

THE EFFECT OF INTENSE LIGHT PULSES ON THE SENSORY QUALITY AND INSTRUMENTAL COLOR OF MEAT FROM DIFFERENT ANIMAL BREEDS

I. Tomašević

Animal Source Food Technology Department, Faculty of Agriculture, University of Belgrade, Nemanjina 6, 11080 Belgrade, Republic of Serbia
Corresponding author: tbigor@agrif.bg.ac.rs
Original scientific paper

Abstract: Intense light pulses (ILP) are an emerging processing technology, which has a potential to decontaminate food products. The light generated by ILP lamps consists of a continuum broadband spectrum from deep UV to the infrared, especially rich in UV range below 400 nm, which is germicidal. Evaluation of the effect of intense light pulses (ILP) on sensory quality of meat, game and poultry was performed using two kinds of red meat (beef and pork), two kinds of poultry (chicken and turkey) and three game meat samples (deer, rabbit and kangaroo). All the samples were treated with 1 and 5 light pulses (pulse duration of 300 μ s and pulse intensity of 3.4 J/cm²) at a rate of one pulse per 2 seconds. Sensory quality changes induced by intense light pulses were different and depended on animal species, type of meat and ILP dose applied. Only the odour of all the meat, poultry and game samples suffered significant changes after the pulsed light treatment. Of all kinds of meat investigated only turkey received scores below the good quality grade after the treatment. Instrumental colour values remained unaffected in chicken and rabbit meat samples while higher doses of ILP significantly compromised both redness and yellowness only in pork and turkey meat.

Keywords: intense light pulses, meat, game, poultry, sensory quality, colour

Introduction

Intense light pulses (ILP), also known as pulsed light (*Oms-Oliu et al., 2010*), high intensity broad spectrum pulsed light (*Roberts and Hope, 2003*), pulsed white light (*Kaack and Lyager, 2007; Marquenie et al., 2003*) and pulsed UV light (*Bialka and Demirci, 2007, 2008; Keklik et al., 2009*) are included among the emerging technologies that are intensely investigated as an alternative to thermal treatment for killing pathogenic and spoilage microorganisms (*Barbosa-Canovas et*

al., 2000; *Elmnasser et al.*, 2007; *Gomez-Lopez et al.*, 2007; *Palmieri and Cacace*, 2005; *Woodling and Moraru*, 2005).

The inactivation mechanism of ILP is similar to that of continuous UV-C light; it causes the formation of thymine dimers which renders microbial cells unable to replicate; this is called the photochemical effect (*Gómez-López*, 2012). Additionally, photophysical and photothermal effects have been identified (*Krishnamurthy et al.*, 2010). Its big advantage is that it can inactivate microorganisms very fast. Different studies have demonstrated the sensitivity of bacteria to ILP on meat (*Hierro et al.*, 2012), poultry (*Keklik et al.*, 2010; *Paskeviciute et al.*, 2011) meat products (*Ganan et al.*, 2013; *Hierro et al.*, 2011), meat contact surfaces (*Rajkovic et al.*, 2010) and seafood (*Cheigh et al.*, 2013; *Ozer and Demirci*, 2006). However, if microbial inactivation is a critical requirement, it is also essential to keep the nutritional and sensory properties of the product, minimizing the possible loss of quality caused by the treatment (*Hierro et al.*, 2012).

The aim of this study was to systematically evaluate the effect of intense light pulses (ILP) on sensory quality and color of 7 different varieties of meat, game and poultry.

Materials and Methods

Samples preparation

Two kinds of red meat (beef and pork), two kinds of poultry (chicken and turkey) and three game meat samples (deer, rabbit and kangaroo) were used in this study. All of the samples used were purchased from a local retailer and kept refrigerated at $2\pm 2^{\circ}\text{C}$ until treated. All the fresh meat, poultry and game was cut into 10 cm chunks before the ILP treatment.

