

SHRINKAGE DETERMINATION AND PHYSICO-CHEMICAL PARAMETERS OF MEAT TISSUE DURING REFRIGERATED STORAGE

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**Written for presentation at the
CSBE/SCGAB 2017 Annual Conference
Canada Inns Polo Park, Winnipeg, MB
6-10 August 2017**

ABSTRACT During the refrigerated storage of the meat, there are significant changes on the physico-chemical parameters, affecting its quality. The objective of this work was to study the behavior of the physico-chemical parameters in the pork meat during its refrigeration and the interaction between them. For this purpose, 27 cylinder cuts of *Semimembranosus* muscle were placed randomly into refrigeration chambers ($5\pm 2^{\circ}\text{C}$) for 9 days. Each day, three cylinder samples were taken out from the refrigeration chamber and the values of pH, color, moisture, texture, weight, shrinking and volume were determined. Kinetics and experimental data were modelled by empirical models and mathematical equations considering the shrinkage in function of radius changes, moisture and volume of the samples. A decrease in the weight was observed through the storage with a range from 52.17 to 20.01 g. Moisture content presented values from 76.41% to 51.96%. Regarding to the color and texture, samples showed an increase in firmness values with the storage from 3.32 to 23.48 N, while the parameters L^* and b^* decreased from 46.67 to 26.52 and from 12.19 to 9.35, respectively, and for a^* (6.05 to 16.49) increased, which represents the loss

of lightness and pink tonality. The pH values increased with storage from 5.9 to 6.49. A good fit was obtained between the experimental and calculated data for the physical-chemical parameters ($R^2 > 0.95$). A mathematical equation was obtained considering the shrinkage in function of radius, moisture and volume.

Keywords: Quality, mathematical models, pork meat, physical-chemical parameters, refrigeration.

INTRODUCTION

The Codex Alimentarius defines meat as the edible muscles' part of health bovines, ovidae, suidae, caprids, equine and camelids, that are slaughter in hygiene conditions, it is worth to mention that most of the meat in the market comes from young and castrated males known as steer. Mainly the meat composition is 60-85% water; 16-22% protein and few quantities of other nitrogen components; 2-13% fat; carbohydrates, lactic acid, minerals and vitamins (FAO, 2015). This high nutritional value and meat quality are attributes required by consumers and should be kept in storage.

The post-mortem storage (aging) of meat at chill temperatures has been practiced for many years, this allows to maintain during long periods the meat quality and remains as an important procedure for producing tender meat in the modern meat industry. It is known that different muscles from one carcass or animal species react differently to post-mortem storage and present changes in their appearance in a different way.(Hoffman et al., 2012). In fact, the appearance of meat is important to retail shoppers. Appearance includes size; shape; the relative quantities and distribution of lean tissue, fat and bone; and color. Each of these factors is evaluated, either consciously or unconsciously, by consumers. Likewise, the meat quality may be estimated based on the pH changes, these results from the post-mortem enzymatic decomposition (Shu et al. 1993), which are responsible of different meat characteristics and related to its freshness (Kamruzzaman et al., 2012,). Therefore, the pH can be potentially used as a meat quality evolution indicator (Scheier et al., 2013). In the same way, the moisture of meat has an important contribution on its quality, the loss of moisture, its distribution and mobility in the meat, have a deep influence on the quality and the essentials attributes like juiciness, tenderness, firmness and appearance (Scheier et al., 2013). Loss of water causes dehydration and stresses in the cellular structure of the food leading to change in shape and decrease in dimension (Mayor and Sereno, 2004). This is the case of fiber muscles contractions during meat dehydration which causes loss of volume and changes in its capacity of water retention (Huff-Lonergan and Lonergan, 2005), influencing their physical properties, which in turn modify final texture.

Thus, the objective of this study was to evaluate and compare the color, moisture, pH, volume and texture changes in fresh pork meat during its refrigeration.

