THE EFFECT OF PEEL AND SEED REMOVAL ON THE PHYSICAL AND CHEMICAL PROPERTIES OF THE TOMATO FRUITS (*SOLANUM LYCOPERSICUM L.*)

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Further to assessing the effect of the peel and seed removal, which are two procedures usually carried out either at home or within the processing industry, on the physical and chemical properties and on the content of bioactive compounds of the tomato fruits beloging to five Romanian varieties coming from the Buzău Station of Research and Development for Vegetable Farming (Kristinica, Darsirius, Florina, Hera and Andrada), the result was that both procedures brought forth significant losses of nutritional and physical-chemical properties to each grower.

In the main, peeling was more harmful, as it caused a more pronounced drop of the hydrogen potential pH and of the content of dry substance (D.S. %). By comparison with the other varieties, a significant drop of the hydrogen potential after removing the peel was noticed at the Florina variety, namely from the 5.298 average value to the 4.758 one. At this variety we also noticed the modification of the dry substance content (D.S. %), i.e. from 6.275 to 5.570.

Keywords: bioactive compounds, tomato processing, peeling

1. Introduction

The tomato (*Solanum lycopersicum L.*) is one of the most popular vegetables. It derives from the same family as the hot peppers, the potatoes, the marrows and the tobacco, namely the Solanaceae family.

Even though the tomato is a fruit from the botanical point of view, it is generally eaten and cooked as a vegetable. Tomatoes are amongst the most popular and commercial products currently existing on the Romanian market. Even if in the past the species was reluctantly embraced by the Europeans, its farming on a large scale soon spread extensively and the tomato became one of the most popular and sought-for vegetable plants, thanks to its multiple assets and uses.

The tomato fruits are easy to grow, cheap and healthy. Moreover, they can be used and processed in many various ways. They can be used in soups, sauces,

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salads and they are delicious on a slice of bread, too. The international cuisine includes more than 125 dishes [1].

The chemical composition of the fresh tomato fruits (according to several authors) [2, 3, 4, 5] approximately varies within the following limits: dry substance: 4 - 9 %, sugars: 2.5 - 4.5 %, raw protein substances: 0.6 - 1.5 %, cellulose: 0.25 - 0.90 %, hemicellulose: 0.1 - 0.2 %, total acids (expressed as citric acid): 0.6 - 1.0 %, lipids: 0.25 - 0.35 %, ash: 0.5 - 0.6 %, vitamins, pectic substances, pigments and so forth.

The content of the tomato fruits in macroelements for 100 g of fresh product is the following one: potassium: 226 mg, phosphorus: 24.7 mg, sodium: 17.9 mg, magnesium: 11.3 mg and calcium: 8.3 mg; the most important microelements, still in 100 g of fresh product, are: aluminium: 1.80 mg, iron: 0.55 mg, manganese: 0.15 mg, copper: 0.12 mg and zinc: 0.09 mg [5].

The vitamins are diverse, yet in low amounts. At 100 g of fresh fruit, the vitamins have got the following values: vitamin A: 0.8 - 0.9 mg, the complex of vitamins B: 0.12 - 0.13 mg, vitamin C: 20 - 60 mg, vitamin PP: 0.10 - 0.25 mg and so on [6].

The energetic value of the tomatoes is relatively low, as one kilogram of fresh tomatoes provides around 190 Kcal [7].

Tomatoes have got an extremely high nutritional density. The advantages of eating various types of fruits and vegetables are impressive and tomatoes are no different. As the amount of vegetable foodstuff in one's diet increases, the risk of developing heart diseases, diabetes and cancer decreases.

The benefits for health may vary, according to the types. For instance, cherry tomatoes have got a higher content of beta-carotene than regular tomatoes. The wide consumption of fruits and vegetables is also linked to a healthy skin and a healthy hair, to increased energy and to a lower weight. The enhancement of fruit and vegetable consumption considerably mitigates the risk of obesity and general mortality.

