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EFFECTS OF SHORT MASSAGING TIME AND DRUM SPEED ON TEXTURE AND STRUCTURE CHANGES OF CHICKEN AND TURKEY BREAST MUSCLES

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ABSTRACT

Changes in texture parameters (hardness, cohesiveness, chewiness) and structural elements (fibre cross-sectional area, and thickness of peri- and endomysium) of chicken and turkey breast muscles, subjected to effective massaging for ½, 1, 1½ , 2, 4 h were followed.

Turkey breast muscles with thier higher cross-sectional area thicker peri- and endomysium, compared with chicken breast muscles, were harder, more chewiness and cohesiveness.

Massaging resulted in an increase in the mean fibre cross-sectional area, changes in thicknes of the peri- and endomysium, and reduction in hardness and chewiness and in augmentation of cohesiveness of the muscles studied.

Turkey breast muscles were the less susceptible than the other muscles tested to mechanical tenderisation and should be effective massaged for more than 2 h or more intensely.

Chicken breast muscles massaged longer than 2 h at 20 rpm drum speed caused an over-massaging of meat and as the consequences an increase in hardness, chewiness and thermal drip.

Key words: poultry muscles, massaging, texture, structure.

INTRODUCTION

In meat industry massaging is the one of the widely known ways of loosening and damaging meat structure [18, 25]. As a result of histological changes, massaging causes an increase in meat tenderness [8, 22, 31].

Final effects of massaging is connected with the both raw material (type and muscle size) and with the massaging parameters (injection with curing brine, massaging time, temperature, drum speed, massaging cycle, kind of massaging devices) [7, 17, 25].

However, the final effects of massaging, could be caused by two main determinants: massaging time and drum speed [11, 18, 24]. On the one hand, too shorter-lasting massaging causes tough and jammed product structure – on the other too longer-lasting massaged muscles (over-massaged) may characterized excessive damaging meat structure, decrease in WHC and yield [17, 24]. Also the improperly applied drum speed may caused to obtain final products with low-quality. Similarly to above, too slow drum speed, even with longer-lasting massaging may result in poorly damaged muscle structure, and too fast drum speed may to worsen product structure.

The present work was aimed at following effects of massaging time and drum speed on texture and structure of chicken and turkey breast muscles.

MATERIALS AND METHODS

The study involved breast muscles dissected out of the carcasses of pure breed chicken Lohmann and turkey White Widebreast slaughtered at 7 and 14 weeks respectively.

The muscles were stored at the cold room for 24 h. A total of 70 kg each muscles were selected to this study, injected with curing brine containing 11% NaCl, 1.5% Almonat Super Combi curing mixture of A. Mittermayer & Söhne GmbH, and 87.5% water, until a 20% weight increase was obtained.

The poultry muscles (50 kg of each type of muscle) were massaged in a MP-74 PEK-MONT s.c.® vacuum massaging apparatus under following massaging conditions:

- 5 and 20 rpm drum speed,
- 4 h of effective massaging time in cycle 30 min massaging, 30 min pause
- the drum was filled to about 70% of its capacity
- massaging temperature 4± 1°C
- vacuum: -0.8 bar

The muscle samples were massaged separately depending of muscle type and drum speed. To counteract a substantial reduction of the total muscle weight in the drum because of sampling, the drum contents were supplemented each time with specially marked individual the same poultry muscles, added in the amount equal to that which had been removed.

The brine injection 5 muscles were control (“0” non-massaged) samples.

Each time samples were collected from both the massaged and control meat, muscles were sealed in a heat-resistance PA/PE bag, and subjected to cooking in water heated to 75±1°C, until the temperature inside the sample reached 68±1°C. Subsequently, the samples were cooled down, reweighed and stored at 4±1°C for about 12 h until the assays were made.

