EFFECT OF FREEZING METHOD ON PHYSICOCHEMICAL PROPERTIES OF BEEF MEAT

González-Rodríguez, R.M., Temperán, S., Lorenzo, J.M., García-Fontán, M.C., García, L., González, I., and Franco, D.*

Meat Technology Centre of Galicia, Street Galicia No. 4, Technology Park of Galicia, San Cibrao das Viñas, E- 32900 Ourense, Spain
*e-mail: danielfranco@ceteca.net

Abstract— **The aim of this study was to compare the effect of different freezing systems (commercial and domestic) on the physicochemical quality of beef pieces of different size. Firstly, the time required for freezing and thawing beef pieces of different size for three different freezing systems (a blast chiller, a quick freezing chamber and a domestic freezer) was determined. As a second aim of this work, instrumental measurements of quality of thawed sample (pH, colour, water-holding capacity and texture) were made to compare the effect of each freezing method. Freezing and thawing curves for the four pieces of different size tested followed a similar pattern in the three freezing systems. On the other hand, it was found than commercial systems froze faster than the domestic one. It was noted that lower values of draw losses (DWL) involved higher values of cooking losses (CL); considering the sum of these two losses (DWL+CL), the highest losses were observed with the domestic freezer. The draw and cooking losses did no differ much between the samples of different size, although the lowest values were observed with the smaller ones. Texture analyses showed that there was an inverse relationship between DWL+CL and shear force or hardness.**

Keywords— **beef, physicochemical properties, size piece**

I. INTRODUCTION

Freezing is a widely used method to store meat for relatively long periods of time. However, freezing and frozen storage of meat cuts initiates several physical and physicochemical changes that lead to the deterioration in the quality of the meat. The quality of frozen meat depends on the specific procedures used to freeze, store, and thaw the meat. Ice crystal size is an important factor related to muscle deterioration because the formation of large ice crystals leads to an extensive mechanical damage which results in a lower water holding capacity and a higher cooking loss and, consequently, a risk of less juicy meat. The size and location of ice crystals depend on the freezing rate and final temperature. Slow freezing induces a low nucleation rate forming only a few nuclei and producing large crystals; while if the freezing rate is high, many nuclei are formed and in consequence the crystals are smaller [1-3]. Although frozen foods are microbiologically stable, they are prone to deterioration during storage due to chemical reactions (processes of lipid oxidation and protein degradation), since enzymatic activity slows down, but does not cease. These processes can determine the end point of the display life of frozen products [4].

The aim of this study was to compare the effect of different freezing systems (commercial and domestic) on the physicochemical quality of beef pieces of different size.

II. MATERIALS AND METHODS

A. Samples and experiment design

Three freezing systems were applied in this study: (A) a blast chiller (model IS101L, Angelo Po Grandi Cucine Spa, Carpi, Italy); (B) a quick freezing chamber (model AKD, Interman Refrigeration, Madrid, Spain); and (C) a top freezer of a domestic refrigerator (model KD49NA73SA, Siemens, Madrid, Spain). This selection will allow us to evaluate the effects on the quality meat with the use of commercial (A and B) and domestic (C) freezing systems.

Beef samples (from silverside cut or *Biceps femoris* muscle) of different size were evaluated in each freezing system: (1) 10 cm high piece entire (≈ 1000 g); (2) 10 cm high piece filleted (≈ 1000 g); (3) 5 cm high piece entire (≈ 300 g); and (4) 2 cm high piece entire (≈ 200 g). All samples were initially weighed.

Each sample tested was packed in a plastic bag to avoid evaporation losses and was placed in each freezer until reached internal temperature of -18 ºC, controlled by thermocouples type K and recorded (using a scanning time of 10 minutes) with a Diligence EVG N3014 data logger (Comark, United Kingdom;

data were exported directly into a PC using the EV Standard software (V1.0.0) of Comark. Time required for each product to freeze from 5 ºC to -18 ºC was determined. Once tested samples reached -18ºC in each system (1-4), all frozen samples were thawed in air at 4 ºC before analysis.

