.764
Cl^{-}	$5.09\cdot10^{-6}$	$1.39\cdot10^{-8}$	$1.81\cdot10^{-4}$	$4.9\cdot10^{4}$
HCO_2^{-}	22.2	$6.07\cdot10^{-2}$	1.00	$1.5\cdot10^{4}$
$H_2PO_2^{-}$	$2.89\cdot10^{-5}$	$7.89\cdot10^{-8}$	$1.88\cdot10^{-3}$	$1.0\cdot10^{4}$
$H_2PO_3^{-}$	3.07	$8.39\cdot10^{-3}$	$2.49\cdot10^{2}$	$3.4\cdot10^{3}$
HCO_3^{-}	$3.02\cdot10^{-12}$	$8.25\cdot10^{-15}$	$1.84\cdot10^{-10}$	1.1
HPO_3^{-2}	$5.28\cdot10^{-9}$	$1.44\cdot10^{-11}$	$4.22\cdot10^{-7}$	$1.2\cdot10^{9}$
HPO_4^{-2}	$2.47\cdot10^{-15}$	$6.73\cdot10^{-18}$	$2.37\cdot10^{-13}$	$1.0\cdot10^{10}$
K^{+}	12.4	$3.39\cdot10^{-2}$	$4.85\cdot10^{2}$	0.2817
$Mg(HCO_3)$	$3.15\cdot10^{-5}$	$8.60\cdot10^{-8}$	$2.69\cdot10^{-3}$	15.515
Mg^{+}	1.53	$4.18\cdot10^{-3}$	37.1	3.4
$MgCl^{+}$	1.48	$4.05\cdot10^{-3}$	88.7	1.6
$MgOH^{+}$	$1.25\cdot10^{-9}$	$3.41\cdot10^{-12}$	$5.16\cdot10^{-8}$	100
NH_4^{+}	$1.26\cdot10^{-1}$	$3.45\cdot10^{-4}$	2.28e	0.197
Na^{+}	6.35	$1.73\cdot10^{-2}$	$1.46\cdot10^{2}$	1.2706
H^{+}	$6.04\cdot10^{-3}$	$1.65\cdot10^{-5}$	$6.09\cdot10^{-3}$	0.0494
H_2O	38.5	$1.05\cdot10^{-1}$	1.90	1
Liquid				
CO_2	-	$9.39\cdot10^{-1}$	4.24	1
H_2O	-	51.5	95.34	0.0052
S	-	$3.74\cdot10^{-3}$	3.84	1
KCl	-	$4.03\cdot10^{-2}$	96.16	1

Table 5. *Gases parameters of the system: tomato-water-sodium nitrate.*

Components	*Fugacity*	*Log fugacity*	*Partial pressure*	*Log partial pressure*	*Coeff. fugacity*
NH_3	$4.19\cdot10^{-10}$	-9.38	$4.19\cdot10^{-10}$	-9.3	1
CO_2	$1.78\cdot10^{-2}$	-1.75	$1.78\cdot10^{-2}$	-1.7	1
N_2	$9.85\cdot10^{-62}$	-61.0	$9.85\cdot10^{-62}$	-61	1
O_2	$1.00\cdot10^{-70}$	-110	$1.00\cdot10^{-70}$	-110	1
H_2O	$4.26\cdot10^{-3}$	-2.37	$4.26\cdot10^{-3}$	-2.3	1

