

Halothane genotype and pork production. 2 Processed pork products

P. Fisher* and F.D. Mellett

Department of Animal Sciences, University of Stellenbosch, 7600 Stellenbosch, South Africa

Received 19 July 1996; accepted 22 May 1997

The effect of the halothane gene on processed pork characteristics was investigated using the meat from 59 Landrace × Large White pigs of known halothane genotype (NN = 31, Nn = 17, nn = 11). The backs and hams were used to prepare canned hams and smoked bacon. The bacon prepared from the meat derived from the NN pigs showed an improved net bacon yield and lower moisture loss during processing (2.5 vs 7.7% for nn, $p < 0.001$). Chemical analyses of the bacon samples showed that the bacon prepared from NN pigs had the highest moisture (50.2%) and protein content (72.4%), with an intermediate fat content (5.9%). The bacon from nn pigs had the lowest protein and highest fat content, with moisture content intermediate. The NN pigs had the lowest sodium content (12 096 ppm), with nn the highest (13 446 ppm). The percentage cookout from the canned hams was also highest for the genotypes with the halothane gene (Nn = 16.73%; nn = 15.45%) vs 13.33% for NN. The results indicate that the presence of the halothane gene causes inferior processed pork products, such as is experienced with pale, soft exudative meat. The intentional use of the halothane gene is strongly discouraged.

Die invloed van die halotaangeen op die eienskappe van geprosesseerde varkvlies is ondersoek deur gebruik te maak van die vleis afkomstig vanaf 59 Landras- × Grootwitvarke met bekende halotaangenotipe (NN = 31, Nn = 17, nn = 11). Die lendes en hamme is gebruik vir bereiding van geblikte hamme en gerookte spek. Die spek afkomstig van die NN varke het 'n hoër persentasie spekopbrengs en 'n laer persentasie vogverlies gehad tydens prosessering (2.5 vs 7.7% vir nn, $p < 0.001$). Chemiese ontleding van die spekmonsters toon dat die spek afkomstig van die NN varke die hoogste voginhoud (50.2%) en proteïeninhoud (72.4%) gehad het, met 'n intermedieë vetinhoud (5.9%). Die spek van die nn varke het die laagste proteïen- en hoogste vetinhoud gehad, met voginhoud intermedieër. Natriuminhoud was die laagste vir die NN varke (12 096 ppm) en die hoogste vir die nn varke (13 446 ppm). Die geblikte ham afkomstig vanaf genotipes wat die halotaangeen bevat het die grootste persentasie kookverliese getoon (Nn = 16.73%; nn = 15.45%) vs 13.33% vir NN. Die resultate dui aan dat die teenwoordigheid van die halotaangeen swak kwaliteit geprosesseerde varkprodukte veroorsaak, ooreenkomstig met produkte afkomstig van BPW vleis. Die doelbewuste gebruik van die halotaangeen word sterk afgeraai.

Keywords: processed products, pigs, halothane gene

* Author to whom correspondence should be addressed

Introduction

Although it was believed that halothane genotype (NN, Nn or nn) can seriously influence pork quality (PSE, normal, DFD), the technique to accurately determine halothane genotype was only developed recently (Fujii *et al.*, 1991). This enabled researchers to investigate directly the effect of the halothane genotype on pork quality. The quality of pork received a lot of attention in processing. For instance, the reduced water holding capacity (WHC) of PSE meat may lead to an increased percentage gelatinous cookout in canned meat products, owing to a higher than normal degree of aggregation of meat proteins, especially for pasteurised, canned hams (Wisner-Pedersen, 1968). Hams prepared from PSE meat showed significant improvement in WHC and technological yield when polyphosphates were used (Davis *et al.*, 1975). Honkavaara (1988) compared PSE pork ($\text{pH}_1 < 5.8$) with non-PSE pork ($5.8 < \text{pH}_1 < 6.4$) in cooked cured ham production. PSE pork resulted in an acceptable product, yet with decreased sensory scores and a technological yield of 94%, compared to 105.9% for non-PSE pork. Similar relationships between pH and ham quality was reported by Müller (1991). Increased pH values resulted in higher cooked ham yields, with a concomitant decrease in the amount of juice exudation.