Texture

The 20±1 mm thick slabs were cut off, across the fibres, from each group of muscles by electric knife. Muscle textural characteristics were assayed following the Texture Profile Analysis (TPA) procedures [1], with a computer-interfaced Instron 1140. The test involved driving a 0.96 cm diameter shaft twice into a 20ą1 mm high sample, parallel the fibres, down to 80% of its height (16 mm), 50 mm min^{-1} crosshead rate being applied. The force-deformation curve obtained served to calculate meat hardness, chewiness and cohesiveness. The TPA test was repeated 10 times on each sample of muscle depending on muscle type, massaging time and drum speed.

Structure

Samples measuring about 5 mm x 5 mm x 5 mm were cut out, parallel to the fibres, from the middle part of raw muscles, both massaged and non-massaged (control).

The samples were fixed in the Sannomiya solution, passed through the alcohol series, and embedded in paraffin. The paraffin blocks were cut transversely into 10 µm slices with microtome MPS-2. Each slice was stained in hematoxylin and eosin [4]. Each muscle of different massaging time and drum speed produced 4-5 microscope mounts.

Fibre cross-sectional area as well as perimysium and endomysium thickness per muscle fibre bundle in each mounts were determined, using an image analysis programme MULTISCAN. The vertical and horizontal diameters of muscle fibres were also measured. The shape of the muscle fibre was determined by the ratio diameters H and V. If the rate of diameters H and V is nearer 1, the shape of fibres was more regular.

Exude viscosity measurement

Viscosity of exudates collected from the surface of massaged meat was determined with an RV2 Rheotest 2 rotating viscometer. After placing 30 ml exudate samples maintaining 4±1°C in measuring cylinder S_2, viscosity was measured at the shear rate of 145.8 cm s^{-1}. Viscosity was measured twice on each sample.

Thermal drip measurement

Cooking loss (the percentage of weight loss) was determined by weighing individual muscles, both massaged and non-massaged (control). before and after cooking. The data is the mean from 5 measurements.

Statistical treatment

All the calculations were performed with Statistica v.6.0 PL StatSoft® software. A mean and standard deviation was calculated for each samples. A significance of differences was explored by applying Student's *t* test at $\alpha = 0.05$.

RESULTS AND DISCUSSION

Comparison of two non-massaging poultry muscles texture parameters (Table 1 and 2) showed that the turkey breast muscle (MPI) was shown to have the highest hardness, chewiness and cohesiveness (by about 23, 43 and 14% respectively than chicken breast muscle (MPK)).

Table 1. The effects of massaging time and drum speed on texture parameters changes of chicken breast muscle (PM)

Effective massaging time [h]	Hardness [N]		Chewiness [N x cm]		Cohesiveness [-]	
	5 rpm	20 rpm	5 rpm	20 rpm	5 rpm	20 rpm
0	**21.30**±1.14$^{a}_{1}$	**21.30**±1.14$^{a}_{1}$	**9.75**±1.00$^{a}_{1}$	**9.75**±1.00$^{a}_{1}$	**0.35**±0.06$^{a}_{1}$	**0.35**±0.06$^{a}_{1}$
0.5	**19.70**±1.20$^{ab}_{1}$	**18.50**±1.16$^{bf}_{1}$	**8.79**±0.71$^{ab}_{1}$	**8.60**±0.47$^{a}_{1}$	**0.35**±0.03$^{a}_{1}$	**0.37**±0.02$^{a}_{1}$
1.0	**18.00**±1.12$^{b}_{1}$	**16.40**±1.02$^{cf}_{1}$	**7.45**±0.50$^{b}_{1}$	**7.19**±0.54$^{be}_{1}$	**0.36**±0.04$^{a}_{1}$	**0.39**±0.04$^{a}_{1}$
1.5	**16.90**±1.10$^{c}_{1}$	**14.10**±1.10$^{d}_{1}$	**6.83**±0.45$^{c}_{1}$	**6.31**±0.30$^{c}_{1}$	**0.38**±0.04$^{a}_{1}$	**0.40**±0.04$^{a}_{1}$
2.0	**15.80**±0.85$^{d}_{1}$	**13.80**±1.05$^{e}_{1}$	**6.48**±0.32$^{c}_{1}$	**5.22**±0.43$^{d}_{1}$	**0.40**±0.05$^{a}_{1}$	**0.42**±0.08$^{a}_{1}$
4.0	**14.90**±0.75$^{e}_{1}$	**17.20**±0.60$^{f}_{1}$	**6.29**±0.22$^{c}_{1}$	**7.39**±0.25$^{e}_{1}$	**0.44**±0.04$^{a}_{1}$	**0.46**±0.07$^{a}_{1}$

a – numbers in columns. marked with identical superscripts are not significantly different within a group at the 0.05 level of probability.
1 – numbers in columns. marked with identical subscripts are not significantly different between groups at the 0.05 level of probability.

