PENETROMETRICAL CHARACTERIZATION OF AGEING RATE OF BEEF AFTER LOW-FREQUENCY MEDIUM-INTENSITY ULTRASOUND TREATMENT

Dariusz M.Stasiak, Zbigniew J.Dolatowski

Agricultural University, Department of Animal Food Technology, ul. Doświadczalna 44, 20-236 Lublin, Poland

Key words: meat, ageing, ultrasound

Background

It has been recognized for many years that ultrasounds have considerable potential for industrial use. Some of processes are already being used at an industrial scale, e.g., homogenisation, emulsification, process activation, surface cleaning. The interactions of ultrasounds with homogenous or heterogeneous media are physical (mass transport, degradation, destruction) or chemical (initialisation, enhancing chemical reactions) (Mason et al., 1996). There are small number of research on ultrasonically accelerated meat processing, especially meat ageing (Dolatowski, 1989; Got et al., 1999). The energy dissipation of high-frequency (above 1 MHz) ultrasounds causes greater heating of media than low (25–50 kHz) ultrasounds. "Micromassaging" of meat generated by ultrasounds does not change f its normal pH (statistically not significant), but its water holding capacity is ultrasonically changed and correlated with mechanical properties (Got et al. 1999; Sajas and Gorbatow, 1978). Factors such as texture, colour, flavour, odour, safety are major quality attributes of meat and meat products perceived by consumers. It is important to create new meat processing methods based on studies, which will open possibilities for above factors modification.

Objective

The objective of the research was the influence of low-frequency medium-intensity ultrasounds on meat ageing 5 days after slaughter. The experiment was realized in 10 repetitions.

Methods

The raw meat samples about 1 [kg] each from *Semimembranosus* muscle excised from beef carcass 1–2 hours after slaughter (young cows). Samples were immediately processed with ultrasounds at 25 [kHz] frequency and 2,5 [$W \cdot cm^{-2}$] intensity. Meat was putt on wet, active surface of transducers for 1, 3 or 5 minutes. Treated samples were rotated by a half turn (opposite surface exposition) every half-minute. All meat samples (treated and untreated) exhibiting a typical rate of pH-fall were stored in the same way (15°C for 1st day, 4°C for next days) for max. 5 days.

The mechanical properties of meat were investigated using universal testing machine INSTRON 4302. The samples of 210 [cm^2] were put in cylindrical cap of 65 [mm] diameter, fitted on the machine and penetrated (3–5 replication for each) with cylindrical elements of 3 [mm] or 6 [mm] diameter. Machine's crosshead moved perpendicularly to the main myofibryle axis at 60 [$mm \cdot s^{-1}$]. The regression of stress-strain curves of meat after ultrasonic treatment was determined in range to yield-point (range of distance 18–22 [mm]). Data were analysed using PC Statgraphics v.5 procedure (i.e. regression and variance analysis, t-Student test).

The pH of the control and pre-rigor ultrasonically treated samples was measured (electronic pH-meter with combined electrode) in water extract prepared from the grinded meat. Water holding capacity (WHC) of samples (meat homogenized with water) was determined on supernatant volume from centrifugation for 10 min at 30000×g. Sample's pH and WHC were calculated as mean values from 3 measurements (Wierbicki, 1962).

