INFLUENCE OF FREEZING RATE AND STORAGE TIME ON BEEF QUALITY

R. Hanenian[1], G.S. Mittal[1] and W.R. Usborne[2], [1]School of Engineering and [2]Dept. of Food Science, University of Guelph, Guelph, Ontario, CANADA, N1G-2W1

SUMMARY

The effects of pre-chilling, freezing method and frozen storage at -17°C on ground beef pattie quality were investigated. The patties frozen by liquid nitrogen immersion exhibited significantly lower water-holding-capacity (WHC), higher cooking losses and a paler appearance. Liquid nitrogen freezing did however, result in a lower product dehydration. The advantage associated with fast freezing may be more applicable to intact cuts of meat where cellular damage has not yet taken place, or to cases where the freezing rate is controlled such as by spraying so that undesired fractures would not occur in the product. The overall quality of the patties deteriorate with frozen storage time, as indicated by the adverse changes in several of the quality parameters. Product tenderness decreased and TBA number increased during storage.

INTRODUCTION

The application of freezing for the preservation of foods has been practiced for several years, to maintain its quality during storage,distribution and marketing. Although meat freezing is generally conceded to cause tissue damage and some quality loss, it remains the method of preference for long term storage. In North America, the hamburger, also known as the ground beef patty, has become an integral part of the diet. Palatability associated with beef patties has been shown to be a function of freezing rate (Sebranek et al. 1978), mechanical treatment of raw materials (Berry et al. 1981) and pre-cooking (Joseph et al. 1980). This paper discusses the effects of pre-chilling, freezing method or rate, and frozen storage period on shrinkage, texture, pH, water-holding-capacity (WHC), surface colour and TBA number of ground beef patties.

Table 1: Analysis of variance using Gerneral Linear Model Procedure (SAS 1985)

		Run	PR	MET	(Run)(MET)(PR)	STOR	Error	Total
Degrees of Freedom		1	1	3	8	3	36-39	52-55
FL:	SS	0.77	0.18	37.2	0.84	0.03	0.39	40.5
	P>F	**	0.22	**	**	0.49		
SL:	SS	0.04	1.10	0.56	3.51	8.66	7.5	21.2
	P>F	0.65	0.15	0.74	0.04	**		
CL:	SS	109.2	2.61	66.0	21.4	8.2	75.3	298
	P>F	**	0.35	0.01	0.25	0.26		
TL:	SS	110	13	7	10	9	89	265
	P>F	**	0.01	0.2	0.8	0.3		
WBS	SS	7.5	0.01	0.06	0.8	1.0	1.5	10.9
	P>F	**	0.8	0.9	0.01	**		
HARD	SS	1409	0.01	191	806	2167	3032	7866
	P>F	0.0002	0.99	0.6	0.3	0.0002		
COH:	SS	0.01	0.00	0.00	0.00	0.04	0.06	0.12
	P>F	0.01	0.4	0.4	0.98	0.001		
EL:	SS	1.7	0.01	0.27	0.96	0.72	3.1	6.9
	P>F	**	0.8	0.6	0.2	0.05		

		Run	PR	MET	(Run)(MET)(PR)	STOR	Error	Total
Degrees of Freedom		1	1	3	8	3	36-39	52-55
GUM:	SS	346	0.5	27	168	97	351	1039
	P>F	**	0.8	0.7	0.05	0.03		
CHEW:	SS	91	0.1	8	33	22	73	238
	P>F	**	0.9	0.6	0.07	0.02		
pH:	SS	0.67	0.03	0.06	0.13	0.04	0.23	1.16
	P>F	**	0.2	0.3	0.02	0.08		
WHC:	SS	88	26	116	74	31	370	693
	P>F	0.005	0.1	0.05	0.5	0.4		
COL-1:	SS	687	15	56	62	71	165	1063
	P>F	**	0.2	0.15	0.1	0.002		
COL 2:	SS	20	17	3.6	35	5	13	93
	P>F	**	0.08	0.8	**	0.004		
COL3:	SS	61	0.1	5	1	1	10	79
	P>F	**	0.4	0.003	0.8	0.2		
TBA:	SS	0.4	0.0	0.0	0.01	0.02	0.02	0.4
	P>F	**	0.4	0.8	0.05	**		

** $P \geq 0.0001$; SS- sum of squares (type III).

EXPERIMENTAL METHODS

A 2x4x4 factorial randomized block design involving two runs was used to study the effects of pre-chilling (cold air at -10°C or CO_2 snow), freezing method (liquid nitrogen immersion, CO_2 snow, air blast at -25°C or -14°C) and frozen storage at -17°C for 6-9, 24-30, 56-63 or 88-98 days on ground beef pattie quality.

