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Effect of microwave cooking on the microstructure and quality of meat in goat and lamb

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ABSTRACT

Fat cell distribution in the structure of semimembranosus muscle of goat and lamb was studied. The effect of various heating methods including conventional, domestic and industrial microwave were investigated using fluorescent light microscopy. Frequency used for microwave heating was 2450 MHz with two wattages levels of 700 (domestic microwave) and 12000 (industrial microwave). All samples were heated to internal temperature of 70 °C. The roasted samples in conventional oven were compared with microwave cooking. Fat distribution was different in various heat treatments. The roasted samples had greater fat retention in semimembranosus muscle. Results showed that uneven distribution of fat in muscle system influenced fat loss during cooking. The fat cells in the interior of muscle were lost more slowly compared to the fat located near the surface of the muscle. The overall migration of fat globules during microwave cooking was higher than conventional cooking.

1. Introduction

The muscle system can be identified as lean and lipid portions. The lipid component in muscle structure is located in groups of spherical fat cells. These fat cells can be shown using fluorescent microscopy. Fat cells have the same originality to connective cell (fibroblasts) and localization of fat cells is normally in the perimysium and endomysium (Lepetit, 2007; Tornberg, 2005). The accumulation of intramuscular fat in meat had been an area of interest. Studies have been carried out on intramuscular fat with regard to its effect on the quality of meat (Wood et al., 2003).

Several methods have been developed for assessing intermuscular fat (Cook & Bray, 1961; Wood et al., 2003, 2008). Difficulties in this area have arisen from interpretation of results when the variable distribution and level of fat in muscles such as the longissimus dorsi are taken into account (Cook, Bray, & weckel, 1964). A theory about the effect of muscle structure on the pattern of fat deposition has been suggested by Wood et al. (2003). Other researchers have studied the fat cell by determination of fat cell diameter in ovine and bovine muscle during different stages of growth (Wood et al., 2003). Savell and Cross (1988) have explained the important role of fat in the palatability of beef and lamb. They believed that fat may affect juiciness by enhancing the water holding capacity of meat, by sensation of juiciness or by stimulating salivary flow during Mastication. The cooking process affects the fat content of beef (Johansson & Laser-Reuterswaerd, 1987; Bejerholm & Aaslyng, 2003). Quantitative measurement of visible fat and lean in meat was done by applying video image analysis. Results showed little variation within fat depots, but there were considerable differences between fat depots (Newman, 1987; Russ, 2005).

Since fat content is very crucial in quality and tenderness of meat after cooking, usually it must be attempted to apply the suitable heating technique. The cooking method will directly affect the fat distribution and subsequent tenderness of the meat. By using the correct heat treatment, it is possible to have less fat loss from the muscle. On the other hand such a relationship of fat contents leads to better quality and tenderness of heated muscle. The proper duration of heating is one of the essentials for success in heat processing of meat (Kadim, Mahgoub, & Purchas, 2008). Fat tissue firmness (hardness), shelf life (lipid and pigment oxidation) and flavour have technological effect on the meat quality. Although there have been suggestions that dietary fatty acids influence tenderness and juiciness, these are more likely to be affected by the total amount of fatty acids rather than individual ones. The effect of fatty acids on firmness is due to the different melting points of the fatty acids in meat (Wood et al., 2003).

Marbling has been researched as a factor influencing the tenderness of meat in various animal species. Marbling is mostly associated with the juiciness and flavour of fresh meat products. The total fat content of muscle (i.e. neutral lipid plus phospholipids), termed marbling fat, has long been recognized as a factor in eating quality, especially juiciness and tenderness. There are several

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possible explanations for a positive effect of lipid on tenderness, including the location of neutral lipid in fat cells within the perimysium which may have a physical effect in separating muscle fiber bundles, beginning the process of tenderization by "opening up the muscle structure". Lipids can also entrap the moisture in muscle which leads to improvement of juiciness (Wood et al., 2003). The influences of several heat treatments including pan broiling, roasting and broiling in water on the fat content of beef were studied (Johansson & Laser-Reuterswaerd, 1987; Bejerholm & Aaslyng, 2003). The advantage of roasting to other cooking methods is larger fat retention in semimembranosus muscle. No study was done to compare the effect of various heating methods on the quality and microstructure of meat in goat and lamb. In this study the effect of microwave cooking on the microstructure and quality of goat and lamb meat was investigated and compared with conventional heating methods.