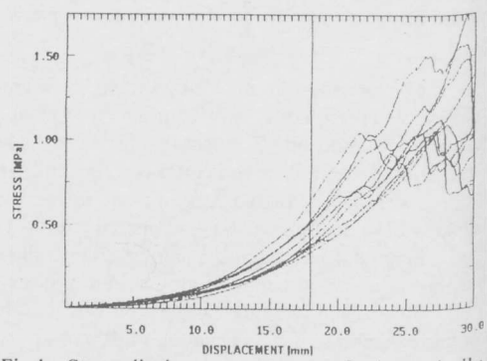

Fig.1. Stress-displacement curves of ultrasonically treated meat

Results and discussion

Regression analysis showed that the best mathematical function describing penetrometrical load-displacement curves (Fig.1) of meat after treatment in field of ultrasound was $f(m) = A \times m^B$, where: A, B – coefficients, m – displacement [mm] ($R^2 > 0.99$) (Fig.2a, 2b). On the base of variance analysis of coefficients A and B significant changes of mechanical properties of meat samples (assigned to ultrasound and not) were qualified. It was found that meat sonication caused statistically ($p<0,05$) significant A coefficient value growing and decrease of coefficient B of the function compared to control samples. Further analysis of results showed statistically significant ($p<0.05$) positive correlations between penetrator displacement and values of: yield point of samples, work of penetration and module. The standard deviation of yield point decrease with length of treatment time was ascertained.

The B coefficient of f(m) function was in range with value of mean $B_m=2.13$ (SD=0.56). Then, it was concluded the penetrometrical curves of meat after sonication would be described by $f'(m)=A' \times m^2$ ($R^2=0.70–0.95$) square function, where the A' coefficient is the stress [Pa] evaluation. And it was assumed, that texture properties of the sonicated meat samples were composed of load and cutting stress in range to yield point of curves. The A' coefficient depended on rela-

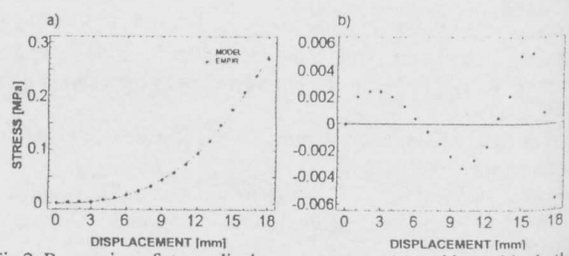

Fig.2. Regression of stress-displacement curves (a) and its residuals (b)

tion of penetrator forehead size (area) to its length of circuit (Peleg and Bagley, 1983). Analysis of variance showed statistically significant ($p<0.05$) influence of time after slaughter and length of processing with ultrasounds on Λ' value. The meat samples ultrasonically treated in comparison to control samples (ultrasonically untreated) were characterized with lower values of Λ' parameter. It meant the lower mechanical stress of meat penetration (Fig.3). The variance analysis of coefficient Λ' of f(m) function showed the significant ($p<0.05$) correlation ($r=-0.722$) with penetrator diameters. Peleg and Bagley (1983) also confirmed participation of load and cutting stress remaining in high correlation with penetrator diameter.

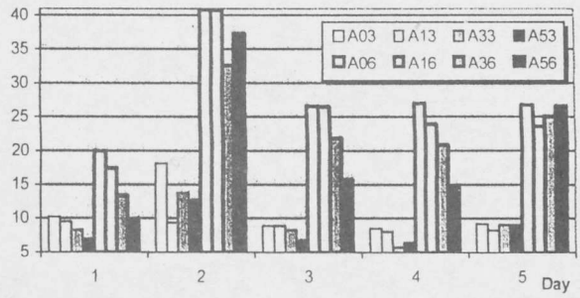

Fig.3. Changes of Λ' coefficient (1st digit – time of sonication [s], 2nd digit – diameter of penetrator [mm])

Pre-rigor meat sonication did not show significant ultrasonically induced pH differences (except from fifth-day sample) in comparison to control sample. It is supposed, that changes of pH were too small to be detected and the fast post-mortem meat transformation disturbed the ultrasonically generated effect. The WHC of meat samples significantly ($p<0.05$) differed after first day of investigations. Data analysis showed, the sonication decrease the WHC except the 2nd day, where the WHC was higher than control sample. For this reason, statistically significant ($p<0.05$) high correlation coefficient r=(0.724, 0.734) of Λ' and WHC were result of water retention in meat tissue.