B. Analytical methods

In all thawed samples, pH, colour, water-holding capacity and texture profile analyses were determined. The pH was measured using a HI99163 pH-meter (Hanna Instruments, Eibar, Spain) equipped with a glass probe for penetration. A CR-400 portable colorimeter (Konica Minolta, Osaka, Japan) was used to measure meat colour in the CIELAB space (Lightness, L*; redness, a*; yellowness, b*) [5]. Samples were allowed to bloom for 1 h before measuring directly in contact with air [6].

The water-holding capacity (WHC) was measured in four ways: draw loss (DWL), cooking loss (CL), drip loss (DL) and pressing loss (PL). CL, DL and PL were evaluated with the thawed meat samples. Each of these losses were determined by weighing the initial sample (P_o), reweighing it after a specific treatment (P_f) and using the Equation 1.

$$WHC = \frac{P_0 - P_f}{P_0} \times 100 \quad [1]$$

DWL was calculated by determining the difference in weight between the samples before and after being frozen. CL was calculated by measuring the difference in weight between the cooked and raw thawed sample; samples were cooked placing vacuum package bags in a water bath with automatic temperature control (80 ºC) until reached an internal temperature of 70 ºC, controlled by thermocouples. Cooked samples were cooled at room temperature before weigh them. To determine PL, a sample of intact meat of 5 g was placed onto two disk of filter paper and a mass of 2.5 kg was applied for 5 min. To determine DL, a sample of intact meat (80-100 g) was placed on the top of a net inside a closed container which was placed in a chamber at 4 ºC for 48 h.

Meat tenderness was measured by two textural tests in a TA. XT.plus texture analyzer (Stable Micro Systems, Surrey, United Kingdom): Warner-Bratzler (WB) and textural profile analysis (TPA). For both tests, cooked and cooled samples from CL determination were used. The samples for WB shear test were obtained by cutting pieces of approximately 1 x 1 x 2.5 cm (height x width x length) of cross section, parallel to the muscle fibre direction. They were completely cut through using a WB shear blade with a triangular slot cutting edge (1 mm of thickness) at a crosshead speed of 3.33 mm/s, determining three parameters: (i) the maximum shear force, represented by the highest peak of the force-time curve thus representing the maximum resistance of the sample to the cut; (ii) the shear firmness, represented by the slope from the beginning of the cut up to the highest point of the force-time curve; and (iii) the total work required to cut the sample, represented by the area under the curve obtained. Samples for TPA were obtained by cutting cubes of 1 x 1 x 1 cm approximately perpendicular to the muscle fibre direction and then compressing to 80% with a compression probe of 19.85 cm^2 of surface contact at a crosshead speed of 3.33 mm/s. Between the first and second compression, there was an interval of 2 s. In this test the following variables were obtained: hardness, cohesiveness, springiness, gumminess and chewiness.

III. RESULTS AND DISCUSSION

A. Freezing and thawing curves

Fig. 1 shows the freeze-thaw curves for the four meat samples of different size (1-4) in each freezing system evaluated (A-B). The behaviour of the 4 pieces of different size tested was similar in the three freezing systems. The smaller piece (4: 2 cm) was the first one to reach an internal temperature of -18 º C and it needed less time to thaw. The intermediate-sized piece (3: 5 cm) took a little more time to freeze and thaw, while larger parts (1: 10 cm and 2: 10 cm filleted) took twice as long as previous pieces within each system. Some differences were observed in the curves of equal-sized pieces of 10 cm (1 and 2), so the piece filleted (2) needed more time to freeze and thaw that the piece in a single block (1). On the other hand, commercial freezing systems (A and B) showed faster freezing than the domestic refrigerator (C); due to the formation of smaller ice crystals, the use of these commercial systems is recommended since it would mean less damage on the quality of frozen meat.