ILP equipment and treatment

The ILP treatments were performed using a laboratory-scale batch-fed pulsed-light system unit: Tecum - Mobile Decontamination Unit (Claranor, Manosque - France). Light pulses with duration of 300 μs and pulse intensity of 3.4 J/cm^2 , measured with SOLO 2 - Power and Energy Meter (Gentec Electro-Optics, Inc., Quebec, Canada), were generated by four 20 cm cylindrical Xenon flash lamps (Flashlamps Verre & Quartz, Bondy, France), with an input voltage of 3000 V.

The samples were ILP-treated with 1 pulse (1P) and 5 pulses (5P) at a rate of one pulse per 2 seconds, respectively. During treatments, samples were placed in the system unit at a distance of 6 cm from the top and bottom lamps, and 10 cm from the left-hand and right-hand lamps. No treatment was applied to the control groups of samples.

Sensory Analyses

Sensory evaluation was performed by a professional panel of eight panelists, members of the Department of Food Safety and Food Quality-University of Ghent, Belgium and of the Meat Science and Technology Department-University of Belgrade, Serbia. The panel was trained according to international standards (*ISO, 1993*) and additionally trained for three days in the sensory assessment of meat and meat products by a panel leader with over 2,000 h of sensory testing experience of meat and meat products.

Sensory tests were performed in a controlled sensory analysis laboratory (Food Safety and Food Quality Department/University of Ghent - Belgium) built in accordance to the general guidance for the design of test rooms intended for the sensory analysis of products (*ISO, 2007*) with individual booths equipped with computer terminals and provided with red light to mask any differences in color when needed.

Five-Point-Scale Scoring Method

The test was carried out as described by *Tomic et al. (2008)* with slight modifications. Selected sensory attributes (Table 1) were assessed using the 5-point scale with the following descriptions: 5=(excellent, typical quality, without visible defects); 4=(good quality, with minimal visible defects); 3=(neither good nor poor quality, still can be used for its intended purpose); 2=(poor quality, reworked could be used for its intended purpose); and 1=(unacceptable, extremely poor quality, cannot be used for its intended purpose), with ability of giving semi scores (4.5, 3.5, 2.5 and 1.5). Scores given to each of assessed attributes were corrected by corresponding coefficients of importance (Table 1).

Table 1. Selected sensory attributes of the samples assessed using the 5-point scale, with corresponding coefficients of importance (CI)

Meat, poultry & game: Beef, Pork, Chicken, Turkey, Deer, Rabbit, Kangaroo		Meat products:		
			Cooked ham, Parisian sausage, Bacon	Parma ham, Fermented sausage
Attribute	CI	Attribute	CI	
Appearance	7	Appearance	4	4
Color	8	Color	5	4
Odor	5	Odor and Taste	7	8
		Texture and Juiciness	4	4

Coefficients of importance (CI) show the relative importance of a single sensory attribute to the total sensory quality. Sum of all CIs is arranged to be 20, and in that way the sum of corrected scores gives the "percentage of total sensory

quality" in a given situation. Dividing the total value by the sum of CI gives the "pondered average value of total sensory quality". A section in the score card was included for panelists to leave their comments.

Instrumental color measurement

Instrumental color readings of samples were measured using a Konica Minolta spectrophotometer CM-2500d (Konica Minolta, Osaka, Japan), operating in the CIE L*a*b* color space. The L* (lightness), a* (redness) and b* (yellowness) values (a single repetition) were determined from the mean of 10 random readings on the surface of each sample, using D₆₅ illuminant and 10° standard observer. The measurement was repeated in triplicate (n=3) and the values averaged. The instrument was calibrated with a white calibration tile and black calibration box. Data acquisition was performed using the Spectramagic NX color data software, version 1.52 (Osaka, Japan).

Statistical analysis

Data entry and decoding were 100% verified. A one-way ANOVA was conducted to compare the results of the different assays, using SPSS Statistics 17.0 (Chicago, Illinois, USA) data analysis software. An alpha level of $p < 0.05$ was used to determine significance.

