IMPACT OF TUMBLING TIME ON PROTEIN CHARACTERISTICS DURING COOKED HAM PRODUCTION

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Abstract – In this study, the influence of tumbling time (5h30, 19h and 26h) on protein solubility and free thiol (SH) content of hams with different technological quality, i.e. normal (pH_{12h} ± 5.8), inferior (pH_{12h} ± 5.4) and mixed (pH_{12h} 5.4-5.8) quality, was investigated. Sarcoplasmic and myofibrillar protein solubility as well as total amount of free SH groups were determined on 1) the *Semimembranosus* (SM) muscles of the tumbled hams and 2) the exudate samples collected after tumbling. Increasing the tumbling time from 5h30 to 19h resulted in significantly higher myofibrillar protein solubility, especially when inferior quality hams were selected. A decreasing trend in free SH groups was observed at tumbling times longer than 5h30, independently of the technological quality of the fresh ham. Results indicated that insufficiently tumbling of fresh hams has an impact on protein characteristics during cooked ham production. However, further investigation is needed to get a better insight into the impact of more intensive tumbling on the protein characteristics.

Key Words – Meat quality, protein solubility, pork

I. INTRODUCTION

During the production of cooked ham quality, defects on the end product are often noticed [1,2]. Although the technological quality of the fresh ham has a large impact on the characteristics of the final product, effects of the used process conditions may not be underestimated. Hugenschmidt et al. [3] indicated that fresh hams of the same pig carcass, each produced to cooked ham by a different meat company, resulted in cooked hams with different end quality. Tumbling of the raw material is one of the key process steps in the production of cooked ham. It is used to damage the connective tissue and to get a good distribution of the brine [4,5]. Additionally, while meat parts are tumbled, functional proteins are set free at the surface of the meat resulting in an increase of the water holding capacity [6]. During the cooking process, the extracted proteins bind the meat parts together so that a reconstituted and sliceable product is formed. It can be concluded that suboptimal tumbling of meat parts can lead to quality defects in the final product despite a good technological quality of the raw material. As proteins play an important role during cooked ham production, changes in protein characteristics between normal and suboptimal tumbling could provide more information on the quality of the tumbling process. Functionality of proteins is related to their structural and physicochemical properties such as solubility, hydrophobicity and thiol (SH) content [7]. Sharedeh et al. [8] reported that an intensive tumbling process can lead to an increased protein solubility. Lachowicz et al. [9] stated that higher cooking losses can be observed when ham is intensively tumbled and this due to excessive structural damage. Li et al. [10] showed that less proteins are solubilized when meat parts are insufficiently tumbled which affects the brine uptake and cooking losses. Variations in free SH content can give information about protein gelation as they increase the gel strength by formation of disulfide (S-S) bridges [11].

The aim of this study was to gain better insight into the impact of tumbling time on protein characteristics, i.e. sarcoplasmic and myofibrillar protein solubility and SH content, of hams with different technological quality.

II. MATERIALS AND METHODS

Sample collection and measurements

A 3x3 experimental set-up was performed in which hams of 3 classes fresh meat quality were subjected to 3 types of tumbling processes. For each batch, 8 fresh hams were selected in a cutting room at industrial level based on pH values measured 12 hours *post mortem* in the *Semimembranosus* (SM) muscle. The selected hams were divided into normal (pH_{12h} ± 5.8), inferior (pH_{12h} ± 5.4) and mixed quality (pH_{12h} 5.4-5.8) hams. After selection, the fresh hams were transported to the laboratory and further stored at 4°C. The ultimate pH and PQM were measured 24 hours *post mortem* on the raw, deboned hams, in particular on the SM and *Biceps femoris* (BF) muscle. Using a HunterLab colorimeter, CIE $L^*a^*b^*$ color values were measured at level of the SM and BF muscle. After a 12% brine injection, the 3 classes of fresh meat quality were tumbled as given in Table 1. As the rotational speed of the barrel was 8 rpm, a total of 1200, 3360 and 4480 rotations in case of respectively 5h30, 19h and 26h tumbling was achieved.

Table 1. Tumbling conditions of the 3 classes of fresh meat quality at different tumbling times.