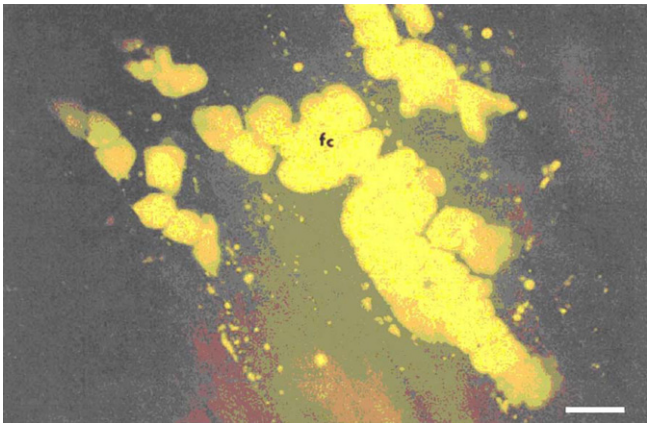

Fig. 1. Distribution of fat cells in microstructure of lamb raw SM muscle. Magnification: ×25, fc: fat cells, scale bar: 100 μm.

2. Materials and methods

2.1. Lamb and goat meat preparation

About 10 kg of deboned meat chunks, 1–2 kg in size were obtained from Ovine and Chevon within 5 h of being slaughtered by the traditional halal method from a local meat market. They were packed in low density polyethylene (LDPE) bags and conditioned at 4 °C for 24 h.

2.2. Microstructure analysis

Olympus system microscope (model BHC with BH2-RFL reflected light fluorescent attachment, Tokyo, Japan) was used for observation of fat cells distribution in Semimembranosus Muscle (SM). Thirty specimens were cut by Lipshaw microtom (model 70 A, Chicago, IL, USA) for each treatment (Yarmand & Sarafis, 1997). For measuring cook loss, the weight loss of the samples was determined before and after heating. Conventional heating at 163 °C was done by an oven (KH208, Shenzhen, China) to reach an internal temperature of 70 °C. Domestic and industrial microwave heating were applied at 2450 MHz. The wattages for domestic and industrial microwave were 700 and 12000 W, respectively. The internal temperature was regulated to 70 °C in all heat treatments. Nile Red was used as a selective fluorescent stain for the intracellular location of lipid droplets.

2.3. Statistical analysis

The experiment was replicated three times and the generated data were evaluated statistically by analysis of variance (ANOVA) at the institute's computer centre. Critical difference and Duncan's multiple range tests were used for comparing the means. The smallest difference ($D_{5\%}$) for two means to be significantly different ($P < 0.05$) is reported.

3. Results and discussion

Fat content affects tenderness, juiciness and flavour of meat considered as three aspects of eating quality. As shown in raw sample of lamb (Fig. 1), fat cells were dispersed in a protein matrix without showing fat coalescence. Fat distribution was altered by using various heat treatments such as conventional and microwave heating. Generally, uneven distribution of fat in muscle system influenced fat loss during cooking and the fat cells which are located in the interior of muscle, were lost more slowly compared to the fat cells located near the surface of the muscle. Fat hardness is very important from a heating point of view but the mobility of fat is inversely associated with the hardness of fat. As the fat softens, it becomes larger and approaches a maximum when solid fat content reaches 0%. As temperature is risen, the fat cells start to become soft and coalescence. This is in agreement with Lee, Carroll, and Abdollahi (1981). As a result, the fat cells did not remain globular during cooking but joined each other and formed larger droplets without escaping from the matrix to produce a single phase in both lamb and goat (Fig. 2). Conventional heating of goat semimembranosus muscle led to deformation and separation of globular fat cells from the matrix. In addition, the composition of fat is probably slightly different in lamb and goat. This might affect the melting point feature of the fat and has resulted in variation in melting point. It was shown that the total lipid of semimembranosus muscle contained higher concentrations of 18:3, 20:5 and 22:6 in the grass-fed lambs (Fisher et al., 2000).

