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(REVIEW ARTICLE)

The tomato (*Solanum lycopersicum* L.) in community development: An overview focused on nutritional properties, agronomic constraints, recent achievements and future prospective

Oscar Cyrille Adantchédé Akotowanou, Euloge Sènan Adjou *, Adéyèmi Berane Olubi, Sylvain Daton Kougblenou, Edwige Dahouenon Ahoussi and Dominique CK Sohounhloué

Laboratory of Study and Research in Applied Chemistry, Polytechnic School of Abomey-Calavi, University of Abomey-Calavi, 01 POB 2009, Cotonou. Bénin.

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Abstract

Tomato is an important horticultural product cultivated worldwide and a major crop subject of studies. The present study therefore aims to review the state of the art of research on tomato. To do this, search was carried out in scientific databases (Science Direct, Scopus, PubMed and Agora), A suitable scientific research works were selected and analyzed. From the results, it appears that tomato is a fruit vegetable, belongs to Solanaceae family and cultivated in many countries of the world and in various climates. Its production can be done in field, but also under controlled conditions by using of artificial lighting, heaters, as well as fertigation to produce high quality tomatoes. Nutritionally, regular intake of tomato fruit increase levels of carotenoids, lycopene, vitamin C, and polyphenols compounds in the daily diet. Regarding the preservation of tomato, research papers mentioned that tomato, like any plant, is subject to agronomic constraints, such as abiotic (light, water supply, salinity, floor structure) and biotic constraints (bacterial, fungal and viruses' attacks). Mechanical damage also influenced external quality traits of tomato. Finally, this review paper presents a brief overview of some recent studies concerning the control of tomato diseases, the valorization of tomato fruits, as well as the using of tomato waste as a bioresource for lycopene extraction. However, it would be interesting that future investigations revolve around the search for more alternatives methods to control bacterial, fungal or virus attacks, such as the use of natural compounds, in particular those from plant origin.

Keywords: Tomato; Nutritional properties; Agronomic constraints; Recent achievements; Benin

1 Introduction

The tomato (*Solanum lycopersicum* L.) originally from South America was domesticated in the fertile valleys of Mexico and was brought back to Europe by the conquistadores. The introduction of tomato in Africa dates from the 17th century (Shankara et al., 2005). Several wild species of tomato can be observed (Villanueva, 2018). However, only two species are edible, the "current tomato" (*Solanum pimpinellifolium*) and the "cherry tomato" (*Solanum lycopersicum var cesariforme*) (De Broglie and Guéroult, 2005; Renaud, 2006).

Tomato cultivation can adapt to several climatic conditions. The production can be done in field, but also under controlled conditions by using of artificial lighting, heaters, as well as fertigation to produce high quality tomatoes (Oda and Saito, 2006). According to Bouzaata, (2016), tomato has long been considered toxic, and was associated with all types of evil virtues because of its resemblance to the mandrake. However, the growing popularity of tomatoes has

* Corresponding author: Euloge Sènan Adjou
Laboratory of Study and Research in Applied Chemisty, Polytechnic School of Abomey-Calavi, University of Abomey-Calavi, 01 POB 2009, Cotonou. Bénin.

resulted in the development of new varieties and in the 20th century, tomato industries have gradually developed to offer increasingly diverse tomato products (Naika et al., 2005).

Several studies reported that in terms of yield, tomato is the second horticultural crop produced in the world and countries with the largest production area are United States, China, India and Turkey (FAO, 2016). Economic data indicated that in 2013, fresh tomato production reached 163.719.357 tons in the world and around 4.5% of this production are traded. The revenues for the tomato export by countries such as Mexico, Netherlands, Jordan in this year are 1195, 1675 and 517 US dollar/ton respectively. However, during this year, countries with the highest relative tomato import were Russia, followed by Germany and France (FAOSTAT, 2013; Villanueva, 2018).

It should also be noted that as others agricultural products, tomatoes losses can occur during production, post-harvest, processing, and distribution (Porat et al., 2018). According to Macheka et al. (2018), to reduce losses, the understanding of different sources of post-harvest losses is important. Indeed, the use of advanced logistics lead in general lower postharvest losses, when compared to the use of basic logistic. Added to this are cultural practices, which are often the basis of bacterial, fungal and viral contaminations. It is therefore necessary that scientific research items more focused on this plant by listing scientific studies carried out, in order to identify relevant information and points of interest capable of supporting future researches.

