QUALITY, BACTERIOLOGY AND SHELF LIFE OF THAWED PORK

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SUMMARY: The current study was designed to determine the effects of freezing (-30°C, 90 days) upon muscle quality, bacterial growth and retail shelf life of thawed (2°C, 2 days) pork chops which were classified, prior to freezing, on the basis of subjective quality: pale, soft, exudative (PSE), normal and dark, firm, dry (DFD). Although effects were small, frozen/thawed pork had significantly higher pH, more soluble protein and darker color than fresh pork.

Bacterial growth and retail shelf life were determined for loin chops under simulated retail conditions. In comparison to fresh, the lag phase of growth was shorter on frozen/thawed pork. However, for either treatment, the lag phase was longest on PSE pork and shortest on DFD pork. Freezing/thawing or muscle quality had only limited effects on the bacterial generation time.

Freezing/thawing produced a significant reduction in the appearance shelf life of loin chops but had no effect upon the odor. Apart from these treatment effects, the deterioration of retail appearance was most pronounced for PSE pork, while DFD pork was most susceptible to the development of objectionable odors.

Significant muscle quality by treatment interactions were observed for muscle pH, soluble protein and appearance shelf life but not with L^* value, bacterial growth or odor shelf life. It was concluded that if thawed pork is to be marketed or utilized for research one should anticipate effects upon objective measures of muscle quality, bacterial growth and retail appearance.

INTRODUCTION: The preservation of meat by freezing and the merchandising of frozen/thawed product improves marketing flexibility. Within the context of research, it is often desirable to select and freeze muscle of a specific quality until sufficient quantities have been accumulated to initiate experiments. However, freezing/thawing can effect significant changes in meat bacteriology. In this regard, freezing/thawing has been observed to reduce bacterial populations (Sulzbacher, 1950; Nassos et al., 1988), extend the lag phase of bacterial growth (Kitchell and Ingram, 1960; Lowry and Gill, 1985) and limit the rate of bacterial growth (Sulzbacher, 1952). The effects of freezing/thawing on meat microbiology and spoilage has been reviewed (Jul, 1984; Lowry and Gill, 1985).

Quality changes, associated with freezing/thawing have been less well defined. There would appear to be few effects upon pork color (Nilsson, 1969, Nocito et al., 1973; Jeremiah, 1980) or palatability traits (Jeremiah, 1980) but dramatic increases in drip losses have been attributed to freezing/thawing (Jeremiah and Wilson, 1987). Studies with beef have revealed that protein solubility was largely unaffected for up to 60 d of frozen storage (Wagner and Anon, 1986). Despite the preceding there is a lack of quantitative data for pork, particularly the potential interactive effects of freezing/thawing and muscle quality. Thus, the current study was designed to determine the effects of freezing upon objective quality measures, bacterial growth and retail shelf life for thawed muscle representative of the pale soft and exudative (PSE), normal and dark, firm, dry (DFD) pork muscle quality groups.

MATERIALS AND METHODS: Ten boneless backs, representative of three pork quality types (PSE, normal, DFD) were selected from a commercial abattoir using the subjective evaluation of appearance and texture according to Agriculture Canada Pork Quality Standards (Anonymous, 1984). Sixteen, 2 cm loin chops were cut along the length of the longissimus dorsi (LD) muscle and alternately assigned to a fresh or frozen storage treatment. Loin chops subjected to the freeze/thaw treatment were vacuum packaged, frozen for 90 days at -30°C and thawed at 2°C for 2 days prior to analyses.

Methods for the subjective determination of muscle quality, bacterial growth and retail shelf life have been described in detail (Greer and Murray, 1988).

Loin chops from the centre and each end of the LD muscle were used for objective measures of pork quality. The pH of the muscle was measured in duplicate on each of the three chops using a Fisher Accumet portable pH meter fitted with a spear type Orion electrode. CIE color coordinates (L*, a*, b*) were measured in duplicate on the same three chops with a Minolta Chroma reflectance meter. Following grinding the LD muscle from the three chops, protein solubility was measured according to the method of Barton-Gade (1984).

