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# EFFECT OF FEED INGREDIENT SOURCE AND MODIFIED ATMOSPHERE PACKAGING WITH CARBON MONOXIDE ON FRESH PORK QUALITY

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## Introduction

Feeding pigs with diets containing animal by-products is common practice in New Zealand and is based on both the historical association of pig production with the dairy industry and the relatively high cost of imported plant-based ingredients (NZPIB, 1998). A typical New Zealand finisher pig diet may contain 10% meat and bone meal, representing 30% of total dietary protein (Hendriks et al., 2002). There is considerable worldwide variation in both regulation of the animal feed and production industries and approaches to the safe use of by-product ingredients (Machin, 2005). Considering that no evidence has emerged showing a susceptibility of pigs to transmissible spongiform encephalopathies through oral exposure (Brooks, 1991; Anil & Austin, 2005), continued use of meat and bone meal can be expected in countries where marketing opinion remains favourable towards this practice and where economic considerations make it the most feasible method of protein and fat incorporation. There is, however, a paucity of data comparing the effects of feed ingredients derived from different by-product sources on pork quality.

Preservative packaging is another key meat quality concern, particularly where products are shipped to distant markets. Modified atmosphere packaging (MAP) using a high carbon dioxide environment is an effective means of prolonging microbial shelf-life during extended storage (Sørheim et al., 1999). In the short term, oxygen, either residual or in the MAP gas mixture, is effective for maintaining an attractive “bloomed” colour in red meats, but prolonged exposure results in the irreversible formation of metmyoglobin and an overwhelming of the myoglobin reducing ability of meat, thus preventing the oxygenation required for an attractive meat colour at retail (Tewari et al., 2002). Addition of carbon monoxide, however, results in the formation of stable, bright red carboxymyglobin, even at low levels of incorporation in the MAP environment (<1.0%; Luño et al., 2000).

## Objectives

This research was undertaken to explore the effects of feeding ingredients from animal by-product and plant material sources on pork quality and to determine the impact of including carbon monoxide in a carbon dioxide MAP atmosphere on the storage of this fresh pork for 8 weeks.

## Methodology

Eight pigs were fed from six weeks post-weaning to an average slaughter weight of 102.0 kg. During each growth phase (weaner, grower, finisher), pig diets were differentiated by their ingredient sources. Half of the pigs received a diet with protein and fat sourced from a combination of animal and plant ingredients (barley + blood meal, fish meal, meat and bone meal, skim milk powder, soybean meal, tallow). The remainder of the pigs received diets based solely on plant ingredients (barley + soybean meal, soy protein isolate, peas, soybean and linseed oils).

Carcass processing was conducted at a commercial plant. Following overnight chilling (~18 h), longissimus muscles were removed from each carcass. All cutting and packaging was completed in a well-sanitized commercial facility at the start of the work day. The lumbar portion (extending 30 cm from the last rib) of each left side muscle was vacuum packaged and returned to the meat lab for evaluation at 48 h postmortem. Fat thickness over the last rib was measured and a muscle tracing was taken and later measured (KP-90 N planimeter, Placom, Japan) to determine area. A pre-weighed 25 mm slice from each muscle was cooked for 60 min at 70oC in a waterbath. After chilling overnight, samples were reweighed to determine cooking loss and from each, six cores with 13 x 13 mm cross-sections were prepared for Warner-Bratzler shearing. Drip loss of a 40 mm cube from each muscle was determined after suspending pre-weighed samples inside pre-inflated plastic bags for 48 h at 0-1°C. Measurement of pH was made on 2.0 g meat samples homogenized with distilled water.

Each right side longissimus muscle was divided into 27 boneless pork chops. Each chop was placed on a polystyrene tray with soaker pad and overwrapped with a highly permeable polyethylene film to produce retail-ready samples. The overwrap film was scored with a knife to permit unrestricted gas exchange once samples were placed in master packs. Three chops from each muscle were designated for immediate evaluation (week 0) upon their return to the lab. The remaining 24 chops from each muscle were allocated to one of two MAP treatments consisting of the placement of six retail-ready samples in transparent, 7-layer, co-extruded barrier bags (O2 transmission rate 0.13 cc/m2/24h/atm at 1°C and 100% RH, Vertex Pacific Ltd, New Zealand). The bags were evacuated and flushed twice (Securepack, Vertex) with an excess of either 100% carbon dioxide (CO-) or a mixture of 80% carbon dioxide, 19.6% nitrogen, and 0.4% carbon monoxide (CO+). Within each modified atmosphere packaging treatment, three chops from each muscle were allocated to refrigerated storage (3°C) for 2, 4, 6, or 8 weeks.