Tumbling process	Time (min)	Temperature (ºC)	Speed (rpm)	Vacuum (%)
Insufficient (5.5h)				
Continuous (1h)	8	2	8	90
	52	-1	8	90
Intermittent (4.5h)	10	1	8	90
	20	1	0	90
	10	1	8	0
	20	1	0	0
Conventional (19h)				
Continuous (1h)	8	2	8	90
	52	-1	8	90
Intermittent (18h)	10	1	8	90
	20	1	0	90
	10	1	8	0
	20	1	0	0
Intensive (26h)				
Continuous (1h)	8	2	8	90
	52	-1	8	90
Intermittent (25h)	10	1	8	90
	20	1	0	90
	10	1	8	0
	20	1	0	0

The 3x3 experimental set-up was carried out in duplicate. After tumbling, an aliquot of the SM muscles was kept at -20°C to determine the sarcoplasmic and myofibrillar protein solubility (mg soluble protein/g total protein) according to Claeys et al. [12] and the amount of free SH groups (nmol SH/mg protein) according to Batifoulier et al. [13]. From each batch, the exudate (= extracted proteins at the surface of the meat parts) was collected to determine protein solubility and free SH groups. Afterwards, hams were prepared to high quality, phosphate-free cooked hams in a controlled pilot plant.

Data analysis

To test significant differences between insufficient (5h30), conventional (19h) and intensive (26h) tumbling for each meat quality separately, data were subjected to a one-way ANOVA using SPSS Statistics (IBM, version 22). Tukey was performed as post hoc test and a significance level of $P < 0.05$ was maintained.

III. RESULTS AND DISCUSSION

Results of the different protein characteristics measured on the SM muscle for the different tumbling conditions of normal, inferior and mixed quality hams are shown in Table 2.

Table 2. Mean and standard deviation (SD) of the protein characteristics measured on the SM muscle after tumbling of normal (n=16), inferior (n=16) and mixed (n=16) quality hams.

Normal quality	5h30 (n=16)		19h (n=16)		26h (n=16)		
	Mean	SD	Mean	SD	Mean	SD	P
SPS (mg/g)	39.74	4.53	38.32	10.01	43.62	12.98	0.296
MPS (mg/g)	6.63	4.42	9.73	4.37	9.49	3.96	0.083
SH (nmol/mg)	63.18	22.71	62.08	29.82	45.50	12.20	0.058
Inferior quality							
SPS (mg/g)	43.37^{b}	6.44	44.55^{b}	3.87	36.38^{a}	2.76	< 0.001
MPS (mg/g)	6.03^{a}	2.49	8.27^{b}	1.78	6.55^{ab}	2.17	< 0.05
SH (nmol/mg)	72.13	32.19	67.51	23.98	57.57	15.62	0.249
Mixed quality							
SPS (mg/g)	39.21^{b}	5.58	44.88^{c}	4.60	31.73^{a}	4.51	< 0.001
MPS (mg/g)	7.60	4.53	7.14	1.72	6.52	2.58	0.628
SH (nmol/mg)	60.84^{b}	18.33	41.31^{a}	7.60	43.75^{a}	9.15	< 0.001

Different letters (a-c) indicate significant differences between tumbling processes; SPS = sarcoplasmic protein solubility; MPS = myofibrillar protein solubility; SH = thiol content.

Normal quality hams tumbled at 19h and 26h showed a slightly higher myofibrillar protein solubility (P = 0.083) compared to normal quality hams tumbled at 5h30. A decreasing trend in free SH groups was observed at processing times longer than 5h30 (P = 0.058) indicating that the longer meat parts are tumbled, the more disulfide bridges are formed which stimulates the protein gelation [11].

Conventional tumbling (19h) of inferior quality hams resulted in a significantly higher myofibrillar (P < 0.05) protein solubility than insufficiently (5h30) tumbling of inferior quality hams. Tumbling at processing times lower than 19h leads to insufficient mechanical action in the tumbler so that less functional proteins can be extracted from the muscle fibers [8]. Increasing the tumbling time to 26h did not cause higher amounts of soluble myofibrillar proteins. This might be attributed to the fact that more water is released during intensive tumbling resulting in a decrease of the total protein concentration. The amount of free SH groups gradually decreased with tumbling times longer than 5h30.

Conventional tumbling (19h) of mixed quality hams resulted in significantly higher soluble sarcoplasmic proteins (P < 0.001) compared to tumbling of mixed quality hams at 5h30. It can also be seen that an increase in tumbling time of mixed quality hams from 5h30 to 26h significantly decreased the total amount of free SH groups (P < 0.001).

Results of the different protein characteristics analyzed on the exudate collected after tumbling of normal, inferior and mixed quality hams are shown in Table 3.

Table 3. Mean and standard deviation (SD) of the protein characteristics analyzed on the exudate samples after tumbling of normal (n=2), inferior (n=2) and mixed (n=2) quality hams.