Results and Discussion

Five-Point-Scale Scoring Method

ILP treatment did not significantly change ($p < 0.05$) appearance and total score values of the beef samples (Table 2). The color score also remained unchanged regardless of the level of fluence applied which is in contrast of the findings of *Hierro et al. (2012)* where the color of beef was assessed by panel members as slightly lighter after the treatment of 11.9 J/cm². The application of 1 pulse (3.4 J/cm²) in our investigation significantly decreased score for odor of beef while the same happened only after 8.4 J/cm² when applied to beef *carpaccio* in the experiments of *Hierro et al. (2012)*. The similar in both investigations was the fact that the beef odor was assessed as acceptable in both cases even after the highest fluency rate applied.

Table 2. Sensory evaluation scores (mean±SD) for 5-Point-Scale Scoring test of the ILP treated meat, poultry and game

		Beef	Pork	Chicken	Turkey	Deer	Rabbit	Kangaroo
Control	Appearance	4.9 ±0.2	4.9 ±0.2	4.9 ±0.2	4.4 ±0.2	4.9 ±0.2	4.9 ±0.2	4.9 ±0.2
	Color	4.9 ±0.2	4.9 ±0.2	4.9 ±0.2	4.4 ±0.2	4.9 ±0.2	4.9 ±0.2	4.9 ±0.2
	Odor	4.9 ±0.2 a	4.9 ±0.2 a	4.9 ±0.2 a	4.4 ±0.2 a	4.9 ±0.2 a	4.9 ±0.2 a	4.9 ±0.2 a
	Total score	4.9 ±0.2	4.9 ±0.2	4.9 ±0.2	4.4 ±0.2	4.9 ±0.2 a	4.9 ±0.2	4.9 ±0.2
1 pulse	Appearance	4.9 ±0.2	4.9 ±0.2	4.9 ±0.2	4.2 ±0.3	4.9 ±0.2	4.9 ±0.2	4.9 ±0.2
	Color	4.9 ±0.2	4.9 ±0.2	4.9 ±0.2	4.3 ±0.3	4.9 ±0.2	4.9 ±0.2	4.9 ±0.2
	Odor	4.4 ±0.2 b	4.6 ±0.4 a,b	4.4 ±0.4 b	3.8 ±0.3 b	4.4 ±0.2 b	4.4 ±0.2 b	4.6 ±0.4 a,b
	Total score	4.8 ±0.2	4.8 ±0.3	4.8 ±0.2	4.1 ±0.2	4.8 ±0.1 a,b	4.8 ±0.2	4.8 ±0.3
5 pulses	Appearance	4.9 ±0.2	4.9 ±0.2	4.7 ±0.4	4.1 ±0.7	4.8 ±0.3	4.9 ±0.2	4.9 ±0.2
	Color	4.9 ±0.2	4.6 ±0.4	4.7 ±0.4	4.1 ±0.7	4.7 ±0.3	4.9 ±0.2	4.7 ±0.3
	Odor	4.4 ±0.2 b	4.3 ±0.3 b	4.2 ±0.4 b	3.4 ±0.2 b	4.1 ±0.2 b	3.9 ±0.2 c	4.4 ±0.2 b
	Total score	4.8 ±0.2	4.6 ±0.3	4.6 ±0.4	3.9 ±0.5	4.6 ±0.1 b	4.7 ±0.2	4.7 ±0.0

a,b,c Values in the same column with different letter are significantly different ($p < 0.05$)

According to our results the odor of beef meat is a bit more sensitive to the ILP than the odor of pork meat, because the odor scores for pork meat have significantly decreased only after the 5-pulses treatment. For the poultry, the only sensory attribute affected by the ILP treatment was odor but not to such extent that could also affect the pondered average values of the total sensory quality for the chicken and turkey meat (Table 2). Similar was found by *Paskeviciute et al. (2011)* where UV light dose higher than 6 J/cm^2 had only some moderate effect on odor of chicken. The odor scores significantly decreased in all game meat samples after the 5-pulses treatment but they were most easily observable in deer meat and essentially contributed to the significant change of its pondered average value of total sensory quality. The effect of the treatment on odor was least pronounced in kangaroo meat. The panelist's comments were unanimous that the effect of ILP on game meat was reflected only by subtle changes in its naturally sour odor.