Table 2. The effects of massaging time and drum speed on texture parameters changes of turkey breast muscle (PM)

Effective massaging time [h]	Hardness [N]		Chewiness [N x cm]		Cohesiveness [-]	
	5 rpm	20 rpm	5 rpm	20 rpm	5 rpm	20 rpm
0	**26.19**±1.66$^{a}_{1}$	**26.19**±1.66$^{a}_{1}$	**14.00**±1.28$^{a}_{1}$	**14.00**±1.28$^{a}_{1}$	**0.40**±0.07$^{a}_{1}$	**0.40**±0.07$^{a}_{1}$
0.5	**25.84**±1.30$^{a}_{1}$	**24.30**±1.10$^{ab}_{1}$	**13.52**±1.09$^{a}_{1}$	**13.10**±0.64$^{ab}_{1}$	**0.40**±0.04$^{a}_{1}$	**0.41**±0.06$^{a}_{1}$
1.0	**25.00**±1.27$^{ab}_{1}$	**23.19**±1.46$^{bc}_{1}$	**13.00**±0.80$^{a}_{1}$	**12.25**±0.43$^{b}_{1}$	**0.42**±0.03$^{a}_{1}$	**0.43**±0.06$^{a}_{1}$
1.5	**23.59**±1.45$^{ab}_{1}$	**22.14**±1.05$^{cd}_{1}$	**12.45**±0.52$^{ab}_{1}$	**11.39**±0.39$^{c}_{1}$	**0.43**±0.04$^{a}_{1}$	**0.45**±0.03$^{a}_{1}$
2.0	**23.28**±1.41$^{b}_{1}$	**21.03**±0.85$^{d}_{1}$	**11.58**±0.39$^{b}_{1}$	**10.59**±0.22$^{d}_{1}$	**045**±0.02$^{a}_{1}$	**0.48**±0.04$^{a}_{1}$
4.0	**22.60**±1.20$^{c}_{1}$	**19.08**±0.54$^{e}_{1}$	**10.45**±0.31$^{c}_{1}$	**9.35**±0.46$^{e}_{1}$	**0.51**±0.05$^{a}_{1}$	**0.55**±0.08$^{a}_{1}$

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The histological analysis of non-massaging muscles revealed statistically significant differences between their structural elements (Table 3 and 4). Turkey breast muscle is characterized by fibres of a higher cross-sectional area (by about 47%) and twofold thicker perimysium and endomysium than chicken breast muscle.

Similar texture-structure relationships in poultry muscles were observed also by, *i.a.,* Smith et al. [26], Lyon and Lyon [16], Gajowiecki et al. [6]; Żych [33] who observed the higher hardness of turkey muscles connected with thicker fibres.

Table 3. The effects of massaging time and drum speed on structure elements changes of chicken breast muscle (PM)

