THE EFFECT OF FREEZING AND THAWING ON MEAT QUALITY OF BEEF LOINS

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Abstract – Meat which is frozen and thawed will undergo physical and chemical changes and the rate at which meat is frozen could affect quality. Meat is frozen to extend shelf-life and take advantage of price fluctuations. In this study we compared colour, water holding capacity (WHC), drip loss, Warner Bratzler Shear Force (WBSF) and sensory attributes of fresh and frozen steaks. Twenty one beef loins were aged for 14 days, processed into steaks and vacuum packed. Three treatment groups namely, 1) Fresh (control), 2) Slow frozen (domestic freezer) and 3) Quick frozen (blast freezer). Each parameter had a sample number of n=21. Both freezing groups recorded twice as much thawing loss compared to the fresh group (P<0.001). No significant differences for WHC were found between any of the groups. Frozen samples reflected less light (P=0.049), had lower chroma and higher hue angle values and higher levels of metmyoglobin compared to the fresh samples (P<0.001). Frozen samples also recorded lower WBSF (P<0.001) but this was not supported by sensory differences. Although frozen meat exhibits poorer visual quality and excessive drip eating quality should not differ from fresh meat.

Key Words – freezing, beef, colour, drip loss, tenderness.

I. INTRODUCTION

The world is becoming more global and the distance between the producer and consumer is increasing. Freezing is widely used to increase the storage life of meat (1). Meat processors also freeze meat in an attempt to stabilize the price to increase profitability and retailers freeze cuts to take advantage of any wholesale price fluctuations and have a greater flexibility in inventory (2, 3).

The quality of frozen meat depends on the specific procedures used to freeze, store (duration, temperature and temperature fluctuations) and thaw the meat, as many physical changes happen during freezing and thawing (4,5,6). Freezing meat damages the cell membranes and results in a lower water holding capacity (WHC) (2). Freezing rate has an effect on the formation of ice crystals. A fast freezing rate leads to the formation of smaller ice crystals and therefore less structural damage and lower purge, where the opposite is true for slower freezing rates (7). The conditions in which frozen meat is stored will affect quality as temperature fluctuations can lead to ice recrystallization resulting in an increase in structural damage and purge (5). Frozen meat, due to enzymatic reactions which do not cease but merely slow down, is prone to deterioration during storage, mainly in the form of lipid oxidation and protein degradation (8). Both processes can affect the aroma and flavour of the final product. In addition, all forms of oxidation are associated with one another and therefore both lipid and protein oxidation, through the formation of pro-oxidants, increase the formation of metmyoglobin (MetMb) leading to poorer colour quality in frozen meat (9, 10). The general consensus is that tenderness (WBSF) improves with freezing due to continued proteolyses and loss of structural integrity (breakdown of myofibrils) as a result of the formation of ice crystals and recrystallization (10).

In general, consumers tend to prefer meat which has not been frozen as it is perceived to be of a lesser quality (11). South African consumers often buy fresh meat in bulk and then freeze it at home. The aim of this study was to compare shear force, drip loss, colour and sensory attributes of frozen meat to that of fresh meat as well as investigate the differences between 2 freezing rates (commercial vs. domestic).

II. MATERIALS AND METHODS

Whole loins (*M. longissimus dorsi*) were collected from 21 carcass sides at a commercial deboning plant. Carcasses were electrically

stimulated for 20 s with a low voltage ECS-1 Jarvis stimulator (ECS-1 Jarvis stimulator, Output: Rectangular DC wave, 150V, maximum amplitude 17Hz, 5ms pulse width, RMS voltage below 50V, Jarvis Products Corporation RSA (Pty) Ltd). pH and temperatures of the loin muscle during the course of rigor mortis reflected ideal rigor conditions (12) described as pH>6 when muscle temperature was above 35 °C and pH<6 when muscle temperature was below 10 °C. In addition all pH_u values (18 h) were below 5.7.

