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Variation in sheepmeat odour and flavour

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INTRODUCTION

Sheepmeat odour and flavour has received only sporadic interest from flavour researchers probably because the species has only minor importance in the huge beef and pork dominated markets of North America and Japan. The characteristic odour and flavour of sheepmeat is one of the reasons its consumption is very low in these affluent markets (Young *et al.,* 1994).

Several researchers have explored the likely biochemical origins and chemical causes of sheepmeat odour and flavour as distinct from all other ruminant meats except perhaps goat. Building on the classical work of Hornstein & Crowe (1960, 1963), who proposed that meat fat was the principal source of species odour, Brennand & Lindsay (1982) showed that fatty tissue was particularly distinguishing for sheepmeat odours. Reid *et al.,* (1993) found that fat oxidation products, so often linked to species odours (Cross & Ziegler, 1965; Rubin & Shahidi, 1988), were probably not involved in the characteristic species odour of sheepmeat. Wong *et al.,* (1975) proposed that certain methyl-branched fatty acids present in subcutaneous fat were directly responsible for sheepmeat odour, and confirmed this with a sensory experiment where 4-methyloctanoic acid was used to lace meat samples. Garton *et al.,* (1972), Duncan & Garton (1978) and later Ha & Lindsay (1990), described plausible diet-linked biochemical pathways for the formation of these fatty acids in sheep as distinct from cattle and deer. Brennand & Lindsay (1992) confirmed that this and related fatty acids were present in cooking volatiles in sufficient quantities to provide the characteristic sheepmeat odour.

Although the branch chain fatty acid hypothesis has endured, several researchers have proposed that other odour volatiles are the cause of the characteristic odour or are important modifiers of it. These include sulphur-containing compounds (Cramer, 1983), various pyrazines and pyridines (Buttery *et al.,* 1977) and a range of phenolic compounds (Ha & Lindsay, 1991).

In the New Zealand situation there are two factors that may impinge on the question of causal agents of the odour. First is the pastoral diet that sustains our enormous production base for export lamb. Does this exacerbate the odour and does the odour profile depend on the particular pasture type?

Second is the matter of meat pH. Graafhuis & Devine (1994) showed that the ultimate pH of New Zealand lamb ranged from pH 5.5 to 6.4, with 15 % of the lamb kill at pH 6 or above. Moreover, Young *et al.* (1993) established that one breed was more prone to the pH condition than another. Experiments with beef (Dransfield, 1981) indicated that as pH increased, beef flavour decreased. If the same were true for sheepmeat, we might expect variation in sheepmeat odour/flavour, for better or worse. In either event, variability must be controlled if quality is to be improved.

In a recent review of sheepmeat odour and flavour, Young *et al.,* (1994) proposed that a perspective view on variation in sheepmeat odour and flavour would require sensory evaluation of muttonness, simultaneous chemical analysis of all the volatiles, and a statistical comparison of the two data sets in the hope that meaningful relationships would emerge. This approach is reported here where we explored the effects of diet and age in one experiment (Experiment 1) and muscle pH in another (Experiment 2).

MATERIALS AND METHODS

Experiment 1: Effects of Diet and Age

Animals

Ram lambs were allotted to six treatments (Table 1) that yielded a number of variations of growth rate and liveweight at slaughter. There was a minimum of six lambs per treatment. A seventh treatment comprised six old ewes.

Treatments 1 to 4 were fed only milk and then grazed with the ewes on a pasture of perennial ryegrass and other grasses with 10% white clover. Fast grown lambs were fed better than slow grown lambs. Grain-fed lambs, treatments 5 and 6, were fed only milk and a grain-based diet, principally maize and wheat (Table 1). Lambs were allocated for slaughter on the basis of carcass weight and age.

Sample preparation

Lean and fat pieces were mixed and minced in the weight ratio of 85:15. The mince was distributed among several 500-ml glass preserving jars, lids applied and steam-cooked to a core temperature of 85°C. Rendered fat

TABLE 1: A summary of experimental design and certain production data.