Fisher & Mellett (1997) showed that halothane type has an

influence on initial pH (pH_1). During bacon manufacturing PSE meat, which has a reduced WHC, yields a lower net gain compared to non-PSE meat. Smith & Leser (1982) reported that PSE carcasses yielded 1.6% less bacon and increased mass (moisture) loss ($\pm 1\%$) compared to normal (non-PSE) carcasses. The relationship between PSE and the appearance of cured bacon is not clear. During curing the added nitrite reacts with the pigments in the meat and converts it to nitrosomyoglobin. Taylor *et al.* (1973) reported that PSE bacon was paler in colour compared to normal bacon when measured with a reflectometer, but visible colour differences were only seen in two toned *semitendinosus* muscles.

Materials and methods

Preparation of back bacon

Frozen (-40°C) backs, topsides and silversides from known genotypes (Fisher & Mellett, 1997) were thawed out and the individual weights recorded. Thawing losses could not be calculated accurately, since the initial (unfrozen) weight could not be determined accurately on the production floor, and were thus disregarded. A brine solution was formulated so that with 20% m/m injection, the ingredients specified in Table 1, would be added to each back.

Thus, the brine solution contained 12% NaCl. A *Belam*

Table 1 Bacon brine ingredients added to deboned backs

Ingredients	Quantity
NaCl	20 g/kg
Dextrose	10 g/kg
Polyphosphate	4 g/kg
NaNO ₂	160 ppm
Sodium ascorbate	500 ppm

multi-needle brine injector, calibrated to pump 20% m/m at an operating pressure of 2 bar, was used for this purpose. To determine actual brine mass absorbed (% pumped yield), the individual injected backs were weighed and the weights recorded, before submersion in the mentioned 12% NaCl brine solution for 24 h, before further processing. After this period the backs were hung on a trolley, allowed to drip for 6 h and smoked at 50°C for 2 h (Maurer smokehouse, with Meranti wood chips). After a 6 h cooling phase at room temperature (10–15°C) the processed back bacons were chilled for 12 h at 2°C and thereafter weights were recorded. The moisture loss (% moisture loss) during the process was calculated relative to the raw mass. The net bacon yield (% bacon yield) was calculated as the net gain of bacon relative to raw mass. For chemical analyses a lean sample was removed from the central portion of each back bacon. This is approximately in the region of the last rib.

Chemical analyses were only done on the lean portion [*M. longissimus thoracis* (MLT)] of each back bacon, because the backs were trimmed to ca 1 cm fat thickness, to simulate production practice. Moisture content was determined by the method of freeze drying. The samples removed from the backs were weighed and placed in a freeze drier for 72 h, whereafter the weight of the samples were again determined. Moisture content was expressed as the weight difference after drying as a percentage of the initial (before drying) weight. Nitrogen content was determined by the Kjeldahl system (AOAC, 1980) and expressed as the percentage protein in the sample on a dry matter (DM) basis. Fat content was determined with ether extraction (AOAC, 1980) and expressed as a percentage of the sample on a DM basis. Sodium content was determined with direct plasma liquid spectrometry and expressed as mg Na⁺ per kg meat on a DM basis.

