2.II - P 32

IS THERE AN INTERACTION BETWEEN FAT TYPE AND METAL ION CONCENTRATION IN DIETS AND WARMED-OVER FLAVOUR (WOF) IN PORK?

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Background.
To improve the nutritional value and healthy image of pork, pig producers use diets rich in ω-3 fatty acids. Pig diets also contain doses of pro-oxidants like iron and copper in excess of the recommended intake. However, these practices have a negative impact on the eating quality of pork since they both increase lipid oxidation and flavour deterioration. Warmed-over flavour (WOF), which is the rapid onset of off-flavours in cooked reheated meat, has been linked to oxidation of phospholipids and proteins. Although Miller et al. (1994) concluded that a reduction in the level of dietary iron did not affect WOF in pork, the author did not take into account the pro-oxidant activity of copper, the interaction between dietary metal ions or the degree of unsaturation of the dietary fat.

Objective.
To investigate the interaction of dietary fat saturation and metal ion concentration on the incidence of WOF in cooked pork.

Methods.
Animals and treatments: 32 Large White female pigs were randomly assigned to one of the four diets with 8 pigs per treatment. Dietary treatments were arranged in a 2 x 2 factorial with 2 fat types (tallow (diets 1&2) or tuna stearin (diets 3&4) at 3%) and two levels of metal ions (low (diets 1&3); 60 ppm Fe, 4 ppm Cu and 45 ppm Zn and high (diets 2&4); 150 ppm Fe, 250 ppm Cu and 150 ppm Zn). 24 hours after slaughter the longissimus lumborum (LL) and rectus femoris (RF) were removed from the carcass, vacuumed packed and stored at –20 °C until analysis (less than 6 months).
Measurements: Lipid oxidation was determined by thiobarbituric acid reactive substances (TBARS) using the extraction method of Witte *et al.* (1970). Samples were stored for 0, 1, 2, 4 or 6 days at 4 °C until required. The results were expressed as malondialdehyde equivalents per kilogram of meat (MDA/kg meat).
Sensory Analysis: An 8 member trained panel evaluated samples from 32 LLs. The meat was tempered overnight and minced through a single cut 8 mm-mincer plate. The homogenised meat was filled into 70 mm impermeable plastic casings and cooked to an internal temperature of 75 °C. The panel assessed the samples after 0, 1, 2 and 4 day of storage at 4 °C, with each panellist evaluating the same randomly selected set of four animals (one from each treatment) for each storage time. Panellists scored the samples on a total of 16 attributes, Table 2, as suggested by Byrne et al. (1999), using an unstructured line scale with anchor points.
Statistical Analysis: Treatment effects within each muscle were statistically analysed using a split-unit design with fat type and metal ion level as whole plot factors and time as a split-unit factor.
The sensory panel was designed as an incomplete Latin Square (8 panellists X 4 treatments X 3 sessions X 4 storage days).
Data were analysed using analysis of variance, with the SAS Institute, 1994 GLM procedure. A pairwise comparison of least squares means was used to evaluate effects, *P* values are given in brackets.

Results and discussion.
Mean liver metal ion concentrations are shown in Table 1. Docosahexaenoic acid (DHA, 22:6ω3) is used to indicate the presence of marine dietary fat. DHA concentrations (%wt/wt of total fatty acids in the phospholipid fraction of the LL) were as follows: diet 1=1.331±0.040, diet 2=1.089±0.040, diet 3=6.935±0.435 and diet 4=7.025±0.435. As expected animals fed diets 1&2 had significantly lower ($P<0.0001$) DHA levels than those fed Diet 3&4.

An analysis of the TBARS scores from cooked stored LL and RF showed highly significant ($P<0.0001$) effects of diet, time and a diet*time interaction. TBARS scores of the RF were significantly higher ($P<0.0001$) than those of the stable LL at all time periods except day 0. Figures 1 and 2 show the increase in TBARS values with days of storage in the LL and RF, respectively. Samples from diet 1 and diet 2 (tallow) had significantly lower TBARS scores than samples from the tuna stearin based diets, (diets 3 and 4) in both the LL and RF at all time points, except Day 0. LL samples from animals fed diet 3 had significantly higher ($P<0.0005$) TBARS values than LL samples from diet 4 at Day 2, 4 and 6. This was unexpected as it was thought the high level of metal ions would catalyse lipid oxidation and that meat from animals fed diet 4 would show a higher TBARS scores than that from diet 3. This unexpected result observed in the TBARS values from the LL was hard to explain but other authors have found that feeding animals high levels of copper increased the antioxidant capacity of the liver (Astrup and Matre, 1987). Additionally, it was found that pork chops from animals fed unsupplemented diets had higher TBARS scores than those from animals with diets supplemented with copper (Lauridsen et al., 1999). This effect was not repeated in the RF. However, meat from animals fed diet 1 had a significantly higher TBARS score than that from diet 2, on day 6 only. In the RF there are no observed differences between the tuna stearin based diets, over the 6 days storage.