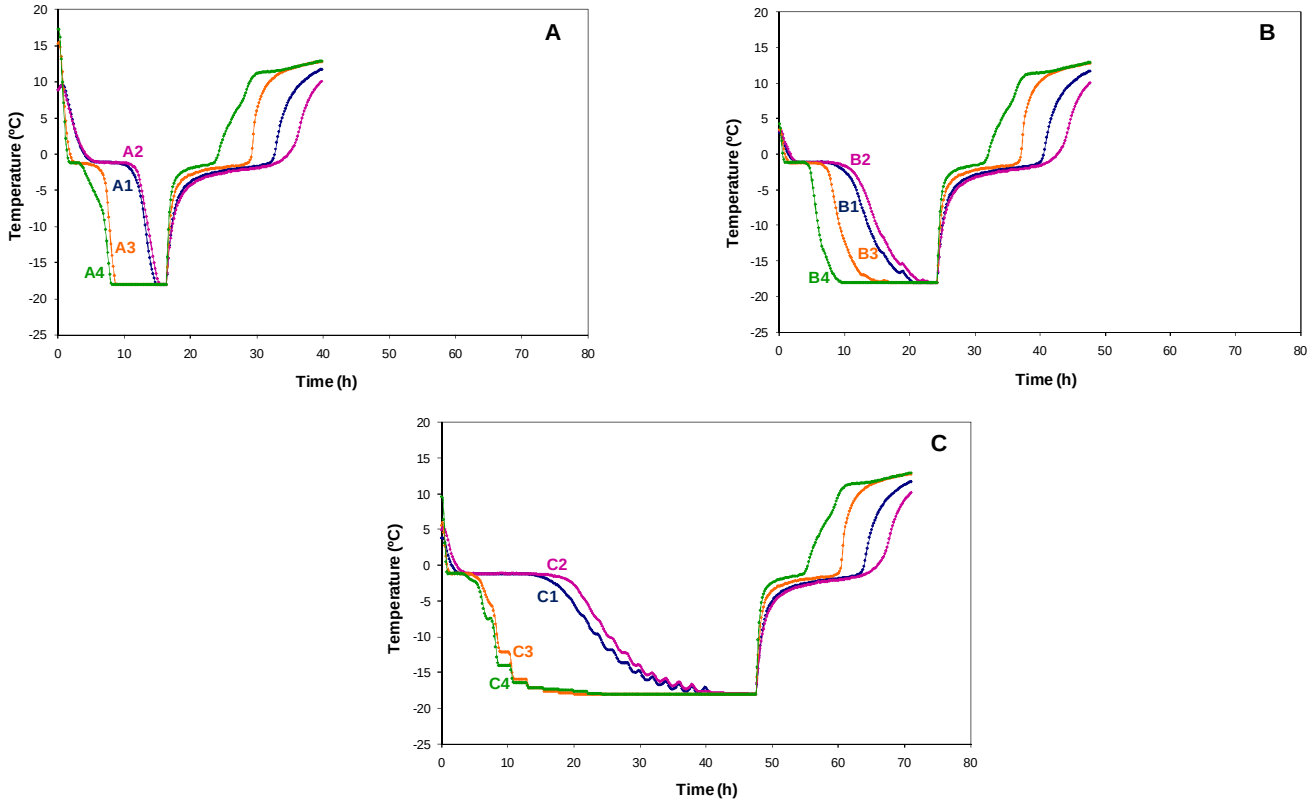

Fig. 1 Freeze-thaw profiles for the four meat samples of different size (1: 10 cm; 2: 10 cm filleted; 3: 5 cm; and 4: 2 cm) using a blast chiller (A), a quick freezing chamber (B) and a domestic freezer (C)

B. pH and instrumental colour

There were no important differences in pH and instrumental colour of thawed samples in any of the 3 freezing systems studied. The stability of these two parameters may be due to the short duration of frozen storage of this study.

C. Water-holding capacity

Table 1 presents the results of water-holding capacity. In our study, drip losses and pressing losses were not affected by the sample size and freezing system.