The hydrogen index of a tomato (Table 1-5, Figure 1) at different temperatures was equal to: 278K, pH = 3.34; T = 283 K, pH = 3.35; T = 288 K, pH = 3.36; T = 293 K, pH = 3.36; T = 298 K, pH = 3.37, i.e. the medium was acidic (Figure 1). Antioxidation nature of the aqueous solution of the tomato was caused by the values of the oxidation-reduction potential of the tomato (Eh, B): T = 278 K, Eh = -0.540; T = 283 K, Eh = -0.535; T = 288 K, Eh = -0.529; T = 293 K, Eh = -0.523; T = 298 K, Eh = -0.518, where Eh <0 and the oxidizing medium. It was noted that with increasing temperature, the acidity of the tomato decreases (Figure 2). Negative values of the thermodynamic parameters ΔG, ΔH, ΔU (Table 1-5) of the system indicate the progress of the ion transport process in phases (the ionic strength was I = 10), while the amount of dissolved substances in 1 kg aqueous tomato solution was (TDS, mg / kg): T = 278.15K, TDS = 1098.0; T = 283.15 K, TDS = 1092.7; T = 288.15 K, TDS = 1087.5; T = 293.15 K, TDS = 1082.4; T = 298.15K, TDS = 1077.7.

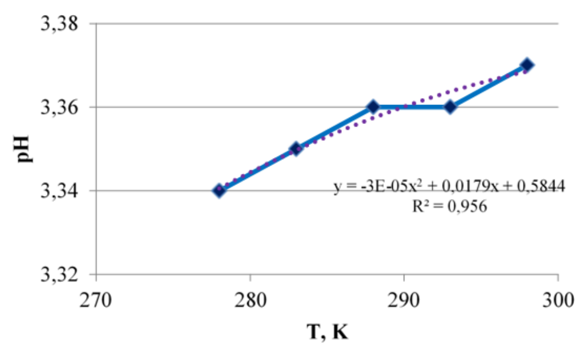

Figure 1. *The change in the pH of an aqueous tomato solution depending on temperature, $NaNO_3$ content of 29.3 mg/l.*

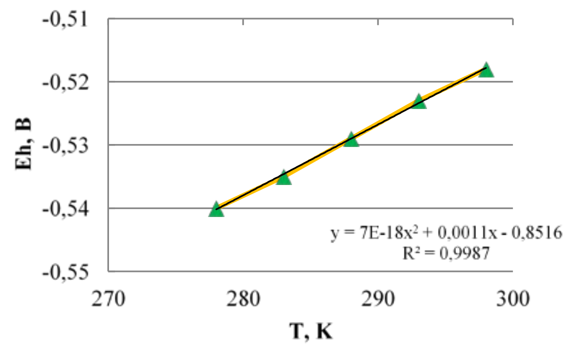

Figure 2. *Change in the redox potential of an aqueous tomato solution depending on temperature, $NaNO_3$ content of 29.3 mg/l.*

With the increase of sodium nitrate in the system: tomato (macroelements) - water - sodium nitrate within the temperature range from 278 to 293 K the hydrogen index of the tomato increases, i.e. the process of neutralizing the acidic medium based on sodium hydroxide proceeds: $NaNO_3$ - 29.3 mg/l, pH = 3.34-3.37; $NaNO_3$ - 29.5 mg/l, pH = 3.63-3.66; $NaNO_3$ -29.6 mg/l, pH = 3.87-3.94; $NaNO_3$ - 29.7 mg/l, pH = 4.31-4.47; $NaNO_3$ - 30 mg/l, pH = 4.76-4.89; $NaNO_3$ - 35 mg/l, pH = 4.77-4.89; $NaNO_3$ - 40 mg/l, pH = 4.77-4.89; $NaNO_3$ - 45 mg/l, pH = 4.77-4.9; $NaNO_3$ - 50 mg/l, pH = 4.78-4.9. It should be noted that the calculated hydrogen value of a tomato determined on the basis of the model compiled corresponds to the experimental pH values measured by the Denver instrument (pH = 3.3-4.38). The total weight balance in the phases was 100% (Table 1-5), and thus confirm the adequacy of the calculated results obtained on the basis of the proposed model of the system: tomato-water-sodium nitrate.

