DIETARY CREATINE AFFECTS MEAT QUALITY OF PURE BREEDS OF DUROC AND LANDRACE DIFFERENTLY

Young, J.F., Bertram, H.C. and Oksbjerg, N.

Danish Institute of Agricultural Sciences, Department of Food Science, Research Centre Foulum, Denmark

Background

Dietary creatine has been shown to increase total muscle creatine (Balsom, Söderlund, Sjödin & Ekblom, 1995), of which approximately two-thirds is creatine phosphate (Balsom, Söderlund & Ekblom, 1994; Casey, Constantin-Teodosiu, Howell, Hultman & Greenhaff, 1996). Increased availability of creatine phosphate is believed to contribute to the increased maximum and total work capacity (Casey & Greenhaff, 2000) and reduce the recovery period (Balsom et al., 1995) of humans supplemented with creatine. In relation to meat quality, it has been suggested that the increased creatine phosphate may delay the lactate formation in the muscle and consequently postpone the pH decline post mortem. On the basis of postponed pH decline, and possible increased water retention due to increased intracellular osmotic draw caused by the creatine phosphate, Berg and Alle (2001) proposed a hypothesis of increased WHC in meat from pigs supplemented with creatine. Alteration in the water mobility has been indicated in several studies by tendencies to greater myofiber hydration (Berg & Allee, 2001), reduced cooking loss (Maddock, Bidner, Carr, McKeith, Berg & Savell, 2002) and increased WHC (James et al., 2001).

Objectives

The objectives was to study interactions among breeds, creatine supplementation, and cooling profile in relation to WHC in pork.

Materials and methods

A total of 80 pigs, 40 Duroc and 40 Landrace pigs were allocated to 4 groups and supplemented with 0, 12.5, 25 or 50 g creatine monohydrate (CMH)/d for 5 days prior to slaughter. Pigs were fed 2 x 1375 g feed mixed with CMH for 5 days prior to slaughter. The body weight was registered in the morning 5 days before slaughter and before transport to the slaughter plant. The development in water mobility and distribution was measured in LD muscles of control and pigs supplemented with 25 g CMH/d by NMR T_2 relaxation (Bertram, Karlsson & Andersen, 2003) from 20 min to 210 min post mortem. The temperature was logged every min from 20 min until 24 h *post mortem*, and duplicate pH measurements were made in *longissimus dorsi* (LD) at 1, 15, 30, 45, 60, 120 and 1440 min (24 h) *post mortem*. After 1 h one half of the carcass was placed in a chilling room at 4°C (temperature profiles in Figure 1) and the other half in the freezer for 1 h at approximately –28°C, and then transferred to a separate chilling room at 4°C. Water holding capacity (WHC) was also determined as drip loss in LD in approximately 100 g samples using the plastic bag method (Honikel, 1998). The data was statistically analysed using the mixed procedure in SAS (SAS V8).

Results and discussion

Body weight gain of the pigs after 5 days of supplementation increased linearly with dietary inclusion of CMH and at a dose of 50 g/d the gain was increased by approximately 2 and 3 kg in Duroc and Landrace respectively (Table 1). When disregarding the breed, all groups of CMH supplemented pigs had a significantly increased weight gain compared to control animals. Weather this increased gain is as lean body mass (Balsom et al., 1995) or as increased water retention (Juhn, 1999) will be investigated further in this study.

In Duroc pigs pH was higher compared to Landrace at all time points, but in control animals and those supplemented with 12.5 g CMH/d this difference was only significant 24 h *post mortem* (Table 2). Contrary, in groups of pigs supplemented with 25 and 50 g CMH/d the Duroc breed had significantly higher pH at all time points, except after 15 and 30 min for pigs supplemented with 50 g CMH/d. Among Duroc animals pH was higher in pigs supplemented with 50 g CMH/d at 30, 45, 60 and 120 min *post mortem* compared to

control Duroc animals, whereas there was no systematic differences between supplementation groups within the Landrace. In general the difference in cooling profile (Figure 1) only affected pH of the meat after 2 and 24 h *post mortem*. As a whole, carcasses frozen for 1 h had a higher pH at 2 h *post mortem* ($P = 0.005$) and specifically Duroc supplemented with 50 f CMH/d and Landrace supplemented with 25 g CMH/d had increased pH upon freezing. After 24 h the effect of cooling profile was more pronounced; generally pH was higher in frozen samples ($P < 0.0001$) and specifically Duroc supplemented with 12.5 g CMH/d and all groups of Landrace had increased pH upon freezing.