MATERIALS AND METHODS. The raw material was 27 fresh pork cylindrical cuts (2 cm in height and 5 cm in diameter) from *Semimembranosus* muscle, bought on a local market in Irapuato Guanajuato, Mexico. These cuts were placed randomly into refrigeration chambers ($5 \pm 2^\circ\text{C}$) for 9 days. Each day, three cylinder samples were taken out from the refrigeration chamber and the values of pH, color, moisture, texture, weight, shrinking and volume were determined.

Color determination: The data of the L^* , a^* , and b^* color parameters in pork meat were taken from a CIE lab system in a Hunter Lab (ColorFlex EZ45/50) colorimeter.

pH determination: The measurements were taken from a potentiometer (Conductronic 110) previously calibrated.

Moisture Content: The moisture content was determined by drying the samples until constant weight at $103 \pm 2^\circ\text{C}$ (AOAC, 1997).

Texture: it was determined by a texture analyzer TA-XT2 (Stable Micro Systems). Each meat sample was penetrated using a 4mm probe and using a 5 kg load cell. Mean values were expressed in terms of peak force (N).

Volume: The data for the volume was obtained by 2 methods:

Method 1: Using a digital Caliper Vernier the dimensions of height and diameter were taken, and it was taken before and after the refrigeration. Then using the equation (1) the volume was calculated.

$$V = \pi * r^2 * h \quad (1)$$

Method 2: The displacement method consists of the measurement of the sample weight immersed and not immersed in fluid (Sablani et al., 2002). Immersion in fluid (oil), this method is based on the variation of weight from the samples with and without being immersed into the oil. To calculate of volume with equation (2) we also need to know the oil density (ρ_a), which was calculated using a pycnometer, based on the volume and mass that the pycnometers can contain. The measures were made in triplicate at four different temperatures, 12, 21, 28 and 35 °C. These temperatures were chosen because they are included in the range in which the volume measurements are taken.

$$V = \frac{(m - m_i)}{\rho_a} \quad (2)$$

where V is volume (m^3), m is weight of the sample (kg), m_i is weight of the sample immersed in oil (kg) and ρ_a is density of oil (kg/m^3).

Mathematical models: For the modelling changes on pH, volume and moisture, mathematical equations were used to represent the data changes. Such equations consider empirical correlation between shrinkage and moisture content

RESULTS AND DISCUSSION

Change of weight in pork meat

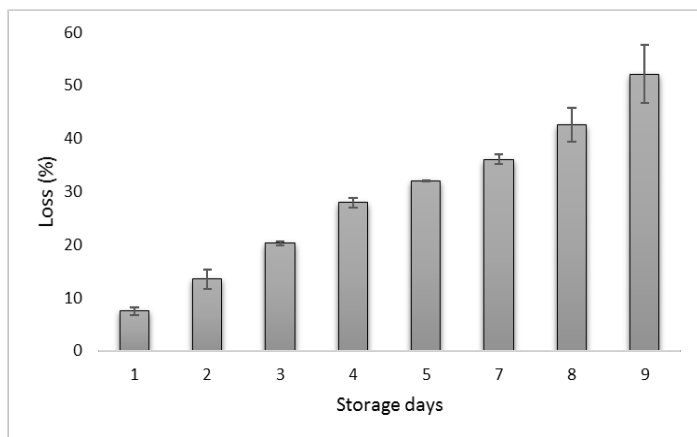


Figure 1 Percentage of weight loss.

The results for the change of weight in meat samples are shown in Fig. 1. As can be observed, the weight loss in meat increased almost linearly with the refrigerated storage time, on the 9th day (52.14% ± 5.48) the percentage of weight loss had a significant change regarding the control (1st day) (7.47% ± 0.69). This change in the weight of the meat is due to the dehydration that it presents and also to the possible exudation of extracellular fluid of the meat during the storage in refrigeration and includes surface discoloration (Hui et al. 2006).

