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EFFECTS OF RAPID CHILLING OF CARCASSES AND EARLIER DEBONING *post-mortem* ON COLOUR OF PORK SEMIMEMBRANOSUS MUSCLE

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Abstract: The effect of rapid air chilling of carcasses, compared to conventional air chilling, and effect of earlier deboning, after rapid air chilling, on colour of pork *M semimembranosus* was investigated. During and at the end of chilling, compared to conventional chill treatment, carcasses that were rapid chilled had significantly ($P < 0.001$) lower internal temperature in the deep leg. Rapid chilled carcasses, reached the temperature of 7°C in deep leg before 8 h *post-mortem*, what resulted in significantly ($P < 0.05$) slower rate of pH value decline in *M semimembranosus.* Different chilling rates and different time of deboning had neither positive nor negative significant effects ($P > 0.05$) on average colour of *M semimembranosus*, but rapid chilling, compared to conventional chilling, resulted in reduced incidence of pale colour.

Key words: pork (*M semimembranosus*), rapid chilling, earlier deboning, colour

Introduction

Due to the danger of spoilage, meat has to be chilled soon after slaughter *(Honikel, 1999)*. On the other hand, rate of heat transfer, i.e. relationship between the rates of temperature and pH value decline can affect some other (technological) meat quality parameters (weight loss, tenderness, water holding capacity, colour *(Savell et al., 2005)*.

Colour is one of the most important meat quality attributes as it is observed and estimated at first sight, and it is important that the colour of meat is acceptable, so the consumers accept it *(Rede and Petrović, 1997)*.

Conventional, spray and rapid chilling systems are commonly used for pork chilling in practice *(Huff-Lonergan and Page, 2001)*. The use of different accelerated chilling systems, i.e. systems for rapid temperature decline of carcasses, can be an effective method to prevent or reduce the incidence of PSE

(pale, soft, exudative) in pork *(Milligan et al., 1998; Springer et al., 2003; Savell et al., 2005)*.

Ultimate pH value is reached in pork with normal glycolysis rates and most biochemical processes (*rigor mortis*) are completed, within 6-9 h *post-mortem (Honikel and Kim, 1985)*, i.e. 6-12 h *post-mortem (Smulders et al, 1992)*, and considering the EU directives for fresh pork *(Council Directive, 64/433/ECC)* according to which pork must not be cut and deboned before reaching 7°C in the deep leg *(Gigiel et al., 1989; Dransfield et al., 1991; Honikel, 1999)* the aim of the study was to determine the effect of rapid air chilling and time of deboning *post-mortem* on colour of pork.

Materials and Methods

At the end of the slaughter line, right control carcass sides, of to 40 carcasses *(*pH_{30min} (*M semimembranosus* - SM) > 5.8 - normal meat quality; of average warm carcass weight 75.5±3.93 kg (including the head) were conventionally air chilled (CC) at 2 to 4°C, till 24 h *post-mortem*. The left trial carcass sides, of all 40 carcasses, were rapid air chilled (RC) in the freezing tunnel for 3 h at –31°C, followed by CC in temperature equalization chill room at 2 - 4°C till 8 h (left carcass sides of the first 20 trial animals) i.e. till 24 h *post-mortem* (left carcass sides of the second 20 trial animals).

Temperature was measured at the start, during and at the end of the chilling process in the deep leg, near the femur, in both sides of all carcasses, using a portable digital thermometer (Consort T651, Turnhout, Belgium).

pH was measured in the center of both SM muscles of all carcasses using the portable pH meter (Consort T651, Turnhout, Belgium) equipped with an insertion glass combination electrode (Mettler Toledo Greifensee, Switzerland) for direct determination of pH value of meat *(SRPS ISO 2917, 2004)*.

Samples for colour measurements were taken from the central part of all SM muscles, perpendicularly to the long axis of SM muscle; the minimum thickness of samples was 2.5 cm. Four replicate measures of surface colour were performed on each fresh cut i.e. sample. The CIE *L*a*b** colour coordinates *(CIE, 1976)* were determined using MINOLTA Chroma Meter CR-400 (Minolta Co., Ltd., Osaka, Japan). The incidence of meat colour of different quality (pale colour: $L^* > 50$; reddish pink colour: $L^* = 43 - 50$; dark colour: $L^* < 43$) was calculated on the basis of all individual lightness (L^* value) measurements, (total 320). A 5 member assessment group performed the sensory analysis of SM muscle colour using the 1 - 5 scale (1 - pale pinkish-grey: 2 - grayish pink; 3 - reddish pink; 4 - purplish red, 5 - dark purpleish red), using the colour standards.