1.1 Botanical characteristic

The tomato is a fruit vegetable, belongs to Solanaceae family and cultivated in many countries of the world and in various climates (Mensah et al., 2019). The cultivated tomato belongs to *Solanum lycopersicum* specie and *Solanum pimpinellifolium* is the closest wild specie with a divergence of 0.6% nucleotide base pairs, according to Villaneuva, (2018). There is others wild species such as *Solanum chmiewelskii*, *Solanum neorickii*, *Solanum chilense*, *Solanum pennilli*, *Solanum juglandifolium*, *Solanum ochranthum*, *Solanum lycopersicoides*, *Solanum sitiens*, *Solanume corneliomuelleri*, *Solanum arranum* and *Solanum galapagense* are generally small, compared to domesticated ones (Peralta et al., 2006). Tomato was classified in 1753 by the botanist Linné Swidish who named it *Solanum lycopersicum*. Several other botanists gave it other names, but it was finally 15 years later that Philipe Mille replaced Linné's name with *Lycopersicon esculentum* (Valimunizigha, 2006).

Figure 1 Flower of tomato (Welty et al., 2007)

Figure 2 Fruits of Tomato (Shankara et al., 2005)

Grown as an annual, tomato is herbaceous, bisexual, reproduces by seed, and has many seeds, kidney or pear shaped (Shankara et al., 2005). The plant produces 7 to 14 compound leaves before flowering and has a very branched root system with a fasciculate tendency. The flowers are united in cymes (Figure 1), and fruits are a fleshy berry with a diameter of 2 to 15 cm (Figure 2). When unripe, it is green, hairy and contains toxic alkaloids (Shankara et al., 2005).

2 Nutritional characteristic and effects of postharvest technologies on fruit quality

According to FAO, (2016), tomatoes are an important food component and the second largest vegetable both in terms of production and consumption. Nutritionally, several researches reported that tomatoes are source of vitamins and pro-vitamins, minerals (potassium) and a lot of secondary metabolites such as lycopene, flavonoids, phytosterols and polyphenols (Beecher, 1998; Luthria et al., 2006). According to Gebhardt and Thomas, (2002), a consumption of 100 g of fresh tomato respectively provided over 46%, 8% and 3.4% of the daily requirements of vitamin A, vitamin C and potassium. Processed tomato currently used in foodstuff, positively contribute to human health by the content of nutritional compounds, and also considered as low source of carbohydrates (Bergougnoux, 2014). However, it important to underline that post-harvest conditions affected the tomato fruit quality (Villaneuva, 2018). Below, nutritional potential of tomato fruits are described (Tables 1-2) and different effects of some postharvest techniques on fruit quality are summarized (Table 3).

Table 1 Nutritional potential of tomato fruits (Grasselly et al., 2000)

Parameters	Contents (%)
Moisture	93.4 - 95.2
Proteins	0.9 - 1.1
Fat	Trace - 0.3
Carbohydrates	2.8 - 4.7
Fibers	0.5 – 1.5

Table 2 Mineral and vitamin contents of tomato fruits (Grasselly et al., 2000)

Parameters	Contents (%)
Calcium (Ca)	9.7 – 15
Potassium (K)	202 – 300
Sodium (Na)	3 – 11
Iron (Fe)	0.2 – 0.6
Magnesium (Mg)	3 – 11
Provitamin A	0.5 – 0.8
Vitamin B1	0.04 -0.06
Vitamin B2	0.02 – 0.06
Vitamin B6	0.08 – 0.1
Vitamin C	15 – 23
Vitamin E	0.04 – 1.2

