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Intermediate Formation of Essential Amino Acids and Division of Amine (NH_2) Group by UV Light as Sterilizer in Vegetables (ISO 15714:2019)

V. M. Beluli[1,2*]

ORCID: 0000-0003-1234-6888

[1]Department of Technology, Faculty of Food Technology, University of Mitrovica "Isa Boletini", Mitrovica, Kosovo.
[2]Department of Industrial Chemistry, Faculty of Natural Sciences, University of Tirana, Albania

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ABSTRACT

Sterilization of fruits and vegetables in the field of food technology can be seen as a good tool to guarantee a better product on the market for consumers, but often radiation can have different effects on food products. Researchers have been studied in this field to provide a higher quality to food products in the sterilization of vegetables (potato, tomato, cucumber) eliminated from microorganisms. This method has a high rate of sterilization in the food industry. The main problem is that the deep penetration of the rays from photochemical reactions in the amino group (-NH_2) fission by the essential amino acid. The essential amino acids that have been studied in potatoes, tomatoes and cucumber are: Arginine, Glutamine, Threonine, Valine, Lysine, Isoleucine, Histidine, Leucine, Aspartic acid, Proline, Histidine, Alanine and Serine are still great issue. The fission of the amine group from the essential amino acids uses a UV-C spectrum irradiation at 200 nm wavelength to form an intermediate in the covalent chemical bonds. This energy is sufficient to break the C-NH_2 bond forming carboxylic acids in vegetable skins and this lowers the shelf life of food. According to our research we have concluded that 200 nm radiation with an energy of 600 kJ/mol causes high potential of photochemical reactions. UV penetration varies depending on the wavelength and type of vegetable. Penetration (Z) of UV rays on potatoes with wavelength (λ) are: UV-C [λ (200-280) nm, Z (1.606 - 2.248) nm], UV-B [λ (280-320) nm and Z (2.208– 2.57) nm], UV-A2 [λ (320-340) nm and Z (2.57-2.73) nm], UV-A1 [λ (340-400) nm and Z (2.73-3.21)]. Penetration (Z) of UV rays on tomatoes with wavelength (λ) are: [λ (280-320) nm and Z (3.45-4.84) nm], UV-B [λ (280-320) nm, Z (4.84 – 5.53) nm], UV-A2 [λ (320-340) nm and Z (5.53-5.87) nm], UV-A1 [λ (340-400) nm and Z (5.87-6.91) nm]. Penetration (Z) of UV rays on cucumbers with wavelength (λ): UV-C [λ (200-280) nm and Z (3.41-4.77) nm], UV-B [λ (280-320) nm and Z (4.77-5.45)], UV-A2 [λ (320-340) nm and Z (5.45-5.79) nm], UV-A1 [λ (340-400) nm and Z (5.79-6.82) nm].

Keywords: UV radiation, Sterilization, Vegetables, Essential amino acids**,** Photochemical reactions, Amine group division

1. Introduction

Ionizing radiation interacting with the composition it comes in contact with, can cause varied changes but may be either useful or harmful. This effect has been studied quite a lot for different purposes. Currently ionizing radiation has found a widespread use in various fields of science and technology, becoming often an irreplaceable tool in the industry [1]. Nonionizing, germicidal, artificial ultraviolet (UV-C) radiation is a novel physical sterilization technique. Unlike chemical sanitizers, UV-C does not leave a residue, and does not require extensive safety equipment. Nevertheless, a few studies have focused on UV-C radiation on fresh-cut fruits and vegetables [2]. There is a growing negative public reaction over chemical preservatives added to foods to

*Corresponding author.
E-mail address: valdrin_beluli@hotmail.com, (V.M. Beluli)
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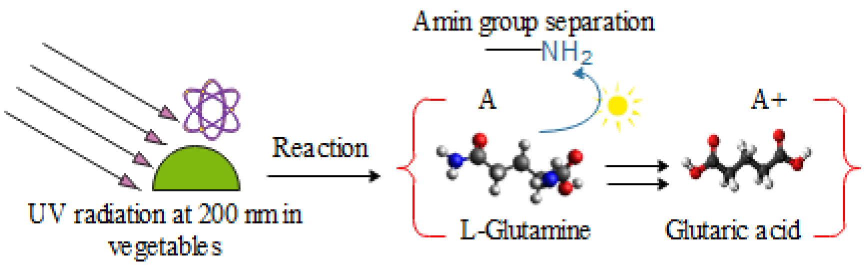


Fig. 1 *UV irradiation of vegetables for sterilization and chemical reactions of essential amino acids*

extend their shelf life and to protect against food-borne pathogens and spoilage microorganisms. As a physical preservation method, ultraviolet (UV)-light irradiation has a positive consumer image and is of interest to the food industry as a nonthermal method of inactivation [3]. Compared to chemical and thermal methods, UV radiation treatment is a very reliably and economically efficient method and can be used in continuous operation on filling lines. If used properly, it takes seconds to deactivate viruses and kill microorganisms such as bacteria, yeasts and fungi in an environmentally friendly manner because no extra chemicals are needed [4].