Delaying the pH decline initially during the conversion of muscle to meat reduces protein denaturation and may consequently reduce the drip loss. In this context the drip loss is assumed to be reduced in meat from Duroc pigs compared to Landrace, and in Duroc pigs supplemented with 50 g CMH/d compared to control Duroc animals. Furthermore, different cooling profiles may affect the drip loss despite the pH of the frozen meat was only significantly higher 2-24 h *post mortem*.

In general terms this theory was confirmed, since drip loss, as determined by the bag drip method, was reduced up to 30% in Duroc but slightly increased in Landrace upon CMH supplementation (Table 1). The difference in cooling profile did not affect drip loss.

NMR T_2 relaxation data were analysed using distributed exponential fitting, which revealed the presence of three water populations in the muscles. The slowest T_2 population, T_{22}, expresses the amount of extra myofibrillar water and has been shown to be positively correlated to the drip loss (Bertram, Donstrup, Karlsson & Andersen, 2002). The difference in drip loss between breeds determined by the bag drip method was not directly reflected in the NMR T_2 population measured initially *post mortem* (Figure 2). This may be due to a difference in the contribution from intra muscular fat to the T_{22} population between the two breeds, since Duroc is known to have more intra muscular fat than Landrace. However the tendencies towards reduced drip loss in Duroc and increased drip loss in Landrace upon CMH supplementation was confirmed by the *post mortem* development in the NMR T_{22} population, which revealed a smaller and larger increase in the T_{22} population in muscles of Duroc and Landrace, respectively, upon CMH supplementation, although none of the NMR data was significantly different because of the variation in the material. A large increase in the T_{22} population *post mortem* is known to result in a high drip loss (Bertram et al., 2003).

Conclusions

In general, a breed by dietary CMH interaction was observed for *post mortem* pH and drip loss. Thus, in Duroc dietary CMH addition increased pH, and reduced driploss, while no significant effects of dietary CMH addition were observed in meat from Landrace pigs.

Table 1. LSMeans of weight gain (g) of the live animals and WHC of the meat expressed as drip loss (%) (n = 10). Weight gain expressed as difference before and after 5 days of creatine monohydrate (CMH) supplementation.

		Duroc CMH supplement (g/d)				Landrace CMH supplement (g/d)			
	SEM	0	12.5	25	50	0	12.5	25	50
Weight gain (G)	0.64-0.72	5.77^{a}	6.98^{ab}	7.32^{ab}	7.86^{b}	5.73^{a}	8.34^{b}	7.13^{ab}	8.70^{b}
Drip loss (%)	0.50-0.51	4.31^{ab}	3.04^{a1}	3.35^{a2}	2.98^{a3}	5.41^{bc}	6.35^{c}	6.22^{c}	6.24^{c}

^{a,b}Means lacking a common superscript differ ($P \leq 0.05$). $^{1\text{-}3}$Significance level in relation to control ^{1} $P = 0.07$, ^{2} $P = 0.17$, ^{3} $P = 0.06$.

Table 2. LSmeans of pH in *Longissimus Dorsi* of Duroc and Landrace supplemented with different creatine monohydrate (CMH) concentrations, measured at various time points *post mortem* (n = 10). Cool: cooling at 4°C after slaughter, Freeze: freezing for 1 h, from 1-2 h *post mortem*.

Time (min) *post mortem*	Cooling profile		Duroc CMH supplement (g/d)				Landrace CMH supplement (g/d)			
		SEM	0	12.5	25	50	0	12.5	25	50
1	-	0.045	6.55^{abc}	6.58^{ab}	6.58^{bc}	6.66^{c}	6.48^{ab}	6.51^{ab}	6.46^{a}	6.51^{ab}
15	-	0.046	6.47^{ab}	6.46^{ab}	6.54^{b}	6.54^{b}	6.44^{ab}	6.41^{a}	6.37^{a}	6.48^{ab}
30	-	0.043	6.40^{ab}	6.44^{bc}	6.50^{bc}	6.55^{c}	6.41^{ab}	6.40^{ab}	6.32^{a}	6.47^{bc}
45	-	0.044	6.42^{ab}	6.40^{ab}	6.49^{bc}	6.56^{c}	6.31^{a}	6.31^{a}	6.31^{a}	6.38^{ab}
60	-	0.051	6.35^{abc}	6.36^{abc}	6.38^{bc}	6.47^{c}	6.28^{ab}	6.28^{ab}	6.23^{a}	6.27^{ab}
120	Cool	0.063	6.19^{bc}	6.23^{bc}	6.24^{bc}	$6.32^{c,x}$	6.10^{ab}	6.11^{ab}	$6.01^{b,x}$	6.12^{ab}
120	Freeze	0.063	6.25^{a}	6.29^{ab}	6.25^{a}	$6.43^{b,y}$	6.17^{a}	6.14^{a}	$6.13^{a,y}$	6.12^{a}
1440	Cool	0.027	5.61^{b}	$5.64^{b,x}$	5.61^{b}	5.62^{b}	$5.49^{a,x}$	$5.48^{a,x}$	$5.49^{a,x}$	$5.47^{a,x}$
1440	Freeze	0.027	5.63^{b}	$5.68^{b,y}$	5.63^{b}	5.69^{b}	$5.53^{a,y}$	$5.55^{a,y}$	$5.57^{a,y}$	$5.52^{a,y}$