Preparation of canned hams

The topsides and silversides were grouped according to genotype and, after thawing, each genotype's meat was minced through a 20 mm mincing plate. After mincing, an 8 kg sample of each genotype's meat was collected for ham preparation. The meat of each genotype (together with the ingredients listed in Table 2) was then tumbled for 1 h in 10 min tumble/rest cycles:

In order to determine actual ham cookout (moisture not bound to the meat) during the sterilisation process no gelatine was added to this formulation. The tumbled meat of each genotype was canned (300 g per can, 20 cans per genotype), vacuum sealed and sterilised at 124°C for 21 min in a Rotomat autoclave. After 24 h cooling the cans were opened and the contents removed. The exposed surface of the meat of

Table 2 Ham brine ingredients added to deboned minced pork

Ingredients	Quantity
Water	260 g/kg
Polyphosphate	9 g/kg
NaCl	25 g/kg
NaNO ₂	160 ppm
Dextrose	9 g/kg
Sodium ascorbate	500 ppm
Total	303.46 g/kg

each can was carefully dried with absorbent paper and weighed. Cooking loss was this dried weight relative to filled weight.

Statistical procedures

A full model, including genotype and sex, was used as described in Fisher & Mellett (1997). However, for the canned hams, sex was excluded as a variable.

Results and discussion

Back bacon

After a 24 h submersion brine bath, the pumped yields were much lower than the expected 20% addition for all genotypes, although control samples showed 20% m/m addition directly after injection. The only variable that showed genotype × sex interaction ($p < 0.0500$) (Table 3) was percentage bacon yield. This interaction was disregarded in this case since the sex of the pig is generally not traceable during or after the manufacturing process of bacon, and since none of the other dependent variables showed interaction (Table 3).

The results from Table 3 indicated that the backs from the nn pigs, in spite of initially absorbing the most brine (% pumped yield) during needle injection, had the highest moisture loss (% moisture loss) ($p < 0.001$) during subsequent processing, compared to the other two genotypes. This resulted in the backs from the nn pigs having the lowest net gain (% bacon yield), though not significant. Fisher & Mellett (1997) reported a high incidence of PSE in the presence of the halothane gene (Nn or nn). Wismer-Pedersen (1968) and Smith & Leser (1982) reported a higher moisture loss and reduced net gain for cured meat products prepared from PSE carcasses. Owing to the design of this study, which only investigated the effect of genotype on meat quality and processing characteristics, statistical analysis was not performed on meat quality type (PSE, DFD or normal). A possible explanation for the initial higher percentage moisture gain (% pumped yield) in meat derived from nn pigs, could possibly be the more open structure of the myofibrils of the PSE meat (Briskey, 1964), thus allowing more moisture into the fibrillar network of the skeletal muscle. The subsequent higher moisture loss (% moisture loss) and resultant lower net gain (% bacon yield) is again probably due to a higher state of protein denaturation in the backs derived from the nn pigs and thus eventually resulted in an impeded moisture-binding capacity. The high percentage of PSE carcasses in the Nn group (Table 2, Fisher & Mellett, 1997) seem to produce anomalous results in

Table 3 The effect of genotype and sex on processed meat quality characteristics (mean \pm std error)

	Genotype			Sex		Genotype \times Sex interaction
	NN	Nn	nn	C	G	P > t
Back bacon						
% pumped yield	9.7 (\pm 1.01)	8.1* (\pm 1.37)	12.6* (\pm 1.69)	10.2 (\pm 0.99)	9.2 (\pm 1.15)	0.1136
% moisture loss	2.5 (\pm 0.70)	1.2 (\pm 0.94)	7.7*** (\pm 1.16)	2.8 (\pm 0.77)	3.6 (\pm 0.90)	0.4226
% bacon yield	7.2 (\pm 1.24)	6.9 (\pm 1.67)	4.8 (\pm 2.08)	7.4 (\pm 1.17)	5.6 (\pm 1.38)	0.0500
Chemical analysis						
% moisture	50.2 (\pm 0.83)	44.8* (\pm 1.12)	49.4 (\pm 1.39)	48.8 (\pm 0.89)	48.1 (\pm 1.04)	0.9846
% protein	72.4* (\pm 0.83)	71.6 (\pm 1.11)	69.1* (\pm 1.38)	71.5 (\pm 0.81)	71.6 (\pm 0.94)	0.4859
% fat	5.9 (\pm 0.49)	5.7 (\pm 0.66)	7.6 (\pm 0.82)	6.3 (\pm 0.50)	5.9 (\pm 0.56)	0.5339
Sodium content (ppm)	12096* (\pm 335)	12477 (\pm 453)	13446* (\pm 563)	12552 (\pm 328)	12328 (\pm 383)	0.9574
Canned hams						
% ham cookout	13.33*** (\pm 0.107)	16.73*** (\pm 0.107)	15.45*** (\pm 0.107)	— —	— —	