Instrumental color measurement

The instrumental color values of beef meat were not affected by 1-pulse treatment, since no significant differences ($p>0.05$) were observed (Table 3). Treatment of 5 pulses significantly decreased redness in beef, while no significant differences were observed for lightness and yellowness. In beef *carpaccio* subjected to ILP, Eva *Hierro et al.* (2012) also observed decrease in a^* values but they were followed with the significant differences in b^* value when the samples were treated with fluences equal to or higher than 8.4 J/cm^2 .

Table 3. Instrumental color values (mean \pm SD) of the ILP treated meat, poultry and game

		Beef	Pork	Chicken	Turkey	Deer	Rabbit	Kangaroo
Cont rol	L^*	42.0 \pm 1.0	54.7 \pm 0.5	58.1 \pm 1.1	53.0 \pm 0.5	33.4 \pm 0.9	57.3 \pm 1.0	35.4 \pm 0.1a
	a^*	16.2 \pm 1.1a	11.1 \pm 0.3a	0.2 \pm 0.3	3.8 \pm 0.1a	9.2 \pm 0.1a	0.5 \pm 0.0	13.1 \pm 0.4
	b^*	14.6 \pm 0.1	16.6 \pm 0.1a	8.8 \pm 1.0	10.3 \pm 0.2a	9.2 \pm 0.1	7.1 \pm 0.2	9.3 \pm 0.1a
1 pulse	L^*	42.3 \pm 1.2	54.2 \pm 0.5	56.8 \pm 0.8	53.0 \pm 0.5	33.0 \pm 1.0	58.1 \pm 1.1	34.6 \pm 0.1b
	a^*	15.8 \pm 0.7a,b	11.0 \pm 0.3a	0.2 \pm 0.3	3.2 \pm 0.1b	9.3 \pm 0.2a	0.5 \pm 0.8	13.2 \pm 0.5
	b^*	13.9 \pm 1.1	16.4 \pm 0.3a	8.7 \pm 0.6	10.2 \pm 0.3a	9.1 \pm 0.3	7.5 \pm 0.3	9.3 \pm 0.1a
5 pulses	L^*	42.5 \pm 1.0	53.8 \pm 0.2	56.5 \pm 1.3	53.0 \pm 0.4	32.9 \pm 0.1	59.3 \pm 1.1	34.1 \pm 0.1b
	a^*	14.1 \pm 0.4b	9.9 \pm 0.1b	0.1 \pm 0.0	2.7 \pm 0.2c	8.6 \pm 0.3b	0.1 \pm 0.0	12.4 \pm 0.3
	b^*	13.4 \pm 0.6	15.3 \pm 0.1b	8.6 \pm 0.1	9.5 \pm 0.3b	8.7 \pm 0.3	7.4 \pm 0.1	8.7 \pm 0.1b

^{a,b,c}Values in the same column with different letter are significantly different ($p<0.05$)

The same was the case in our investigation with the pork meat treated with 17 J/cm^2 when both values, a^* and b^* , significantly decreased after the treatment. Chicken color values were not significantly changed ($p>0.05$) irrespective of the level of treatment. This is in agreement with the results of *Keklik et al.* (2010) indicating that mild and moderate pulsed light treatments also did not affect the color of chicken samples ($p>0.05$), although extreme ILP treatment did increase the lightness (L^*), redness (a^*), and yellowness (b^*) of samples significantly ($p<0.05$). The a^* value of treated turkey samples were significantly lower than that of the untreated samples with the significant difference observed among the fluences assayed. The redness gradually decreased as fluence increased. The yellowness was found significantly lower to control samples only after the treatment of 5 pulses. Similar ILP color resistance to the one of chicken meat, in our experiment, was observed only in rabbit meat samples (Table 5). Dear meat suffered significant decrease in redness value after the 5-pulses treatment while the kangaroo meat was significantly lower in L^* (after 1 pulse) and in b^* (after 5 pulses).

Conclusion

Our study indicated that the sensory quality changes induced by intense light pulses are different and depend on animal species, type of meat and ILP dose applied. Only the odor of all the meat, poultry and game samples suffered significant changes after the pulsed light treatment. Of all kinds of meat investigated only turkey received scores below the good quality grade after the treatment. Instrumental color values remained unaffected in chicken and rabbit meat samples while higher doses of ILP significantly compromised both redness and yellowness only in pork and turkey meat.