It can be seen from Table 6 that as the temperature of the aqueous tomato solution increases, the concentrations of $CaOH^{+}$, Cl^{-}, $H_2PO_2^{-}$, HCO_3^{-}, HPO_3^{2-} increase, and such particles as Ca^{+2}, $Mg(HCO_3)^{+}$ decrease slightly. Concentrations of $CaCl^{+}$,HCO_2^{-}, $H_2PO_3^{-}$, HPO_4^{2-}, K^{+}, Mg^{+2}, $MgCl^{+}$, $MgOH^{+}$, NH_4^{+}, Na^{+}, $NaCl^{+}$, $H^{+}$and H_2O remain constant.

Table 6. *Concentration distribution of cations and anions in an aqueous tomato solution as a function of temperature. The content of $NaNO_3$ = 29.3 mg/l.*

Particle distribution in moles	*Temperature, K*			
	278.15	*288.5*	*293.15*	*298.15*
Ca^{+2}	$1.8\cdot10^{-3}$	$1.67\cdot10^{-3}$	$1.61\cdot10^{-3}$	$1.55\cdot10^{-3}$
$CaCl^{+}$	$1.7\cdot10^{-3}$	$1.82\cdot10^{-3}$	$1.88\cdot10^{-3}$	$1.94\cdot10^{-3}$
$CaOH^{+}$	$6.1\cdot10^{-14}$	$1.43\cdot10^{-13}$	$2.13\cdot10^{-13}$	$3.12\cdot10^{-13}$
Cl^{-}	$3.4\cdot10^{-9}$	$8.91\cdot10^{-9}$	$1.39\cdot10^{-8}$	$2.13\cdot10^{-8}$
HCO_2^{-}	$6.0\cdot10^{-2}$	$6.07\cdot10^{-2}$	$6.07\cdot10^{-2}$	$6.07\cdot10^{-2}$
HCO_3^{-}	$4.7\cdot10^{-15}$	$6.7\cdot10^{-15}$	$8.25\cdot10^{-15}$	$1.01\cdot10^{-14}$
$H_2PO_2^{-}$	$1.1\cdot10^{-8}$	$5.03\cdot10^{-8}$	$7.89\cdot10^{-8}$	$1.24\cdot10^{-7}$
$H_2PO_3^{-}$	$8.9\cdot10^{-3}$	$8.39\cdot10^{-3}$	$8.39\cdot10^{-3}$	$8.39\cdot10^{-3}$
HPO_3^{2-}	$4.2\cdot10^{-12}$	$9.76\cdot10^{-12}$	$1.44\cdot10^{-11}$	$2.09\cdot10^{-11}$
HPO_4^{2-}	$3.2\cdot10^{-18}$	$5.39\cdot10^{-18}$	$6.73\cdot10^{-18}$	$8.26\cdot10^{-18}$
K^{+}	$3.3\cdot10^{-2}$	$3.37\cdot10^{-2}$	$3.39\cdot10^{-2}$	$3.41\cdot10^{-2}$
$Mg(HCO_3)^{+}$	$1.7\cdot10^{-7}$	$1.09\cdot10^{-7}$	$8.6\cdot10^{-8}$	$6.95\cdot10^{-8}$
Mg^{+2}	$4.3\cdot10^{-3}$	$4.25\cdot10^{-3}$	$4.18\cdot10^{-3}$	$4.1\cdot10^{-3}$
$MgCl^{+}$	$3.8\cdot10^{-3}$	$3.98\cdot10^{-3}$	$4.05\cdot10^{-3}$	$4.13\cdot10^{-3}$
$MgOH^{+}$	$1.2\cdot10^{-12}$	$2.46\cdot10^{-12}$	$3.41\cdot10^{-12}$	$4.67\cdot10^{-12}$
NH_4^{+}	$3.4\cdot10^{-4}$	$3.45\cdot10^{-4}$	$3.45\cdot10^{-4}$	$3.45\cdot10^{-4}$
Na^{+}	$1.7\cdot10^{-2}$	$1.74\cdot10^{-2}$	$1.73\cdot10^{-2}$	$1.73\cdot10^{-2}$
$NaCl^{+}$	$2.5\cdot10^{-4}$	$3.42\cdot10^{-4}$	$3.95\cdot10^{-4}$	$4.52\cdot10^{-4}$
H^{+}	$1.6\cdot10^{-5}$	$1.64\cdot10^{-5}$	$1.65\cdot10^{-5}$	$1.66\cdot10^{-5}$
H_2O	$1.0\cdot10^{-1}$	$1.04\cdot10^{-1}$	$1.05\cdot10^{-1}$	$1.07\cdot10^{-1}$

