LOW STARCH/SUGAR CONTENT IN DIETS FOR LATE FATTENNING MAY REDUCE PORK QUALITY

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Abstract – Drip losses and colour changes are quality factors of high economical impact on the meat industry. The aim of this research was to study the effect of diets with two different glycemic indexes on some meat quality characteristics such as drip loss and colour parameters. One hundred and ninety castrated-male pigs (PIC x L337) were distributed into two groups and fed either a diet with low (45.3 %) or high (50.6%) starch and sugar content for 20 days. Drip losses, colour changes and meat pigments were measured in *longissimus lumborum* muscle along time of storage. Meat from pigs fed the diet with low glycemic index had higher drip loss when compared to the group fed the diet with high glycemic index (P=0.008). The low-glycemic index group showed higher luminosity (P=0.011), yellowness (P=0.0009) and saturation of the colour (P=0.0018) when compared to the group fed the high-glycemic index diet. The low-starch group had higher serum insulin concentration previous to slaughter. Not only starch/sugar content but also the glycemic response to diets has to be taken into consideration in order to maintain quality characteristics of meat.

Key Words – glycemic response, drip loss, meat quality.

I. INTRODUCTION

One of the main quality attributes of fresh meat is its water holding capacity, because it influences consumer acceptance, the final weight of the product and the nutritive value, as drip contains about two-thirds of the protein concentration of meat [1]. This characteristic is mainly influenced by the extent of the post-mortem fall in pH.

Colour is other food quality characteristic relevant to market acceptance being the first quality attribute evaluated by consumers [2]. Many dietary interventions have been tested during the last years in order to improve meat quality. One possibility is based in the use of the rate of starch digestion in the intestine (glycemic index). Hence, a rapid or slow digestible starch affects the postprandial glucose availability, energy utilization and metabolism [3]. Previous studies developed by different available dietary carbohydrate reported that the capacity of a glycogen-reducing diet to alter glycolytic potential was limited to muscles such as semitendinosus, which was a more oxidative muscle and where glycogen depletion occurred faster [4]. However, other authors found that diets containing low starch and high fiber also modified quality of *longissimus* muscle [5]. Furthermore, many studies reported that a low glycolytic potential of muscle was related to improved meat quality [4,5]; however, there are some studies in which this effect was not found in barrows [4]. In these studies wide differences in starch content of diets were used. Moreover, it has been reported that blood glucose and the glycemic index of diets are a function of the rate of appearance into the systemic circulation and the rate of disappearance of glucose [6], so this response may modify the glycolytic potential of muscle. Consequently, further diet formulations need to be explored.

The objective of this research was to study the effect of dietary glycemic index based in diets with narrow difference in the starch and sugar content on some meat quality characteristics such as drip loss and colour parameters in *longissimus* muscle of castrated male pigs.

II. MATERIALS AND METHODS

One hundred and ninety castrated male pigs (PIC x L337) (RN and halothane negative) were randomly selected and distributed into two groups that were fed different diets. Diets were isoenergetic and isoproteic and were formulated in order to provide two different glycemic indexes for 20 days. High-glycemic index diet (**H-GI**) contained 44.7% starch, 50.6% starch+sugar, 5.4% fat, and 12.4% NDF, whereas low-glycemic index diet (**L-GI**) contained 41.3% starch, 45.3% starch+sugar, 5.3% fat and 13% NDF. At the end of the experimental period, pigs were sent to a commercial slaughterhouse (Incarlopsa, Tarancón, Cuenca, Spain) stunned with CO_2 and slaughtered after a fasting period of 18 h. Electrical conductivity and pH were measured by means of a LFStar conductivity meter (Mattahäus Ingenieurbüro, Klausa, DE) and a portable pH meter pH*K21 (NWK Binar, Puergen, DE), respectively. Samples of approximately 15 cm in size were taken from the *longissimus lumborum* muscle at the level of the last rib for analysis (n=60). To determine weight loss during storage, approximately 1 cm^3 of sample (weighing approximately 10 g) was taken, weighed and placed under refrigerated conditions at 4°C in a saturated atmosphere. Samples were weighed again after 96 hours of storage. The difference between initial and final weights was used to calculate drip loss, which was expressed as a percentage of the initial weight [7].

Colour measurement and pigment concentrations in muscle were assessed on days 0, 3, 6 and 9 of refrigerated storage at 4°C. 2-cm-thick samples were placed on trays and kept at 4ºC. Muscle colour was evaluated by means of a Chroma Meter (CM 2002, Minolta, Camera, Osaka, Japan) previously calibrated against a white title in accordance with the manufacturer's recommendations [8] and using the illuminant D_{65}. The average of three random readings was used to measure lightness (L*), redness (a*) and yellowness (b*). Meat pigments (oxymyoglobin, deoxymyoglobin and metmyoglobin) were calculated by the isobestic wavelengths measured by means of the Chroma Meter. Oxymyoglobin was calculated as the ratio of measurement at 610/525 nm, deoxymyoglobin as the ratio at 474/525 nm and metmyoglobin as the ratio at 572/525 nm [9].