For preservation of foods, the type of radiation applied is referred to as ionizing radiation because it produces electrically charged ions as the energy interacts with target molecules [5]. Radiating vegetables to destroy microorganisms on their surface is being seen as a good option for food quality. Radiation emission is widely used in Europe Union but the problem exists that UV rays excite organic molecules that create ionized organic products. Radiation in the UVA-C spectrum has the ability to excite essential amino acids in the skin of vegetables such as potatoes, cucumbers, tomatoes. If the essential amino acids produce ionically unimportant metabolic products, then it can be said that UV radiation creates changes in chemical structures especially at 200 nm UV radiation (Figure 1). The study of fruit and vegetable radiation in many literatures lacks information about the effects that UV rays can give. We, in the literature see only positive effects that have UV rays for the destruction of microorganisms, but in our case, we have researched many weak points of UV radiation in vegetables and will strengthen the information in this field of UV radiation.

2. Material and Methods

Ultraviolet detection technology has a wide range of applications [6]. There are also different types of UV rays, based on the amount of energy they have. Higher-energy UV rays are a form of ionizing radiation. This means they have enough energy to remove an electron from (ionize) an atom or molecule [7]. The UV radiation consists of distinct regions depending on the wavelengths (i.e., UV-A between the wavelengths 320 to 400 nm, UV-B between the wavelengths of 280 to 320 nm, and UV-C with shorter wavelengths from 200 to 280 nm) [8].

UVC microbicide lamps in the use of fruits and vegetables

Table 1. The electromagnetic spectrum of ultraviolet radiation (UVR), defined most broadly as 10–400 nanometres can be subdivided into a number of ranges recommended by the ISO standard ISO-21348 [10]

UV light	Abbreviation	Wavelength (nm)	Photon energy (eV)	Notes
Ultraviolet C	UV-C	100–280	4.43–12.4	Short-wave, germicidal, completely absorbed by the ozone layer and atmosphere: hard UV.
Ultraviolet B	UV-B	280–315	3.94–4.43	Medium-wave, mostly absorbed by the ozone layer: intermediate UV
Ultraviolet A	UV-A	315–400	3.10–3.94	Long-wave, black light, not absorbed by the ozone layer: soft UV.

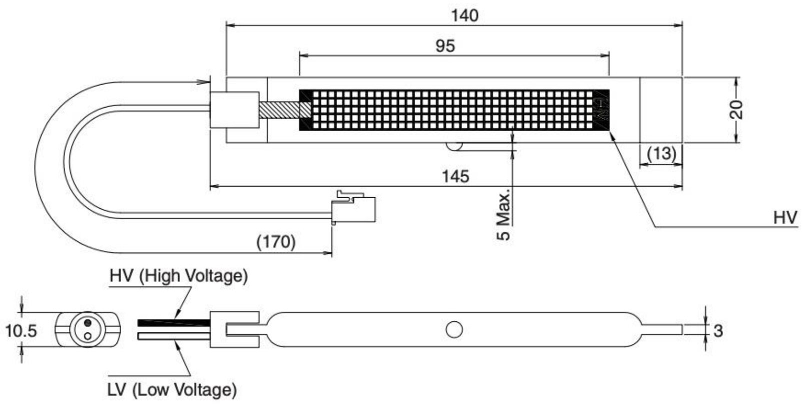


Fig. 2 *UV lamp for sterilization of fruit and vegetable surface [9]*

UV light is used in many food industry applications as it is completely safe, low maintenance and does not require the use of any chemicals or pesticides. UV lamps can effectively eliminate viruses like E. Coli and Salmonella as well as many other microbes which cause food to spoil. UV-C germicidal lamps also prevent bug infestations in fruit and vegetables and help to prevent imported fruit from bringing insects into the country. Germicidal UV-C lamps are proven to eliminate many viruses and bacteria, molds and spores as well as fungi and yeasts [9].

2.1 Essential amino acid in potato, tomato and cucumbers

Proteins are complex chemical structures consisting of polypeptide chains. These chains are formed by amino acids linked sequentially to each other [11]. Taking into consideration the role of proteins and healthy eating patterns related to protein, it is important to analyse the consumption of food with respect to the share of particular food groups in the contribution of energy and nutrients. As far as protein and amino acids are concerned, type of protein to be eaten, protein quality and protein density should be analysed [12]. The essential amino acids that have been studied in this research in vegetable skin such as tomato, cucumber and tomato are: Arginine, Glutamine, Threonine, Valine, Lysine, Isoleucine, Histidine, Leucine, Aspartic acid, Proline, Histidine, Alanine and Serine [13], [14], [15].

2.2 Chemical reactions of essential a-amino acids

The characteristic of these reactions is the separation of the amine group from the amino acids *etc*. Recognition of these reactions has implications for many aspects of protein chemistry [16]. It is theoretically possible for UV light at 253.7 nm to affect the O-H, C-C, C-H, C-N and H-N bonds if it’s absorbed [17].

The first step in this reaction is the absorbance of a photon by a reactant molecule (A), leading to the production of an electronically excited intermediate. The excited state can be for a period of 10^{-10} to 10^{-8} s, during which the energy of the electrons is increased by the amount of photon energy. The summary of representative values of the bond energies that characterize some of the common bonds of molecular groups relevant to biomolecules and organic molecules are given in Table 1. From this summary, it is evident that the bond energies of interest are generally coincident with photon energies in the UV portion of the spectrum. In particular, radiation with wavelength less than approximately 320 nm appears to be sufficiently energetic to promote photochemical reactions in biomolecules [18].