Tomatoes are an excellent source of vitamin C and other anti-oxidisers. Thanks to these components, tomatoes may help fight the development of free radicals, which are known to cause cancer. Tomatoes are the richest source of lycopene - a natural colouring agent that provides the red pigment to foodstuff. Tomatoes are also strong anti-oxidisers, soluble in fats, with beneficial effects on our health and able to be absorbed more efficiently in the body when exposed to thermal cooking [8].

The highly oxidising action of lycopene may bring forth a few benefits for health. In time, scientists have wondered whether there is a connection between the consumption of lycopene and the prevention and/or the slowing down of the development of certain types of cancer, such as the prostate, stomach, lung, breast or colon ones. Many of the trials are observational and call for more investigations in order to reach definite results. Nevertheless, some conclusions are worth mentioning.

In 2002, a team of specialists collected the answers of a food-related questionnaire applied to 47,365 men in 1986, 1990 and 1994, noticing that more than two portions of tomato sauce consumed per week were associated to lower chances for the appearance of the prostate cancer [9].

In another research (2001), 32 patients suffering from prostate cancer were recommended to consume tomato sauce every day, for three weeks, prior to the prostate removal surgery. The analysis showed a 20 % drop in the level of the prostate-specific antigen (PSA) in the blood - that protein generated by the prostate cells - and another test showed a low level of oxidative stress in the patients' body [10].

In 2008, after seven years of investigations, a team of specialists reached the conclusion that a greater contribution of lycopene had reduced the chances for the appearance of breast cancer in 84,805 post-menopause women [11].

Nonetheless, the inclusion of tomatoes in the diet runs certain risks. Each year, the Environmental Working Group (EWG) draws up a list of the fruits and the vegetables with the highest levels of pesticide residues, these food items are termed 'Dirty Dozen'.

In 2017, the tomatoes were number 10 and the cherry tomatoes number 14 on the list. Even though it has not yet been proven that the consumption of organic food is generally beneficial to health, EWG suggests that people should buy organic tomatoes wherever possible. The purchase of organic products mitigates the exposure to pesticides, even though this has not been proven to prevent diseases [12].

2. Materials and methods

2.1. Chemical products and reacting agents

The distilled water - a solution of 0.1 N NaOH -, the phenolphtalein, HNO_3 65 % Suprapure Merck, H_2O_2 30 % Suprapure Merck, n-hexane were purchased from the Merck company. All the aqueous solutions were made with Milli-Q filtered water (18.2 MΩ cm resistivity (25ºC) and the TOC value ≥ 5 ppb) and the samples were analysed at SC Biosol psi SRL (Biosol psi Trading Co., Ltd.) of Ploieşti. The reaction of the soil on which the experiment was carried out is neutral (table 1), owing to the content of carbonates. In case of these values, the ions of Ca^{2+} and Mg^{2+} (at a pH of 7) and NH_4^+ and MoO_4^{2-} (a pH of 7-8) are absorbed preferentially. The pH values in the soil under study fall into the optimum range of values for tomato growing (5.5 to 7.0) [13].

For the analysis of the soil we used the following methods, according to the methodology of the Bucharest Institute of Research for Pedology and

Agrochemistry : the soil acidity (the pH acidity) was measured by means of the potentiometric method (STAS 7184/13), for the content of hummus - the Schollenberger method (STAS 7184/21-82), for determining the total nitrogen - the Kjeldahl method (STAS 7184/2-85), for determining the mobile phosphorus - the Egner-Riehm-Domingo colorimetric method (STAS 7184/19-82), for determining the values of mobile potassium - the flame photometric method (STAS 7184/18-80), the total content of soluble salts was set up by the conductometric method (STAS 7184/7-87) and the nitrogen index was calculated subject to the content of hummus and to the degree of base saturation. The reaction of the soil is neutral, the potential of hydrogen is 7, the content of hummus has got high values - of 4.53 % - and the organic matter has got the 6 % value, as the soil is very well supplied. The content of nitric nitrogen is high and the hydrosoluble phosphorus and potassium are between the 'high' and 'very good' standards. On the other hand, the content of hydrosoluble magnesium has got very low values.