At the conclusion of each storage period, colour and bacteriology of each pork chop were evaluated. Immediately after opening each master pack, instrumental colour (L*, hue, chroma; Minolta ChromaMeter CR-200, Japan) was measured through the overwrap film. Pork chops were then aseptically sampled and prepared for enumeration of total aerobes and anaerobes (plate count agar; Merck, New Zealand) and presence/absence of Listeria spp. (prepoured Difco Oxford agar, Fort Richards Laboratories Ltd, New Zealand; Single Path test, Merck, New Zealand). Colour measurements were repeated after microbiological sampling was completed. The remainder of each sample was freeze dried and prepared for thiobarbituric acid reactive substances assay (Inoue et al., 1998) to assess lipid oxidation status.

Statistical analyses of meat and storage quality data were conducted with the GLM procedure of SAS, using repeated measures for colour measurements. Means were deemed significantly different at $P < 0.05$.

**Results & Discussion**

Dietary treatment did not affect fat depth or longissimus muscle area (Table 1), indicating that similar carcass yields can be expected when pigs are fed to a common slaughter weight on diets containing either animal or plant ingredients. Similarly to Lettner et al. (2001) who reported a lack of significant difference on drip loss and taste panel scores for tenderness, juiciness, and flavour of pork from pigs fed diets containing 10-12% meat meal versus 25% soy, no other meat quality attributes were affected by dietary treatment (Table 1).

Table 1. Effect of ingredient source on carcass and meat quality attributes

| | Ingredient source | | | |
|---|---|---|---|---|
| Quality attribute | Animal by-products | Plant material | SEM | P-value |
| Fat depth (mm) | 11.9 | 12.0 | 0.53 | 0.86 |
| Muscle area ($cm^2$) | 40.3 | 40.8 | 1.50 | 0.77 |
| Shear force (kg) | 7.4 | 7.6 | 0.39 | 0.66 |
| Cooking loss (%) | 29.5 | 29.7 | 0.51 | 0.80 |
| Drip loss (%) | 3.9 | 3.9 | 0.35 | 0.89 |
| pH | 5.53 | 5.57 | 0.042 | 0.48 |

Dietary treatment of the live pigs did not affect the subsequent bacteriology of the pork chops, and differences in bacterial counts were neither practically significant nor consistent across MAP environments and storage time (Table 2). Mean aerobic counts moved from 3.2 to 3.6 log CFU·g-1 between 0 and 8 weeks of storage ($P = 0.04$), while anaerobes averaged 2.0 log CFU·g-1 at week 0, decreased to 1.5 log CFU·g-1 by week 2 and gradually increased to 2.2 log CFU·g-1 by the conclusion of the study ($P < 0.01$). Reflecting the general level of hygiene in the processing facility, bacterial counts did not reach levels anywhere near the 6.0 log CFU·g-1 threshold for spoilage.

Table 2. Effect of ingredient source and presence of CO in the MAP environment on total plate counts of aerobic and anaerobic bacteria over 8 weeks of refrigerated storage

| | Ingredient source and CO presence | | | | | P-value | | |
|---|---|---|---|---|---|---|---|---|
| Plate count, | Animal byproducts | | Plant material | | | | | |
| log CFU·$g^{-1}$ | CO+ | CO- | CO+ | CO- | SEM | IS | CO | IS x CO |
| Aerobes | | | | | | | | |
| Week 0 | 3.3 | 3.3 | 3.0 | 3.0 | 0.09 | 0.48 | - | - |
| Week 2 | 3.7 | 3.7 | 3.3 | 3.2 | 0.11 | 0.07 | 0.85 | 0.80 |
| Week 4 | 2.9 | 3.3 | 3.0 | 3.6 | 0.20 | 0.75 | 0.03 | 0.75 |
| Week 6 | 3.3 | 3.4 | 3.4 | 3.4 | 0.19 | 0.88 | 0.80 | 0.69 |
| Week 8 | 3.8 | 3.4 | 4.1 | 3.0 | 0.34 | 0.76 | 0.04 | 0.41 |
| Anaerobes | | | | | | | | |
| Week 0 | 2.2 | 2.2 | 1.9 | 1.9 | 0.19 | 0.65 | - | - |
| Week 2 | $1.7^{a}$ | $1.3^{b}$ | $1.2^{b}$ | $1.6^{ab}$ | 0.16 | 0.67 | 0.75 | <0.01 |
| Week 4 | 1.0 | 1.7 | 1.4 | 1.7 | 0.27 | 0.49 | 0.08 | 0.45 |
| Week 6 | 1.7 | 1.9 | 1.7 | 2.1 | 0.25 | 0.94 | 0.28 | 0.70 |
| Week 8 | 2.7 | 2.1 | 2.4 | 1.8 | 0.40 | 0.98 | 0.16 | 0.99 |