Table 1. Typical bond energies of important biological moieties and their corresponding wavelengths [18]

Bond	Typical Bond Energy (kj/mole)	Corresponding Wavelength (nm)
O-H	460	260
C-H	410	290
N-H	390	310
C-O	370	320
C=C	830	140
C=N	850	140
C=O	740	160
C=N	600	200

2.3 Dielectric properties of food materials

Radiation may be defined as the emission and propagation of energy through space or through a material medium. The type of radiation of primary interest in food preservation is electromagnetic [19]. The dielectric properties of food materials indicate how much microwave energy is absorbed, transmitted, reflected and concentrated during interaction between the food and electromagnetic energy [20]. Dielectric properties of tomatoes crucially affect their heating behaviours in an electromagnetic field and are essential for developing microwave pasteurization and sterilization processes for different tomato products [21].

Table 2. Constant of the dielectric material and lost factor for vegetables [24]

Vegetables	ε'-Constant of the dielectric material	ε''-lost factor
Potato	48.7	293.5
Tomato	47.87	19.73
Cucumber	71	11

The microwave heating rate depends on dielectric properties of the material. Dielectric properties are commonly represented by a complex number, the relative complex permittivity ε* = ε' – ε'', where the real part ε' is the dielectric constant and the imaginary part ε'' is the dielectric loss factor. Here ε' indicates the material's ability to store electrical energy and ε'' is a measure of its ability to dissipate the electrical energy in the form of heat [22]. The dielectric loss mechanisms of biological materials in electromagnetic energy fields mainly include polar, electronic and atomic [21]. The following equations have been used to measure the penetration of UV rays into vegetables in our research, see Eq. 1 and Eq. 2 [1] [23].

$$\alpha = \frac{2\cdot\pi}{\lambda}\left[\frac{\varepsilon'}{2}\left(\sqrt{1+\varepsilon''}-1\right)\right]^{\frac{1}{2}} \quad (1)$$

$$Z = \frac{\lambda}{2\pi}\left[\frac{2}{\varepsilon'\left(\sqrt{1+\varepsilon''}-1\right)}\right]^{\frac{1}{2}} \quad \text{or} \quad Z=\frac{1}{\alpha} \quad (2)$$

Where α- mitigation factor, Z- depth of penetration, ε' - the dielectric constant of the material, ε''- lost factor and λ- value length, see Fig.3.

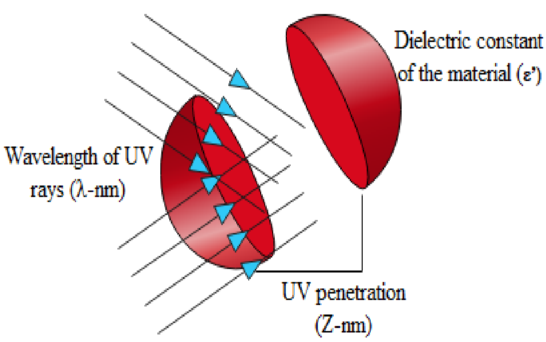


Fig. 3 *Penetration of UV rays in vegetables that depends on the dielectric constant of the material and the wavelength of UV rays*

For determining of penetration of UV rays into potato, tomato and cucumber as in our case, it is important to now constant of the dielectric material (ε') and lost factor (ε''), see Table 2.

3. Results and Discussions

The penetration of UV rays into vegetables is important to study because many nutrients are found inside vegetables. E. coli and Salmonella as two major problems in the food industry are destroyed by radiation in the UV-C spectrum. Destruction of microorganisms by UV radiation is an important step for vegetable sterilization but penetration of UV rays into vegetables can cause photochemical reactions.

The average penetration of UV rays in potatoes is:

a. In the UV-C (200-280) nm spectrum the average penetration is 1.92721 nm, see Fig. 4.
b. In the UV-B (280-320) nm spectrum the average penetration is 2.4224 nm, see Fig. 5
c. In the UVA-2 (320-340) nm spectrum the average penetration is 2.62984 nm, see Fig. 6
d. In the UVA-1 (340-400) nm spectrum the average penetration is 2.95104 nm, see Fig. 7

The average UV ray penetration in tomatoes is:

a. In the UV-C (200-280) nm spectrum the average penetration is 4.14946 nm, see Fig. 4
b. In the UV-B (280-320) nm spectrum the average penetration is 5.26093 nm, see Fig. 5
c. In the UV-A2 (320-340) nm spectrum the average penetration is 5.66229 nm, see Fig. 6
d. In the UV-A1 (340-400) nm spectrum the average penetration is 6.39709 nm, see Fig. 7

The average UV ray penetration in the cucumber is:

a. In the UV-C (200-280) nm spectrum the average penetration is 4.13433 nm, see Fig. 4
b. In the UV-B (280-320) nm spectrum the average penetration is 5.14305 nm, see Fig. 5
c. In the UV-A2 (320-340) nm spectrum the average penetration is 5.58348 nm, see Fig. 6
d. In the UV-A1 (340-400) nm spectrum the average penetration is 6.30805 nm, see Fig. 7

For more information on UV penetration in potatoes, tomatoes and cucumbers you can see Appendix.