Pattie Preparation: The beef for each run was obtained from a different carcass, aged at 2 ± 2°C. Muscles were selected mainly from the forequarters of the carcass. Fatty tissues were also removed from the carcass. The lean beef and beef fat were both coarse ground through a 6 mm plate using a Hobart grinder (model 4532). A Butcher Boy Mixer (model L50) was used for mixing. Proximate analysis of lean and fat samples were then determined (AOAC 1984). The lean and fat were combined to form four 20 kg groups of desired composition. The mean moisture and fat contents of the patties were 58.0% and 22.7% in the first run, and 59.5% and 21.5%, respectively in the second run. Meat batches were reground through a 3.2 mm plate. Two of the batches were remixed with the addition of about 1.3 kg of CO_2 snow, while the remaining two were remixed after being chilled in an air blast freezer at about -10 ± 2°C for 1.25 to 2 hours. The temperatures of the batches following the CO_2 and air chilling treatments were 1 ± 1°C and 4.5 ± 1°C, respectively. Patties were formed using a hollymatic pattie maker (model 200-U).

Freezing: (1) Four patties were laid on evenly spaced stainless steel circular mesh grids, and submerged in a dewar flask filled with liquid nitrogen. (2) A styrofoam box was filled with about 2.5 cm of CO_2 snow. At each freezing, patties were laid on the CO_2 and covered with another layer of snow. (3) For both air blast freezing, patties were laid on wire trays placed on a trolley.

Storage: The patties were packaged in polyethylene lined card board boxes, and interleaved with wax paper prior to frozen storage. Then kept in an air blast freezer at −17 ± 2°C.

Quality determination: Samples removed from the freezer upon the completion of the frozen storage periods were placed in a cooler at 2 ± 2°C for thawing. Freezing loss (FL) represented the change in patty mass as a result of freezing, and determined by the ratio of the mass difference to the mass of the patties before freezing. Storage loss (SL) was described by the change in patty mass as a result of frozen storage and thawing. Cooking loss (CL) was described by the change in patty mass as a result of cooking. Patties were grill cooked at 191°C for 2.5 min on one side, followed by 2 min on the second side. The cooked patties were placed in cardboard boxes lined with paper towels. The patties were cooled off for 34 ± 3 min at room temperature prior to weighing. The ratio of the mass difference over the mass of the patties prior to freezing, represented cooking losses. Total loss (TL) represented the combined total for freezing, cooking and storage losses.

Texture analysis included a texture profile analysis (TPA) on an Instron testing machine (model TM), and the Warner Bratzler shear (WBS) test. These were determined on core samples, 2.2 cm in diameter and 1 cm in average thickness, taken from cooked patties. The WBS method was used to measure the maximum force required to shear pattie cores. The sensitivity of the system was set at 10%. In case of TPA analysis, a chart speed of 10 cm/min, and cross-head speeds of 1 or 5 cm/min were used. Samples were compressed to 75% of their original height in each cycle. The following parameters were calculated from the resulting profiles: hardness (HARD), cohesiveness (COH), elasticity (EL), gumminess (GUM) and chewiness (CHEW).

Samples for pH determination were prepared by blending 10 g of pattie with 100 ml of distilled water. A modified version of the Wardlaw et al. (1973) method was used for determining the WHC. Surface colour measurements were made using a Spectrogard colour system (model 96), with a Hunter lab colour scale. Three colour parameters were measured (Frye et al. 1985). These included "Lh" (Col 1), "ah" (Col 2) and "bh" (Col 3). "Col1" indicates the degree of whiteness; "Col 2" determines the intensities of red and green, with lower values in the negative range indicating higher degrees of green; and "Col 3" indicates the intensities of yellow and blue, with lower values in the negative range representing higher degrees of blue.