Moisture determination

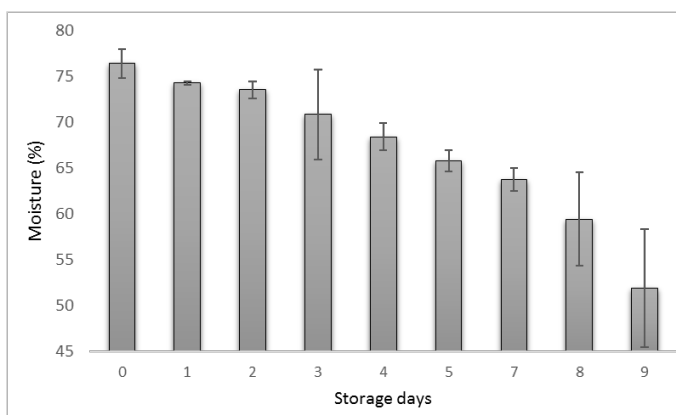


Figure 2 Percentage of moisture content in samples.

Figure 2 shows the percentage of the moisture content of the meat samples during the storage in refrigeration. The initial water content of the cylinders was 76.41% on wet basis. The moisture percentage in meat decreased with the refrigerated storage time (76.41% - 51.96%). The decrease in this parameter was linearly with the refrigerated storage time, and more marked in the 9th day, the moisture loss was close to 25% at the end of storage. The observed dehydration phenomenon typically occurs during the refrigerated storage of meat, since the thermodynamic tendency to equilibrium between meat and surrounding medium causes the water loss in meat (Katekawa et al., 2006) and thus weight loss (Fig.1)

Color determination in pork meat

Table 1 Determination of L*, a* and b* parameters in pork samples

Days	L*		a*		b*	
	\bar{x}	σ	\bar{x}	σ	\bar{x}	σ
0	45.665	1.520	6.045	1.831	12.185	0.771
1	38.920	1.796	12.035	0.997	12.740	0.891
2	41.090	2.517	12.035	0.148	14.235	0.134
3	37.980	4.271	12.095	0.163	14.845	0.898
4	33.105	1.379	15.040	0.424	13.805	0.389
5	32.830	3.974	15.115	0.035	12.420	2.956
7	27.940	0.297	14.470	0.424	9.275	0.092
8	29.955	3.444	16.635	0.445	9.230	2.234
9	26.520	0.396	16.485	0.346	9.350	0.057

Table 1 shows the values of the parameters of color in pork samples during refrigerated storage. Knowing that the color is one of the most important parameter for a consumer in order to buy or prepare the pork meat, these results have a significant importance. As can be observed on Table 1, the chromatic scale L* (luminosity) decreased significantly with the refrigerated storage time (45.67 ± 1.52 to 26.52 ± 0.40), which means that the meat turns darker than at the beginning. Furthermore, the chromatic scale a* (from green to red) in general the values are closer to the red color; however, these present a significant change from a lighter red (6.05 ± 1.83) to a darker red (16.49 ± 0.34), which is something not desired in the pork meat, its more desired a pink or a light red color. Regarding to the chromatic scale b* (from yellow to blue), in general the values are around the yellow color, which is something desired, nevertheless at the end of refrigerated storage, the meat presents a significant change, from a darker yellow (12.19 ± 0.77) to a lighter yellow (9.35 ± 0.06), which is something not desired, because the yellow is important to give a pink tonality to the pork meat.