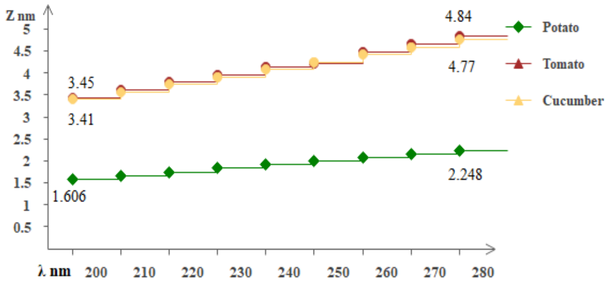


Fig. 4 Radiation and penetration of UV-C rays (200-280) nm in potatoes, tomatoes and cucumbers

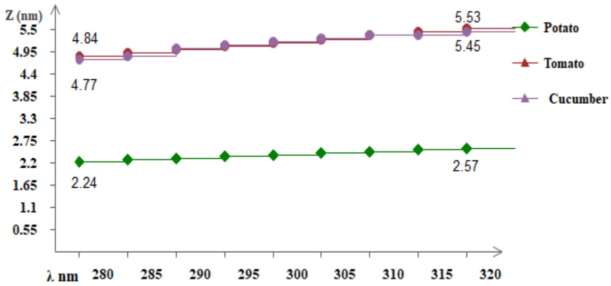


Fig. 5 Radiation and penetration of UV-B rays (280-320) nm in potatoes, tomatoes and cucumbers

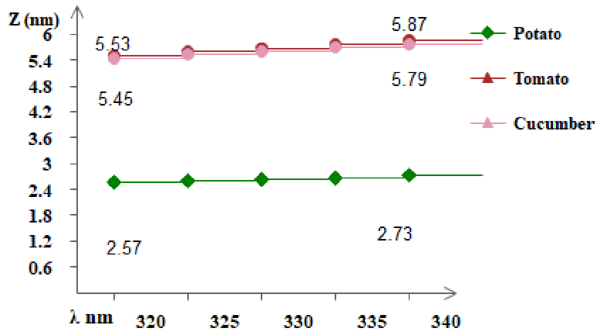


Fig. 6 Radiation and penetration of UV-A2 rays (320-340) nm in potatoes, tomatoes and cucumbers

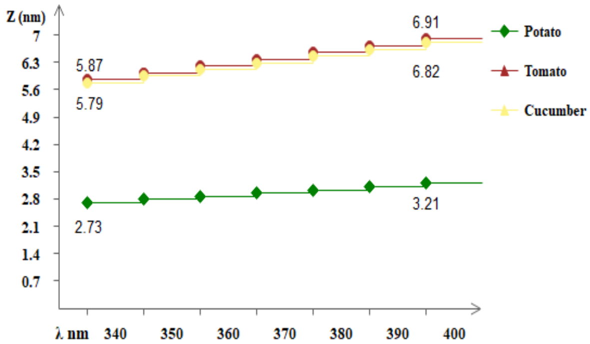


Fig. 7 Radiation and penetration of UV-A1 rays (340-400) nm in potatoes, tomatoes and cucumbers

3.1 UV radiation and division of the amine group on the essential amino acids of potato, tomato and cucumber

In conjunction with discoveries of new photoreactions, the development of theoretical and physical concepts related to triplet state, radiative and radiationless transitions, and energy and electron transfer have contributed to the vigorous growth of the field of organic photochemistry [25]. Although radiation techniques, as the other traditional or emerging techniques, can impair alterations that can modify the chemical composition and the nutritional value of foods, these changes depend on the food composition, the irradiation dose and factors such as temperature and presence or absence of oxygen in the irradiating environment [26].

Photochemical reactions proceed as a direct result of radiation energy (photons) being introduced to a system. In view of the wavelengths used in most UV-light treatments, the molecules (A) are primarily affected by energy absorption that results in photochemical reactions. In the general case, the process may be viewed as: [18]

$$A + \text{radiation} \rightarrow A^{+} + \text{Product (B)}$$

UV rays have the potential for photochemical reactions to change electron positions between C-H, C-C and C-N covalent bonds. Radiation at 200 nm (600 kj/mol) has the ability to change covalent bonds and form chemical intermediates. Separation of the amine group from the essential amino acids and the formation of carboxylic acids applies a radiation energy of 600 kj/mol. This radiation energy destroys microorganisms very well for vegetables but the problem is that during UV radiation, the product causes the formation of carboxylic acids. UV radiation first forms an intermediate chemical space, after which the covalent electrons are transformed to make the covalent bonds as stable as possible. If the electrons are stable in the C-H bonds then new chemical bonds are formed forming a radiated product. As an example, we have taken the UV reaction mechanism of L-Histidine and L-Proline, see Figure 8. Other essential amino acids in potatoes, tomatoes and cucumber are reactions with a simpler amine group division mechanism, (see Table 4, Table 5 and Table 6).