Table 1

The content of macroelements of the soil on which the experiment took place*

Determination	P 1	P 1
pH - soil reaction	7.0	neutral
h - hummus (%)	4.53	very good
OM - organic matter (%)	6.0	very good
f.c.w. - field capacity for the water (%)	27	very good
HA - hydrolytic acidity (me)	0.372	neutral - slightly alkaline
S_B - sum of bases (me)	99.1	
V - degree of base saturation (%)	100	
NI - nitrogen index (%)	4.51	very good
H - humidity (%) in case of fresh soil	19	medium
Initial H as % from cca	70	medium
CS - concentration of soluble salts (%)	0.0482	good
$N\text{-}NO_3$ - nitric nitrogen ($mg \cdot kg^{-1}$)	18	good
$N\text{-}NH_4$ - ammonia nitrogen ($mg \cdot kg^{-1}$)	absent	normal
P_{H2O} - hydrosoluble phosphorus ($mg \cdot kg^{-1}$)	11	very good
P_{AL} - mobile phosphorus ($mg \cdot kg^{-1}$)	126	good
K_{H2O} - hydrosoluble potassium ($mg \cdot kg^{-1}$)	48	very good
K_{AL} - exchangeable potassium ($mg \cdot kg^{-1}$)	340	very good
Ca_{H2O} - hydrosoluble calcium ($mg \cdot kg^{-1}$)	100	good
Mg_{H2O} - hydrosoluble magnesium ($mg \cdot kg^{-1}$)	6	very low
Na_{H2O} - hydrosoluble sodium ($mg \cdot kg^{-1}$)	21	very well

* The tests were carried out by the Agrochemistry, Physiology and Biochemistry Laboratory within the Vidra Institute of Research for Vegetable and Flower Growing, values calculated for the dry soil at 105℃

Soil fertility, meaning the capacity of underpinning the production of plants, is due to the interactions among the physical, chemical and biological processes. In particular, soil texture, pH and the organic matter highly affect the functions of the soil, as well as water and nutrients availability [14, 15].

The importance of the physical quality of the soil for the tomatoes growth and yield, as well as the chemical and biological conditions of the soil have been well documented in the literature [16, 17, 18].

As far as the chemical properties are concerned, nitrogen and calcium carbonate are two of the most important nutrients for the production of plants; they also play critical roles in the cell structures and in the plants metabolism, influencing both the content and the quality of the plant secondary metabolites [17, 19].

The microbial mass of the soil, which includes bacteria (83 %), actinomycetes (13 %), fungi (3 %), protozoa, algae and viruses (0.2 - 0.8 %), improves soil structure and plant growth by the decomposition of the atmospheric organic matter, the nitrogen consolidation, the cycle of the nutrients (C and N) and the symbiosis with the plants [14, 20].

Tomatoes are very choosy in terms of nutrition. Nitrogen is a highly important nutritional element, and its absence has repercussions upon the plants yield and quality. A shortage in nitrogen brings forth reduced vegetative growths, the fruits are smaller and sensitive to the attack of diseases and pests. An excess of nitrogen, on the other hand, causes exaggerated vegetative growths, detrimental to fructification, and it delays fruit riping. Phoshorus provided in optimal doses directly influences the tomatoes earliness and level of productivity. The absorption of phosphorus is influenced by light and temperature. Potassium has got effects on the quality of fruits, thereby influencing taste and colour, and it provides resistance to diseases and pests. Insufficient potassium brings in fruit staining during maturation, whereas its excess causes a shortage of magnesium. The latter one is also responsible for the quality of the fruits, as well as for their resilience to transportation and to storage. Chlorophyll and vitamins synthesis is caused by manganese and iron, whereas zinc plays a part in the breathing process. The plant functions as a living organism: it breathes, sweats and experiences metabolic processes. All such metabolic processes are influenced by the said nutrients. Their absence or excess lead to serious disorders of metabolism in the plant, with consequences upon the fruit’s quality and, implicitly, taste.

Further to the tests carried out onto the soil where the tomatoes were cultivated, the results achieved have proved that that respective soil has got all the positive features (pH, content of hummus, organic matter, humidity, micro- and macroelements) for an optimum development of the tomatoes.