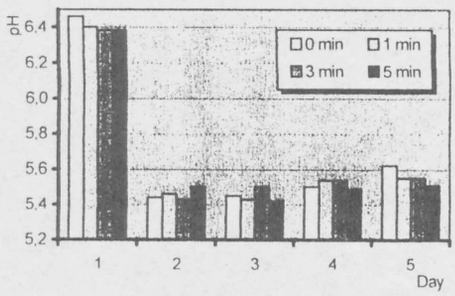

Fig.4. Effects of ultrasound on the pH changes of meat

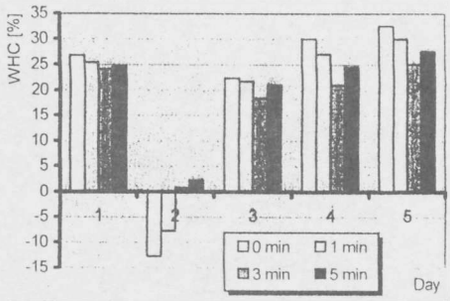

Fig.5. Effects of ultrasound on the WHC changes of meat

In conclusion, the results of investigations of the selected physical properties of meat after pre-rigor ultrasonic treatment were confirmed by observation of meat ultrastructural modification during ageing (Dolatowski 1999; Got 1996). However the Got's (1996) observations did not confirm the ultrasonically generated changes of post-mortem rate of tenderisation. It was found, the changes of meat structure, differences in myofibrillar spaces, destruction of morphological elements of tissue (lisosoms especially) and more others could be the main results (primary effects) of pre-mortem ultrasound treatment.

The realized works confirm, that sonication realised with low-frequency medium-intensity ultrasound modified course of meat ageing. The time of exposure was the main factor determining the changes of meat ageing. However, the time post-mortem, field of ultrasound parameters were significant too (Dolatowski 1999, Sayas 1978). In conclusion, there were possibilities to ultrasonically generated modification of physical properties of meat during ageing to obtain desirable meat quality.

Conclusions

Physical proprieties of meat (especially its mechanical proprieties) can be successfully modified by low-frequency (25 [kHz]) middle-intensity (2 [W·cm ^{2}]) ultrasound waves. The penetrometrical test curves (i.e. load-displacement, stress-strain) of meat after sonication can be described using function $f(m) = \Lambda \times m^{B}$, especially the square function ($R^2>0.98$). The shape of stress curves (Λ' coefficient) is significantly correlated with diameter of penetrators and mechanical (physical and chemical also) proprieties of meat. The Λ' coefficient can be used to estimate and classify the processed meat after sonication. The works did not confirm statistically significant ($p>0.05$) influence of pre-rigor ultrasound treatment of meat on course of its pH during ageing. Sonication of meat causes significant changes of its water retention. Correlations between mechanical proprieties, water holding capacity and pH of meat suggest that the main reasons of above are primary effects of ultrasound propagation, i.e. micromassaging with mechanical energy absorption.

References

Dolatowski Z.J., 1989: Ultrasonics. 2 – Influence of ultrasonics on the ultrastructure of muscle tissue during curing. Fleischwirtschaft 68, 1301–1303.

Dolatowski J.Z., 1999: Wpływ obróbki ultradźwiękami o niskiej częstotliwości na strukturę i cechy jakościowe mięsa. Wyd. AR Lublin, nr 221.

Got F., Culioli J., Berge P., Vignon X., Astruc T., Quideau J.M., Lethiecq M., 1999: Effects of high-intensity high-frequency ultrasound on ageing rate, ultrastructure and some physico-chemical properties of beef. Meat Science 51, 35–42.

Mason T.J., Paniwnyk L., Lorimer J.P., 1996: The uses of ultrasound in food technology. Ultrasonics Sonochemistry 3, S253–S260.

Peleg M., Bagley E.B., 1983: Physical properties of foods, Avi Publ.Comp., Inc., Westport, Connecticut.

Sajas J.F., Gorbatow W.M., 1978: Use of ultrasonics in meat technology. Fleischwirtschaft 6, 1009–1012.

Wierbicki E., Tiede M.C., Burrel R.C., 1962: Die Bestimmung der Fleischquellung als Methode zur Untersuchung der Wasserbindungskapazitat von Muskelprotein mit geringen Safthaltevermogen, Fleischwirtschaft 14, 948–951.