All data are presented as means ± standard deviation. All results were evaluated statistically by calculating the mean ($\bar{x}$), standard deviation (σ) and using the analysis of variance and Duncan's multiple range test.

Results and Discussion

The average temperatures, at the end of the slaughter line (Table 1), measured in the deep leg of left and right carcasses were identical, 41.6°C ($P > 0.05$). Highly significant lower temperatures were found ($P < 0.001$) in RC carcasses during (4, 6 and 8 h *post-mortem*) and at the end of chilling (24 h *post-mortem*) and the difference of the average temperatures increased with chilling time. In RC the internal temperatures in deep leg below 7°C, which is the upper limit of deboning start *(Council Directive 64/433/EEC; Gigiel et al., 1989; Dransfield et al., 1991; Honikel, 1999)*, were reached somewhat before 8 h *post-mortem*. The investigations showed that the RC regime resulted in significantly shorter time of carcass chilling compared to time of CC carcasses, by almost 16 hours, i.e. from the microbiological standpoint, deboning can start after 8 h *post-mortem*, and this was one aim of these investigations. The obtained results are in accordance with the results i.e. opinion of other authors who found that the chilling time i.e. the pork production is shorter applying rapid chilling *(Gigiel et al., 1989; Dransfield et al., 1991; Okanović, 1993; Savell et al., 2005)*.

Table 1. Effect of rapid chilling and earlier deboning *post-mortem* on internal ham temperature and pH value of *M. semimembranosus*

Chilling method[1]	CC	RC
Carcass side	Right	Left
Time of deboning *post-mortem* (hours)	24	24/8
N (number of *M. semimembranosus*)	40	20/40
Means ± standard deviation	$\bar{x} \pm \sigma$	$\bar{x} \pm \sigma$
Ham temperature (°C)		
T_{30min}	41.6 ± 0.55	41.6 ± 0.59
T_{4h}	32.7^{A} ± 0.84	25.7^{B} ± 1.44
T_{6h}	24.2^{A} ± 0.74	13.0^{B} ± 1.40
T_{8h}	19.1^{A} ± 0.75	6.2^{B} ± 1.16
T_{24h}	5.1^{A} ± 0.36	3.8^{B} ± 0.53
M. semimembranosus pH		
pH_{30min}	6.18 ± 0.18	6.22 ± 0.27
pH_{8h}	5.88^{b} ± 0.18	6.02^{a} ± 0.16
pH_{24h}	5.70 ± 0.19	5.77 ± 0.22

[1] CC - conventional chilling; BH - rapid chilling.
[AB] indicates significant difference at $P < 0.001$.
[ab] indicates significant difference at $P < 0.05$.

At the end of the slaughter line (Table 1), i.e. 30 min *post-mortem*, the difference between average initial pH values of SM muscles (pH_{30min} = 6.18 and 6.22), was not significant ($P > 0.05$). Also, it is important to mention that not one individual initial pH value was below 5.8, i.e. not one SM muscle, according to criterion for pH value, was not potentially of PSE quality *(Wismer-Pedersen, 1959; Honikel, 1999; Toldrà and Flores, 2000; Tomović, 2002; Džinić, 2005)*. However, rapid chilling of carcasses had a significant effect on slowing of the rate of pH value decline in SM muscles. In SM muscles from RC carcasses, 8 h *post-mortem*, the average pH was 6.02, i.e. by 0.14 units significantly higher average pH value ($P < 0.05$) compared to the SM muscles from CC carcasses. Similarly, as in this paper, significantly slower pH value decline in SM muscles in first several hours *post-mortem*, as the consequence of rapid air chilling of carcasses was found in a number of studies *(Jones et al., 1993; Jossel et al., 2003; Hambrecht et al., 2004)*. Contrary results were obtained in investigations by *Dransfield et al. (1991), Okanović (1993), Zagorac (1994), Kerth et al. (2001)* and *Springer et al. (2003)*, where during RC, compared to CC, no significant slowing of the rate of pH value decline in SM muscles was observed.