[a-c]Means within a row lacking a common superscript differ ($P \leq 0.05$). [x,y]Means within a column and within a specific time lacking a common superscript differ ($P \leq 0.05$).

Figure 1. Mean of temperature in longissimus dorsi (LD) of carcass sides cooled at 4°C throughout, and sides frozen for 1 h from 1-2 h *post mortem* (n = 80). Dotted lines indicate SEM.

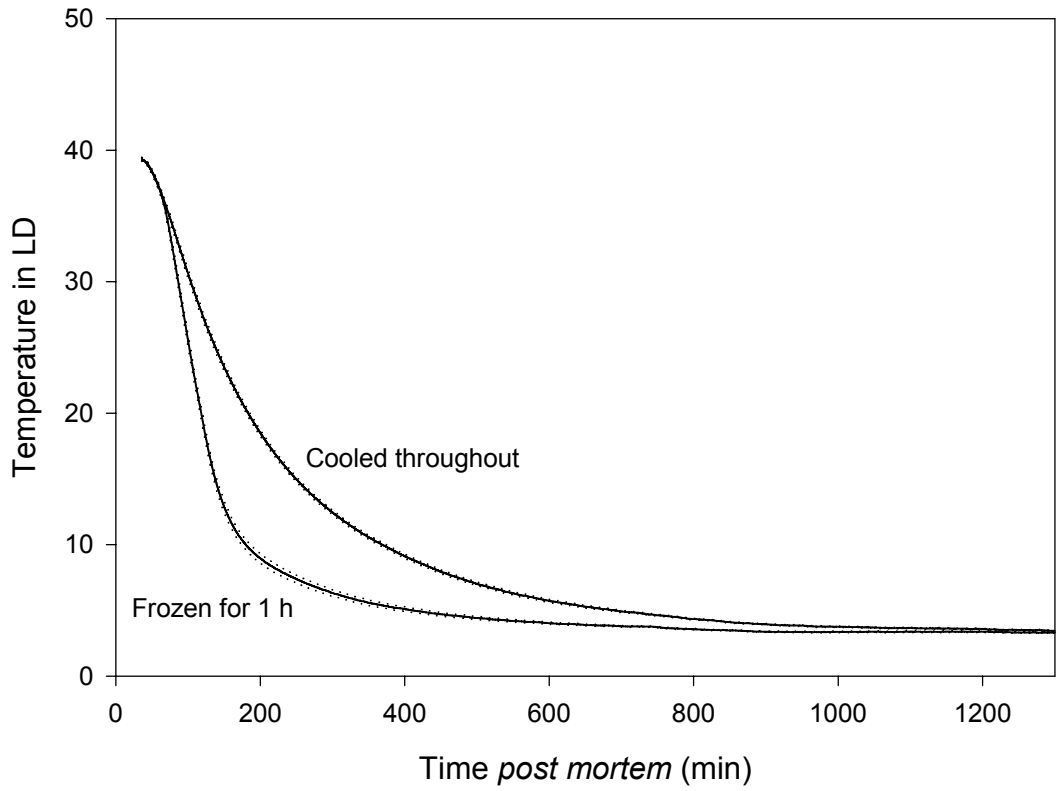
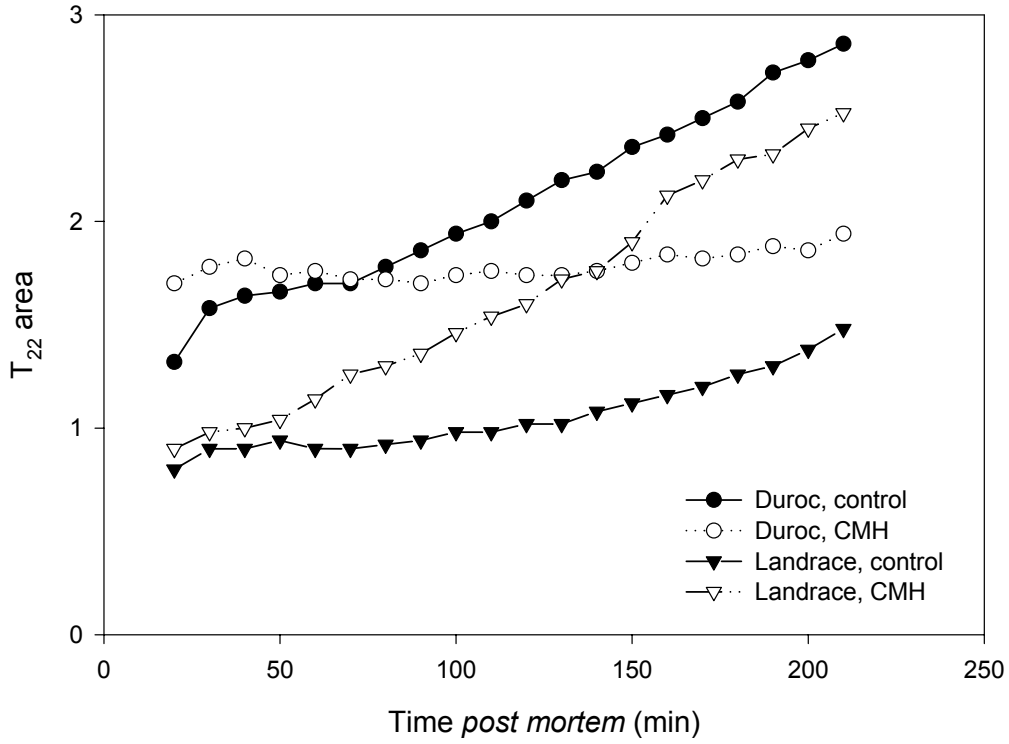