Acknowledgements

The data presented in this paper are an integral part of the PhD research of dr Igor Tomašević accomplished at Department of Food Safety and Food Quality, Ghent University, Belgium and funded by BASILEUS PROJECT-EM ECW programme approved by European Commission. All the help, guidance and support received from the colleagues at the University of Ghent, Belgium as well as the loan of the equipment from Claranor, France is gratefully acknowledged.

Efekat intenzivnih svetlosnih pulseva na senzorni kvalitet mesa, divljači i živine

I. Tomašević

Rezime

Ispitivanje efekata dekontaminacione tehnike intenzivnih svetlosnih pulseva na senzorni kvalitet i boju mesa obavljeno je na dve vrste crvenih (govedina i svinjetina), na dve vrste mesa (piletine i ćuretina) i na tri vrste mesa divljači (jelen, zec i kengur). Sve vrste uzoraka tretirane su sa 1 i 5 svetlosnih pulseva (dužina trajanja pulsa 300 μ s uz intenzitet pojedinačnog pulsa od 3.4 J/cm²) učestalošću od 1 pulsa svake dve sekunde. Senzorni kvalitet mesa varirao je u odnosu na vrstu mesa i jačinu primenjenog tretmana. Miris je jedini senzorni atribut koji je kod svih vrsta ispitivanog mesa pretrpeo značajne promene nakon primenjenog tretmana. Samo je ćureće meso ocenjeno kao "ispod prosečnog kvaliteta" nakon promena pretrpljenih dejstvom svetlosnih pulseva. Instrumentalne vrednosti boje ostale su

nepromenjene kod pileline i zečijeg mesa dok je jači primenjeni tretman značajno izmenio vrednosti udela crvene i žute boje samo kod svinjskog i ćurećeg mesa.

References

- BARBOSA-CANOVAS G.V., SCHAFFNER D.W., PIERSON M.D., ZHANG Q.H. (2000): Pulsed Light Technology. *Journal of Food Science*, 65, 82-85.
- BIALKA K.L., DEMIRCI A. (2007): Decontamination of *Escherichia coli* O157:H7 and *Salmonella enterica* on Blueberries Using Ozone and Pulsed UV-Light. *Journal of Food Science*, 72(9), 391-396.
- BIALKA K.L., DEMIRCI A. (2008): Efficacy of Pulsed UV-Light for the Decontamination of *Escherichia coli* O157:H7 and *Salmonella spp.* on Raspberries and Strawberries. *Journal of Food Science*, 73(5), 201-207.
- CHEIGH C.I., HWANG H.J., CHUNG M.S. (2013): Intense pulsed light (IPL) and UV-C treatments for inactivating *Listeria monocytogenes* on solid medium and seafoods. *Food Research International*, 54(1), 745-752.
- ELMNASSER N., GUILLOU S., LEROI F., ORANGE N., BAKHROUF A., FEDERIGHI M. (2007): Pulsed-light system as a novel food decontamination technology: a review. *Canadian Journal of Microbiology*, 53(7), 813-821.
- GANAN M., HIERRO E., HOSPITAL X.F., BARROSO E., FERNANDEZ M. (2013): Use of pulsed light to increase the safety of ready-to-eat cured meat products. *Food Control*, 32(2), 512-517.
- GÓMEZ-LÓPEZ V.M. (2012): Decontamination of fresh and minimally processed produce. In: Chichester, West Sussex, UK: Blackwell Pub.
- GOMEZ-LOPEZ V.M., RAGAERT P., DEBEVERE J., DEVLIEGHERE F. (2007): Pulsed light for food decontamination: a review. *Trends in Food Science & Technology*, 18(9), 464-473.
- HIERRO E., BARROSO E., DE LA HOZ L., ORDONEZ J.A., MANZANO S., FERNANDEZ M. (2011): Efficacy of pulsed light for shelf-life extension and inactivation of *Listeria monocytogenes* on ready-to-eat cooked meat products. *Innovative Food Science & Emerging Technologies*, 12(3), 275-281.
- HIERRO E., GANAN M., BARROSO E., FERNÁNDEZ M. (2012): Pulsed light treatment for the inactivation of selected pathogens and the shelf-life extension of beef and tuna carpaccio. *International Journal of Food Microbiology*, 158(1), 42-48.
- ISO (1993). ISO 8586-1:1993 Sensory analysis -- General guidance for the selection, training and monitoring of assessors. In Part 1: Selected assessors. Geneva, Switzerland.
- ISO (2007). ISO 8589:2007 Sensory analysis -- General guidance for the design of test rooms. In: Geneva, Switzerland.
- KAACK K., LYAGER B. (2007): Treatment of slices from carrot (*Daucus carota*) using high intensity white pulsed light. *European Food Research and Technology*, 224(5), 561-566.