In model investigations *Bertram et al. (2001)* have found that the temperature effect on the buffer capacity of muscle is the major determining factor in the detected difference in pH between rapid and conventionally chilled muscle samples (*M. longissimus dorsi*), while any contribution from temperature induced delayed progress in lactate formation *post-mortem* seems negligible.

At the end of chilling i.e. 24 h *post-mortem* (Table 1), both average pH values of SM muscles were in the range characteristic for pork, 5.3 - 5.8 *(Smulders et al., 1992; Honikel, 1999)*. The results obtained in the present study are in accordance with the studies of *Dransfield et al. (1991), Jones et al. (1993), Okanović (1993), Kerth et al. (2004)*, where no significant pH difference was found between SM muscles chilled in different ways (conventional and rapid). Contrary results were obtained in studies by *Jones et al., (1993)* and *Josell et al. (2003*), where at the end of chilling (24 h *post-mortem*) significantly higher pH value was found in SM muscles from RC carcasses compared to the pH value determined in SM muscles from CC carcasses.

Colour is a very important technological and sensory characteristic of meat. On the basis of results obtained for colour determination of SM muscles (Table 2), the colour of all three groups of investigated SM muscles, independently on rate of carcasses chilling and time of deboning corresponds on average to the colour of normal quality meat i.e. the muscles are reddish pink *(L* = 42 - 50, Warner et al., 1997; L* = 43 - 50, Joo et al., 1999; Džinić, 2005; L* = 44 - 50, Toldrà and Flores, 2000)*. The highest numerical average *L** value (lightness) and highest numerical Y value (brightness), i.e. lightest colour, were found in SM muscles from CC carcasses, while in SM muscles from RC carcasses deboned 24 h i.e. 8 h

post-mortem, had numerically somewhat lower average *L** and Y values, i.e. somewhat darker colour was found. However, the differences between the average *L** and Y values, for SM muscles chilled in different way and deboned in different time *post-mortem*, were not significant ($P > 0.05$).

Table 2. Effect of rapid chilling and earlier deboning *post-mortem* on colour of *M. semimembranosus*

Chilling method[1]	CC	RC	RC
Carcass side	Right	Left	Left
Time of deboning *post-mortem* (hours)	24	24	8
N (number of *M. semimembranosus*)	40	20	20
Means ± standard deviation	$\bar{x} \pm \sigma$	$\bar{x} \pm \sigma$	$\bar{x} \pm \sigma$
*CIE L*a*b* system*			
*L** value (lightness)	48.05 ± 3.53	45.74 ± 4.50	46.82 ± 2.22
*a** value (redness)	9.21 ± 1.62	9.32 ± 1.37	9.00 ± 1.78
*b** value (yellowness)	4.68 ± 0.89	4.62 ± 1.27	4.85 ± 0.73
CIE Yxy system			
Y value (brightness) (%)	17.24 ± 2.75	15.49 ± 3.29	16.17 ± 1.74
Dominant wavelength - λ (nm)	590.3 ± 3.53	591.4 ± 4.37	590.6 ± 2.26
Purity - P (%)	14.2 ± 1.56	14.5 ± 1.73	14.4 ± 1.37
Incidence of pale, reddish pink and dark colour (%)			
Pale (*L** > 50)	39.2	31.0	22.5
Reddish pink (*L** = 43 - 50)	39.2	33.3	50.0
Dark (*L** < 43)	21.5	35.7	27.5
Colour - sensory (1 to 5)	2.70 ± 0.44	2.90 ± 0.52	2.85 ± 0.41

[1] CC - conventional chilling; BH - rapid chilling.

Muscle colour may not only be influenced by protein denaturation, but also by the absorption characteristics of myoglobin *(Lawrie, 1998)*. The reduced light scattering of the surface of the rapidly chilled meat is typically associated by high ultimate pH value, i.e. lower protein denaturation *(Shaw and Powell, 1955; Lawrie, 1998)*. According to *Kim et al. (1996)* the *L** value increased consistently from 45 min to 24 h *post-mortem* in all pork quality muscle. However, in the presented study, although higher pH value was found (8 h *post-mortem*) in RC SM muscles, and that half of RC SM muscles was deboned 8 h *post-mortem* (16 h earlier), RC and earlier deboning did not result in significantly darker colour.