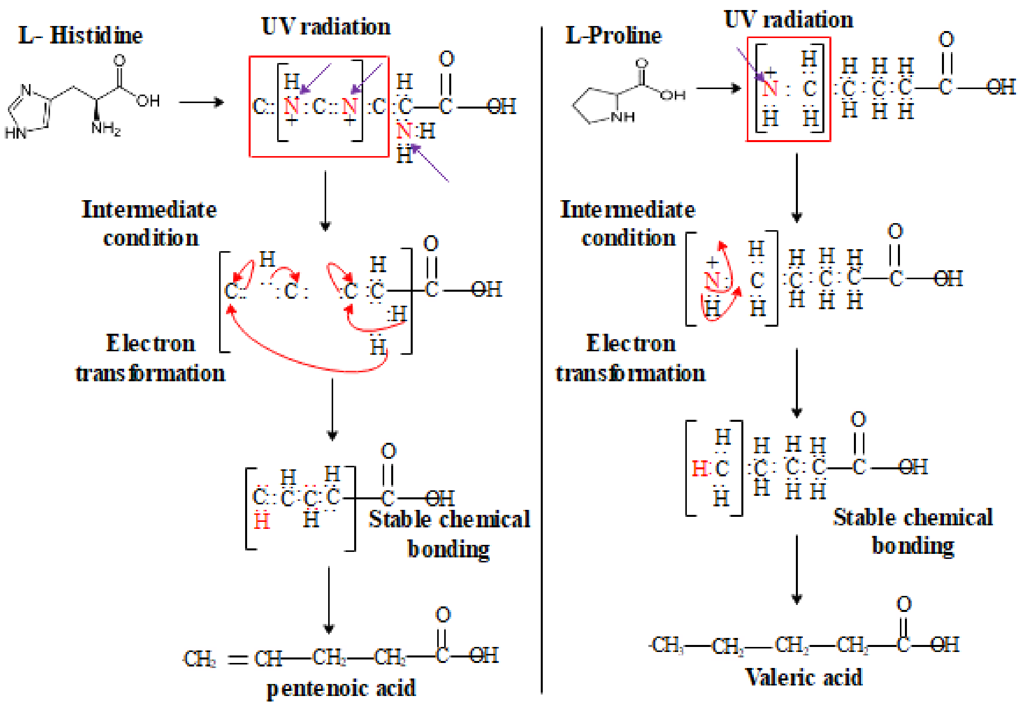


Fig. 8 *Amine group fission mechanism and C-NH cyclic covalent bond division in L-Histidine and L-Pyrolin*

Table 4. Photochemical reactions to essential amino acids in cucumbers

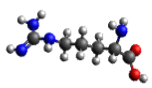
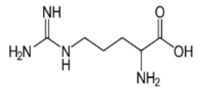
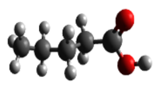
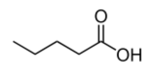
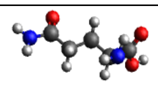
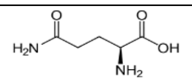
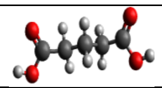
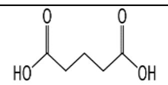
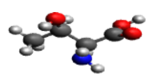
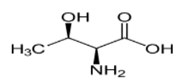
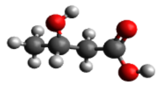
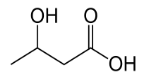
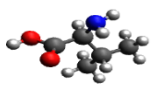
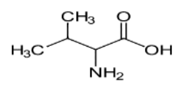
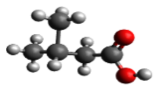
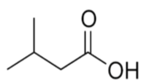
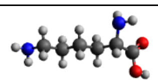
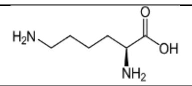
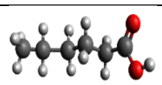
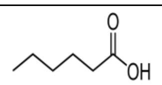
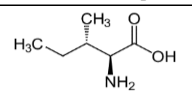
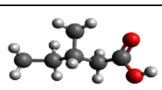
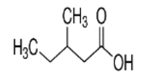
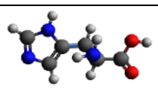
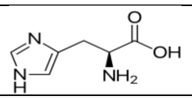
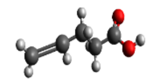
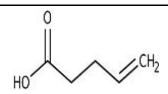
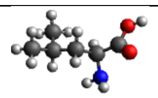
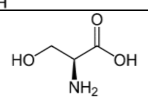
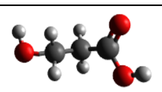
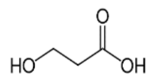
	A			B	
L-Arginine $C_6H_{14}N_4O_2$			Valeric acid $C_5H_{10}O_2$		
L-Glutamine $C_5H_{10}N_2O_3$			Glutaric acid $C_5H_8O_4$		
L-Threonine $C_4H_9NO_3$			β-Hydroxybutyric acid $C_4H_8O_3$		
L-Valine $C_5H_{11}NO_2$			β-methylbutyric acid $C_5H_{10}O_2$		
L-Lysine $C_6H_{14}N_2O_2$			Caproic acid $C_6H_{12}O_2$		
L-Isoleucine $C_6H_{13}NO_2$			3-Methyl valeric acid $C_6H_{12}O_2$		
L- Histidine $C_6H_9N_3O_2$			Pentenoic acid $C_5H_8O_2$		
L-Leucine $C_6H_{13}NO_2$			4-Methyl pentatonic $C_6H_{12}O_2$		