With increasing sodium nitrate content in the aqueous tomato solution, the concentrations of $CaOH^{+}$, $H_2PO_2^{-}$, HCO_3^{-}, HPO_3^{2-}, HPO_4^{2-}, $Mg(HCO_3)^{+}$, $MgOH^{+}$, H^{+}were increased, and such particles as Ca^{+2}, $CaCl^{+}$, Cl^{-}, HCO_2^{-}, $H_2PO_3^{-}$, K^{+}, Mg^{+2}, $MgCl^{+}$, NH_4^{+}, Na^{+}, $NaCl^{+}$, and H_2O change a little or remain constant (Table 7).

Table 7. *Concentration distribution of cations and anions in an aqueous solution of a tomato depending on the content of sodium nitrate. Temperature is 293 K.*

Particle distribution in moles	*Concentration of sodium nitrate in an aqueous solution of tomato, mg/l*							
	29.3	*29.5*	*29.7*	*30.0*	*35.0*	*40.0*	*45.0*	*50.0*
Ca^{+2}	$1.61\cdot10^{-3}$	$1.61\cdot10^{-3}$	$1.61\cdot10^{-3}$	$1.61\cdot10^{-3}$	$1.57\cdot10^{-3}$	$1.53\cdot10^{-3}$	$1.48\cdot10^{-3}$	$1.44\cdot10^{-3}$
$CaCl^{+}$	$1.88\cdot10^{-3}$	$1.88\cdot10^{-3}$	$1.88\cdot10^{-3}$	$1.88\cdot10^{-3}$	$1.83\cdot10^{-3}$	$1.79\cdot10^{-3}$	$1.74\cdot10^{-3}$	$1.69\cdot10^{-3}$
$CaOH^{+}$	$2.13\cdot10^{-13}$	$4.15\cdot10^{-13}$	$2.51\cdot10^{-12}$	$6.66\cdot10^{-12}$	$6.54\cdot10^{-12}$	$6.42\cdot10^{-12}$	$6.3\cdot10^{-12}$	$6.18\cdot10^{-12}$
Cl^{-}	$1.39\cdot10^{-8}$	$1.39\cdot10^{-8}$	$1.39\cdot10^{-8}$	$1.39\cdot10^{-8}$	$1.39\cdot10^{-8}$	$1.38\cdot10^{-8}$	$1.38\cdot10^{-8}$	$1.37\cdot10^{-8}$
HCO_2^{-}	$6.07\cdot10^{-2}$	$6.07\cdot10^{-2}$	$6.07\cdot10^{-2}$	$6.06\cdot10^{-2}$	$6.04\cdot10^{-2}$	$6.01\cdot10^{-2}$	$5.99\cdot10^{-2}$	$5.97\cdot10^{-2}$
HCO_3^{-}	$8.25\cdot10^{-15}$	$1.61\cdot10^{-14}$	$9.72\cdot10^{-14}$	$2.58\cdot10^{-13}$	$2.60\cdot10^{-13}$	$2.60\cdot10^{-13}$	$2.62\cdot10^{-13}$	$2.64\cdot10^{-13}$
$H_2PO_2^{-}$	$7.89\cdot10^{-8}$	$4.07\cdot10^{-8}$	$6.73\cdot10^{-9}$	$2.53\cdot10^{-9}$	$2.51\cdot10^{-9}$	$2.49\cdot10^{-9}$	$2.47\cdot10^{-9}$	$2.44\cdot10^{-9}$
$H_2PO_3^{-}$	$8.39\cdot10^{-3}$	$8.39\cdot10^{-3}$	$8.39\cdot10^{-3}$	$8.39\cdot10^{-3}$	$8.39\cdot10^{-3}$	$8.39\cdot10^{-3}$	$8.39\cdot10^{-3}$	$8.39\cdot10^{-3}$