The loins were vacuum-packed and aged for 14 days and then processed into 25mm steaks that were allocated to three treatment groups namely, fresh (FR, used as a control), slow frozen (SF) in a domestic freezer for 18h reaching a core temperature of -20ºC and quick frozen (QF) in a blast freezer for 3h reaching -30ºC (Fig. 1). The temperature was monitored by a YCT thermostat logger (YC-747UD model, Taiwan, type K thermo couple).

Purge (24h in vacuum packaging) and thawing loss were determined expressed as a percentage of the original weight of the cut. WHC of samples was determined using the filter paper press method described by Irie *et al.* (13).

For sensory analyses and WBSF 3 steaks from each loin cut were prepared according to an oven-broiling method using direct radiant heat (200°C) [14] to an end temperature of 70°C. Coded bite size samples from 2 steaks were presented to 10 trained panel members to evaluate flavour and aroma intensity, juiciness and 3 aspects of tenderness using an 8-point structured category scale with verbal descriptors. WBSF was performed on 6 x 12.5 mm (diameter) cores removed from the remaining steak after being cooled down to room temperature (18°C).

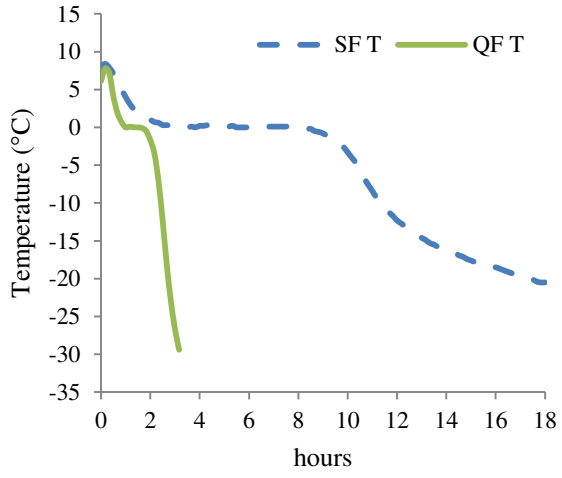

Fig. 1: Temperature profile (T) of slow frozen (SF) and quick frozen (QF) samples.

Instrumental colour (CIE: L*a*b*) and myoglobin fractions were measured with a Konica-Minolta 600d spectrophotometer and SpectraMagic NX Pro software package (Konica-Minolta, Japan) on 3 random positions 60 min after steaks were removed from vacuum packaging (D65 illuminant, di 8° de 8°, observer angle 10°, measurement aperture 8 mm, spectral component excluded). Reflectance was measured from 400 to 740 nm in increments of 10 nm. The myoglobin fractions MetMb, deoxymyoglobin (DeOxyMb) and oxymyoglobin (OxyMb) were calculated according to Krzywicki [15] using the reflex attenuation (log 1/R) at the isobestic points 572, 525 and 473 nm (calculated by linear interpolation), and at 730 nm. Chroma was calculated as square root of $a^{*2} + b^{*2}$ and hue angle was defined as $\tan^{-1}$ (b/a)(16).

Data of WBSF, drip loss, WHC, colour and sensory attributes were subjected to analysis of variance with freezing method as the main effect (17).

III. RESULTS AND DISCUSSION

Both the slow frozen and quick frozen treatments recorded twice as much thawing loss compared to the drip loss of the fresh samples (P<0.001, Table 1). This was expected due to the formation of ice crystals causing damage to the structure of the muscle (2) and was in agreement with findings of other trials (11, 18). Our findings however showed no significant difference between the two freezing rates. This was unexpected as a faster freezing rate normally leads to smaller ice crystals and less structural damage (7). However, Ngapo *et al.* (19) reported that initially samples frozen at a faster rate produced thawing losses similar to that of the