The results of investigation of the effects of rapid chilling of carcasses on average lightness (*L** value), obtained in the presented study, are in accordance with the results of *Milligan et al. (1998), Kerth et al. (2001), Jossell et al. (2003)* and *Springer et al. (2003)*. Applying lower accelerated air chilling rates of carcasses, *Jones et al. (1993)* found no significant effect on the colour (lightness - *L** value) improvement, whereas in the same investigations, applying higher rates

of accelerated chilling significantly decrease of lightness (L^* value) i.e. significantly darker colour was found.

On the other hand, analyzing the individual L^* values (Table 2), the decrease of pale colour incidence ($L^* > 50$) by 20.9% (from 39.2 to 31.0%) was found in RC and 24 h *post-mortem* deboned SM muscles, compared to CC SM muscles and deboned 24 h *post-mortem*. Compared to CC SM muscles deboned 24 h *post-mortem*, in RC and 8 h *post-mortem* deboned SM muscles, decrease of pale colour incidence ($L^* > 50$) by 42.6% (from 39.2% to 22.5%) was found, i.e. compared to RC and 24 h *post-mortem* deboned SM muscles, in RC and 8 h *post-mortem* deboned SM muscles the pale colour incidence ($L^* > 50$*)* decreased by 27.4% (from 31.0% to 22.5%). Also, the incidence of dark colour ($L^* < 43$), in the same muscles, increased by 66.0% (from 21.5% to 35.7%) and by 27.9% (from 21.5% to 27.5%), i.e. decreased by 23.0% (from 35.7% to 27.5%). The highest incidence of reddish pink colour ($L^* = 43 - 50$) was found in SM muscles from RC carcasses deboned 8 h *post-mortem* (50.0%), and the lowest in SM muscles from RC carcasses deboned 24 h *post-mortem* (33.3%).

Similarly, like between average L^* and Y values, in this study (Table 2), no significant effect ($P > 0.05$) of chilling rate and time of deboning *post-mortem* was found on a^* value (redness), b^* value (yellowness) i.e. on dominant wavelength (λ) and colour purity (P).

Even if many consumers do not admit it, sensory factors are the decisive ones for consuming meat *(Honikel, 1999)*, therefore, the sensory colour assessment was also performed (Table 2). However, different chilling rates of carcasses and different times of deboning *post-mortem* had no significant effect on colour of SM muscle ($P > 0.05$). The colour of all investigated SM muscle groups was assessed as somewhat lighter from the optimal, i.e. the average scores for the colour were in the range from 2.90 (3 – reddish pink - optimal colour) to 2.70 (2 - pale pinkish grey).

Conclusion

Investigating the effect of rapid chilling of carcasses and the effect of earlier deboning *post-mortem* (8 h *post-mortem*) after rapid chilling on the rate of biochemical changes in the muscles, i.e. the colour of produced pork (SM muscle) and discussing the obtained results, the following was concluded:

1. During (4, 6 and 8 h *post-mortem*) and at the end of chilling (24 h *post-mortem*) in RC carcasses, compared to CC carcasses, highly significant faster rates of temperature decline in the deep leg ($P < 0.001$), near the femur, was found, and the demanded temperature, 7°C in deep leg of RC carcasses, was reached till 8 h *post-mortem*, i.e. almost 16 hours earlier, compared to CC carcasses.

2. In RC SM muscles, a significantly ($P < 0.05$) slower pH decline was found 8 h *post-mortem* compared to CC SM muscles. Also, 24 h *post-mortem* no significant effect ($P > 0.05$) of different chilling rates was found on ultimate pH values in SM muscles.
3. The average colour (*L*, a*, b*, Y, λ, P*, sensory) which corresponds to normal meat quality, is not affected by chilling rate of carcasses and time of deboning *post-mortem*, i.e. no significant differences in colour ($P > 0.05$) were found between SM muscles chilled in different way and deboned different time *post-mortem*.
4. Compared to CC SM muscles, the incidence of pale colour decreased by 20.9% and 42.6% in RC SM muscles deboned 24 h *post-mortem*, i.e. RC SM muscles deboned 8 h *post-mortem*.