Effective massaging time [h]	Muscle fibre cross-sectional area [µm^2]		Perimysium thickness [µm]		Endomysium thickness [µm]		Shape of muscle fibre (Hdiameter/Vdiameter)	
	5 rpm	20 rpm	5 rpm	20 rpm	5 rpm	20 rpm	5 rpm	20 rpm
0	**1301**±65 $^{a}_{1}$	**1301**±65 $^{a}_{1}$	**5.62**±0.10 $^{a}_{1}$	**5.62**±0.10 $^{a}_{1}$	**0.60**±0.03 $^{a}_{1}$	**0.60**±0.03 $^{a}_{1}$	0.911	0.911
0.5	**1355**±49 $^{ab}_{1}$	**1472**±74 $^{b}_{1}$	**5.70**±0.09 $^{ab}_{1}$	**5.83**±0.07 $^{b}_{1}$	**0.66**±0.05 $^{a}_{1}$	**0.66**±0.02 $^{b}_{1}$	0.920	0.926
1.0	**1429**±37 $^{b}_{1}$	**1592**±48 $^{bc}_{1}$	**5.82**±0.04 $^{b}_{1}$	**6.12**±0.09 $^{c}_{1}$	**0.68**±0.02 $^{a}_{1}$	**0.70**±0.01 $^{c}_{1}$	0.927	0.937
1.5	**1561**±39 $^{c}_{1}$	**1688**±37 $^{d}_{1}$	**6.06**±0.08 $^{c}_{1}$	**6.40**±0.11 $^{d}_{1}$	**0.72**±0.03 $^{b}_{1}$	**0.75**±0.02 $^{d}_{1}$	0.936	0.951
2.0	**1686**±54 $^{d}_{1}$	**1800**±52 $^{e}_{1}$	**6.26**±0.07 $^{d}_{1}$	**6.71**±0.10 $^{e}_{1}$	**0.75**±0.01 $^{c}_{1}$	**0.79**±0.01 $^{e}_{1}$	0.945	0.964
4.0	**1823**±63 $^{e}_{1}$	**1905**±39 $^{f}_{1}$	**6.65**±0.11 $^{e}_{1}$	**6.93**±0.10 $^{f}_{1}$	**0.78**±0.02 $^{d}_{1}$	**0.82**±0.02 $^{f}_{1}$	0.957	0.973

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Table 4. The effects of massaging time and drum speed on structure elements changes of turkey breast muscle (PM)

Effective massaging time [h]	Muscle fibre cross-sectional area [µm^2]		Perimysium thickness [µm]		Endomysium thickness [µm]		Shape of muscle fibre (Hdiameter/Vdiameter)	
	5 rpm	20 rpm	5 rpm	20 rpm	5 rpm	20 rpm	5 rpm	20 rpm
0	**1921**±87 $^{a}_{1}$	**1921**±87 $^{a}_{1}$	**12.10**±0.41 $^{a}_{1}$	**12.10**±0.41 $^{a}_{1}$	**1.20**±0.03 $^{a}_{1}$	**1.20**±0.03 $^{a}_{1}$	0.915	0.915
0.5	**2060**±54 $^{a}_{1}$	**2079**±65 $^{ab}_{1}$	**12.32**±0.19 $^{a}_{1}$	**12.63**±0.24 $^{ab}_{1}$	**1.21**±0.02 $^{a}_{1}$	**1.22**±0.01 $^{a}_{1}$	0.919	0.921
1.0	**2103**±97 $^{ab}_{1}$	**2147**±69 $^{bc}_{1}$	**12.47**±0.22 $^{ab}_{1}$	**13.00**±0.34 $^{bc}_{1}$	**1.23**±0.02 $^{a}_{1}$	**1.25**±0.02 $^{ab}_{1}$	0.925	0.931
1.5	**2153**±29 $^{b}_{1}$	**2197**±31 $^{c}_{1}$	**12.58**±0.12 $^{b}_{1}$	**13.36**±0.11 $^{c}_{1}$	**1.25**±0.03 $^{ab}_{1}$	**1.26**±0.01 $^{b}_{1}$	0.934	0.942
2.0	**2201**±44 $^{b}_{1}$	**2254**±23 $^{d}_{1}$	**12.69**±0.14 $^{b}_{1}$	**13.59**±0.07 $^{d}_{1}$	**1.26**±0.01 $^{b}_{1}$	**1.30**±0.02 $^{c}_{1}$	0.940	0.953
4.0	**2280**±31 $^{c}_{1}$	**2331**±36 $^{e}_{1}$	**13.19**±0.15 $^{c}_{1}$	**13.79**±0.05 $^{e}_{1}$	**1.30**±0.02 $^{c}_{1}$	**1.33**±0.03 $^{c}_{1}$	0.950	0.965

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The correlations between textural parameters vs. structural elements in non-massaged chicken and turkey muscles allow to conclude that a poultry muscle's hardness, and chewiness, similarly to the slaughter animal muscles, increases with increasing fibre cross-sectional area and the thickness of peri- and endomysium [5, 10, 14, 15, 20].