HPO_3^{2-}	$1.44\cdot10^{-11}$	$2.81\cdot10^{-11}$	$1.69\cdot10^{-10}$	$4.52\cdot10^{-10}$	$4.55\cdot10^{-10}$	$4.62\cdot10^{-10}$	$4.62\cdot10^{-10}$	$4.66\cdot10^{-10}$
HPO_4^{2-}	$6.73\cdot10^{-18}$	$2.56\cdot10^{-17}$	$9.35\cdot10^{-16}$	$6.61\cdot10^{-15}$	$6.72\cdot10^{-15}$	$6.95\cdot10^{-15}$	$6.95\cdot10^{-15}$	$7.07\cdot10^{-15}$
K^{+}	$3.39\cdot10^{-2}$	$3.38\cdot10^{-2}$	$3.38\cdot10^{-2}$	$3.38\cdot10^{-2}$	$3.37\cdot10^{-2}$	$3.37\cdot10^{-2}$	$3.36\cdot10^{-2}$	$3.35\cdot10^{-2}$
$Mg(HCO_3)^{+}$	$8.6\cdot10^{-8}$	$1.67\cdot10^{-7}$	$1.02\cdot10^{-6}$	$2.7\cdot10^{-6}$	2.69e-06	$2.67\cdot10^{-6}$	$2.67\cdot10^{-6}$	$2.67\cdot10^{-6}$
Mg^{+2}	$4.17\cdot10^{-3}$	$4.17\cdot10^{-3}$	$4.17\cdot10^{-3}$	$4.17\cdot10^{-3}$	$4.13\cdot10^{-3}$	$4.08\cdot10^{-3}$	$4.04\cdot10^{-3}$	$3.99\cdot10^{-3}$
$MgCl^{+}$	$4.05\cdot10^{-3}$	$4.05\cdot10^{-3}$	$4.05\cdot10^{-3}$	$4.05\cdot10^{-3}$	$4.01\cdot10^{-3}$	$3.96\cdot10^{-3}$	$3.92\cdot10^{-3}$	$3.87\cdot10^{-3}$
$MgOH^{+}$	$3.41\cdot10^{-12}$	$6.64\cdot10^{-12}$	$4.01\cdot10^{-10}$	$1.07\cdot10^{-10}$	$1.06\cdot10^{-10}$	$1.06\cdot10^{-10}$	$1.06\cdot10^{-10}$	$1.05\cdot10^{-10}$
NH_4^{+}	$3.45\cdot10^{-4}$	$3.47\cdot10^{-4}$	$3.49\cdot10^{-4}$	$3.53\cdot10^{-4}$	$4.12\cdot10^{-4}$	$4.71\cdot10^{-4}$	$5.29\cdot10^{-4}$	$5.88\cdot10^{-4}$
Na^{+}	$1.73\cdot10^{-2}$	$1.73\cdot10^{-2}$	$1.73\cdot10^{-2}$	$1.74\cdot10^{-2}$	$1.74\cdot10^{-2}$	$1.75\cdot10^{-2}$	$1.75\cdot10^{-2}$	$1.76\cdot10^{-2}$
$NaCl^{+}$	$3.95\cdot10^{-4}$	$3.95\cdot10^{-4}$	$3.95\cdot10^{-4}$	$3.95\cdot10^{-4}$	$3.96\cdot10^{-4}$	$3.97\cdot10^{-4}$	$3.98\cdot10^{-4}$	$3.99\cdot10^{-4}$
H^{+}	$1.65\cdot10^{-5}$	$8.46\cdot10^{-6}$	$1.40\cdot10^{-6}$	$5.26\cdot10^{-7}$	$5.2\cdot10^{-7}$	$5.14\cdot10^{-7}$	$5.08\cdot10^{-7}$	$5.04\cdot10^{-7}$
H_2O	$1.05\cdot10^{-1}$	$1.05\cdot10^{-1}$	$1.05\cdot10^{-1}$	$1.05\cdot10^{-1}$	$1.05\cdot10^{-1}$	$1.04\cdot10^{-1}$	$1.04\cdot10^{-1}$	$1.04\cdot10^{-1}$