During microwave heating of goat semimembranosus muscle, overall migration of fat globules was higher than conventional heating and also fat loss observed (Figs. 3 and 4). Fat content reduced in lamb samples after heat treatment, while in goat semimembranosus muscles were in contrast with other results. As shown in Table 1, the amount of fat in raw lamb and goat was reduced after heating. This reduction was greater in microwave cooked goat, while was seen less in lamb. Denaturation of protein during heating caused matrix (tissue) to break down and resulted in the fat separation during cooking (Thomas, Anjaney-

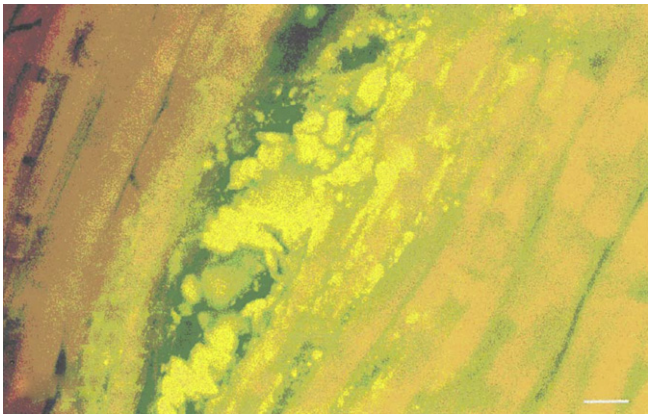

Fig. 2. Illustration of goat SM microstructure cooked by conventional heating method. The beginning of deformation and coalescence of fat cells are visualised in this picture. Magnification: ×100, scale bar: 20 μm.

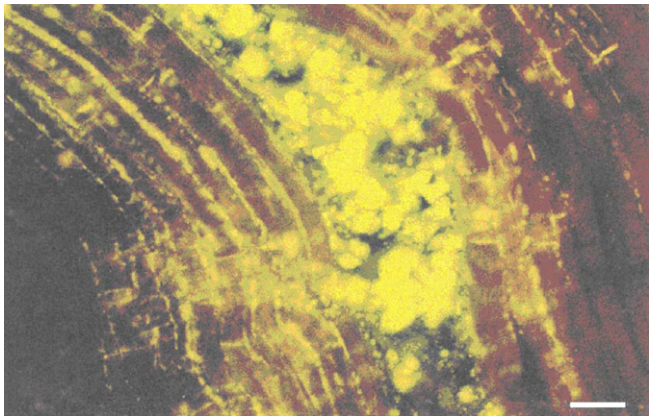

Fig. 3. Illustration of domestic microwave heated SM muscle of lamb. Shrinkage of bundle in muscle fibers is apparent. Magnification: ×25, scale bar: 100 μm.

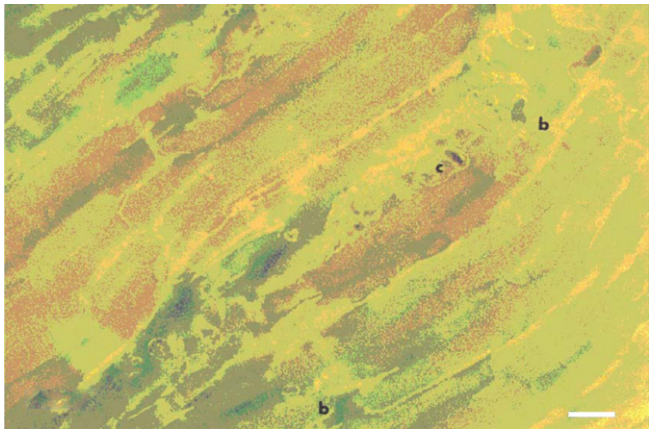

Fig. 4. Illustration of domestic microwave heated SM muscle of goat. Breakdown (b) and coalescence (c) of fat cells are visualised. Magnification: ×100, scale bar: 20 μm.

ulu, Gadekar, Pragati, & Kondaiah, 2007). In domestic microwave cooking, it was very hard to observe coalescence of fat cells except goat specimens. Most probably the high electromagnetic field which was originated from high wattage from the industrial microwave heating had separated fat cells from the muscle matrix and thus enhancing the cooking loss. This could be the reason why cook loss in microwave heating particularly in industrial situations, was more than that in the conventional method.