* Values in the same row with the same caption (genotype or sex) differ ($p < 0.05$), according to contrast analyses (see text).

*** Values in the same row with the same caption (genotype or sex) differ ($p < 0.001$), according to contrast analyses (see text).

this regard, which could call into question the choice of pH values used to discriminate between PSE, DFD and normal carcasses. Future research should include objective meat colour determination in conjunction with pH_i measurements for predicting meat quality more accurately. Since literature is limited regarding the processing characteristics of the different halothane genotypes, comparison to meat quality types was considered appropriate. None of the characteristics for back bacon showed significant differences between the sexes (Table 3), thus justifying the current practice to disregard sex during the manufacturing of meat products.

Results from the chemical analysis (Table 3) of the lean muscle (MLT) of the back bacon indicate that the moisture content was the highest for the NN pigs, differing significantly ($p < 0.05$) from the Nn pigs, but not from the nn pigs. The NN halothane genotype not only retained more moisture, as reflected in the chemical analyses, but also as reflected in the highest bacon yield, despite the fact that this genotype did not have the highest initial pumped percentage or lowest percentage moisture loss during processing. Percentage protein (expressed on a dry matter basis) only differed significantly between NN and nn pigs, with NN having the higher protein content (72.4%). Surprisingly, the MLT bacon sample, prepared from nn pigs, contained the highest amount of marbling fat (7.6%), which supports the finding of Fisher & Mellett (1997) that faster growth of the nn genotype reflected in more fat deposition. Sodium content (expressed on a dry matter basis) (Table 3) was the highest for the nn pigs, differing significantly ($p < 0.05$) from the NN pigs. No significant differences between sexes for any of the chemical characteristics

were observed.

In contrast to the results of the present study, other reports indicate that unadulterated (fresh) lean meat derived from NN pigs has the lowest protein and the highest fat content, with Nn intermediate and nn pigs having the highest protein and lowest fat content (Murray *et al.*, 1989; Sather *et al.*, 1991). This could indicate that nn pigs grow faster, mature faster and thus deposit fat in different depots quicker. However, the correlation between subcutaneous fat and marbling fat (in the MLT, expressed as percentage chemically determined fat) was not significant. Studies show a trend similar to the results in Table 3 (regarding the chemical composition) in that an increase in fat content is accompanied by a corresponding lower moisture content. The higher sodium content of the lean meat from the nn pigs indicates that the high moisture loss causes a higher concentration of sodium in the muscle, thus suggesting that the exudate is mainly unbound water. The high sodium content of the bacon derived from the nn pigs will probably be less acceptable to the quality and health conscious consumer, since it will result in very salty bacon, with a higher sodium content.

Canned hams

The percentage moisture lost after sterilisation differed significantly ($p < 0.001$) between all three genotypes (Table 3). The NN pigs had the lowest percentage exudate. Both the Nn and nn pigs had moisture losses in excess of 15% (16.7% and 15.5% respectively) compared to the NN pigs (13.33%). Owing to the lack of research reports on halothane genotype and ham processing, only comparisons to PSE meat in ham

processing can be made.