The trained panel assessed LL samples according to a total of 16 attributes, 9 attributes showed significant diet effect and 7 attributes showed significant time effects but there was no significant diet*time interactions, Table 2. Generally, meat from animals fed the tallow-based diets were significantly different from meat of animals fed the tuna stearin based diets. Meat from animals fed diets 1 and 2 (tallow) had higher 'cooked pork meat-like flavour' and lower off-flavours, such as 'rancid', 'vegetable-oil-like' and 'fish like flavour', than meat of animals fed the tuna stearin based diets, 3 and 4. Meat of animals fed the tallow diets had lower values for all aroma attributes associated with off-aromas, such as 'cardboard-like', 'linseed-oil-like' and 'rubber-like'. As expected, the off-aromas and flavours of the cooked meat increased with storage time and the 'cooked pork meat-like flavour' and 'sweet' taste decreased with storage time. 'Salt' taste of the meat also decreased with storage time.

From the TBARS and sensory results, it was evident that the degree of saturation of the fat used in the animals' diets had a marked effect on oxidation and off-flavour development. Meat from animals fed the tuna stearin based diets (diets 3 & 4) had consistently higher scores for off-flavour and aroma attributes, and for TBARS values, than that from diets 1 and 2. It appeared that the high level of metals ions in the animals' diets has not increased oxidation compounds or off-flavour development. In fact, diet 4 had significantly lower TBARS than diet 3, in the LL. Although differences between diet 3 and 4 were not evident from the sensory results.

Conclusion.

The degree of unsaturation of the fat in the pigs' diets had a significant effect on the development of warmed over flavour scores. The high level of metal ion in the pigs' diets did not increase oxidation compounds or off-flavour development in either the tallow or fish oil based diets. In fact, the results in the LL show that meat from animals fed the tuna stearin oil based diet with high metal ions had significantly lower TBARS values than that from the tuna stearin oil diet with low metal ions.

References.

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Table 1. Metal Ion Concentration in the Liver of Animals on Experimental Diets (Mean±SE of log [ppm]).

Metal Ion	*Diet 1*	*Diet 2*	*Diet 3*	*Diet 4*
Fe^{2+}	2.450[a]±0.037	2.231[b]±0.037	2.356[ac]±0.037	2.336[bc]±0.040
Cu^{2+}	0.937[a]±0.065	2.060[b]±0.065	0.903[a]±0.065	1.967[b]±0.065
Zn^{2+}	1.286[a]±0.035	1.411[b]±0.035	1.309[a]±0.035	1.460[a]±0.037

[abc] Means followed by different superscripts within a row are significantly different ($P<0.05$).

Table 2: Sensory Attributes used to Score Pork Samples – Diet and Time Effects

Attribute	*Diet Effect (P)*	*Time Effect (P)*	*Attribute*	*Diet Effect (P)*	*Time Effect (P)*
Cardboard-like aroma	0.0244*	0.4490	Nut-like flavour	0.6290	0.7169
Linseed-oil-like aroma	<0.0001*	0.0703	Monosodium glutamate taste	0.7421	0.7906
Rubber-like aroma	0.0115*	0.0512*	Metallic taste	0.6909	0.1746
Cooked pork meat-like flavour	<0.0001*	<0.0001*	Bitter taste	0.6584	0.5318
Rancid flavour	<0.0001*	<0.0001*	Sweet taste	0.6572	<0.0001*
Bread-like flavour	0.8530	0.2265	Salt taste	0.8703	<0.0001*
Vegetable-oil-like flavour	0.0004*	<0.0001*	Sour taste	0.0308*	0.3474
Fish-like flavour	<0.0001*	0.0051*	Astringent aftertaste	0.0033*	0.2232

* Indicates significance ($P<0.05$)

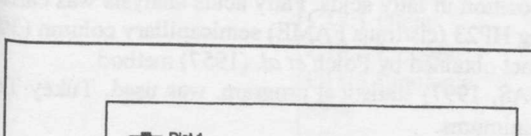

Figure 1. Increase in TBARS in cooked pork LL during storage at 4 °C.

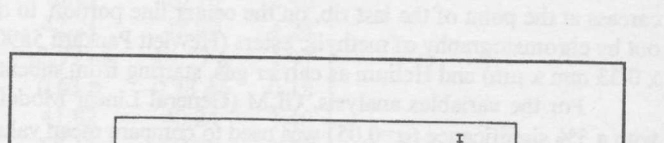

Figure 2. Increase in TBARS in cooked pork RF during storage at 4 °C.