It was noted that lower values of draw losses involved higher values of cooking losses; considering the sum of these two losses (DWL+CL), the highest losses were observed with the domestic freezer. The draw and cooking losses did no differ much between the samples of different size, although the lowest values were observed with the smaller ones (2 cm).

D. Texture

Texture analyses showed that there was an inverse relationship between DWL+CL and shear force or hardness (see Table 2). In the present study, samples from domestic freezer showed the worst values (higher) of shear force and hardness. On the other hand, smaller samples (2 cm) showed the lowest values of shear force and hardness in the three freezing systems.

IV. CONCLUSIONS

In this study, the fastest freeze was obtained with a commercial system (a blast chiller or a quick freezing chamber) and the smallest sample (2 cm). Although no great differences were observed between the samples, was sensed that slower freezing rates of small pieces involved better instrumental measurements of quality.

Table 1 Water-holding capacity in terms of draw loss (DWL), cooking loss (CL), drip loss (DL) and pressing loss (PL) of the samples of different size from each freezing system evaluated

		Draw loss (%)	*Cooking loss (%)*	*DWL+CL (%)*	*Drip loss (%)*	*Pressing loss (%)*
Blast chiller (A)	*10 cm (A1)*	*1.53*	*30.06*	*31.59*	*2.23*	*18.60*
	10 cm filleted (A2)	*4.01*	*26.12*	*30.13*	*2.43*	*20.20*
	5 cm (A3)	*4.95*	*25.35*	*30.30*	*1.83*	*17.20*
	2 cm (A4)	*3.40*	*22.54*	*25.94*	*1.84*	*20.20*
Freezing chamber (B)	*10 cm (B1)*	*4.50*	*23.48*	*27.98*	*2.86*	*18.20*
	10 cm filleted (B2)	*10.95*	*27.50*	*38.45*	*2.14*	*12.80*
	5 cm (B3)	*9.57*	*20.52*	*30.09*	*1.43*	*20.00*
	2 cm (B4)	*4.71*	*23.20*	*27.91*	*2.79*	*17.80*
Domestic freezer (C)	*10 cm (C1)*	*5.03*	*34.64*	*39.67*	*1.06*	*19.00*
	10 cm filleted (C2)	*5.59*	*24.10*	*29.69*	*1.91*	*16.00*
	5 cm (C3)	*3.67*	*29.98*	*33.65*	*1.43*	*16.40*
	2 cm (C4)	*2.70*	*30.12*	*32.82*	*1.20*	*15.40*

Table 2 Texture analysis of the cooked samples of different size from each freezing system evaluated

		WB TEST	**TPA TEST**				
		Shear force (kg/cm^2)	**Hardness (kg)**	**Springiness (mm)**	**Cohesiveness**	**Gumminess (kg)**	**Chewiness (kg·mm)**
***Blast chiller* (A)**	*10 cm (A1)*	3.92	13.98	0.54	0.63	8.78	4.76
	10 cm filleted (A2)	3.85	9.63	0.55	0.60	5.82	3.21
	5 cm (A3)	4.19	8.10	0.52	0.58	4.66	2.43
	2 cm (A4)	2.28	6.75	0.50	0.55	3.67	1.84
***Freezing chamber* (B)**	*10 cm (B1)*	2.51	6.22	0.51	0.59	3.67	1.85
	10 cm filleted (B2)	3.61	9.13	0.54	0.56	5.13	2.77
	5 cm (B3)	2.53	5.74	0.53	0.56	3.21	1.70
	2 cm (B4)	1.88	5.19	0.50	0.55	2.82	1.41
***Domestic freezer* (C)**	*10 cm (C1)*	4.25	6.47	0.49	0.55	3.51	1.73
	10 cm filleted (C2)	4.21	9.15	0.55	0.56	5.18	2.84
	5 cm (C3)	4.27	9.12	0.52	0.58	5.29	2.73
	2 cm (C4)	2.82	8.28	0.53	0.56	4.62	2.45

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