Table 3 Effects of some postharvest technologies on fruit quality

Processes	Impacts	References
Applying of Calcium chloride at 1%, boric acid at 0.1% and 400 ppm of potassium permanganate on green tomatoes, followed by packing in polyethylene film.	Increasing of shelf life up to 32 days	Sammi and Masud (2009)
Applying of 7.5 ppm of potassium permanganate on green tomatoes.	Preserving the texture at 14 to 18 ºC after 21 days	Wabali et al. (2017)
Using of pulse light treatment at 4, 6, and 8 J/ cm2	The Texture was preserved after 10 days of storing and microbial growth was reduced	Valdivia-Nájar et al. (2018)
Applying of hot air treatment during 12 hours at 38ºC on mature green tomatoes.	Delaying of firmness decline, due to slowdown of pectin degradation	Wei et al. (2018)
Using of ultrasound	Tomatoes became brighter and conferred a more orange color compared to untreated tomatoes	Fava et al. (2017)
The use of Lysophosphatidyl ethanolamine (LPE)	Increasing of shelf life and preservation of the quality of tomato	Amalendu et al. (2003)

3 Agronomic constraints

The tomato, like any plant, is subject to two types of agronomic constraints; these are abiotic and biotic constraints (Derksen et al., 2013). Abiotic constrains include temperature, light, water supply, salinity and floor structure.

Indeed, the growing of tomato requires a relatively cool and dry climate to provide an abundant and quality harvest. The tomato is a warm season plant. The optimum for root growth is 15 to 18°C in the phase of fruit enlargement, the optimum for ambient temperature is 25°C during the day and 15°C at night. (Elattir et al., 2003). The tomato plant has adapted to a wide variety of climatic conditions, ranging from temperate to hot and humid tropical climates (Derkaoui, 2011).

Water supply is also an important factor in yield and quality. An irregular water supply leads to an irregular calcium supply and therefore leads to apical necrosis. Water requirements are especially important from the flowering of the second bouquet (Elattir et al., 2003).

According to Rodríguez-Ortega et al., (2019), the first effect of salinity on plants is the "osmotic effect" and it is widely established that salinity acts negatively on germination and growth and also significantly alters the concentration of bioactive compounds in vegetables. A good salinity improves tomato production and the nutritional quality of fruits, in particular by increasing its vitamin and lycopene content (Kinsou et al., 2021).

Moreover, the soil should be well aerated and draining. Root asphyxia, even temporary, is detrimental to the crop. The organic matter content of the soil must be quite high (2-3%) to obtain good yields. According to Elattir and al. (2003), tomato grows well on most mineral soils which have good water-holding capacity and good aeration.

Biotic constraints of tomato production are diseases and parasites that can affect tomato crop. The most important include fungal diseases, bacterial diseases, viral diseases and pests. Indeed, some of the most common fungal diseases include Anthracnose fruit rot, Early blight, Septoria leaf spot, Late blight, and Buckeye rot (Figure 3). Several fungi such as *Alternaria spp, Botrytis cinerea, Fusarium oxysporum, Phytophthora infestans*. *Leveillula taurica*, *Passalora fulva, Trichothecium roseum, Colletotrichum coccodes* and *Sclerotinia sclerotiorum* are reported by the literature being responsible of the reduction of the yield production and the deterioration of the marketability of the tomato (Martinez et *al*., 2005; Jalal, 2010; Liu et *al*., 2011; Kadri et *al*., 2014; Egel et Saha, 2015). The most common bacterial diseases of tomato are Bacterial spot, Bacterial speck and Bacterial canker caused by bacteria such as *Xanthomonas campestris*, *Pseudomonas syringae* and *Clavibacter michiganensis* (Blancard et al., 2009). According to Hanssen et al., (2010), high number of viral species infected tomato crops and caused significant damage to crops. The increasing international travel and trade of plant materials participate to the introducing of new viruses such as *Pepino mosaic virus*, *Begomovirus* species, *Tomato torrado virus* and new *Tospovirus species viruses* into production systems (Figure 4).