As shown in Fig. 5, the mean cooking loss in lamb SM heated in conventional method was 26.96% and increased during microwave heating to 27.67% (700 W) and 28.51% (12000 W). Similar results were obtained for goat SM muscle. Goat SM showed 26.61% cooking loss for conventional cooking which was increased to 29.29 and 30.70% at two power levels for microwave cooking, respectively. In conclusion, the results showed that SM muscle cooked in a microwave oven had greater cooking loss

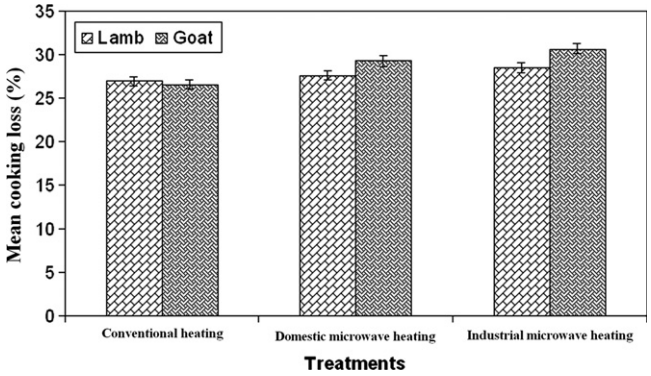

Fig. 5. Cook loss measurements in lamb and goat SM muscle. Error bars indicate standard errors of the mean values.

than that cooked in a conventional oven. This can be considered as a disadvantage for microwave heating. Moreover, transfer of fat globules can occur through the evaporation of moisture in SM muscle which has trapped vapour in the casing. This casing was used to retain cylindrical shape for muscle specimen. As shown in domestic cooked goat (Fig. 4), deformation of fat cells was apparent. Fat cells separated from goat muscle fibers during such treatment. Fat cell size can influence the functional property of the fat (Wilson, Dyett, Hughes, & Jones, 1981). Generally results showed that the size of fat cells in structure of lamb SM muscle was greater than goat. The internal portion of muscle had greater fat cells in comparison to external part of the muscle structure. Similar results were observed for fat cells in goat muscle.

It has been demonstrated that the amount of fat has an indirect influence on juiciness and eating quality of meat (Miller, 1994; Wood et al., 2003). The fat content in muscle can influence the heat transfer. The existence of fat in the structure of muscle is likely to cause a reduction in heat transfer. Therefore, the muscle with high fat content has less heat transfer rate than that in lean muscle. This affects the quality of cooked meat. The reduction of heat transfer rate can decrease the risk of heat shock on protein degradation and the liberation of moisture (Herrero, 2008). Based on this hypothesis, meat with a higher amount of fat requires more time to cook compared to meat with a lower amount of fat because heat transfer by conduction takes place through the muscle fibers. This negates the above hypothesis unless there is a layer of intermuscular fat.

Results showed that lamb SM muscle had a higher amount of fat compared to goat, so that the heat transfer rate would be slower in lamb meat resulting in increased cooking time. In contrast to this, goat SM muscle had a longer cooking time and showed a slower rate of heat transfer in its structure. Thus, it can be said that several parameters including meat source, original texture, thickness of muscle fibre, water holding capacity as well as fat content and distribution can influence heat transfer during cooking. Further studies are needed to understand the relationship between heat transfer and fat distribution in the muscle.

Table 1
Fat percent in semimembranosus muscle of lamb and goat in various heating methods (Mean ± Standard deviation)

Treatment	Raw meat	Conventional heating	Domestic microwave heating	Industrial microwave heating
Lamb	5.98 ± 0.24[a]	5.00 ± 0.18[a]	5.95 ± 0.18[a]	5.90 ± 0.18[a]
Goat	5.33 ± 0.17[a]	3.23 ± 0.23[b]	2.33 ± 0.26[c]	2.34 ± 0.12[c]

[a,b,c] Means in the same row followed by different letters were significantly different ($P < 0.05$).

4. Conclusions

Cooking loss has an important effect on the eating quality of meat. The amount of fat in raw lamb and goat SM muscle was reduced after heating. In microwave heating the fat reduction in goat SM muscle was greater than conventional heating. The cooking loss was also greater in goat SM while in lamb was less. As a result, microstructure of lamb and goat SM muscle might have an influence on the cooking loss and most probably initial distribution of fat cells plays an important role (Garcia-Garrido, Quiles-Zafra, Tapiador, & Luque de Castro, 1999). The fat cells in the interior of muscle, lost more slowly compared to the fat located near the surface of muscle. The overall migration of fat globules during microwave cooking was higher than conventional cooking.