A modified method of the TBA test described by Tarladgis et al. (1960) was used in estimating the degree of oxidative rancidity. Values for TBA were expressed as absorbance units, with higher numbers representing degrees of rancidity.

Data Analysis: Each of the three independent variables, prechilling method (PR), freezing method (MET) and frozen storage period (STOR) were represented by an indicator variable (values 1,2,3 and 4), for statistical analysis. Data were analyzed using the General Linear model (GLM) procedure of SAS (SAS 1985). The significance of the differences between the means was determined using the least squares method (LSM).

RESULTS AND DISCUSSION

Shrinkage: Significant differences were found between freezing methods for freezing losses and cooking losses, between storage time and storage losses, and between PR and total losses (Table 1). The patties, frozen by the two cryogenic methods, had lower freezing losses. The highest freezing losses occurred with the slow air blast method. Cooking losses were significantly higher for patties frozen by liquid N_2 immersion as compared to those frozen by CO_2 snow contact. These findings disagree with Sebranek (1980) and Nusbaum et al. (1983), but in agreement with Jakobsson and Bengtsson (1969) and Lind et al. (1971). Cryogenic freezing caused fragmentation and fracturing of the patties allowing more surface area exposed for evaporative losses during cooking. Total losses were significantly higher in the N_2 freezing. Storage shrink increased with frozen storage time. Air pre-chilling was found to cause significantly higher total losses than CO_2 chilling.

Texture: The WBS values increased with frozen storage time and were significantly higher after the final period (Table 1). These findings are in agreement with Jakobsson and Bengtsson (1973) for beef slices, Neer and Mandigo (1977) for pork sausages, and Roberts et al.

(1976) for beef steaks. Verma et al. (1985), however, found a significant decrease in the WBS values for sausages. The WBS values were not affected by freezing methods, which is in agreement with Carrol et al. (1981) for beef semitendinosus samples.

Significant differences existed between frozen storage periods for all TPA parameters i.e. HARD ($P<0.001$), COH ($P<0.005$), GUM ($P<0.05$) and CHEW ($P<0.05$) (Table 1). The hardness followed the trend similar to WBS. Ockerman and Organisciak (1979) found similar results for beef steaks, but Miller et al. (1980) found the increase in tenderness for frankfurter with storage time. The cohesiveness decreased during the last storage period. The gumminess was significantly higher after the fourth storage period, while the elasticity and chewiness were significantly lower immediately following the first period of the storage. The chewiness increased steadily with storage time.

pH: The pH of the pattie was significantly lower with the CO_2 snow freezing. The pH peaked between the first and second periods of frozen storage before dropping back down, which is in agreement with Ockerman and Organisciak (1979) for restructured beef steaks.

WHC: The WHC was significantly affected by the freezing method (Table 1). The N_2 immersion freezing resulted in a significantly lower WHC than other methods, which was due to higher cooking losses. This is in disagreement with Jakobsson and Bengtsson (1969) for beef patties, however, Sebranek (1980) found no significant differences. The WHC peaked significantly between the first and second storage periods. This trend was similar to pH changes, and thus indicates that WHC increased with the increase in pH. This is in agreement with Miller et al.(1980), however, Sebranek et al. (1979) did not observe any consistent trend in the WHC with frozen storage period at -29°C.

Surface Colour: Table 1 shows that there were significant changes between the frozen storage periods and whiteness (Col 1) and redness

(Col 2); between freezing methods and yellowness (Col 3); and between the prechilling and Col 2. The Col 1 peaked significantly between the third and final storage period indicating that the colour faded during overall storage. This is in agreement with Sebranek et al. (1979). The 'Col 2' peaked significantly between the second and third frozen storage periods. This signifies an increase in redness. The 'Col 1' was significantly lower in the case of the slow air blast freezing as compared to other methods. Values for 'Col 3' were significantly higher for CO_2 snow freezing. The 'Col 2' was higher ($P<0.08$) in CO_2 pre-chilling.