Table 5. Photochemical reactions to essential amino acids in tomato

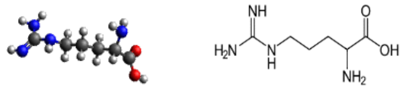
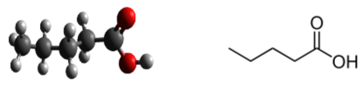
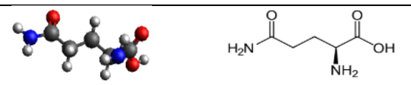
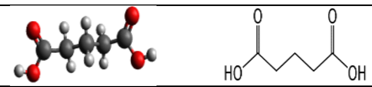
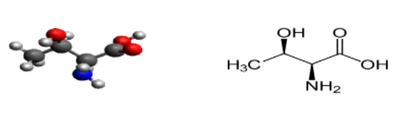
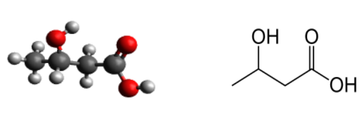
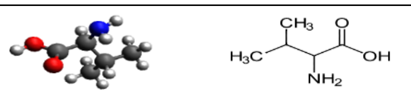
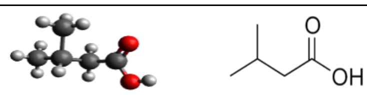
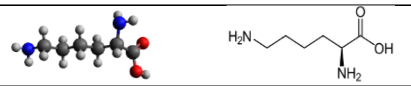
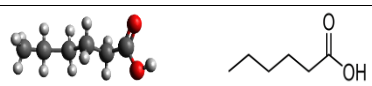
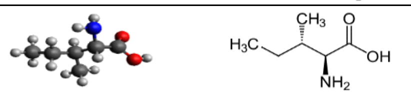
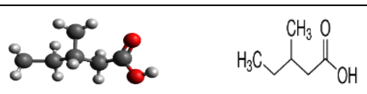
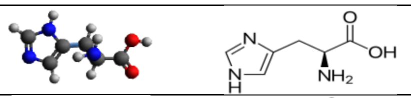
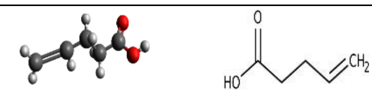
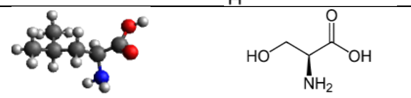
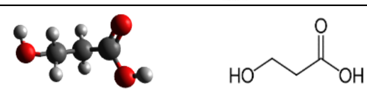
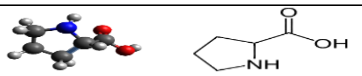
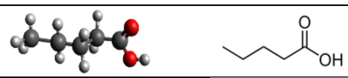
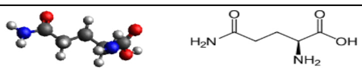
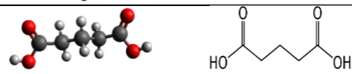
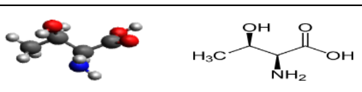
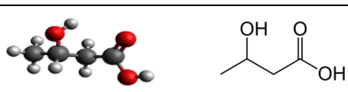
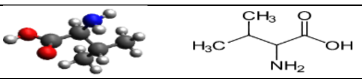
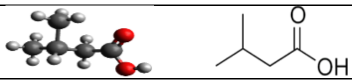
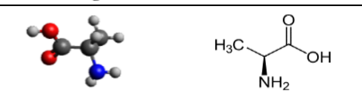
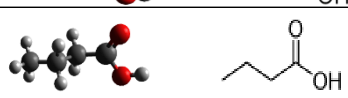
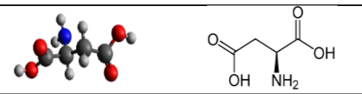
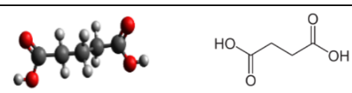
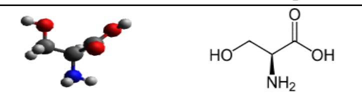
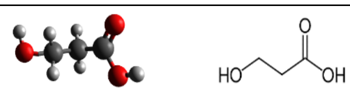
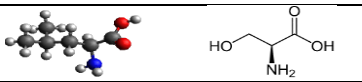
	A		B
L-Arginine $C_6H_{14}N_4O_2$		Valeric acid $C_5H_{10}O_2$	
L-Glutamine $C_5H_{10}N_2O_3$		Glutaric acid $C_5H_8O_4$	
L-Threonine $C_4H_9NO_3$		β-Hydroxybutyric acid $C_4H_8O_3$	
L-Valine $C_5H_{11}NO_2$		β-methylbutyric acid $C_5H_{10}O_2$	
L-Lysine $C_6H_{14}N_2O_2$		Caproic acid $C_6H_{12}O_2$	
L- Isoleucine $C_6H_{13}NO_2$		3-Methyl valeric acid $C_6H_{12}O_2$	
L- Histidine $C_6H_9N_3O_2$		Pentenoic acid $C_5H_8O_2$	
L-Leucine $C_6H_{13}NO_2$		4-Methyl pentatonic $C_6H_{12}O_2$	