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References

Bejerholm, C., & Aaslyng, M. D. (2003). The influence of cooking technique and core temperature on results of a sensory analysis of pork-depending on the raw meat quality. *Food Quality and Preference, 15*, 19–30.

Cook, C. F., & Bray, R. W. (1961). A macro photographic technique for the quantitative determination of marbling and its relative distribution in meat. *Food Technology, 15*, 540–546.

Cook, C. F., Bray, R. W., & weckel, K. G. (1964). Variations in the quantity and distribution of lipid in the bovine longissimus dorsi. *Journal of Animal Science, 23*, 329–334.

Fisher, A. V., Enser, M., Richardson, R. I., Wood, J. D., Nute, G. R., Kurt, E., et al. (2000). Fatty acid composition and eating quality of lamb types derived from four diverse breed production systems. *Meat Science, 55*, 141–147.

Garcia-Garrido, J., Quiles-Zafra, R., Tapiador, J., & Luque de Castro, M. (1999). Sensory and analytical properties of Spanish dry-cured ham of normal and defective texture. *Food Chemistry, 67*, 423–427.

Herrero, A. M. (2008). Raman spectroscopy a promising technique for quality assessment of meat and fish: A review. *Food Chemistry, 107*, 1642–1651.

Johansson, G., & Laser-Reuterswaerd, A. (1987). Effect of cooking on fat content of beef and pork. *Proceedings of the European meeting of meat research workers, 1*, 203–207.

Kadim, I.T., Mahgoub, O., Purchas, R.W. (2008). A review of the growth, and of the carcass and meat quality characteristics of the one-humped camel (Camelus dromedaries). doi:10.1016/j.meatsci.2008.02.010.

Lee, C. M., Carroll, R., & Abdollahi, A. (1981). A microscopical study of the structure of meat emulsions and its relationship to thermal stability. *Journal of Food Science, 46*, 1789–1793.

Lepetit, J. (2007). A theoretical approach of the relationships between collagen content, collagen cross-links and meat tenderness. *Meat Science, 76*, 147–159.

Miller, R. K. (1994). Quality Characteristics in Muscle Foods. In D. M. Kinsman (Ed.) (pp. 301–305). New York: Chapman and Hall.

Newman, P. B. (1987). The use of video image analysis for quantitative measurement of visible fat and lean in meat. Lipid content variation in commercial processing beef and its prediction by image analysis. *Meat science, 19*, 129–137.

Russ, J. C. (2005). *Image Analysis of Food Microstructure*. Boca Raton: CRC Press. pp. 21–369.

Savell, J.W., Cross, H.R. (1988). The role of fat in the palatability of beef, pork and lamb. In Designing foods, animal product options in the market place (pp. 78–224). Washington: National Academy Press.

Thomas, R., Anjaneyulu, A. S. R., Gadekar, Y. P., Pragati, H., & Kondaiah, N. (2007). Effect of comminution temperature on the quality and shelf life of buffalo meat nuggets. *Food Chemistry, 103*, 787–794.

Tornberg, E. (2005). Effects of heat on meat proteins. Implications on structure and quality of meat products. *Meat Science, 70*, 493–508.

Wilson, N. R. P., Dyett, E. J., Hughes, R. B., & Jones, C. R. V. (1981). *Meat and Meat Products. Factors Affecting Quality Control*. London: Applied Science publisher. pp. 133–175.

Wood, J. D., Enser, M., Fisher, A. V., Nute, G. R., Sheard, P. R., Richardson, R. I., et al. (2008). Fat deposition, fatty acid composition and meat quality: A review. *Meat Science, 78*, 343–358.

Wood, J. D., Richardson, R. I., Nute, G. R., Fisher, A. V., Campo, M. M., Kasapidou, E., et al. (2003). Effects of fatty acids on meat quality: A review. *Meat Science, 66*, 21–32.

Yarmand, M. S., & Sarafis, V. (1997). An improved maceration technique with polarised light microscopy in the study of muscle. *Egyptian Journal of Food Science, 25*, 425–431.