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Uticaj brzog hlađenja polutki svinja i ranijeg otkoštavanja *post-mortem* na boju *M. semimembranosus*

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Rezime

U ovom radu je ispitan uticaj brzog vazdušnog hlađenja polutki, u poređenju sa konvencionalnim vazdušnim hlađenjem polutki, kao i uticaj ranijeg otkoštavanja polutki, nakon brzog hlađenja, na boju svinjskog mesa, odnosno *M. semimembranosus*. Tokom i na kraju hlađenja, kod brzo hlađenih polutki, u poređenju sa konvencionalno hlađenim polutkama, utvrđena je visoko značajno ($P < 0.001$) niža temperatura u dubini buta. Kod brzo hlađenih polutki temperatura od 7°C dostignuta nešto pre 8 sati *post-mortem*, što je rezultiralo značajnim ($P < 0.05$) usporavanjem brzine pada vrednosti pH u *M semimembranosus*. Različite brzine hlađenja polutki i različito vreme otkoštavanja *post-mortem* nisu doveli niti do pozitivne niti do negativne značajne razlike ($P > 0.05$) u prosečnoj boji (parametri: *L**, *a**, *b**, Y, λ, Č, senzorno) *M semimembranosus*, ali je brzim hlađenjem, u poređenju sa konvencionalnim hlađenjem, smanjena učestalost pojavljivanja blede boje *M semimembranosus*.

References

BERTRAM H.C., DØNSTRUP S., KARLSSON A.H., ANDERSEN H.J., STØDKILDE-JØRGENSEN H. (2001): *Post-mortem* energy metabolism and pH development in porcine *M. longissimus dorsi* as affected by two different cooling regimes. A ^{31}P-NMR spectroscopic study. Magnetic Resonance Imaging, 19, 7, 993-1000.

CIE (1976): International Commission on Illumination, Colorimetry: Official Recommendation of the International Commission on Illumination. Publication CIE No. (E-1.31) Bureau Central de la CIE, Paris, France.

COUNCIL DIRECTIVE of 26 June 1964 (64/433/EEC) on health conditions for the production and marketing of fresh meat. Official Journal of the European Union, L 121, 1-30.

DRANSFIELD E., LEDWITH M.J., TAYLOR A.A. (1991): Effect of electrical stimulation, hip suspension and ageing on quality of chilled pig meat. Meat Science, 29, 1, 129-139.

DŽINIĆ N. (2005): Uticaj endogenih i egzogenih faktora na kvalitet svinjskog mesa. Doktorska disertacija, Tehnološki fakultet, Univerzitet u Banjoj Luci, Banja Luka.

GIGIEL A., BUTLER F., HUDSON B. (1989): Alternative methods of pig chilling. Meat Science, 26, 1, 67-83.

HADŽIVUKOVIĆ S. (1991): Statistički metodi. Drugo prošireno izdanje, Poljoprivredni fakultet, Univerzitet u Novom Sadu, Novi Sad.

HAMBRECHT E., EISSEN J.J., DE KLEIN W.J.H., DUCRO B.J., SMITS C.H.M., VERSTEGEN M.W.A., DEN HARTOG L.A. (2004): Rapid chilling cannot prevent inferior pork quality caused by high preslaughter stress. Journal of Animal Science, 82, 2, 551-556.

HONIKEL K.O. (1999): Biohemijske i fizičko-hemijske karakteristike kvaliteta mesa. Tehnologija mesa, 40, 3-5, 105-123.

HONIKEL K.O., KIM C.J. (1985): Über die ursachen der entstehung von PSE-Schweinefleisch. Fleischwirtschaft, 65, 9, 1125-1131.

HONIKEL K.O. (1998): Reference methods for the assessment of physical characteristics of meat. Meat Science, 49, 4, 447-457.

HUFF-LONERGAN E., PAGE J. (2001): The role of carcass chilling in the development of pork quality. Facts, National Pork Producers Council, Pork Quality, American Meat Science Association, pp. 1-8. Available: http://www.meatscience.org/Pubs/factsheets/chilling.pdf

JONES S.D.M., JEREMIAH L.E., ROBERTSON W.M. (1993): The effect of spray and blast-chilling on carcass shrinkage and pork muscle quality. Meat Science, 34, 3, 351-362.