Normal quality	5h30 (n=2)		19h (n=2)		26h (n=2)		
	Mean	SD	Mean	SD	Mean	SD	P
SPS (mg/g)	29.59	8.86	35.65	8.91	43.86	0.28	0.287
MPS (mg/g)	6.30	0.61	12.67	7.29	23.77	23.85	0.543
SH (nmol/mg)	40.80	6.04	56.1	41.55	40.68	13.31	0.798
Inferior quality							
SPS (mg/g)	32.57	2.78	33.50	1.52	29.65	1.67	0.295
MPS (mg/g)	14.87	11.99	18.87	17.86	7.72	0.22	0.694
SH (nmol/mg)	49.97	23.01	41.54	10.37	45.03	7.51	0.863
Mixed quality							
SPS (mg/g)	27.69	6.18	37.96	16.87	29.97	0.55	0.630
MPS (mg/g)	7.96	2.93	24.47	24.54	6.65	0.27	0.474
SH (nmol/mg)	43.56	5.67	32.63	0.01	25.20	7.76	0.098

SPS = sarcoplasmic protein solubility; MPS = myofibrillar protein solubility; SH = thiol content

Concerning the determination of protein characteristics on the exudate samples collected after tumbling, no significant differences were observed. However, an increasing trend in sarcoplasmic and myofibrillar protein solubility in function of tumbling time was observed, especially when exudate was collected after tumbling of normal quality hams.

IV. CONCLUSION

Changes in protein solubility and total amount of free SH groups could be observed when increasing the tumbling time from 5h30 to 19h. However, an extension of the tumbling time up to 26h did not always result in an additional increase or decrease of the corresponding protein characteristic. In future research, prolongation of the tumbling time up to 40h will be carried out to get a better insight into the impact of intensive tumbling on the protein characteristics.

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REFERENCES

1. Le Roy, P., Monin, G., Kerisit, R., Jeanot, G., Cartirez, J.C, Amigues, Y., Lagant, H., Boulard, J., Billon, Y., Elsen, J.M. & Sellier P. (2001). Effets interactifs des genes RN et HAL sur la qualité de la viande: résultats obtenus lors de la fabrication du jambon cuit prétranché. Journées de la Recherche Porcine 31: 331-333.
2. Vautier, A., Minvielle, B., Boulard, J., Bouyssiere, M. & Houix, Y. (2004). Viandes déstructurés: Effet du système d'abattage et des conditions météorologiques. TechniPorc 27: 19-23.
3. Hugenschmidt, G., Hadorn, R., Scheeder, M.R.L., Silacci, P., Scherrer, D. & Wenk, C. (2010). The effects of early post-mortem pH and ultimate pH on level and amount of destructured zones in cooked cured hams. Meat Science 85: 632-639.
4. Ghavimi, B., Althen, T.G. & Rogers, R.W.(1987). Effects of tumbling at various speed on some characteristics of restructured cured beef. Journal of Food Science 52: 543-544.
5. Katsaras, K. & Budras, K.-D. (1993). The relationship of the microstructure of cooked ham to its properties and quality. Lebensmittel-Wissenschaft & Technologie 26: 229-234.
6. Patrascu, L., Ianitchi, D., Dobre, I. & Alexe, P. (2011). Effect of tumbling time and injection rate on the processing characteristics, tenderness and color of pork Biceps Femoris muscle. Food technology 35 (1): 9-18.
7. Boyer, C., Joandel, S., Ouali, A. & Culiolo, J. (1996). Determination of Surface Hydrophobicity of Fast and Slow Myosins from Rabbit Skeletal Muscles: Implication in Heat-Induced Gelation. Journal of Agricultural Science 72: 367-375.
8. Sharedeh, D., Vénien, A., Favier, R., CHekrar, F., Gatellier, P., Astruc, T. & Daudin, J.D. (2012). Incidence of mechanical action during tumbling of meat on mass transfer, tissue structure and protein solubilisation. Poster presentation at EFFoST conference, 20-23 November 2012, Montpellier, France.
9. Lachowicz, K., Sobczak, MK, Gajowiecki, L. & Zyck, A. (2003). Effect of massaging time on texture, rheological properties and structure of three pork ham muscles. Meat Science 63: 225-233.
10. Li, C., Szwzepaniak, S., Steen, L., Goemaere, O., Impens, S., Paelinck, H. & Zhou, G. (2011). Effect of tumbling time and cooking temperature on quality attributes of cooked ham. International Journal of Food Science and Technology 46: 2159-2163.
11. Wang, H., Pato, M., Pietrasik, Z. & Shand, P. (2009). Biochemical and physicochemical properties of thermally treated natural actomyosin extracted from normal and PSE pork *Longissimus* muscle. Food Chemistry 113: 21-27.
12. Claeys, E., De Vos, E. & De Smet, S. (2002). Protein solubility of longissimus from stress sensitive and stress resistant pigs. Proceedings 48th International Congress of Meat Science and Technology, 25-30 August 2002, Rome, Italy, 479-480.
13. Batifoulier, F., Mercier, Y., Gatellier, P. & Renerre, M. (2002). Influence of vitamin E on lipid and protein oxidation induced by H2O2-activated MetMb in microsomal membranes from turkey muscle. Meat Science 61: 389-395.

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