Massaging resulted in a reduction of hardness and chewiness and an augmentation of cohesiveness, however the drum speed and time-dependent changes differed between the muscles. (Table 1 and 2). A significant hardness changes of MPI were recorded after 2 h of massaging at 5 rpm drum speed and after 1 h at 20 rpm drum speed. The significant massage-induced changes in texture at 5 rpm drum speed were observed in MPK muscle massaged effectively for 1 h, a corresponding changes at 20 rpm drum speed being observed in this muscle in half an hour of effective massaging, respectively (Table 1 and 2). It could be concluded that the more intensive massaging is connected with the higher decrease in hardness and chewiness of both muscles tested. A similar to our research, effect of drum-speed on muscle texture changes was observed by Rosing [24] and Lachowicz et al. [12, 13].

As shown in this work, an increase in values of texture parameters of MPK muscles subjected to massaging for 2 h and at 20 rpm drum speed were observed what may be an indication of muscle over-massaging [18].

No significant correlations between massaging time and drum speed vs. muscle cohesiveness during massaging were found (Table 1 and 2), however the longer-lasting and more intensely massaging caused an increase in muscle cohesiveness compared to the control (non-massaged) muscle. The increase in the cohesiveness, especially observed at 20 rpm drum speed, recorded in this study during massaging, may be an indication of a myofibrillar proteins extraction [17, 23, 32]. That conclusions was corroborated by data placed at table 6; long-lasting massaging, especially at high drum speed, caused an increase of exudate viscosity. As demonstrated by data obtained, regardless of drum speed, the highest rate of viscosity changes was obtained during first 2 h of effective massaging.

Table 5. The effects of massaging time and drum speed on thermal drip changes of chicken and turkey breast muscles

Effective massaging time [h]	Thermal drip [%]			
	chicken breast muscle		turkey breast muscle	
	5 rpm	20 rpm	5 rpm	20 rpm
0.	**19.5**±1.1 $^{a}_{1}$	**19.5**±1.1 $^{a}_{2}$	**22.0**±0.5 $^{a}_{1}$	**22.0**±0.5 $^{a}_{2}$
0.5	**18.0**±0.3 $^{b}_{1}$	**16.0**±0.5 $^{b}_{2}$	**21.5**±0.7 $^{ab}_{1}$	**21.2**±0.2 $^{b}_{2}$
1.0	**16.4**±0.4 $^{c}_{1}$	**12.1**±0.6 $^{c}_{2}$	**20.7**±0.6 $^{bc}_{1}$	**19.8**±0.4 $^{c}_{2}$
1.5	**13.2**±0.2 $^{d}_{1}$	**9.9**±0.3 $^{df}_{2}$	**19.9**±0.5 $^{c}_{1}$	**18.3**±0.3 $^{d}_{2}$
2.0	**10.9**±0.2 $^{e}_{1}$	**7.0**±0.3 $^{e}_{2}$	**19.0**±0.2 $^{d}_{1}$	**17.0**±0.4 $^{e}_{2}$
4.0	**8.0**±0.4 $^{f}_{1}$	**9.8**±0.3 $^{f}_{2}$	**17.6**±0.3 $^{e}_{1}$	**15.1**±0.3 $^{f}_{2}$

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Table 6. The effects of massaging time and drum speed on exude viscosity