Volume determination Comparison between Measurement Methods

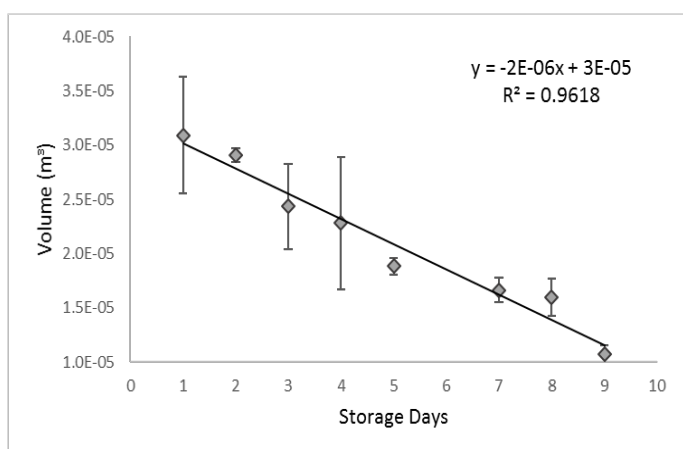


Figure 3 volume determination using a digital Caliper Vernier

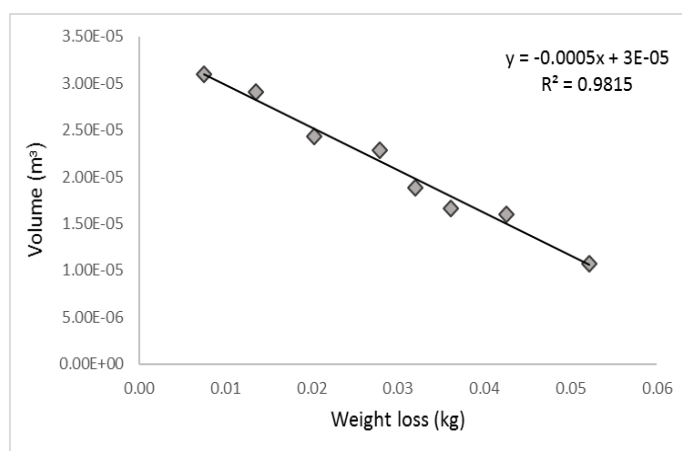


Figure 4 Comparison between the volume obtained from the Caliper Vernier and the weight loss

Figure 3 shows the values of the volume of meat samples using a digital Caliper Vernier. The volume of the pork meat cylinders decreased over the days in refrigerated storage with a significant change ($p < 0.05$) between the first day ($3.09 \text{ E-}05$) and the 9th day ($1.07 \text{ E-}05$), the latter is more than 3 times lower. In order to compare the behaviour between the volume and moisture in meat samples, the experimental volume of the samples obtained from the Caliper Vernier was plotted versus the weight loss (Fig. 4). As can be observed, the high the water loss, the lower the volume. Other authors describe the dependence of volume on water content in food, such as Corzo et al. (2004) when studying dehydrated sardine sheets and the changing moisture contents, Clemente et al. (2009) in pork meat cylinders during drying and Gabas et al., (2001) when working in dehydrated fruits.

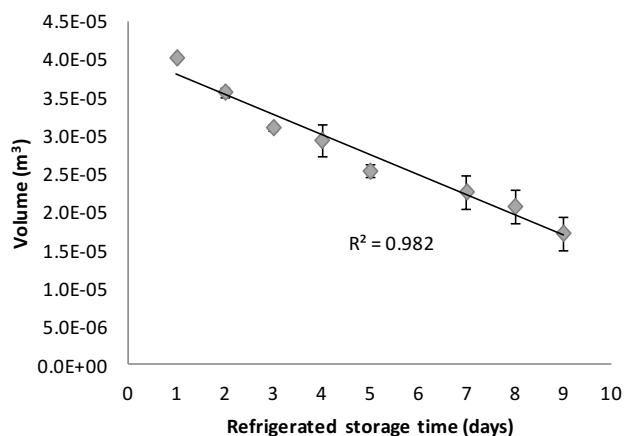


Figure 5 Volume determination by meat oil immersion

Figure 5 shows the values of the volume of meat samples using a oil immersion. The volume decrease with the refrigerated storage time, from $3.58 \text{ E-}05$ to $1.72 \text{ E-}05$, the latter is more than 2 times lower. In comparison, the values of volume determined using a digital Caliper Vernier (Fig. 3) were lower than for those obtained with oil immersion.

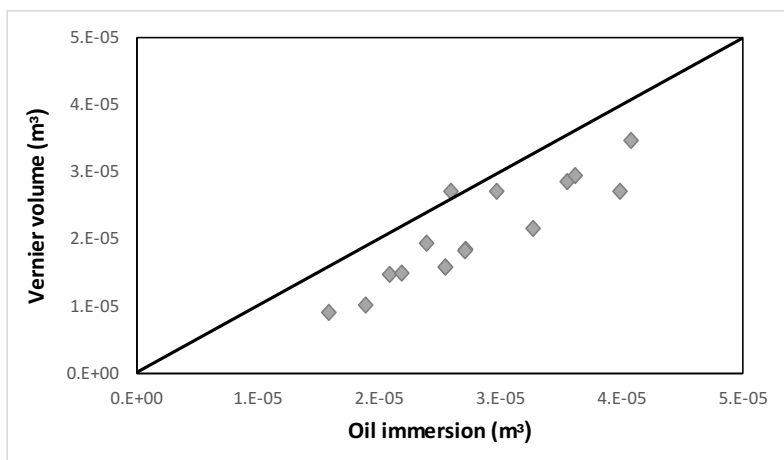


Figure 6. Comparison between volume by oil immersion and volume using a digital Caliper Vernier.