Data were analyzed using the general linear model procedure in SAS 9 [10] to study the effects of the dietary treatment and storage time. Means were analyzed using the Duncan test. Slopes of the regression equations were compared by means of "t" student test.

III. RESULTS AND DISCUSSION

Starch/sugar content of diet did not modify lean percentage or fat thickness of the carcass. In addition, pH at 3, 24 or 40 hours and electric conductivity were not statistically affected by the dietary treatment (Table 1). Other authors [4], found a limited influence of diet on carcass.

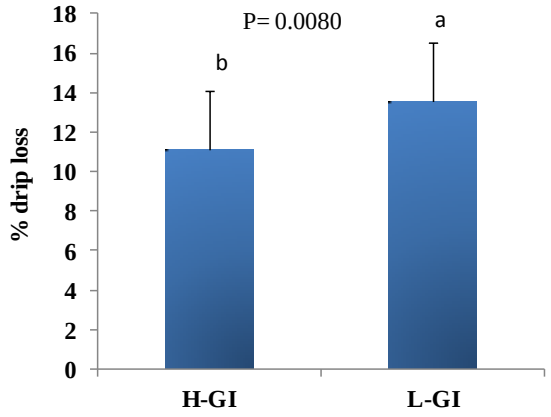
When the effect of diets on drip loss was evaluated, interesting results were found. Hence, meat from pigs fed the L-GI diet had lower water holding capacity and then drip was higher when compared to the group fed the H-GI diet (Figure 1). The rate and extent of post mortem decrease in pH is one of the most important physiological factors influencing drip loss, and this can be affected by the ante mortem concentration of glycogen in muscle [1, 4]. In the present study, differences in the fall rate in pH were not statistically affected by the dietary treatment; however, low-starch/sugar group seemed to have numerically lower pH at 24 and 40 h.

Table 1. Effect of either low (L-GI) or high (H-GI) starch/sugar content on pH at 3, 24 and 40 hours and electric conductivity (EC) of meat

	H-GI	**L-GI**	**RMSE[1]**	**P**
Lean percentage, %	56.96	56.31	4.190	0.4900
Fat thickness, mm	25.47	25.50	3.440	0.6500
pH_3h	6.25	6.26	0.240	0.6500
pH_24h	5.68	5.64	0.137	0.2865
pH_40h	5.71	5.68	0.160	0.4928
EC	3.94	3.91	1.467	0.9253

[1] RMSE: Root of the mean square error of time effect

Figure 1. Effect of either low (L-GI) or high (H-GI) starch/sugar content of diet on drip loss of muscle



Other authors [4] reported that diets containing low starch or low available carbohydrates resulted in lower muscle drip loss, which is opposed to the results observed in the present study. These authors attributed the results to a lower glycolytic potential of muscle. However, Li et al. [5] reported that muscle glycogen content was not changed by a low starch high fat diet when compared to a high starch diet. In the present study, L-GI group had higher (P=0.016) serum insulin concentration (0.45 vs. 0.32 µg/l), previous to slaughter. The lower glycolityc potential of muscle may not only be due to a lower rate of appearance of blood glucose but also to a higher hyperinsulinemia and an earlier increase in the rate of disappearance of glucose from blood to tissues [6]. Hence, according to the present results, the glycolytic potential of muscle from groups fed the low-starch/sugar diet might have been higher.

Instrumental colour of muscle was also evaluated (Table 2). The L-GI diet showed higher luminosity (L*, P=0.011), yellowness (b*, P=0.0009) and saturation of the colour (chroma, P=0.0018) when compared to the H-GI group. Also, the a* to b* ratio tended to be higher (P=0.068) in meat from pigs fed L-GI, whereas deoxymyoglobin tended to be lower (P=0.073) when compared to meat from groups fed H-GI diet. Larger ratios of a* to b* indicate less discolouration. Previous studies developed in pork based in the administration of different dietary energy sources reported no differences in colour *longissimus* muscle [5]; however, others [4] found that the lower glycolytic potential of *semitendinosus* muscle of pigs fed diet with low available carbohydrate content resulted in lower L* values. The effect of dietary treatment on colour changes of the present study is in turn with those observed for muscle drip loss

Table 2. Effect of starch/sugar content of diet on instrumental colour and pigments of pork

	H-GI		L-GI		RMSE[1]	P[2]
L*	54.10	b	55.49	a	3.99	**0.0115**
a*	1.93		2.33		1.76	0.1001
b*	11.26	b	11.96	a	1.52	**0.0009**
chroma	11.59	b	12.31	a	1.67	**0.0018**
H (hue angle)	0.86		0.99		0.98	0.3266
a*/b*	0.15		0.19		0.15	**0.0677**
Ratio 630/580	1.68		1.68		0.17	0.8635
Oxymyoglobin	4.27		3.98		2.43	0.3761
Deoxymyoglobin	1.11		1.10		0.03	**0.0725**
Metmyoglobin	8.81		8.36		4.78	0.4887