To simulate retail conditions, loin chops were wrapped in an oxygen permeable film and displayed for 8 days in a fan-assisted, horizontal-type retail display case illuminated for 12 h/day with incandescent lighting to give 1000 lx at the meat surface. Under these conditions the surface temperature of the chops approximated 10°C. For each of the two treatments (fresh, frozen/thawed), five loin chops/quality group were evaluated by an experienced 5-member sensory panel on days 0, 2, 4, 6 and 8 of retail display. Appearance shelf life was arbitrarily defined as the time in days to reach 3.5 on a 7-point subjective scale and odor shelf life as the time in days to reach 3.0 on a 5-point subjective scale.

Loin chops subjected to sensory evaluation were also sampled at the same time to quantify bacterial growth. Sampling involved homogenization of 10 cm^2 of tissue, serial dilution in 0.1% peptone water and surface plating. Total psychrotrophic bacteria were enumerated following incubation of Plate Count Agar (Difco) for 7 days at 7°C. Pseudomonads, Brochothrix thermosphacta and enterics were determined as described by Baird et al. (1987). The lag phase of bacterial growth and the generation time were determined following a semi-logarithmic plot of time on retail display vs log counts.

Differences in objective muscle quality measures, lag phase, generation time and retail shelf life were determined by two-way analysis of variance including, as classification variables, quality group (PSE, normal, DFD) and treatment (fresh, frozen/thawed) as well as their interaction.

RESULTS AND DISCUSSION: There are reports relating variation in bacterial growth (Rey et al., 1976; Greer and Murray, 1988) and objective muscle quality measures (Van der Wal et al., 1988) to inherent differences in pork quality. Few, however, have published data concerning the effects of pork freezing/thawing and the potential interaction with muscle quality.

The data in Table 1 show the effects of pork muscle quality and freezing on pH, soluble protein and L* values. In accordance with

Table 1. Effect of the quality of the longissimus dorsi muscle and freezing on objective measures of pork quality

Quality Group[1] (n = 10)	Treatment	Objective Quality Measure: pH	Soluble Protein (g/kg)	L*[2]
PSE	Fresh	5.39[a]	119[a]	60.1[a]
	Thawed	5.56[b]	122[a]	57.8[b]
Normal	Fresh	5.55[b]	183[b]	51.4[c]
	Thawed	5.66[c]	187[c]	50.3[d]
DFD	Fresh	6.43[d]	205[d]	40.2[e]
	Thawed	6.53[e]	211[e]	38.2[f]
Standard Error		0.01	1.4	0.3

[1] Agriculture Canada pork quality standards (Anonymous, 1984).

[2] Color intensity (CIE).

[a-f] Least squares means within the same column with a similar superscript are not different ($P > 0.05$).

other reports (Van der Wal et al., 1988), PSE demonstrated a lower ultimate pH, paler color (greater L* value) and less soluble protein and DFD had a higher pH, more soluble protein and darker color than normal pork.

More importantly, freezing/thawing produced minor but significant effects ($P<0.05$) upon objective quality measures. Significant ($P < 0.05$) interactions were determined involving quality group and treatment for both pH and soluble protein but not L^* value. Despite the minor contribution of interactions between treatment and quality group, frozen/thawed pork had a higher pH, more soluble protein and a darker color than fresh pork. Also, frozen/thawed pork had lower a* values and higher b* values than fresh (data not shown).

The differences in objective muscle quality due to freezing/thawing in the present study were relatively small and may be of little practical consequence in comparison to the larger differences between muscle of different inherent quality. Thus results are consistent with those of others who have reported that freezing/thawing had little or no effects upon pork color (Nilsson, 1969; Jeremiah, 1980) or the protein solubility of beef muscle (Wagner and Anon, 1986).

The data in Table 2 show the effects of pork quality and treatment upon the growth parameters of the total psychrotrophic bacterial population during the simulated retail display of loin chops. It

Table 2. Effect of the quality of the longissimus dorsi muscle and freezing on psychrotrophic bacterial growth on pork

	Lag Phase (days)	Generation Time (days)
Quality Group (n = 20)[1]		
PSE	1.75^a	0.27^a
Normal	1.65^a	0.20^b
DFD	0.76^b	0.21^b
Standard Error	0.13	0.01
Treatment (n = 30)		
Fresh	1.55^a	0.23^a
Thawed	1.23^b	0.22^a
Standard Error	0.10	0.01

[1]See Table 1.

[a-b]Least squares means within the same column with a similar superscript are not different ($P > 0.05$).

should be stressed that these data were selected for the purpose of demonstration and that pseudomonads, Brochothrix thermosphacta and enterics responded in a similar fashion.

