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An alternative method for meat shear energy estimation during ageing

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Abstract. The aim of this research was to study an alternative method (gravitational impulse method) for meat shear energy estimation. A falling shear blade (guillotine) with constant potential energy was used. Shear energy was determined as the difference between the initial potential energy of the blade and the residual energy measured via the impulse provided by the shear blade during collision with the force plate on the bottom of the device. The shear energy measured by the gravitational impulse method was compared to the data received by the texture analyser TMS PRO based on the Warner-Bratzler method. The meat shear parameters of de-boned beef striploin samples were measured after 2, 7, 14, 21, 28 and 35 days of ageing at 0–2°C. The results of both methods (gravitational impulse method and Warner-Bratzler method) indicated similar trends of shear energy lessening during beef ageing. Based on the preliminary results, it can be concluded that the gravitational impulse method is suitable for evaluation of meat texture during ageing as well. The main advantage of this method is its simplicity and the low price of the device.

Key words: Warner-Bratzler share force test, gravitational impulse method, beef shear energy.

Abbreviation key: MLD – *Musculus longissimus dorsi*, WB – Warner-Bratzler, GIM – gravitational impulse method.

INTRODUCTION

Beef texture is tough, thus it must be aged before consumption to improve the meat tenderness (Field et al., 1971; Jennings et al., 1978; Mottram, 1998). Textural parameters are very important during meat processing and regarding the sensory characteristics of meat products. Special texture analyzers are produced for quantitative evaluation of meat texture, which measure force dynamics at constant cutting speed. Such texture analyzers based on the Warner-Bratzler (WB) methodology and with determined characteristics are mainly used in scientific investigations (Wheeler et al., 1999; Hopkins et al., 2011). Application of these devices in meat industry is not common due to their operational complexity and considerably high price.

The aim of this work was development and evaluation of an alternative device based on the gravitational impulse method (GIM) for estimation of beef shear energy during ageing. Shear energy of aged steak samples was measured by the gravitational impulse method (GIM) and with the TMS PRO equipment based on the Warner-Bratzler method (Tommy et al., 2013) during the study.

MATERIALS AND METHODS

An experimental device using the gravitational impulse method (GIM) for estimation of meat shear energy was developed at the Department of Food Science and Technology of the Estonian University of Life Sciences. The GIM device contains a blade, a cutting table and a force plate with a transducer to record impulses (Fig 1). To carry out measurements, a meat sample is placed on the cutting table between the shear blade and force plate, where the sample is penetrated by the free fall of the blade. After shredding the sample, the blade falls onto the force plate and its transducer generates an impulse, which is recorded by a measurement controller. The weight of the blade is 1.10 kg and its initial height from the force plate is 460 mm. The shear energy can be determined as a difference between the initial potential energy of the blade and the residual energy generating an impulse on the force plate. The softer the structure of the meat, the stronger the strike to the force transducer and vice versa.

Figure 1. The test device to determine the shear energy of meat by using GIM method (1 – blade, 2 – force transducer, 3 – blade leading rods, 4 – slidebearing, 5 – cutting table).

Physics of the GIM device based on energy balance. If the blade is lifted to a certain altitude (h), it holds the potential energy (E_P).

While dropping the blade from that height, the potential energy (E_P) turns into kinetic energy (E_K), the end value of which corresponds to the size of the impulse (i) generated by the force plate transducer 1 (Fig. 2). This can be estimated by calculation of the surface area under the graph of force dynamics. The meat sample on cutting table will consume a part of that energy (shear energy E_L), and the force transducer will record a lower result accordingly.