Our results have shown that the content of K, Ca, Na and Mg was lower in case of the seedless samples ; an exception to the rule was noticed in the

Kristinica and Hera varieties, whereas the concentration of Fe, Mo, Mn, Cu and Ba was lower at the seedless samples, except for the Darsirius variety.

The low concentrations of heavy metals - both in the peel and in the pulp - constitute a positive aspect, because the tomatoes consumed by people cause serious health problems to their body.

2.2. Samples

The trial included fruits from five varieties of tomatoes (Kristinica, Darsirius, Florina, Hera and Andrada), conventionally produced at the Buzău Station of Research and Development for Vegetable Farming. Approximately five kg of fruits belonging to each variety, all of them in the red riping stage, were harvested at random from 10 different tomato plants located in the same plantation area. The freshly collected fruits were washed and used to prepare two distinct sample groups: peelless and seedless fruits and seedless fruits. Before being transferred into a sealed container and stored at -20°C, the samples were homogenized by means of a Grindomix blender.

Fig. 1. Sample preparation

2.3. Physical and chemical characterisation

The samples were analysed in order to determine the potential of hydrogen (pH), the content of humidity (U %), of dry substance (DS %), of titratable acidity (TA), of ash (Cd %) and of micro- & macroelements.

2.3.1. Potential of hydrogen (pH) determination

A sample of 10 g of tomato fruits is taken, put it in a glass and add distilled water nine times the amount of the sample. Then heat it in a water bath for 30 minutes, while stirring occasionally. The pH-meter is calibrated by a buffer solution whose pH is 7 and 4, by dipping the electrode into the tomato solution; reading is made directly on the pH-meter. (! The electrode must be completely dipped in the solution).

2.3.2. Humidity (H %) content and dry substance (DS %) content determination

The dry substance is represented by the totality of the substances that remain in the tomato fruits after the water has vaporised. The determination of the content of dry substance took place by weighing.

The content of water is determined on a 3 g sample, which is inserted in the oven set at 105°C, until obtaining a constant weight. The empty capsules, after being dried up in an oven at 105 °C, are put in a dessicator.

2.3.3. Titratable acidity (TA) determination

Titratable acidity is represented by the sum of the substances with an acid reaction, which can be titrated by an alkaline solution (0.1 N NaOH). The method used for determining the titratable acidity is described by Ilaky, 2011 [21]. Acidity titratation is made by a 0.1 NaOH solution, in the presence of phenolphtalein, as a colour indicator.

Fig. 2. Images of the samples subjected to the filtration

This method is based on the total destruction of any organic carbon particles and on weighing the remaining mineral matter (according to the French Standardisation Association - 1982). The 2 g powder is put in capsules, which are taken into an oven set at 550 °C and kept there for five hours, until obtaining a clear grey or whitish colour. After cooling down, the capsules are weighed.

2.3.5. Micro - and macroelement content determination

The determination of the micro- and macroelement content took place by the official method for determining the heavy metals contained in the foodstuff (AOAC's official method - 01.2015) and by the method recommended by Milestone Ethos Up Digestion Apps. The tomato fruits were sorted, washed with highly pure water and then the representative average sample was selected by weighing 0.250 g of sample on the analytical scales. The following reacting agents were then added to the sample obtained: 8 ml of HNO_3 65 % Suprapure Merck and 2 ml H_2O_2 30 % Suprapure Merck. The witness sample consisted in HNO_3 and H_2O_2. The samples obtained and the witness variant were subjected to digestion by means of the closed digestion system by ETHOS UP microwaves. At the end of the heating cycle, the vessels were kept at the room temperature around 30 minutes, in order to cool down. All samples were processed in triplicate.

Fig. 3. Images of the samples subjected to digestion by ETHOS UP microwaves.

3. Results and discussions

The state of maturation and conservation, as well as the nutritional and commercial values of the tomatoes may be deducted from the assessment of several physical and chemical parameters. For instance, the tomatoes texture, taste and appearance greatly depend on the content of humidity.