Figure 3 Some symptoms of bacterial and fungal diseases on tomato (Mark et Edmunds, 2005; Dalbello, 2008; Egel et Saha, 2015)

Fruit marbling induced by Pepino mosaic virus

Fruit necrosis induced by Tomato marchitez virus

Figure 4 Some symptoms of emerging viruses in tomato plants (Hanssen et al., 2010)

4 Others constraints

Several studies reported that tomato losses can also be caused by unavailability of storage facilities, and injuries (Injuries during the production, and mechanical injuries at harvest) (Campbell et al., 1986; Ayandiji and Omidiji, 2011). Despite the over-ripening of the tomatoes on the plant and unsuitable harvesting techniques, inappropriate containers for transport, unsuitable storage facilities, inappropriate transportation, unsuitable refrigeration, inappropriate drying equipment, traditional processing, and lack of knowledge on management and bumper crops also caused high tomato losses (FAO, 1981). According to Hodges, (2010), improper temperature management during harvest and storage will quickly result in a reduction in value of tomatoes. It also important to underline that transport procedures may lead to postharvest losses through damages or injuries on the skin of the tomatoes (Campbell et al., 1986), resulting in bacterial or fungal contamination during storage (Ayandiji and Omidiji, 2011).

5 Achievements and future prospective

According to Villanueva, (2018) belong horticultural product cultivated worldwide, *Solanum lycopersicum* is the second most important crop and is also considered as model organism of the Solanaceae family, subject of studies both in the laboratory and under field conditions. Faced with the high tomato losses during cultural and storage periods, many researches were conducted with the aim of valorization of tomato fruits, and the preservation of tomato during cultural and post-harvest periods (Table 4). It is important to emphasize that in many African countries, despite the nutritional, economic and sociological importance of tomatoes, the production still remains unorganized, creating a long period of scarcity and a short period of abundance, characterized by post-harvest losses, due to a lack of efficacy storage methods. In many of these countries, industrial processing is not a reality yet and small-scale processing is now advocated as a likely outcome. However, this small-scale processing is often confronted with quality and stabilization problems, because of the risks of microbial proliferation which alters the quality of the product. The use of synthetic chemical preservatives still remains the first-line measure taken to reduce the incidence of contamination, with the consequences of increasing the risk of toxic residues in food products. Therefore, it is urgent that future investigations revolve around the search for alternatives methods, such as the use of natural compounds, in particular those from plant origin which are mainly known for their interesting biological properties, and already fall within the dietary habits of population.

Table 4 Some investigations carried out on valorization tomato

Countries	Investigations carried out	Reference
Algeria	Preservation of tomato paste with an antifungal agent (lemon essential oil)	Himed et al., (2020)
Ethiopia	Effects of preharvest applications of chemicals and storage conditions on the physico-chemical characteristics and shelf life of tomato (*Solanum lycopersicum* L) Fruit	Tagele et al. (2022)
Iran	Improving tomato juice concentration process through a novel ultrasound-thermal concentrator under vacuum condition: a bioactive compound investigation and optimization	Alaei et al. (2022)
Mexico	Tomato waste as a bioresource for lycopene extraction using emerging technologies.	Méndez-Carmona et al. (2022)
Nigeria	Effect of organic preservatives on post-harvest shelf life and fruit quality of tomatoes during storage	Kator et al. (2018)
Canada	Control of Salmonella Newport on cherry tomato using a cocktail of lytic bacteriophages	El-Dougdoug et al. (2019)
Iran	Integration of a resistant variety and a biological agent to control the tomato leaf miner, tuta absoluta (meyrick), under greenhouse conditions	Saeidi and Raeesi (2021)
Italy	Role of grafting in the resistance of tomato to the virus	Spanò et al. (2020).
Kazakhstan	Screening a collection of local and foreign varieties of *Solanum lycopersicum* L. In kazakhstan for genetic markers of resistance against three tomato viruses	Pozharskiy et al. (2022)
Japan	Production of gaba-enriched tomato juice by *Lactiplantibacillus plantarum* kb1253	Nakatani et al. (2022)
Turkey	Effects of aminoethoxyvinylglycine treatment by vacuum infiltration method on postharvest storage and shelf life of tomato fruit.	Candir, et al. (2017)
Argentina	A study on structure (micro, ultra, nano), mechanical, and color changes of *Solanum lycopersicum* L. (cherry tomato) fruits induced by hydrogen peroxide and ultrasound	Fava et al. (2017)

6 Conclusion

Based on the presence of a lot of knowledge relative to the nutritional characteristics, agronomic constraints, as well as information on traditional and modern technology available, it is possible to understand a relation of tomato plants with the environment, and more manage factors linked to good production and storage practices. Then, the challenges for scientific researchers and political decision-makers are to consider the best processes for the development of agricultural resources while taking into account human needs.