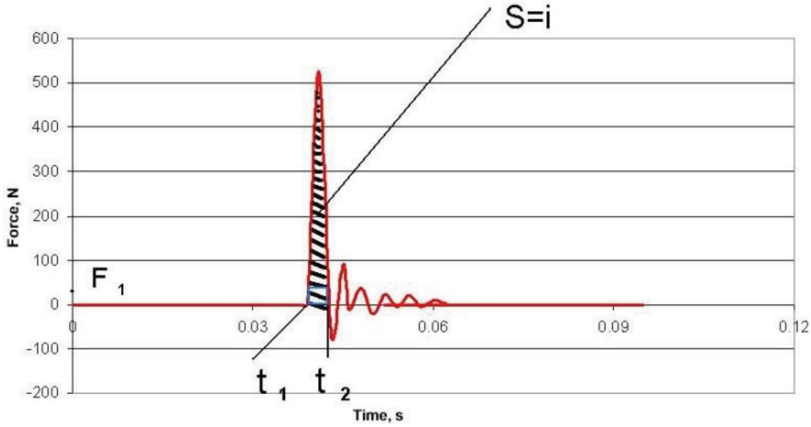

Figure 2. Example of the force dynamics recorded by the force plate transducer of the GIM device during a measurement cycle.

Experiments were carried out at the Department of Food Science and Technology (Estonian University of Life Sciences) in 2013. Three deboned *M. longissimus dorsi* muscles (MLD) removed from beef carcasses two days after slaughtering were used for the experiments. Each muscle was cut into six samples with the weight of about 300 g each and aged in vacuum packages at 0–2°C for 2, 7, 14, 21, 38 and 35 days. Hanzelková et al. (2011) have suggested that for improvement of beef tenderness it should be aged for at least 14 days. The total ageing time in our investigation was chosen to cover all spans reported in the literature on different meat ageing studies (Koohmaraie et al., 1995; Sañudos et al., 2004; Vieira et al., 2007; Muchenje et al., 2008). Preparation of probes for analyses was carried out according to the methodology of WB (Savell et al., 2013). Probes were obtained from the meat samples by using a hollow drill with the inner diameter of 20 mm. Up to ten probes were drilled off each of the MLD segments along the muscle fibres (Fig. 3). The shear force dynamics of both raw and thermally treated samples of aged beef were registered by the WB and GIM methods. Later, total shear energy was calculated from force dynamics. Probes were sheared from the middle perpendicularly to the muscle fibres in six separate trials. For thermal treatment, meat samples were heated in a water bath until the inner temperature reached 72–76°C.

Figure 3. Samples of meat taken by hollow drill.

The texture analyzer TMS PRO with a 1000 N force transducer and blade movement speed of 500 mm min^{-1} was used for the WB method. Total shear energy consumption during cutting the probe was estimated by calculating the surface area under the force dynamic curve (Fig. 4). The blades in both (WB and GIM) devices had similar configurations with a 60° V-shaped incision and thickness of 1.016 mm).

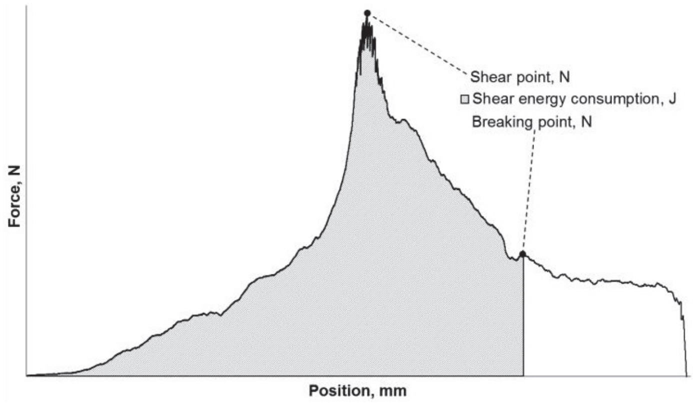

Figure 4. Force dynamics during the Warner-Bratzler test and determination of shear energy by calculating the surface area under the curve (Luno et al., 1999).

To assess the effect of ageing on the shear energy of samples, a one-way analysis of variance was performed with the spreadsheet program Excel 2010. For determination of statistical difference between the devices, student's t-test was used. The mean differences in shear energy between ageing days were evaluated by the statistical package R (R Core Team, 2013).

RESULTS AND DISCUSSION

The data of the WB method showed lower shear energy consumption when cutting raw meat samples compared to thermally treated ones ($P < 0.001$). The latter consumed 0.62 J more energy in comparison with raw meat (P = 0.001) (Fig. 5). The parameters of raw and thermally treated meat samples did not differ significantly ($P = 0.880$) when using the GIM method. It can be concluded that the GIM method is not suitable for determining the differences between boiled and raw meat.