Figure 2. Development in NMR T_{22} population after slaughter in control pigs and pigs supplemented with 25 g CMH/d. LSMean values are shown, SEM = 0.38 (n = 10).



References

Balsom, P. D., Söderlund, K., & Ekblom, B. (1994). Creatine in humans with special reference to creatine supplementation. *Sports Medicine, 18*(4), 268-280.

Balsom, P. D., Söderlund, K., Sjödin, B., & Ekblom, B. (1995). Skeletal muscle metabolism during short duration high-intensity exercise: influence of creatine supplementation. *Acta Physiologica Scandinavia, 154*(3), 303-310.

Berg, E. P. & Allee, G. L. (2001). Creatine monohydrate supplemented in swine finishing diets and fresh pork quality: I. A controlled laboratory experiment. *Journal of Animal Science, 79*, 3075-3080.

Bertram, H. C., Donstrup, S., Karlsson, A. H., & Andersen, H. J. (2002). Continuous distribution analysis of T2 relaxation in meat - an approach in the determination of water-holding capacity. *Meat Science, 60*, 279-285.

Bertram, H. C., Karlsson, A. H., & Andersen, H. J. (2003). The significance of cooling rate on water dynamics in porcine muscle from heterozygote carriers and non-carriers of the halothane gene - a low-field NMR relaxation study. *Meat Science, 65*, 1281-1291.

Casey, A., Constantin-Teodosiu, D., Howell, S., Hultman, E., & Greenhaff, P. L. (1996). Creatine ingestion favorably affects performance and muscle metabolism during maximal exercise in humans. *American Journal of Physiology, 271*(1 Pt 1), E31-E37.

Casey, A. & Greenhaff, P. L. (2000). Does dietary creatine supplementation play a role in skeletal muscle metabolism and performance? *American Journal of Clinical Nutrition, 72*(2 Suppl), 607S-617S.

Honikel, K. O. (1998). Reference methods for the assessment of physical characteristics of meat. *Meat Science, 49*(4), 447-457.

James, B. W., Goodband, R. D., Unruh, J. A., Tokach, M. D., Nelssen, J. L., Dritz, S. S., O' Quinn, P. R., & Andrews, B. S. (2001). Effect of creatine monohydrate on finishing pig growth performance, carcass characteristics and meat quality. *Animal Feed Science and Technology, 96*(3-4), 135-145.

Juhn, M. S. (1999). Oral creatine supplementation. *The Physician and Sportsmedicine, 27*, 47-89.

Maddock, R. J., Bidner, B. S., Carr, S. N., McKeith, F. K., Berg, E. P., & Savell, J. W. (2002). Creatine monohydrate supplementation and the quality of fresh pork in normal and halothane carrier pigs. *Journal of Animal Science, 80*, 997-1004.