Compliance with ethical standards

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Disclosure of conflict of interest

Authors have declared that no competing interests exist.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

References

[1] Alaei B, Chayjan RA, Zolfigol AM. (2022). Improving tomato juice concentration process through a novel ultrasound-thermal concentrator under vacuum condition: a bioactive compound investigation and optimization. Innovative Food Science & Emerging Technologies, 77:102983. doi.org/10.1016/j.ifset.2022.102983.

[2] Amalendu C, Arun SM, Hosahalli S (2003). Handbook of postharvest technology: cereals, fruits, vegetables, tea, and spices, New York, CRC Press Taylor and Francis Group.

[3] Ayandiji A, Omidiji D. (2011). Determinant post-harvest losses among tomato farmers in imeko-afon local government area of Agun state, Nigeria. Global Journal of Science Frontier Reserarch, 11: 23-27.

[4] Beecher GR (1998). Nutrient content of tomatoes and tomato products. Proceedings of the Society for Experimental Biology and Medicine, 218: 98-100.

[5] Bergougnoux, V. (2014). The history of tomato: From domestication to biopharming. Plant Biotechnology,32: 170-189.

[6] Blancard D, Laterrot H, Marchoux G, Candresse T (2009). Tomato diseases. ed. INRA. p. 690.

[7] Bouzaata C. (2016). Valorization of by-products of four varieties of industrial tomato (Solanum esculentum M.) in eastern Algeria. (Doctoral thesis). Badji Mokhtar University, Annaba, Algeria.

[8] Campbell DT, Prussia SE, Shewfelt RL (1986). Evaluating Postharvest Injury to Fresh Market Tomatoes. Journal of Food Distribution Research, 86: 16-25.

[9] Candir E, Candir A, Sen F (2017). Effects of aminoethoxyvinylglycine treatment by vacuum infiltration method on postharvest storage and shelf life of tomato fruit. Postharvest Biology and Technology, 125: 13-25.

[10] De Broglie L.A. Guéroult D. (2005). Tomatoes of yesterday and today. Paris, Hoëbeke. 143.

[11] [11] Derkaoui KM, (2011). Morphological, physiological and anatomical responses of tomato (Solanum lycopersicum L.) roots to salt stress. Master's degree; University of Oran, Algeria, 109p.

[12] Derksen H, Rampitsch C, Daayf F, (2013). Signaling crosstalk in plant disease resistance. Plant Science, 207:79-87.

[13] Egel DS, Saha SK, (2015). Tomato disease management in greenhouses, Purdue Extension publication BP-197-W and University of Kentucky Cooperative Extension publication ID-233.

[14] Elattir H, (2003). Plant density effects on processing tomato grown in Morocco. Acta horticultuae 613: VIII International symposium on the processing tomato.

[15] El-Dougdoug NK, Cuci S, Abdelhamid AG, Brovkob L, Kropinski AM, Griffiths MW, Ananya H. (2019). Control of Salmonella Newport on cherry tomato using a cocktail of lytic bacteriophages. International Journal of Food Microbiology 293: 60–71

[16] FAO (1981). Food loss prevention in perishable crops. Rome-Italy: Food and Agriculture Organization of the United States.

[17] FAO (2016). Food and Agriculture Organization of the United Nations [Online]. Rome-Italy: Food and Agriculture organiation of the United States.

[18] FAOSTAT (2013). Crops and livestock products [Online]. Food and Agricultural Organization of the Unided Nations.

[19] Fava J, Nieto A, Hodara K, Alzamora SM, Castro MA (2017). A Study on Structure (Micro, Ultra, Nano), Mechanical, and Color Changes of *Solanum lycopersicum* L. (Cherry Tomato) Fruits Induced by Hydrogen Peroxide and Ultrasound. Food and Bioprocess Technology, 10: 1324-1336.