The potential of hydrogen and the titratable acidity are important criteria during fruit processing, because they influence the tomatoes period of validity and are used as indicators of trust for the general quality of the fruits. Flavour is also dependant on the acid concentration. Nitrogen plays an important part in tomato growing and fruit bearing. Phosphorus is important in the nitrogen assimilation, as it stimulates the tomatoes blooming and fruit bearing. It has got a positive effect on the precocity and the development of the radicular system. Potassium has also got a favourable influence, by enhancing the structural-textural firmness of the horticultural products, the titratable acidity, it increases the resistance to diseases and it improves the taste-related features.

Tomatoes consume large amounts of potassium, contributing to the creation and the transport of the carbohydrates and of the ascorbic acid in the fruits. A favourable K/N ratio adds to the enhancement of the radicular system. Calcium has a remarkable role for strengthening the radicular system, for maintaining the integrity of the cell membranes and it acts like an agent of cementing the cell walls, under the form of calcium pectate. Magnesium influences the quality of the fruits, as well as the resistance to transport and storing. Microelements play an crucial part in tomato growing and fruit bearing. Borine and manganese influence the synthesis of the carbohydrates and the evolution of the fruit bearing organs. Iron has got an important role in photosynthesis. Zinc contributes to the auxin synthesis and to the breathing processes. The extent to which all these variables are affected by peel and seed removal - in case of the five variants under study - is set out in Table 2 and in Figs. 4 and 5, respectively.

Table 2

Physical and chemical characterisation of the various samples of tomato fruits (1 - seedless, 2 - peelless and seedless) obtained from the variants under study : the values for the potential of hydrogen (pH), humidity (H %), the content of dry substance (DS %), the content of ash (Cd %), (TA) citric acid content (mg/100 g) *

TOMATO TYPE	PHYSICAL AND CHEMICAL CHARACTERISATION				
	pH	H (%)	DS (%)	Cd (%)	TA (mg/100 g)
$Kristinica_1$	4.751	94.274	5.726	0.136	178
$Kristinica_2$	4.656	93.567	6.432	0.138	187
$Darsirius_1$	4.865	93.353	5.647	0.138	232
$Darisirius_2$	4.888	93.006	6.993	0.104	184
$Florina_1$	5.298	93.905	6.094	0.125	181
$Florina_2$	4.758	94.191	5.808	0.113	176
$Hera_1$	4.591	93.725	6.275	0.093	181
$Hera_2$	4.748	94.430	5.570	0.092	134
$Andrada_1$	4.665	94.426	5.574	0.076	246
$Andrada_2$	4.758	93.416	6.584	0.120	162

*Values expressed as arithmetic average, ensued from five measurements per tomato variety.
For each variety, the values obtained show significant differences, caused by peel or seed removal.

Technically speaking, peel and seed removal had no effect on the samples humidity; instead, it kind of affected the potential of hydrogen, DS %, Cd, TA and the content of micro- and macroelements. The effect of peeling on the pH is not easy to explain, because in case of the Florina and Kristinica varieties there is a significant drop, whereas at the Darsirius, Hera and Andrada varieties there was a slight increase. Seed removal led to a considerable enhancement of the pH in case of the Kristinica, Hera and Andrada varieties. This probably derives from the fact that the seeds have got a high content of organic acids and tannins. Furthermore, seed removal was accompanied by a significant drop of TA, which is directly linked to the loss of the yellowish seeds, rich in the aforementioned compounds.

Peeled tomatoes contained a smaller quantity of pigments and seedless tomatoes are less acid per mass unit.