Treatment	Diet	Growth rate	Mean age at slaughter (days)	Mean carcass weight (kg)	Testes weight (g)
1	Lambs, milk then pasture	Fast	81	13.3	93
2	Lambs, milk then pasture	Slow	211	12.9	460
3	Lambs, milk then pasture	Fast	101	17.1	200
4	Lambs, milk then pasture	Slow	217	17.6	467
5	Lambs, milk then grain	Fast	71	13.4	67
6	Lambs, milk then grain	Fast	98	17.9	166
7	Ewes fed mainly pasture	NA	8.5yr	NA	-

was removed from the surface of the cooked meat and used for sniffing or volatiles analysis (see later). Cooked meat was reheated for presentation to the panel.

Evaluation of cooked meat and rendered fat by sensory panel

A single panel was used for fat odour and meat flavour assessments. Ten attributes were selected for cooked meat flavour and 11 for rendered fat odour. In each of six sessions, panellists assessed seven samples (one from each treatment), for odour of fat and flavour of meat on a 1-20 intensity scale.

Experiment 2: Effects of pH

Animals and sample preparationAnimals

Randomly selected Coopworth ewes received varying subcutaneous doses of adrenaline before slaughter to generate a wide range of meat ultimate pH values. The ultimate pH of each carcass was measured 28 hours post-slaughter. Thirty *semimembranosus* muscles were selected to give three distinct groups of 10 samples with non-overlapping pH values, 5.66 for the Low pH group, 6.26 for the Medium group and 6.81 for the High group.

For sensory analysis, the whole *semimembranosus* from each carcass was diced and minced twice through a 3 mm plate mincer with enough back fat from the same carcass to produce a mince with 20 % (w/w) fat content. Samples were cooked to an internal temperature of 75°C and the cooked meat assessed after the fat was drained.

Sensory analysis

Hot samples were assessed by panellists as two randomly selected samples from each of the three pH groups at each ensory session. Twelve panellists were asked to score for overall, sheepmeat and foreign odours, and equivalent flavours on a 1-100 intensity scale. Panellists were also asked to record self-generated descriptions of the odours and flavours.

Collection of volatiles, gas chromatography and mass spectrometry

Volatiles from 2g of rendered fat from the cooked meat were collected on Tenax after being swept from the surface of the hot fat (100°C) in a dynamic headspace apparatus. The trapped volatiles were thermally desorbed onto a DB5 column and eluted volatiles were detected with a mass spectrometer. Identification of eluted volatiles, each with a Kovat number, were principally made by comparisons of spectra with library spectra.

RESULTS AND DISCUSSION

Experiment 1: Effects of Age and Diet

Lamb production

As expected, it was easier to achieve superior production performance with a grain-based diet due to its higher energy content. Testes weights were highest in treatments 2 and 4, because of the onset of puberty in these older lambs, (Table 1).

A summary of odour and flavour assessments

The relationship between the flavour and odour data is compared in Table 2, which ranks treatment-significant attributes. For the two significant attributes common to odour and flavour, namely ‘sheepmeat’ and ‘animal’, treatments 2 and 4 were the most intense in both assessments. Because odour is perceived during eating, through the internal opening at the back of the throat (Jellinek, 1985), this result confirms that fat is the true source of sheepmeat species odour and flavour. Lambs raised on concentrates, treatments 5 and 6, dominated the low intensity end of sheepmeat odour and flavour. The same was true of animal odour.

TABLE 2: Odour and flavour attributes affected by treatment ranked by intensity.