[1] RMSE: Root of the mean square error of treatment effect
[2] Means with different superscripts were statistically different (P<0.05)

Table 3. Effect of days of storage on instrumental colour and pigments of pork[1]

	Day 0		Day 3		Day 6		Day 9		SE[2]
L*	55.93	a	54.57	ba	54.33	b	54.24	b	3.99
a*	0.52	c	2.94	a	2.97	a	2.06	b	1.76
b*	10.90	c	11.53	b	11.45	cb	12.50	a	1.52
chroma	11.04	c	12.00	b	11.92	b	12.78	a	1.67
H	0.43	b	1.11	a	1.16	a	1.01	a	0.98
a*/b*	0.04	c	0.24	a	0.25	a	0.16	b	0.15
630/580	1.77	a	1.76	a	1.62	b	1.57	b	0.17
OxyMb	3.70		3.95		4.31		4.56		2.43
DeoxyMb	1.21	a	1.05	c	1.05	c	1.12	b	0.03
MetMb	8.19		8.74		8.68		8.77		4.78

[1] Means with different superscripts were statistically different (P<0.05)
[2] RMSE: Root of the mean square error of time effect

Moreover, colour changes with time of storage were expected (Table 3). L*, a*, ratio 630/580 and deoxymyoglobin decreased with storage time. Previous reports indicate that this variables

show a reduction with time as the pigment oxidation increase [11]. However, b* and hue angle as indicator of development of colour from red to yellow, increased with time. No interactions were found between storage time and the dietary glycemic index effect.

Drip loss was directly related to L* and b* values according to the regression equation:

Drip loss=-6.92(±4.7) +0.21 L* (±0.10) +0.65 b* (±0.30) (R^2=0.30; RSD= 2.59; P=0.0001).

In addition in our results could be observed that although pH was not statistically affected by dietary treatment, it was found a relationship between pH at 24 hours and b* according to the dietary treatment following the regression equations:

b* (L-GI) = 56.2(±7.9) – 7.9xpH(±1.4) b (R^2=0.57; RSD= 0.98; P=0.0001)

b* (H-GI) = 62.6(±6.6) – 9.2xpH(±1.2) a (R^2=0.70; RSD= 0.82; P=0.0001)

The results of the present study show that feeding a diet with low glycemic index based in a low-starch/sugar content not always has the potential to produce beneficial effects on pork quality.

CONCLUSION

Not only starch/sugar content but also the glycemic response of diets has to be taken into consideration for diets formulation in order to maintain quality characteristics of meat.

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REFERENCES

1. Hertog-Meischke, M.J.A., Van Laack, R.J.L.M. and Smulders, F.J.M. The water holding capacity of fresh meat. (1997). Veterinary quarterly 19: 175-81.

2. Wu, D., and Sun, Da-Wen (2013). Colour measurements by computer vision for food quality control- A review. Trends in Food Science & Technology 29: 5-20.

3. Drew, M.D., Schafer, T.C., and Zjijlstra, R.T. (2012). Glycemic index of starch affects nitrogen retention in grower pigs. Journal of Animal Science, 90: 1233-1241.

4. Bee, G., Biolley, C., Guex, G., Herzog, W., Lonergan, S.M., Huff-Lonergan, E. (2006). Effects of available dietary carbohydrate and preslaughter treatment on glycolytic potential, protein degradation, and quality traits of pig muscles. Journal of Animal Science 84:191-203.

5. Li, Y., Li, J, Zhang, L., Yu, C., Lin, M., Gao, F., Zhou, G., Zhang, Y., Fan, Y. and Nuldnali, L. (2015). Effects of dietary energy sources on post mortem glycolysis, meat quality and muscle fiber type transformation of finishing pigs. Plos One, 1-16.

6. Schenk, S., Davidson, C.J., Zderic, T.W., Byerley, L.O., and Coyle, E.F. (2003). Different gylcemic indexes of breakfast cereals are not due to glucose entry into blood but to glucose removal by tissue. American Journal of Clinical Nutrition, 78: 742-748.

7. Honikel, K. O. (1997). Reference methods supported by the OECD and their use in Mediterranean meat products. Food Chemistry, 59, 573-582.

8. CIE (1976). Recommendations on uniform colour spaces-colour difference equations-psychometric colour terms. Commission Internationale de l'Eclairage, Suppl. 2 to CIE. Publication nº 15 (E-1.31) 197/ (TC-1.3). Bureau de la CIE, Paris.

9. Tang, J., Faustman, C., & Hoagland, T. A. (2004). Krzywicki Revisited: Equations for Spectrophotometric Determination of Myoglobin Redox Forms in Aqueous Meat Extracts. Journal of Food Science, 69, 717-720

10. SAS, V.9 (1999). In SAS user's guide. SAS Institute Inc., Cary, NC.

11. Rey, A.I., López-Bote, C.J., Kerry, J.P, Lynch, P.B., Buckley, D.J., and Morrissey, P. (2001). Effects of dietary vegetable oil inclusion and composition on the susceptibility of pig meat to oxidation. Animal Science, 72, 457-463.