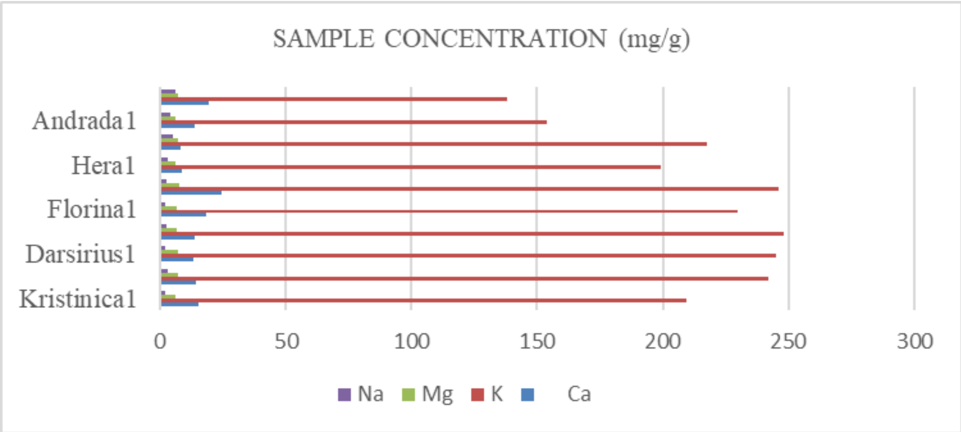

Fig. 4. The macroelement content of the various samples of tomato fruits
(1 - seedless, 2 - peelless and seedless)

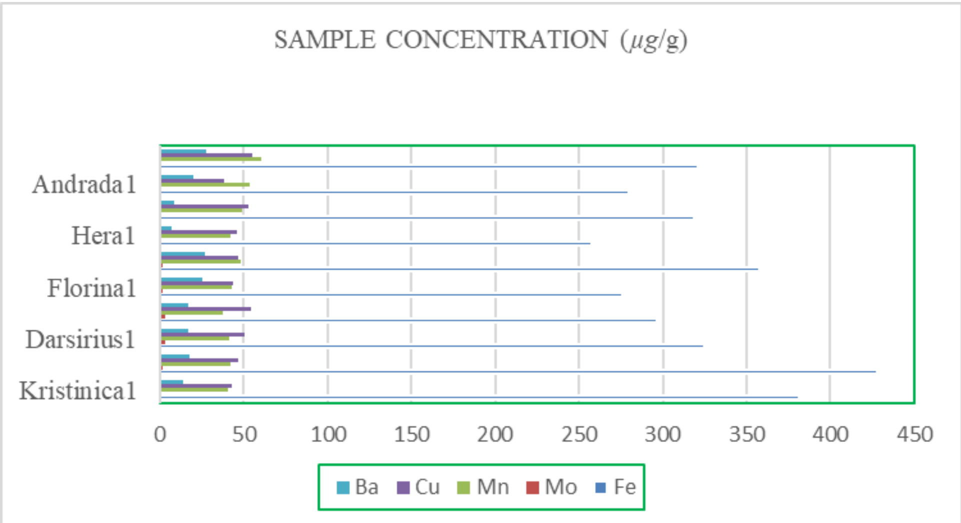

Fig. 5. The microelement content of the various samples of tomato fruits
(1 - seedless, 2 - peelless and seedless)

Acidity tends to decrease alongside fruit maturity [22]. No significant differences ($p > 0.05$) between the varieties and the maturity stages for the average values of the titratable acidity, expressed in mg /100 g of citric acid, were noticed. A slight increase was seen at the Kristinica variet. The method of cultivation and the variety had a significant influence upon the content of K, Ca, Na or Mg. The main factor that influences the micronutrients in case of the tomatoes was the variety.

Our results showed that the content of K, Ca, Na and Mg was lower at the seedless samples; the exception to the rule was noticed at the Kristinica and Hera varieties. The concentration of Fe, Mo, Mn, Cu and Ba was lower at the seedless varieties, except for the Darsirius variety.

4. Conclusions

There are many factors, such as the variety, the method of cultivation and the region of cultivation, that influence the chemical composition of the tomatoes. The variety is a factor more influent than the methods of cultivation, for differentiating the samples of tomatoes subject to the chemical characteristics. The main factor that influenced the mineral content of the tomatoes was the variety. The results obtained showed that peel and seed removal mostly affected the physical and chemical properties of the Kristinica and Florina varieties, whereas the other varieties of tomatoes were affected in a very low degree.

The results of this research substantiate the idea that in order to enjoy the full nutritional and antioxidant potential that the tomato can offer, people have to eat the entirety of the fruit. When this is not feasible, the peel and the seeds ought to be valorised as secondary products, given their nutritional value.

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