Figure 6 shows the comparison between the volume measurement methods used in this study. The volumes calculated when measuring the cylinders meat using the caliper Vernier are different from the ones obtained from the oil immersion methods, also they are also more dispersed. This relation, we can appreciate that the values are under the diagonal which means that there was a mistake in the Vernier measure, this mistake can be proportionated by the operator. That means that direct measurement (using a Caliper vernier) is more subjective than the others. The differences are smaller when the volume is measured during long drying times (final volume) (Figs. 3 and 4) probably due to the fact that then the meat is stiffer. Clemente et al. (2009) studied the shrinkage of pork meat cylinders during drying. These authors observed that values of volume meat measurement using the caliper Vernier were lower than the ones obtained from the fluid immersion.

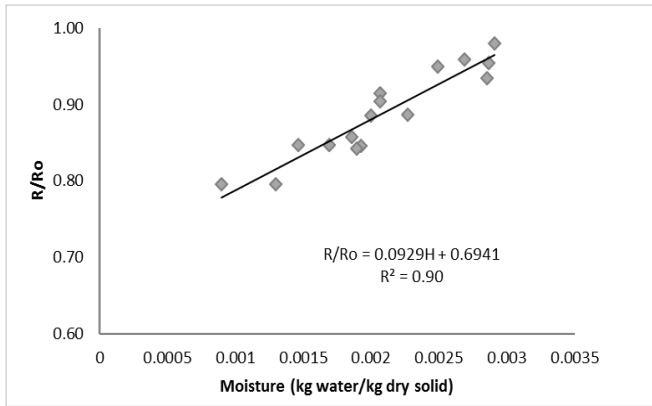


Figure 7. Comparison between the radius and

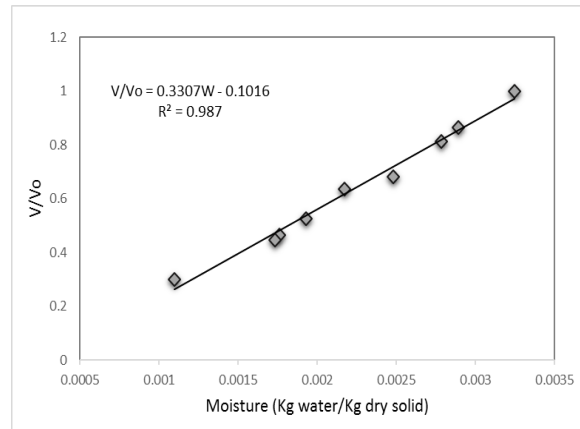


Figure 8. Comparison between moisture and volume

The contraction functions were determined from the initial radius (R_0), initial volume (V_0) volume (V), radius (R) during refrigerated storage of samples, and these parameters related to the moisture content. In Figures 7 and 8 the results obtained are shown. In these figures, we can observe that the quotient R/R_0 and V/V_0 are related linearly with the moisture content satisfactorily ($R^2 > 0.90$). The samples length variation was calculated from the obtained adjustments for the radius and the volume as can be expressed in equation 4 and 5.