Effective massaging time [h]	Exude viscosity [P]			
	chicken breast muscle massaged at 5 rpm	chicken breast muscle massaged at 20 rpm	turkey breast muscle massaged at 5 rpm	turkey breast muscle massaged at 20 rpm
0.	-	-	-	-
0.5	**30.7**±0.9 $^{a}_{1}$	**54.1**±1.8 $^{a}_{2}$	**35.1**±0.9 $^{a}_{1}$	**58.0**±1.8 $^{a}_{1}$
1.0	**45.8**±1.4 $^{b}_{1}$	**66.9**±2.5 $^{b}_{2}$	**50.3**±1.4 $^{b}_{1}$	**72.2**±2.5 $^{b}_{2}$
1.5	**52.3**±1.8 $^{c}_{1}$	**91.7**±3.0 $^{c}_{2}$	**59.7**±1.8 $^{c}_{1}$	**97.3**±3.0 $^{c}_{2}$
2.0	**71.9**±2.3 $^{d}_{1}$	**115.6**±3.6 $^{d}_{2}$	**89.9**±2.3 $^{d}_{1}$	**109.0**±3.6 $^{d}_{2}$
4.0	**95.5**±3.7 $^{e}_{1}$	**125.7**±4.1 $^{e}_{2}$	**107.4**±3.5 $^{e}_{1}$	**145.7**±5.8 $^{e}_{2}$

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The data of histological analysis of poultry muscles, placed at Table 3 and 4 showed a higher mean cross-sectional area and thicker peri- and endomysium of both massaged muscles compared to non-massaged (control) meat. Regardless of massaging time and drum speed, the most extensive structural elements changes were observed in chicken breast muscle.

The significant massage-induced changes in the MPI thickness of peri- and endomysium at 5 rpm drum speed were observed in muscles massaged effectively for 2 h, a corresponding changes in connective tissue thickness at 20 rpm drum speed being observed in this muscle after 1.5 h of effective massaging.

The higher rate of structure elements changes were observed in MPK muscles massaged at 5 rpm drum speed after 1.5 h and at 20 rpm drum speed in muscles massaged effectively for 1 h.

An increase by about 40% in the mean cross-sectional area of MPK muscle and by about 18% in MPI muscle after 4 hours of effective massaging at 5 rpm drum speed were observed, compared to increased by about 46 and 21% at 20 rpm drum speed, respectively.

Increased mean cross-sectional area of muscle fibres is an evidence of their swelling, induced by mechanical forces and brine [8, 27]. The changes in connective tissue thickness, may be an indication of a damage and separations of fibrils. Thus it can be inferred that it was responsible for the fastest and more intensive fibre swelling in chicken breast muscle and in it's consequence a higher reduction of hardness during massaging, than in turkey breast muscle (MPI).

The longer-lasting and more intensely massaging resulted in fibre cross-sectional area changes; the shape of fibres became more and more round. (If the rate of diameter H to V is nearer 1, the shape of fibres will be more round). As shown by presented data, this changes, as a result of an increase in brine sorption were specially observed in chicken breast muscle.

The different susceptibility of the muscles studied to massaging was evidence also by differences in the amount of cooking loss produced by them (Table 6). Comparison of two non-massaging muscles showed the turkey breast muscle to have by about 13% higher thermal drip than chicken breast muscle. After 4 h of massage at 5 and 20 rpm drum speed, the reduction in thermal drip of the turkey breast muscle amounted to about 20 and 30%, respectively, relative to the control; the chicken breast muscle thermal drip decreased by about 53 and 50%, respectively.

As demonstrated by data obtained, an increase of thermal drip being observed in MPK over 2 h effective massaging at 20 rpm drum speed, thus it can be inferred that over-massaging, and in it's consequence too intensive damage of muscle structure was responsible for the significant increase in thermal drip.

CONCLUSIONS

1. Massaging resulted in a reduction of hardness, chewiness and thermal drip, and in augmentation of cohesiveness. Depending on the massaging time and drum speed the rate of change differed between the muscles.
2. Turkey breast muscle (MPI) was the less susceptible than the other muscles tested to mechanical tenderisation thus for this reason, to achieve a significant reduction of hardness MPI required longer massaging time.
3. The effective massage at 5 rpm drum speed during 2 h did not result in any significant change in texture and structural elements in MPI, so this muscle should be effective massaged for more than 2 h or more intensely.
4. As a result of damaging chicken breast muscle (MPK) structure, longer than 2 h mechanical tenderisation at 20 rpm drum speed caused an over-massaging of meat and as the consequences an increase in hardness, chewiness and thermal drip.

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