fresh samples while slow frozen samples had increased thawing losses. However after 4 weeks storage, the frozen samples recorded higher thawing losses compared to the drip loss in fresh samples irrespective of initial freezing rates, suggesting that recrystallization occurred. In addition, there was also no difference in thawing loss between samples after 4 weeks storage compared to the slow frozen samples with no storage, suggesting there is a maximum crystal size which is formed. Hansen *et al*. (20) also suggested a storage temperature of -55 ºC would be ideal to prevent any changes in quality during storage which is significantly lower than the conditions our meat was stored at. In our study after reaching their final temperature of -30 °C in the blast freezer, the QF samples were stored at -20 °C for approximately 2 weeks. This is possibly the same practice in commercial processing plants and could have caused recrystallization and formation of larger ice crystals.

Table 1 Effect of freezing method on meat quality
FR: fresh, control; QF: quick frozen, blast freezer; SF: slow frozen, domestic freezer

Attribute	FR	QF	SF	SEM	*P* value
Moisture:					
Drip/ Thaw loss	1.6[a]	3.1[b]	3.1[b]	0.118	<0.001
WHC	0.39	0.37	0.38	0.008	0.537
Colour:					
L*	38.5[b]	36.7[a]	36.9[ab]	0.571	0.049
Chroma	21.0[b]	18.0[a]	18.3[a]	0.413	<0.001
Hue	42.8[a]	49.5[b]	48.7[b]	0.955	<0.001
MetMb	17.1[a]	37.6[b]	35.0[b]	1.269	<0.001
DeOxyMb	20.1	19.3	21.0	0.770	0.299
OxyMb	62.8[b]	43.1[a]	44.0[a]	1.465	<0.001
WBSF	3.6[b]	2.7[a]	2.8[a]	0.158	<0.001
Sensory:					
Aroma	5.5	5.5	5.5	0.059	0.866
Juiciness	5.0	4.9	4.9	0.078	0.830
Flavour	5.1	5.2	5.2	0.058	0.541
First bite	5.7	6.0	5.6	0.132	0.149
Overall tenderness	5.6	5.9	5.6	0.126	0.118
Residue	5.2	5.5	5.2	0.125	0.095

[abc] Means with different superscripts are significantly different ($P < 0.05$)
SEM –standard error of means

Frozen samples showed lower values for L* (less light reflected, P=0.049) compared to fresh samples and this could be attributed to the samples being drier due to the increased drip loss (Table 1). Frozen samples had an overall poorer colour quality (P<0.001) with a lower chroma value (meat a duller colour) and higher levels of MetMb (meat a browner colour) accompanied by lower levels of OxyMb when compared to the FR samples. This is in agreement with the findings of Leygonie *et al*. (21) and can be attributed to an increase in pro-oxidants due to lipid and protein oxidation (9) and the denaturing of the globin moiety myoglobin molecule (4) which occurs during freezing and storage. There were no significant differences in colour between the freezing methods and this could possibly be due to the storage time involved.

The two methods of freezing had lower values for WBSF (Table 1) and were therefore more tender compared to the fresh steaks (P<0.001). This could be due to the breakdown of the fibres due to structural damage occurring during the formation of ice crystals. Lower WBSF values were however not supported by higher sensory scores for tenderness. Likewise there were no differences for any of the other sensory attributes. This is in agreement with Muela *et al*. (22) who found no differences in sensory attributes between fresh and frozen meat scored by a trained taste panel and concluded that consumers should have no concerns about buying frozen meat or consuming thawed meat.

IV. CONCLUSION

Freezing meat results in a product that has poorer visual quality and excessive drip loss but the potential to be more tender than fresh meat. Under the conditions of this study, rate of freezing had no effect on meat quality although this difference could have been negated due to storage time. Freezing had no effect on sensory perceptions and the eating quality of properly frozen meat, domestic or industrial, should therefore not differ from fresh meat. Consumer resistance will however have to be overcome to sell frozen meat successfully.

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