$$\frac{L}{L_0} = \frac{V}{V_0} \left[\frac{R_0}{R} \right]^2 \quad (4)$$

$$\frac{L}{L_0} = (0.3307W - 0.1016) * \left(\frac{1}{0.1309W + 0.608} \right) \quad (5)$$

pH and texture determination in pork meat during its refrigeration

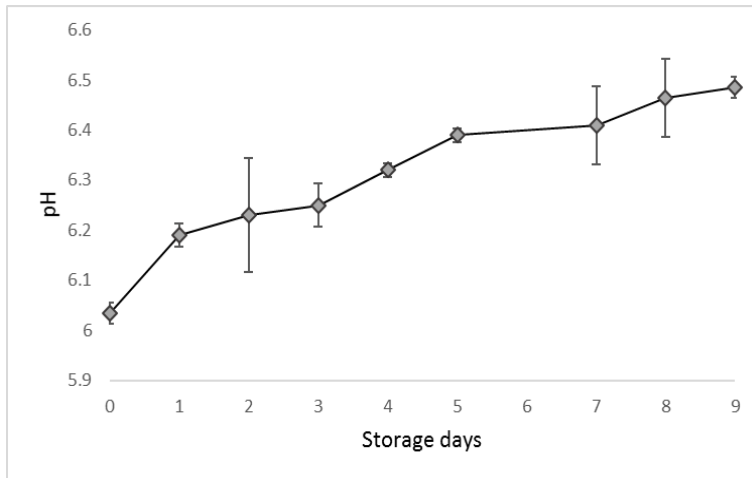


Figure 9 pH changes in pork meat for 9 days

Figure 9 shows the pH changes in pork meat during the refrigerated storage. As can be observed, the pH of the meat increase with the refrigerated time, which means that the meat became more neutral, at the beginning there was a pH of 6.04 ± 0.02 on the other hand in the 9th day the pH was 6.49 ± 0.02 , which is not such a big variation but it has a significant importance in the meat. The values obtained for the parameters of pH were comparable to those obtained by other authors, such as Young et al., (2004) when studying a method for determination of pH in meat, Josell et al. (2003) when working on the Sensory quality of PSE of pork meat, and Silva et al., 1999, when studying the influence of pH on bovine meat tenderness.

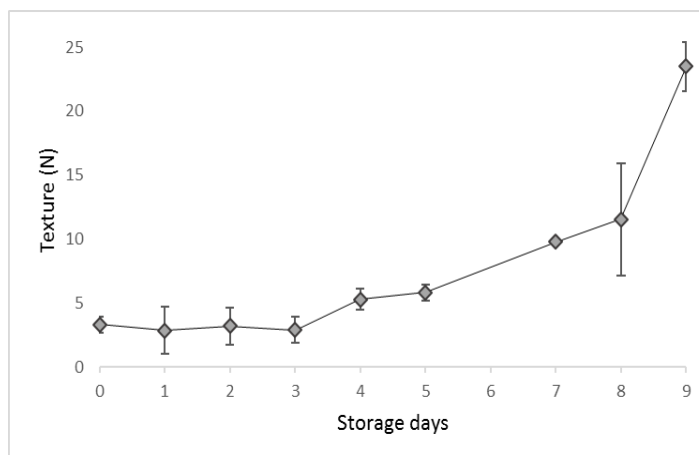


Figure 10. Texture changes in pork meat during its refrigerated storage.

In order to study the effect of refrigerated time on the texture of pork meat, the experimental texture of each cylinder was plotted versus refrigerated time (Figure 10). The texture increases since the first day ($2.87N \pm 1.85$), but is not until the seven day ($9.80N \pm 0.01$) that it was noted a significant variation, and since it increased potentially finishing on the Ninth day with a texture of ($23.48N \pm 1.91$). The results shows that with 9 refrigeration days the meat turns significantly harder, because of the loss of moisture that suffers during the refrigeration storage. These changes in the texture of meat could be affected by changes in the soluble proteins, myofibrillar proteins, and connective tissue of the meat.

CONCLUSION The refrigerated storage has a significant negative repercussion in the physicochemical parameters in the pork meat evaluated in this work. All the parameter shows negative repercussions: the weight decreased, the volume of water loss increased, the moisture content decreased, the color turned to a not desirable one, the volume decreased, the pH increased until it almost became neutral and the texture increased negatively. It was better to measure the volume by oil immersion in comparison with the method of measurements. Finally, we obtained mathematical models considering the shrinkage in function of radius, moisture and volume.

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