Thus, the synergistic effect of temperature and sodium nitrate were observed only in such complex pair particles as $CaOH^{+}$, $H_2PO_2^{-}$, HCO_3^{-}, HPO_3^{2-}, where their content grows in an aqueous solution of tomato due to their low migration, and apparently due to the significant partial pressure of carbon dioxide and the chemical potential of the phosphorus-containing particles in the system. (Table 1-5).

4. Conclusions

Physicochemical modeling of the system: tomato-water-sodium nitrate was carried out. In the calculations, the macronutrient composition and humidity of the tomato were used at various temperatures and concentrations of sodium nitrate. The hydrogen index of a tomato was calculated at various temperatures, and it was noted that the medium of tomato was acidic. With an increase in the sodium nitrate content in the system: tomato - water - sodium nitrate within the temperature range from 278 to 293 K, the hydrogen index of the tomato increases, i.e. the process of neutralizing the acidic medium based on sodium hydroxide proceeds. The calculated hydrogen value of the tomato corresponds to the experimental values of pH = 3.3-4.38. The oxidation-reduction potential (Eh, B) of the tomato-water-sodium nitrate system at different temperatures was established, and it was confirmed that the medium was oxidizing (Eh <0). It was noted that with increasing temperature, the acidity of the tomato decreases. As the temperature of the aqueous tomato solution increases, the concentrations of $CaOH^+$, Cl^-, $H_2PO_2^-$, HCO_3^-, HPO_3^{2-} increase, and such particles as Ca^{+2}, $Mg(HCO_3)^+$ decrease slightly. Concentrations of $CaCl^+$,HCO_2^-, $H_2PO_3^-$, HPO_4^{2-}, K^+, Mg^{+2}, $MgCl^+$, $MgOH^+$, NH_4^+, Na^+, $NaCl^+$, H^+ and content of H_2O remain practically constant. With increasing sodium nitrate content in the aqueous tomato solution, the concentrations of $CaOH^+$, $H_2PO_2^-$, HCO_3^-, HPO_3^{2-}, HPO_4^{2-}, $Mg(HCO_3)^+$, $MgOH^+$, H^+ are increased, and such particles as Ca^{+2}, $CaCl^+$, Cl^-, HCO_2^-, $H_2PO_3^-$, K^+, Mg^{+2}, $MgCl^+$, NH_4^+, Na^+, $NaCl^+$and H_2O change little or remain constant. The synergistic effect of temperature and sodium nitrate was observed only in such complex pair particles as $CaOH^+$, $H_2PO_2^-$, HCO_3^-, HPO_3^{2-}, where their content grows in an aqueous solution of tomato due to their low migration, and apparently due to the significant partial pressure of carbon dioxide and the chemical potential of the phosphorus-containing particles in the system.

References

[1] Adeniyi H., Ademoyegun O. “Effects of different rates and sources of fertilizer on yield and antioxidant components of Tomato”. African Journal, 7(2), (2012), 135-138.

[2] Oguntibeju O.O., Truter E.J., Esterhuyse A.J. “The Role of Fruit and Vegetable Consumption in Human Health and Disease Prevention”. Diabetes Mellithus – Insight and Perspectives, (2013), 117 – 130.

[3] Slunkhe D.K., Jadhav S.J., Yu M.H. “Quality and nutritional composition of tomato fruit as influenced by certain biochemical and physiological changes”. Qual.Plant. Plant Foods Hum. Nutr., 24, (1974), 85.