[20] Gebhardt SE, Thomas GR (2002). Nutrivive value of foods, Beltsbille, Maryland, USDA

[21] Grasselly D, Navez B, Letard M, (2000). Tomato, for a quality product. p. 112.

[22] Hanssen IM, Lapidot M, Thomma BPHJ (2010). Emerging Viral Diseases of Tomato Crops. Molecular Plant-Microbe Interactions. 23 (5):539–548

[23] Himed L, Merniz S, Benbraham M, Boudjouada E, Barkat M (2020). Preservation of tomato paste with an antifungal agent (essential lemon oil), Afr. J. Food Agric. Nutr. Dev., 20(2): 15608-15618.

[24] Hodges RJ, (2010). Postharvest losses and waste in developed and less developed countries: opportunities to improve resource use. Journal of Agricultural Science, 149: 37-45.

[25] Jalal HSI (2010). Isolation and identification of some fungi from certain solanaceous seeds in Sulaimania and Germian regions and their exudate effects on germination rate. Agric. Biol. J. N. Am.,1(4): 615-619.

[26] Kadri O, Ouazzani Touhami A, Benkirane and Douira A (2014). Pathogenic power of Botrytis cinerea on Catharanthus roseus at different vegetative stages. Journal of Applied Biosciences, 76 : 6338-6351.

[27] Kator L, Iheanacho AC, Aloho KP, (2018). Effect of organic preservatives on postharvest shelf life and fruit quality of tomatoes during storage. Asian Journal of Research in Crop Science 2(1): 1-34.

[28] Kinsou E, Amoussa AM, Mensah ACG, Kpinkoun JK, Assogba Komlan F, Ahissou H, Lagnika L, Gandonou CB, (2021). Effect of salinity on flowering, fruiting and nutritional quality of fruits of the local cultivar Akikon of tomato (Lycopersicon esculentum Mill.) from Benin. Int. J. Biol. Chem. Science. 15(2) : 737-749.Liu F, Hyde KD et Cai L (2011). Neotypification of *Colletotrichum coccodes*, the causal agent of potato black dot disease and tomato anthracnose. Mycology, *2*(4): 248-254.

[29] Luthria DL, Sudarsan M, Krizek DT, Krizek DT (2006). Content of total phenolics and phenolic acids in tomato (Lycopersicon esculentum Mill.) fruits as influenced by cultivar and solar UV radiation. Journal of Food Composition and Analysis, 19

[30] Macheka L, Spelt EJH, Bakker E-J, Van Der Vorst JGAJ, Luning PA (2018). Identification of determinants of postharvest losses in Zimbabwean tomato supply chains as basis for dedicated interventions. Food Control, 87: 135-144.

[31] Martinez F, Dubos B., Fermaud M (2005). The role of saprotrophyans virulence in the population dynamics of B. cinerea in vineyards. Photopathology. 95: 692-700.In: Assignment of different lifestyles in the vineyard to certain genetic entities of the phytopathogenic fungus Botrytis cinera. Activity report 2004-2006. INRA, Bordeaux-Aquitaine.p56.

[32] Méndez-Carmona JY, Ascacio-Valdes JA, Olga B, Ayerim Y., Guzman NR, Sepúlved L, Aguilar-González MA, Ventura-Sobrevilla JM, Cristóbal N. Aguilar. 2022. Tomato waste as a bioresource for lycopene extraction using emerging technologies. Food Bioscience. Volume 49 (2): 101966. doi.org/10.1016/j.fbio.2022.101966.

[33] Mensah ACG, Sikirou RAKF, Y BB, Midingoyi S-K, Honfoga J, Dossoumou M-É, Kpera GN and Djinadou AKA (2019). Better produce tomatoes at all times in Benin, National Institute of Agricultural Research of Benin (INRAB), Support Project for the Development of Market Gardening (PADMAR), pp56.

[34] Naika S, Lidt de Jeude VJ, Goffau De M, Hilmi M, Van Dam B (2005). Tomato cultivation: production, processing and marketing, Agromisa Foundation and CTA, Wageningen, Agrodok 17, 105p.Nakatani Y, Fukaya T, Kishino S, Ogawa J, (2022). Production of GABA-enriched tomato juice by *Lactiplantibacillus plantarum* KB1253, Journal of Bioscience and Bioengineering. doi: 10.1016/j.jbiosc.2022.08.008.