Since the lag phase and generation time were not influenced by a significant interaction ($P>0.1$) between pork muscle quality and treatment, the data in Table 2 show the main effects, only. The lag phase of bacterial growth was significantly shorter on DFD ($P<0.05$) in comparison to PSE or normal pork. Although the generation time of psychrotrophic growth was significantly longer on PSE pork ($P<0.05$) this proved to be an exception and in consideration of all four bacterial groups and both treatments there were few statistically significant effects of pork muscle quality on the bacterial generation time (data not shown).

These findings support previous conjecture (Greer and Murray, 1988) that pork muscle quality had more significant effects upon the lag phase of bacterial growth than upon the generation time. Other researchers have also concluded that muscle quality can effect the duration of the bacterial lag phase (Rey et al., 1976; Newton and Gill, 1978). The more rapid onset of bacterial growth on DFD beef muscle has been attributed to the higher ultimate pH (Newton and Gill, 1978).

Although the lag phase of bacterial growth was reduced ($P<0.05$) by freezing/thawing, the generation time was not changed ($P>0.05$). This latter finding is in accordance with published data (Kitchell and Ingram, 1960; Yul, 1984; Lowry and Gill, 1985), where bacterial growth in thawed muscle has been shown to be similar to that of fresh.

The unexpected finding of the current study was the observation that the lag phase of growth was shorter in previously frozen and thawed muscle. In this regard, most investigators would agree that bacteria injured by freeze/thaw stress would demonstrate a longer lag phase (Kitchell and Ingram, 1960; Rey et al., 1972; Lowry and Gill, 1985).

The data in Table 3 show the main effects of muscle quality and freezing/thawing upon the retail shelf life of pork. It is noteworthy that the appearance shelf life was affected significantly ($P<0.01$) by a muscle quality by freezing treatment interaction. This interaction was demonstrable since the effects of freezing/thawing were considerably larger on normal muscle than on either PSE or DFD. No such interactive effects were determined when odor was used as a shelf life criterion.

As evident in Table 3, the direction of the response to muscle quality was identical for both fresh and thawed pork. The results provide support to a related study (Greer and Murray, 1988) by demonstrating that the deterioration in retail appearance was most pronounced in PSE pork, while DFD pork was most susceptible to the development of offensive odors.

The data in Table 3 also show that freezing/thawing significantly ($P<0.05$) reduced the appearance shelf life of pork but had no significant effect ($P>0.05$) upon the odor shelf life. Possibly, freezing/thawing had no effect upon bacterial-induced spoilage (odor)

Table 3. Effect of the quality of the longissimus dorsi muscle and freezing on the retail shelf life of pork

	Shelf Life (days)	
	Appearance	Odor
Quality Group (n = 20)[1]		
PSE	2.36^{a}	7.14^{a}
Normal	3.89^{b}	6.97^{a}
DFD	6.61^{c}	5.22^{b}
Standard Error	0.16	0.18
Treatment (n = 30)		
Fresh	4.99^{a}	6.63^{a}
Thawed	3.58^{b}	6.26^{a}
Standard Error	0.13	0.15

[1] See Table 1.

[a-c] Least squares means within the same column with a similar superscript are not different (P > 0.05).

but effected a non-bacterial deterioration of appearance (Fox et al., 1980). In this regard there are data to support the view that freezing/thawing does not render meat more susceptible to bacterial spoilage (Kitchell and Ingram, 1960; Yul, 1984; Lowry and Gill, 1985).

CONCLUSIONS: The current study provides evidence to support the conclusion that freezing/thawing pork loin chops may promote a number of small but significant changes in objective measures of muscle quality (pH, soluble protein, color reflectance), increase bacterial numbers and reduce the acceptability of appearance.

The interpretation of freezing/thawing effects may also be confounded by the interactive effects of pork muscle quality (PSE, normal, DFD). Relative to this, the magnitude of the response to freezing/thawing of pH, soluble protein and appearance shelf life, differed with quality group. Contrarily, the response to freezing/thawing of the L^* value, bacterial lag phase, generation time and odor shelf life was similar for all quality groups.

Despite these quantitative effects, the direction of the response of all variables was the same. Thus, one would expect pork muscle quality to have similar qualitative effects upon objective quality measures, bacteriology and shelf life; whether fresh or thawed muscle be evaluated. These observations have important implications if pork, representative of distinct muscle quality groups, is maintained in the frozen state and thawed prior to marketing or research.

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