Estimation of shear energy is especially important in the course of aging, because a decrease in it characterizes the enzymatic processes in the muscle, which have an effect on the muscle fibres where myofibrillar proteins degrade and meat becomes softer (Koohmaraie et al., 1995). The shear energy consumption measured by the WB method in our experiments decreased significantly ($P < 0.001$) during ageing (Fig. 6a). The shear energy of thermally treated meat (compared to raw meat) was 0.8 J higher at the beginning of ageing (day 2), however, at the end of ageing (day 35), the difference had decreased to 0.35 J.

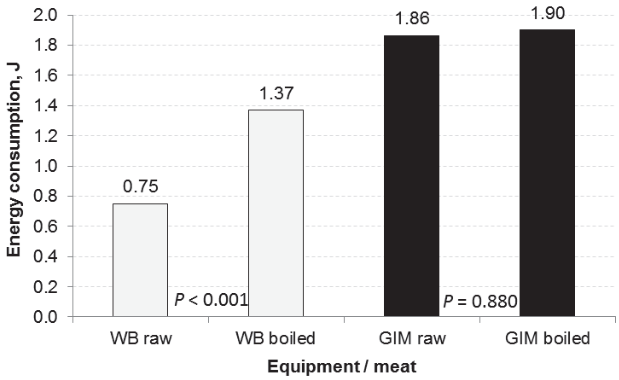

Figure 5. The shear energy consumption of raw and thermally treated meat in comparison with the WB and the GIM methods.

The shear energy consumed by the GIM method for cutting raw meat samples decreased even more during ageing (Fig. 6b), with a little bit lower statistical reliability ($P = 0.028$).

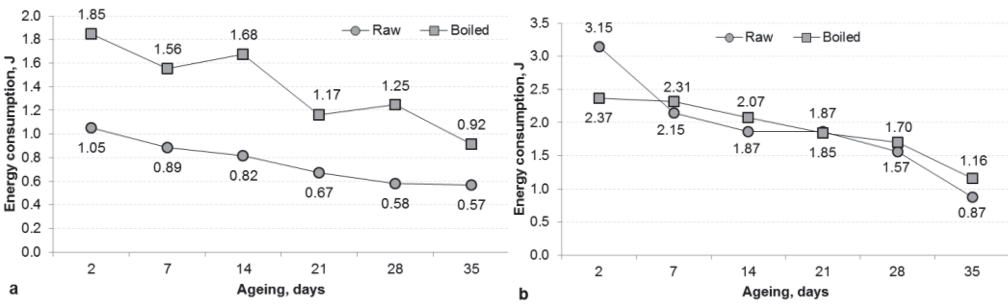

Figure 6. Changes in shear energy consumption by raw and thermally treated meat during ageing estimated with WB (a) and GIM (b) devices.

Different studies about the effect of beef ageing have produced somewhat different results. Roncalés et al. (1995) found that increasing MLD muscle ageing time changed the texture of the meat – meat tenderised throughout the whole ageing period. Huff & Parrish (1993) and Sañudos et al. (2004) concluded that 21-day ageing of MLD muscles decreased the shear force evenly in time. Our experimental data confirmed this statement. Vieira et al. (2007) and Muchenje et al. (2008) obtained different results – the conclusion of the first study was that the WB shear force value of MLD muscle decreased ($P < 0.1$) between 14 and 28 ageing days, and the second study showed that MLD muscle already reached the final tenderness by the second day of ageing and the WB shear force did not reduce significantly later (up to the 21st ageing day).

Accioli et al. (1995) found that the WB shear force values differed significantly between the 9th and 16th days of ageing, however, there were no significant differences between the 16th and 23rd day.

In our investigation, the average shear energy of raw and thermally treated meat samples decreased during ageing by using both (WB and GIM) meat shearing methods (Tables 1, 2, Figs 7, 8).