[a,b]Means followed by common letters are not significantly different ($P > 0.05$)

The presence/absence of *Listeria* spp. was assessed as an indicator of the presence and distribution of psychrotrophic pathogens. Five of the eight muscles had at least one pork chop that tested positive for this organism and these were equally distributed across both dietary and MAP treatments. Once a sample tested positive, subsequent samples from that muscle tended to remain positive until the sixth week of storage, after which time no positive results were recorded. The relatively wide distribution of *Listeria* indicates that caution must be exercised and due attention paid to personal hygiene procedures where retail-ready products are produced. Although the source of contamination was not known, its introduction and spread across multiples samples within a muscle were suspected to have been by a member of the packaging team and not by cutting facility staff. While this did not affect the shelf-life of the product, it is clearly a point of concern.

Feed ingredient source had no effect on meat colour (Table 3), nor did Lettner et al. (2001) observe an effect on reflectance. The CO+ samples had a lighter (L*), more intense (chroma), red (hue) colour than the pork chops exposed to 100% $CO_2$. After exposure to atmospheric oxygen this MAP treatment effect was sustained. Upon visual assessment we concluded that the CO+ pork chops were a more attractive and appealing pink-red colour than the samples packaged without CO.

Table 3. Effect of ingredient source and presence of CO in the MAP environment on instrumental colour measurements of packaged meat and meat exposed to atmospheric oxygen

| | Ingredient source and CO presence | | | | | P-value | | |
|---|---|---|---|---|---|---|---|---|
| | Animal by-products | | Plant material | | | | | |
| Colour | CO+ | CO- | CO+ | CO- | SEM | IS | CO | IS x CO |
| In package | | | | | | | | |
| L* | 58.1 | 57.1 | 57.7 | 56.9 | 0.28 | 0.78 | <0.01 | 0.70 |
| Chroma | 11.4 | 8.6 | 11.1 | 8.4 | 0.20 | 0.86 | <0.01 | 0.79 |
| Hue | 16.4 | 22.4 | 17.7 | 23.0 | 0.61 | 0.75 | <0.01 | 0.62 |
| Open package[z] | | | | | | | | |
| L* | 56.0 | 55.0 | 55.8 | 55.2 | 0.37 | 0.79 | 0.03 | 0.63 |
| Chroma | 14.14 | 13.0 | 13.8 | 12.4 | 0.39 | 0.39 | <0.01 | 0.70 |
| Hue | 31.7 | 37.9 | 31.6 | 39.2 | 0.65 | 0.87 | <0.01 | 0.31 |

[z]Effect of exposure to atmospheric oxygen P <0.01 for all colour measurements

As expected, pork from animals fed a diet containing only plant-derived ingredients displayed a significantly higher level of lipid oxidation (animal = 0.63, plant = 1.42 ± 0.076 µg MDA·$g^{-1}$ fat, P <0.01) since propensity to oxidize increases with level of fat unsaturation (Wood et al., 2003). The MAP gas environment had no effect on lipid oxidation (CO+ = 1.02, CO- = 1.03 ± 0.067 µg MDA·$g^{-1}$ fat, P = 0.89), although Luño et al. (2000) reported increased inhibition of lipid oxidation with increased CO concentration in the MAP atmosphere.

## Conclusions

Feeding pig diets containing either animal by-products or plant materials did not significantly affect quality or bacteriology of fresh pork, although lipid oxidation was greater in pork from pigs fed the plant ingredient diet, a source of polyunsaturated fatty acids. Either type of diet can be recommended for producing pork of acceptable quality, however, further investigation of the impact of plant ingredients on pork rancidity and palatability with extended storage is warranted. Where care is taken to control hygiene at the time of packaging, a carbon dioxide-MAP gas mixture with or without CO provides at least 8 weeks of spoilage-free refrigerated storage for retail-ready pork chops. Although it did not affect lipid oxidation, inclusion of CO provides a clear advantage for the maintenance of a bright, pink-red fresh pork colour under both MAP conditions and after exposure to atmospheric oxygen.

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