[4] Alvarez M. A. B., Gagne S., Antoun H. “Effect of compost on rhizosphere microflora of the tomato and on the incidence of plant growth-promoting rhizobacteria”. App.Environ. Microbial, 61, (1995). 194-199.

[5] Aoun A.B., Lechiheb B., Benyahya L., Ferchich A. “Evaluation of fruit quality traits of traditional varieties of tomato (Solanum lycopersicum) grown in Tunisia”. African Journal of Food Science, 7, (2013), 350-354.

[6] Wang Z.H., Zong Z.Q., Li S.X., Chen B.M. “Nitrate accumulation in vegetables and its residual in vegetable fields”. Environ. Sci., 23, (2002), 79–83.

[7] Phipps R.H., Cornforth I.S. “Factors affecting the toxicity of nitrite nitrogen to tomatoes”. Plant and Soil, 33, (1970), 457.

[8] Ranjan D., Rabha B.K., Ahmed F. “Effect of some plant growth regulators and micronutrients mixture on physio morphic character of tomato”. Ann.Agric.Res.New Series, 26 (4), (2005), 476-480.

[9] Sanyal D., Kar P.L., Longkukar M. “Effect of growth regulators on the physico-chemical composition of tomato (Lycopersicon esculentum Mill.)”. Adv. Hort. & Forestry, 4, (1995), 67-71.

[10] Krumbien A., Auerswald H. “Characterization of aroma volatiles in tomatoes by sensory analyses”. Nahrung, 42(6), (1998), 395-399.

[11] Gajbhiye N. D. “Toxic Effect of Sodium Nitrate on Germinating Seeds of Vigna radiate”. International Journal of Biotechnology and Bioengineering, 7(10), (2013), 1006.

[12] Bokade N. “Effect of growth regulators on growth and yield of summer tomato”. J. Maharashtra Agric. Univ., 31(1), (2006), 64-65.

[13] Desai S.S., Chovatia R.S., Singh V. “Effect of different plant growth regulators and micronutrients on fruit quality and plant micronutrient content of tomato”. International Journal of Agricultural Sciences, 10 (1), (2014), 130-133.

[14] Bosco F., Capolongo A., Ruggeri B. “Effect of temperature, pH, ionic strength, and sodium nitrate on activity of LiPs: Implications for bioremediation”. Bioremediation Journal, 6 (1), (2010), 65-76.

[15] Hojhabrian M. “Effect of different soil pHs on the growth and proceeds of Tomatoes”. Journal of Novel Applied Sciences, 3 (2), (2014), 145-147.

[16] Fan X.H., Li Y.C. “Nitrogen release from slow-release fertilizers as affected by soil type and temperature”. Soil Sci. Soc. Amer. J, 74, (2010), 1635–1641.

[17] Yanar D., Geboloğlu N., Yanar Y., Aydin M., Çakmak P. “Effect of different organic fertilizers on yield and fruit quality of ındeterminate tomato (Lycopersicon esculentum)”. Scientific Research and Essays, 6, (2011), 3623-3628.

[18] Liu C.W., Sung Y., Chen B.C., Lai H.Y. “Effects of Nitrogen Fertilizers on the Growth and Nitrate Content of Lettuce (Lactuca sativa L.)”. Int. J. Environ. Res. Public Health, 11, (2014), 4427-4440.

[19] Ejaz M., Waqas R., Butt M., Rehman S., Manan A. “Role of macronutrients and micronutrients in enhancing the quality of tomato”. IJAVMS, 5 (4), (2011), 401-404.

[20] Xu Y., Barringer S. “Comparison of tomatillo and tomato volatile compounds in the headspace by selected ion flow tube mass spectrometry”. Journal of Food Science, 75(3), (2010), 268-273.

[21] Patana-anake P., Barringer S. “The Effect of Temperature, pH, and Food additives on Tomato Product Volatile Levels”. International Food Research Journal, 22(2), (2015), 561-571.