Wismer-Pedersen (1968) reported that the reduced water holding capacity (WHC) of PSE meat leads to an increased percentage gelatinous cook-out in cans, owing to a higher degree of aggregation of meat proteins, especially for pasteurised canned hams. This could probably explain the high moisture losses or cook-out of the hams from the Nn and nn pigs, since both genotypes had a high proportion (70.6% and 63.6% respectively) of PSE carcasses (Table 2, Fisher & Mellett, 1997) in the samples examined. Ockerman *et al.* (1978) reported that short tumbling (30 min) improved muscle cohesion, but did not significantly affect ham yield, and that longer tumbling periods are required to enhance yield compared to cohesion. The reduced moisture-binding capability of the high proportion of PSE meat present in the Nn and nn genotype in the present study was thus probably enhanced by the short tumbling period (30 min), thus leading to a lower net yield (higher percentage moisture loss) in the final product. The results of this study support results by Honkavaara (1988), who reported a reduced technical yield for cooked cured ham prepared from PSE pork, compared to non-PSE pork. Müller (1991) reported similar relationships between pH and ham quality: meat with higher pH values resulted in higher cooked ham yields with a concomitant decrease in the amount of juice exudation.

The results from this study suggest that the presence of the halothane gene causes higher sodium content and lower WHC (as reflected in moisture content, yields and losses), eventually resulting in a product of inferior quality and subsequent diminished returns for pork processors. It is suggested that processors should consider paying a premium on pork derived from animals that are free of the halothane gene.

References

- A.O.A.C., 1980. Official methods of analysis of the Association of Official Analytical Chemists. 13th edn. Ed W. Horwitz. AOAC, Washington, D.C. p.376.

- BRISKEY, E.J., 1964. The etiological status and associated studies of pale, soft and exudative porcine musculature. *Adv. Food Res.* 13, 89.
- DAVIS, G.W., SMITH, G.C., CARPENTER, Z.L. & CROSS, H.R., 1975. Relationship of quality indicators to palatability attributes of pork loins. *J. Anim. Sci.* 41, 1305.
- FISHER, P. & MELLETT, F.D., 1997. Halothane genotype and pork production. 1. Growth and meat quality characteristics. *S. Afr. J. Anim. Sci.* 27, 22.
- FUJII, J., OTSU, K., DE LEON, V.K., WEILER, J., O'BRIEN, P.J. & MACCLENNAN, D.H. 1991. Identification of a mutation in porcine ryanodine receptor associated with malignant Hyperthermia. *Science* 253, 448.
- HONKAVAARA, M., 1988. Influence of PSE pork on the quality and economics of cooked, cured ham and fermented, dry sausage manufacture. *Meat Sci.* 24, 201.
- MÜLLER, W.-D., 1991. Cooked, cured products. *Fleischwirtsch.* 71, 544.
- MURRAY, A.C., JONES, S.D.M. & SATHER, P., 1989. The effect of preslaughter feed restriction and genotype for stress susceptibility on pork lean quality and composition. *Can. J. Anim. Sci.* 69, 83.
- OCKERMAN, H.W., PLIMPTON, R.F. Jr., CAHILL, V.R. & PARRETT, N.A., 1978. Influence of short-term tumbling, salt and phosphate on cured canned pork. *J. Food Sci.* 43, 878.
- SATHER, A.P., MURRAY, A.C., ZAWADSKI, S.M. & JOHNSON, P., 1991. The effect of the halothane gene on pork production and meat quality of pigs reared under commercial conditions. *Can. J. Anim. Sci.* 71, 959.
- SMITH, W.C. & LESER, D., 1982. An economic assessment of pale, soft, exudative musculature in the fresh and cured pig carcass. *Anim. Prod.* 34, 291.
- TAYLOR, A.A., DANT, S.J. & FRENCH, J.W.L., 1973. Processing Wiltshire bacon from PSE-prone pigs. *J. Food Technol.* 8, 167.
- WISMER-PEDERSEN, J., 1968. The pH dependent water-binding capacity of pork muscle in relation to processing. In: Recent points of view on the condition and meat quality of pigs for slaughter. Eds. Sybesma, W., Van der Wal, P.G. & Walstra, T. Schoonoord, Zeist, The Netherlands, p. 53.