- KEKLIK N.M., DEMIRCI A., PURI V.M. (2009): Inactivation of *Listeria monocytogenes* on Unpackaged and Vacuum-Packaged Chicken Frankfurters Using Pulsed UV-Light. *Journal of Food Science*, 74(8), 431-439.
- KEKLIK N.M., DEMIRCI A., PURI V.M. (2010): Decontamination of unpackaged and vacuum-packaged boneless chicken breast with pulsed ultraviolet light. *Poultry Science*, 89(3), 570-581.
- KRISHNAMURTHY K., TEWARI J.C., IRUDAYARAJ J., DEMIRCI A. (2010): Microscopic and Spectroscopic Evaluation of Inactivation of *Staphylococcus aureus* by Pulsed UV Light and Infrared Heating. *Food and Bioprocess Technology*, 3(1), 93-104.
- MARQUENIE D., MICHIELS C.W., VAN IMPE J.F., SCHREVEN E., NICOLAÏ B.N. (2003): Pulsed white light in combination with UV-C and heat to reduce storage rot of strawberry. *Postharvest Biology and Technology*, 28(3), 455-461.
- OMS-OLIU G., MARTÍN-BELLOSO O., SOLIVA-FORTUNY R. (2010): Pulsed Light Treatments for Food Preservation. A Review. *Food and Bioprocess Technology*, 3(1), 13-23.
- OZER N.P., DEMIRCI A. (2006): Inactivation of *Escherichia coli* O157 : H7 and *Listeria monocytogenes* inoculated on raw salmon fillets by pulsed UV-light treatment. *International Journal of Food Science and Technology*, 41(4), 354-360.
- PALMIERI L., CACACE D. (2005): 11 - High Intensity Pulsed Light Technology. In D.-W. Sun (Ed.), *Emerging Technologies for Food Processing* (pp. 279-306). London: Academic Press.
- PASKEVICIUTE E., BUCHOVEC I., LUKSIENE Z. (2011): High-power pulsed light for decontamination of chicken from food pathogens: a study on antimicrobial efficiency and organoleptic properties. *Journal of Food Safety*, 31(1), 61-68.
- RAJKOVIC A., TOMASEVIC I., SMIGIC N., UYTENDAELE M., RADOVANOVIC R., DEVLIEGHIERE F. (2010): Pulsed UV light as an intervention strategy against *Listeria monocytogenes* and *Escherichia coli* O157:H7 on the surface of a meat slicing knife. *Journal of Food Engineering*, 100(3), 446-451.
- ROBERTS P., HOPE A. (2003): Virus inactivation by high intensity broad spectrum pulsed light. *Journal of Virological Methods*, 110(1), 61-65.
- TOMIC N., TOMASEVIC I., RADOVANOVIC R., RAJKOVIC A. (2008): "Uzice Beef Prshuta": Influence of different salting processes on sensory properties. *Journal of Muscle Foods*, 19(3), 237-246.
- WOODLING S.E., MORARU C.I. (2005): Influence of Surface Topography on the Effectiveness of Pulsed Light Treatment for the Inactivation of *Listeria innocua* on Stainless-steel Surfaces. *Journal of Food Science*, 70(7), 345-351.