Table 6. Photochemical reactions to essential amino acids in tomato

	A		B
L-Piroline $C_5H_9NO_2$		Valeric acid $C_5H_{10}O_2$	
L-Glutamine $C_5H_{10}N_2O_3$		Glutaric acid $C_5H_8O_4$	
L-Threonine $C_4H_9NO_3$		β-Hydroxybutyric acid $C_4H_8O_3$	
L-Valine $C_5H_{11}NO_2$		β-methylbutyric acid $C_5H_{10}O_2$	
L- Alanine $C_3H_7NO_2$		Butyric acid $C_4H_8O_2$	
L- Aspartic acid $C_4H_7NO_4$		Succinic acid $C_4H_6O_4$	
L-Serine $C_3H_7NO_3$		3-Hydroxy propionic acid $C_3H_6O_3$	
L-Leucine $C_6H_{13}NO_2$		4-Methyl pentatonic $C_6H_{12}O_2$	

4. Conclusion

In the food industry there is still a great challenge in protecting foods from microorganisms and increasing shelf life. Our research has explained very well that UV radiation is a first step for the destruction of microorganisms but two steps back due to photochemical reactions by UV radiation inside vegetables. In the use of different UV radiation spectra from 200 - 400 nm in potatoes, tomatoes and cucumbers the penetration of UV rays is not the same. The spectrum of UV-C radiation is important for the destruction of microorganisms in general but also for the complete destruction of E. coli and Salmonella. The UV-C radiation spectrum, according to our research, possesses a deep penetration of vegetables, and this deep penetration is capable of forming UV radiation reactions, specifically on the essential amino acids of tomatoes, potatoes and cucumbers such as: Arginine, Glutamine, Threonine, Valine, Lysine, Isoleucine, Histidine, Leucine, Aspartic acid, Proline, Histidine, Alanine and Serine. Essential amino acids in vegetables (potato, tomato, cucumber) after UV irradiation at 200 nm wavelengths cause separation of the amine group (-NH_2) from the C-N bond and the formation of carboxylic acids (-COOH) such as: Valeric acid, Glutaric acid, β-Hydroxybutyric acid, Butyric acid, Succinic acid, 3-Hydroxy propionic acid, 4-Methyl pentatonic, β-methyl butyric acid, caproic acid, 3-Methyl valeric acid. According to our scientific research we have concluded that UV-C spectra create photochemical reactions if the radiation is irradiated at this wavelength. So, in conclusion, a 200 nm wavelength of 600 kj/mol energy separates (fission) the amine group from the essential amino acids by converting them into carboxylic acids and this type of radiation is unnecessary for the food industry due to the characterization of the essential amino acids as a nutrient important for a normal metabolism like human.

Conflict of Interest

The authors have no conflict of interest.

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Appendix. UV (200-400) nm penetration in potatoes, tomatoes and cucumber