[35] Oda M, Saito T (2006). Tomato. Horticulture in Japan. Kyoto Japan: The Japanese Society for Horticulture Science.

[36] Peralta I, Knapp S, Spooner D (2006). Nomenclature for wild and cultivated tomatoes. Tomato Genetics Cooperative Report. AGRIS

[37] Porat R, Lichter A, Terry LA, Harker R, Buzby J (2018). Postharvest losses of fruit and vegetables during retail and in consumers' homes: Quantifications, causes, and means of prevention. Postharvest Biology and Technology, 139 : 135-149

[38] Pozharskiy A, Kostyukova V, Taskuzhina A, Nizamdinova G, Kisselyova N, Kalendar R, Karimov N, Gritsenko D (2022). Screening a collection of local and foreign varieties of *Solanum lycopersicum* l. In kazakhstan for genetic markers of resistance against three tomato viruses, Heliyon 8: 10095

[39] Renaud V, (2006). Les tomates qui ont du goût. Paris, Eugen Ulmer. 95.

[40] Rodríguez-Ortega WM, Martínez V, Nieves M, Simón I, Lidón V, Fernandez-Zapata JC, Martinez-Nicolas JJ, Cámara-Zapata JM, García-Sánchez F (2019). Réponses des plants de tomates Cultivé dans différentes cultures sans sol, Systèmes avec de l'eau saline sous Conditions de serre. Rapports scientifiques 67p.

[41] Saeidi Z, Raeesi M, (2021). Intégration d'une variété résistante et d'un agent biologique pour lutter contre la mineuse de la tomate, Tuta absoluta (Meyrick), dans des conditions de serre. Bulletin de recherche entomologique 111: 357–363.

[42] Sammi S, Masud T (2009). Effect of different packaging systems on the quality of tomato (Lycopersicon esculentum var. Rio Grande) fruits during storage. International Journal of Food Science & Technology, 44: 918-926.

[43] Shankara N, Van lidt de jeud J, de Goffau M, Hilmi M, Van Dam B, Florijin A (2005). La culture de la tomate : production, transformation et commercialisation. 5eme (ed). foundation agromisa et CTA, Wageningen.

[44] Spanò R, Ferrara M, Gallitelli D, Mascia T, (2020). The Role of Grafting in the Resistance of Tomato to Viruses. Plants 2020, 9, 1042; doi:10.3390/plants9081042.

[45] Tagele A, Woldetsadik K, Gedamu F, Mohammed MR (2022). Effects of preharvest applications of chemicals and storage conditions on the physico-chemical characteristics and shelf life of tomato (*Solanum lycopersicum* L.) fruit. Heliyon, 8(6): 09494.

[46] Valdivia-Nájar CG, Martín-Belloso O, Soliva-Fortuny R (2018). Impact of pulsed light treatments and storage time on the texture quality of fresh-cut tomatoes. Innovative Food Science & Emerging Technologies, 45 : 29-35.

[47] Valimunizigha C. (2006). Étude du comportement physiologique et agronomique de la tomate (*Solanum lycopersicum* L.) en réponse à un stress hydrique précoce. Ed. Press.Univ.de Louvain, 196p.

[48] Villanueva EE (2018). An overview of recent studies of tomato (*Solanum lycopersicum spp*) from a social, biochemical and genetic perspective on quality parameters. Alnarp-Sweden: Sveriges lantbruksuniversitet. 61p.

[49] Wabali VC, Esiri A, Zitte L (2017). A sensory assessment of color and textural quality of refrigerated tomatoes preserved with different concentrations of potassium permanganate. Food Science & Nutrition, 5 : 434-438.

[50] Wei Y, Zhou D, Wang Z, Tu S, Shao X, Peng J, Pan L, Tu K (2018). Hot air treatment reduces postharvest decay and delays softening of cherry tomato by regulating gene expression and activities of cell wall-degrading enzymes: Effect of hot air treatment on cherry tomato. Journal of the Science of Food and Agriculture, 98 : 2105-2112.