Table 1. The effect of ageing on raw meat shear energy consumption by using the WB and GIM methods (a, b, c, and d – the means within each effect with one letter in common do not differ significantly, $P > 0.05$)

Energy consumption, J	Ageing, days					
	2	7	14	21	28	35
WB method	1.05^{a}	0.89^{ab}	0.82^{abc}	0.68^{bc}	0.58^{c}	0.57^{c}
GIM method	3.15^{a}	2.15^{ab}	1.87^{ab}	1.87^{ab}	1.56^{ab}	0.87^{b}

Table 2. The effect of ageing on boiled meat shear energy consumption by using the WB and GIM methods (a, b, c, and d – the means within each effect with one letter in common do not differ significantly, $P > 0.05$)

Energy consumption, J	Ageing, days					
	2	7	14	21	28	35
WB method	1.85^{a}	1.56^{ab}	1.68^{ab}	1.17^{bc}	1.25^{bc}	0.92^{c}
GIM method	2.37^{a}	2.31^{a}	2.07^{a}	1.85^{a}	1.71^{a}	1.16^{a}

The effect of ageing on the shear energy of raw meat is illustrated on Fig. 8. The statistical significance of this effect was < 0.001 in the case of the WB method and 0.02 in the case of the GIM method. The shear energy values obtained by the GIM method were larger compared to the WB method throughout the total ageing period. Shearing energy decreased noticeably faster at the beginning of the ageing period in comparison with the end of the period. On the second day of ageing, the shear energy consumption by the GIM was 2.1 J (3.15–1.05 J) higher than that of the WB. At the end of the ageing period (35 days), this difference had decreased to 0.3 J. These data indicate the much greater sensitivity of the GIM method in the first week of ageing, compared to the WB method. Therefore, development of a new express device for evaluation of the initial stage of meat ageing would be reasonable.

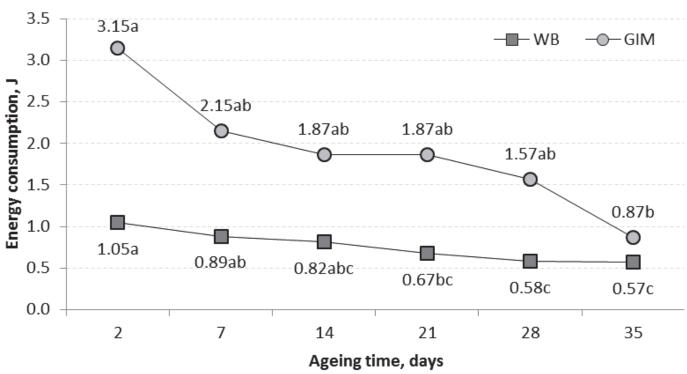

Figure 7. Changes in raw meat shear energy consumption measured by WB and GIM devices during the beef ageing period.

Thermally treated and raw meat showed similar trends in the changes of shear energy consumption for both (WB and GIS) methods (Table 2, Fig. 8) with differences in statistical significance. Shearing of thermally treated meat with the WB method showed a significant decrease in shear energy consumption during ageing days ($P < 0.001$), but the GIM method did not show a significant difference ($P = 0.38$).

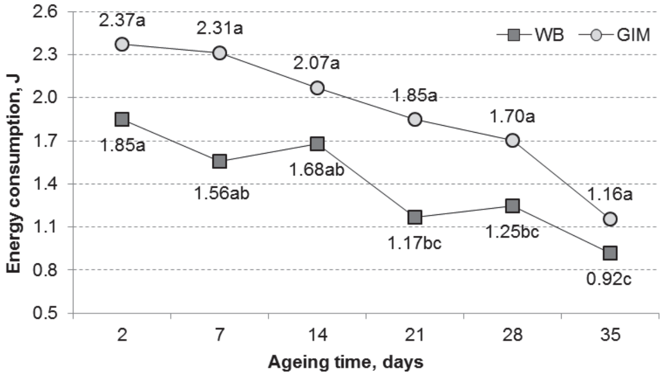

Figure 8. Changes in thermally treated meat shear energy consumption measured by WB and GIM devices during the ageing period.

CONCLUSIONS

1. The effect of ageing on the structure of meat can be determined both by the classical (WB) and the gravitational impulse method (GIM).

2. The GIM method is more sensitive in determining the tenderness of aged raw meat compared to the WB method. The advantage of the gravitational method is its simplicity.

3. On the base of the GIM method, development of a new texture analyzer for meat industry would be reasonable.

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