[22] Mukta S., Rahman M.M., Mortuza M.G. “Yield and nutrient content of tomato as influenced by the application of vermicompost and chemical fertilizers”. J. Environ. Sci. & Natural Resources, 8 (2), (2015), 115-122.

[23] Dabire C., Sereme A., Parkouda C., Somda M.K., “Traore A. S. Influence of organic and mineral fertilizers on chemical and biochemical compounds content in tomato (solanum lycopersicum) var. mongal F1”. Journal of Experimental Biology and Agricultural Sciences, 4 (6), (2016), 631-636.

[24] Kazeniac S.J., Hall R.M. “Flavor chemistry of tomato volatiles”. Journal of Food Science, 35(5), (1970), 519-530.

[25] Çolpan E., Zengin M., Özbahçe A. “The effects of potassium on the yield and fruit quality components of stick tomato”. Horticulture, Environment and Biotechnology, 54, (2013), 20-28.

[26] Makinde A.I., Jokanola O.O., Adedeji J.A., Awogbade A.L., Adekunle A.F. “Impact of Organic and Inorganic Fertilizers on the Yield, Lycopene and Some Minerals in tomato (Lycopersicum esculentum Mill) Fruit”. European Journal of Agriculture and Forestry Research, 4, (2016), 18-26.

[27] Abduli M.A., Amiri L., Madadian E., Gitipour S., Sedighian S. “Efficiency of vermicompost on quantitative and qualitative growth of tomato plants”. International Journal of Environmental Research, 7(2), (2013), 467-472.

[28] Naresh B. “Response of foliar application of boron on vegetative growth, fruit yield quality of tomato var. Pusa-Ruby”. Indian Journal of Hill Farming, 15(1), (2002), 109-112.

[29] Yadav P.V.S., Abha T., Sharma N.K. “Effect of zinc and boron on growth, flowering and fruiting of tomato (Lycopersicon esculentum, Mill)”. Haryana Journal of Horticultural Science, 30(1/2), (2001), 105-107.

[30] Davies G.M., Hobes G. “The constituent of tomato fruit the influence of environment nutrition and genotypes”. Critical Review Food Sci. & Nutr., 15, (1981), 205-280.

[31] Huang J.S., Snapp S.S. “The effect of boron, calcium, and surface moisture on shoulder check, a quality defect in freshmarket tomato”. J. American Soc. Hort. Sci., 129(4), (2004), 599 – 607.

[32] Santamaria P. “Nitrate in vegetables: Toxicity, content, intake and EC regulation”. J. Sci. Food Agr., 86, (2006), 10–17.

[33] Petersen A., Stoltze S. “Nitrate and nitrite in vegetables on the Danish meaket: content and intake”. Food Addit. Contam., 16, (1999), 291–299.

[34] Karpov I.K., Chudnenko K.V., Kulik D.A., Bychinskyi V.A. “The convex programming minimization of five thermodynamic potential other than Gibbs energy in geo-chemical modeling”. American J. Science., 302, (2002), 281-311.

[35] Helgeson H.C., Delany J.M., Nesbitt H.W., Bird D.K. “Summary and critique of the thermodynamic properties of rock-forming minerals”. American J. Science., (1978), 278-A: 1-229.

[36] Maimekov Z.K., Abdykadyrova R.E., Sambaeva D.A., Isaev A.D., Izakov J.B., Maymekov T.Z. “Physicochemical modeling of a heterogeneous complex system: soil-water-sodium nitrate and ecological assessment of the concentration distribution of components and particles in a slurry solution”. Science, New technologies and Innovations of Kyrgyzstan-Bishkek, 1, (2018), 18-23.

[37] Karpov I.K., Chudnenko K.V., Kulik D.A. “Modeling chemical mass transfer in geochemical processes: Thermodynamic relations, conditions of equilibria, and numerical algorithms”. American J. Science., 297, (1997), 767-806.

[38] Bekseev Sh. G. “Early vegetable growing. Breeding, cultivation, seed growing”, 1st edition. Nauka, St. Peterburg. (2006), 131-140.