JOO S.T., KAUFFMAN R.G., KIM B.C., PARK G.B. (1999): The relationship of sarcoplasmic and myofibrillar protein solubility to colour and water-holding capacity in porcine *longissimus* muscle, Meat Science, *52*, 3, 291-297.
JOSELL Å., VON SETH G., TORNBERG E. (2003): Sensory and meat quality traits of pork in relation to post-slaughter treatment and *RN* genotype. Meat Science, 66, 1, 113-124.
KERTH C.R., CARR M.A., RAMSEY C.B., BROOKS J.C., JOHNSON R.C., CANNON J.E., MILLER M.F. (2001): Vitamin-mineral supplementation and accelerated chilling effects on quality of pork from pigs that are monomutant or noncarriers of the halothane gene. Journal of Animal Science, 79, 9, 2346-2355.
KIM C.J., LEE E.S., JOO S.T., KIM B.C., KANG J.O., KAUFFMAN R.G., YOO I.J., KO W.S., CHOI D.Y. (1996): Chemical, physical and structural characteristics of pork loins from four quality groups. In: Proceedings 42nd International Congress of Meat Science and Technology, pp. 312-313, Lillehammer, Norway.
LAWRIE R.A. (1998): Lawrie's Meat Science (sixth edition). Woodhead Pulishing Limited, Abington Hall, Abington Cambridge, England.
MILLIGAN S.D., RAMSEY C.B., MILLER M.F., KASTER C.S., THOMPSON L.D. (1998): Resting of pigs and hot-fat trimming and accelerated chilling of carcasses to improve pork quality. Journal of Animal Science, 76, 1, 74-86.
NPPC (National Pork Producers Council) (1991): Procedures to evaluate market hogs, 3rd edition. National Pork Producers Council, Des Monica, Iowa, USA.
OKANOVIĆ Đ. (1993): Investigation of changes in pork ham in the process of cooked ham production early *post-mortem*. PhD Thesis, Faculty of Technology, University of Novi Sad, Novi Sad.
REDE R., PETROVIĆ LJ. (1997): Meat Science and Technology. Faculty of Technology, University of Novi Sad, Novi Sad.
SAVELL J.W., MUELLER S.L., BAIRD B.E. (2005): The chilling of carcasses. Meat Science, 70, 3, 449-459.
SHAW F.D., POWELL V.H. (1995): Meat quality aspects of hot boning. Proceedings of Meat, 95, 12B1-12B3.
SMULDERS F.J.M., TOLDRÁ F., FLORES J., PRIETO M. (1992): New technologies for meat and meat products. Utrecht, The Netherlands: Audet Tijdschriften.
SPRINGER M.P., CARR M.A., RAMSEY C.B., MILLER M.F. (2003): Accelerated chilling of carcasses to improve pork quality. Journal of Animal Science, 81, 6, 1464-1472.
SRPS ISO 2917. (2004): Meat and meat products. Measurement of pH (Reference method).
TOLDRÁ F., FLORES M. (2000): The use of muscle enzymes as predictors of pork meat quality. Food Chemistry, 69, 4, 387-395.

TOMOVIĆ V. (2002): Influence of selection and multi–race cross–breeding of pigs on quality of halves and technological, nutritional and sensory quality of meat. MSc Thesis, Faculty of Technology, University of Novi Sad, Novi Sad.
WARNER R.D., KAUFFMAN R.G., GREASER M.L. (1997): Muscle protein changes *post-mortem* in relation to pork quality traits. Meat Science, 45, 3, 339-352.
WISMER-PEDERSEN J. (1959): Quality of pork in relation to rate of pH change *post-mortem*. Food Research, 24, 6, 711-727.
WISMER-PEDERSEN, J. (1987): Chemistry of animal tissues. Part 5. In: Science of meat and meat products (3rd editions), J. F. Price and B. S. Schweigert (Eds.), pp. 141–154, Food and Nutrition Press, Inc., Westport, Connecticut, USA.
ZAGORAC S. (1994): Investigation of the influence of cooling rate on the quality of pork and cooked ham. MSc Thesis, Faculty of Technology, University of Novi Sad, Novi Sad.

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