TBA: The 2-Thibarbituric acid (TBA) numbers were significantly dependent on frozen storage period. The TBA increased as a function of storage time, indicating fat oxidation during storage. This is in agreement with Miller et al. (1980), Awad et al. (1968) and Verma et al. (1985) for ground beef and beef muscles. There were no significant differences between the TBA for the freezing methods. This is in disagreement with Sebranek et al. (1979).

CONCLUSIONS

Liquid N_2 immersion freezing resulted in a poorer quality than other methods. Patty quality diminished with frozen storage time at -17±2°C. This was shown by adverse changes in several of the quality parameters. The type of prechilling method did not affect patty quality significantly. The patties frozen by N_2 immersion exhibited lower WHC and freezing losses, and higher cooking and total losses. The benefits of fast freezing can be obtained if the freezing rate is controlled so that fractures would not occur. For this purpose a spray system can be used in place of direct immersion. The advantage associated with fast freezing may be more applicable with intact cuts of meat where cellular damage has not yet taken place.

Storage losses increased significantly during storage period. However, neither cooking nor total losses rose during storage. Patty tenderness decreased during storage, as shown by the increased values of WBS, hardness, gumminess and chewiness. The cohesiveness, however, decreased, indicating a loss of firmness with time. Surface reflectance peaked significantly between about 8 and 13 weeks of storage, indicating that the patties faded during storage time. TBA number increased, suggesting a increase in oxidative rancidity.

Carbon dioxide chilling resulted in significantly lower freezing, storage and total losses, and less pale and more red appearances. WHC was higher in air pre-chilling.

REFERENCES

AOAC (1984). Official methods of analysis. AOAC, Arlington, VA, USA.

Awad, A., Powrie, W.D. and Fennema, O. (1968). *J. Food Sci.* **33**:227.

Berry, B.W., Marshall, W.H. and Koch, E.J. (1981). *J. Food Sci.* **46**:856.

Carrol, R.J., Cavanaugh, J.R. and Rorer, F.P. (1981). *J. Food Sci.* **46**:1091.

Frye, C.B., Calkins, C.R. and Mandigo, R.W. (1985). *J. Food Sci.* **50**:1560.

Jakobsson, B. and Bengtsson, N.E. (1969). 15th European Meeting of Meat Research Workers Proc. p482.

Jakobsson, B. and Bengtsson, N.E. (1973). *J. Food Sci.* **38**:560.

Joseph, A.L., Smith, G.C. and Cross, H.R. (1980). *J. Food Sci.* **45**:168.

Lind, M.L., Harrison, D.L. and Kropf, D.H. (1971). *J. Food Sci.* **36**:629.

Miller, A.J., Ackerman, S.A. and Palumbo, S.A. and (1980). *J. Food Sci.* **45**:1466.

Neer, K.L. and Mandigo, R.W. (1977). *J. Food. Sci.* **42**:738.

Nusbuam, R. P., Sebranek, J.G., Topel, D.G. and Rust, R. E. (1983). *Meat Sci.* **8**:135.

Ockerman, H.W. and Organisciak, C.S. (1979). *J. Food. Prot.* **42**(2):126

Roberts, J.E., Field, R.A., Booren, A. and Meyers, T.G. (1976). *J. Food Sci.* **41**:1107.

SAS (1985). SAS User's Guide: Statistics. SAS Institute Inc., Cary, NC.

Sebranek, J.G. (1980). Quick Frozen Foods, Aug., P,51.

Sebranek, J.G., Sang, P.N., Rust, R.E., Topel, D.G. and Kraft, A.A. (1978). *J. Food Sci.* **43**:842.

Sebranek, J.G., Sang, P.N., Topel, D.G. and Rust, R.E. (1979). *J. Anim. Sci.* **48**:1101.

Tarladgis, B.G., Watts, B.M., Younathan, M.T. and Dugan,L. (1960). *J. Amer. Oil chem. Soc.* **37**:44.

Verma, M.M., Rojo, A.D., Ledward, D.A. and Lawrie, R.A. (1985). *Meat Sci.* **12**:125.

Wardlaw, F.B., McCaskill, L.H. and Acton, J.C. (1973). *J. Food Sci.* **38**:421.