UV Radiation	Vegetables		Potato		Tomato		Cucumber	
	λ (nm)	*f (Hz)*	*a (1/m)*	*z (nm)*	*a (1/m)*	*z (nm)*	*a (1/m)*	*z (nm)*
UV-C	200	$1.5\cdot10^{15}$	$6.23\cdot10^{8}$	1.606	$2.89\cdot10^{8}$	3.458	$2.93\cdot10^{8}$	3.41
	205	$1.46\cdot10^{15}$	$6.07\cdot10^{8}$	1.646	$2.82\cdot10^{8}$	3.544	$2.86\cdot10^{8}$	3.495
	210	$1.43\cdot10^{15}$	$5.93\cdot10^{8}$	1.686	$2.75\cdot10^{8}$	3.631	$2.79\cdot10^{8}$	3.58
	215	$1.4\cdot10^{15}$	$5.79\cdot10^{8}$	1.726	$2.69\cdot10^{8}$	3.717	$2.73\cdot10^{8}$	3.665
	220	$1.36\cdot10^{15}$	$5.66\cdot10^{8}$	1.767	$2.63\cdot10^{8}$	3.804	$2.67\cdot10^{8}$	3.751
	225	$1.33\cdot10^{15}$	$5.53\cdot10^{8}$	1.807	$2.57\cdot10^{8}$	3.89	$2.61\cdot10^{8}$	3.836
	230	$1.3\cdot10^{15}$	$5.41\cdot10^{8}$	1.847	$2.51\cdot10^{8}$	3.977	$2.55\cdot10^{8}$	3.921
	235	$1.28\cdot10^{15}$	$5.3\cdot10^{8}$	1.887	$2.46\cdot10^{8}$	4.063	$2.5\cdot10^{8}$	4.006
	240	$1.25\cdot10^{15}$	$5.19\cdot10^{8}$	1.927	$2.41\cdot10^{8}$	4.149	$2.44\cdot10^{8}$	4.092
	245	$1.22\cdot10^{15}$	$5.08\cdot10^{8}$	1.967	$2.36\cdot10^{8}$	4.236	$2.39\cdot10^{8}$	4.177
	250	$1.2\cdot10^{15}$	$4.98\cdot10^{8}$	2.008	$2.31\cdot10^{8}$	4.322	$2.35\cdot10^{8}$	4.262
	255	$1.18\cdot10^{15}$	$4.88\cdot10^{8}$	2.048	$2.27\cdot10^{8}$	4.409	$2.3\cdot10^{8}$	4.347
	260	$1.15\cdot10^{15}$	$4.79\cdot10^{8}$	2.088	$2.22\cdot10^{8}$	4.495	$2.26\cdot10^{8}$	4.433
	265	$1.13\cdot10^{15}$	$4.7\cdot10^{8}$	2.128	$2.18\cdot10^{8}$	4.582	$2.21\cdot10^{8}$	4.518
	270	$1.11\cdot10^{15}$	$4.61\cdot10^{8}$	2.168	$2.14\cdot10^{8}$	4.668	$2.17\cdot10^{8}$	4.603
	275	$1.09\cdot10^{15}$	$4.53\cdot10^{8}$	2.208	$2.1\cdot10^{8}$	4.755	$2.13\cdot10^{8}$	4.688
	280	$1.07\cdot10^{15}$	$4.45\cdot10^{8}$	2.248	$2.07\cdot10^{8}$	4.841	$2.09\cdot10^{8}$	4.774
UV-B	285	$1.05\cdot10^{15}$	$4.37\cdot10^{8}$	2.289	$2.03\cdot10^{8}$	4.927	$2.06\cdot10^{8}$	4.859
	295	$1.02\cdot10^{15}$	$4.22\cdot10^{8}$	2.369	$1.96\cdot10^{8}$	5.1	$1.99\cdot10^{8}$	5.029
	300	$1\cdot10^{15}$	$4.15\cdot10^{8}$	2.409	$1.93\cdot10^{8}$	5.187	$1.96\cdot10^{8}$	5.115
	305	$9.84\cdot10^{14}$	$4.08\cdot10^{8}$	2.449	$1.9\cdot10^{8}$	5.273	$1.92\cdot10^{8}$	5.2
	310	$9.68\cdot10^{14}$	$4.02\cdot10^{8}$	2.489	$1.87\cdot10^{8}$	5.36	$1.89\cdot10^{8}$	5.285
	315	$9.52\cdot10^{14}$	$3.95\cdot10^{8}$	2.529	$1.84\cdot10^{8}$	5.446	$1.86\cdot10^{8}$	5.37
	320	$9.37\cdot10^{14}$	$3.89\cdot10^{8}$	2.57	$1.81\cdot10^{8}$	5.533	$1.83\cdot10^{8}$	5.456
UV-A2	325	$9.35\cdot10^{14}$	$3.83\cdot10^{8}$	2.61	$1.78\cdot10^{8}$	5.619	$1.8\cdot10^{8}$	5.541
	330	$9.32\cdot10^{14}$	$3.77\cdot10^{8}$	2.65	$1.75\cdot10^{8}$	5.706	$1.78\cdot10^{8}$	5.626
	335	$9.29\cdot10^{14}$	$3.72\cdot10^{8}$	2.69	$1.73\cdot10^{8}$	5.792	$1.75\cdot10^{8}$	5.711
	340	$9.26\cdot10^{14}$	$3.66\cdot10^{8}$	2.73	$1.7\cdot10^{8}$	5.878	$1.73\cdot10^{8}$	5.797
UV-A1	345	$9.23\cdot10^{14}$	$3.61\cdot10^{8}$	2.77	$1.68\cdot10^{8}$	5.965	$1.7\cdot10^{8}$	5.882
	350	$9.2\cdot10^{14}$	$3.56\cdot10^{8}$	2.811	$1.65\cdot10^{8}$	6.051	$1.68\cdot10^{8}$	5.967
	355	$9.17\cdot10^{14}$	$3.51\cdot10^{8}$	2.851	$1.63\cdot10^{8}$	6.138	$1.65\cdot10^{8}$	6.052
	360	$9.14\cdot10^{14}$	$3.46\cdot10^{8}$	2.891	$1.61\cdot10^{8}$	6.224	$1.63\cdot10^{8}$	6.138
	365	$9.11\cdot10^{14}$	$3.41\cdot10^{8}$	2.931	$1.58\cdot10^{8}$	6.311	$1.61\cdot10^{8}$	6.223
	370	$9.08\cdot10^{14}$	$3.37\cdot10^{8}$	2.971	$1.56\cdot10^{8}$	6.397	$1.59\cdot10^{8}$	6.308
	375	$9.05\cdot10^{14}$	$3.32\cdot10^{8}$	3.011	$1.54\cdot10^{8}$	6.484	$1.56\cdot10^{8}$	6.393
	380	$9.02\cdot10^{14}$	$3.28\cdot10^{8}$	3.051	$1.52\cdot10^{8}$	6.57	$1.54\cdot10^{8}$	6.479
	385	$8.99\cdot10^{14}$	$3.23\cdot10^{8}$	3.092	$1.5\cdot10^{8}$	6.656	$1.52\cdot10^{8}$	6.564
	390	$8.96\cdot10^{14}$	$3.19\cdot10^{8}$	3.132	$1.48\cdot10^{8}$	6.743	$1.5\cdot10^{8}$	6.649
	395	$8.93\cdot10^{14}$	$3.15\cdot10^{8}$	3.172	$1.46\cdot10^{8}$	6.829	$1.48\cdot10^{8}$	6.734
	400	$8.9\cdot10^{14}$	$3.11\cdot10^{8}$	3.212	$1.45\cdot10^{8}$	6.916	$1.47\cdot10^{8}$	6.82