	Least intense treatment		Increasing intensity				Most intense treatment
Statistically significant flavour attribute							
Sheepmeat	6	7	5	1	3	2	4
Liver	6	5	2	4	1	3	7
Poultry	4	7	3	2	6	1	5
Animal	1	5	3	7	6	2	4
Statistically significant odour attribute							
Sheepmeat	6	7	5	1	3	4	2
Cabbage	6	5	1	3	7	2	4
Roast	6	7	1	3	4	5	2
Animal	6	5	7	1	3	2	4
Rancid	3	5	6	1	7	4	2

Volatiles present in rendered fat

The 244 volatiles data set characterised by the mass spectrometer comprised 63 unknowns (26 % of the total), 46 alkanes and alkenes (19%), 24 aliphatic aldehydes (10%) and lesser numbers of other classes. Treatments effects were observed for 47 % of the volatiles at $P < 0.05$. Statistical significance for treatment was, however, not spread equally over all classes.

Long chain alkanes and alkenes (C10 and above) were over-represented, as were branch chain fatty acids, heterocyclic compounds, ketones, hydroxy fatty acids/ lactones, and phenols (Fig. 1). Members of these classes have been postulated as the cause of sheepmeat odour.

Principle component analysis

The 244 volatiles easily discriminated between animal husbandary treatments in that components 1, 2 and 3 accounted for 46% of the variation (Fig. 2). Component 3 was particularly useful in distinguishing the effect of growth rate in lambs whatever the diet, and also resolved the old ewes as a group. Component 3 also resolved animals raised slowly or rapidly on pasture, whatever the slaughter weight of the animal (Table 1).

FIGURE 1: Relative statistical significance of treatment effects for 17 classes of compounds identified in sheepfat volatiles. Values = (Percent of a class significant (at P<0.01)/percent of that class of total volatiles) - 1.0. Above zero, a class was relatively over-represented in treatment effects, and below zero under-represented.

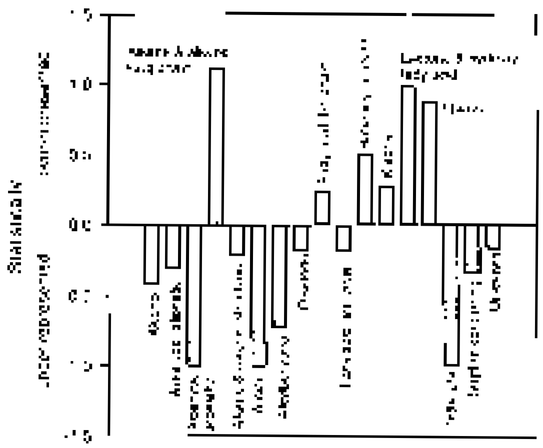
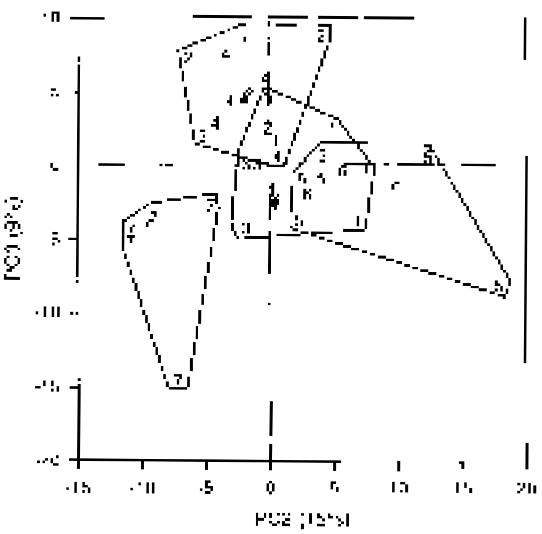


FIGURE 2: Discrimination of animals, labelled by treatment number, using principal component analysis (components 2 and 3) of concentrations of 244 volatiles. The numbers refer to treatment number. The top cluster gathered slow-grown pasture-fed lambs, the central cluster their fast grown equivalents, and the right cluster grain-fed lambs. The ewes, treatment 7, were well also well discriminated.



The circle of correlation relates odour attributes to volatiles through principal component analysis (Fig. 3). Comparing it to Fig. 2 shows that slow-grown pasture-fed lambs were much more strongly associated with certain branch chain fatty acids than the fast-grown equivalents or the old ewes. These were the methyl-branched acids of medium chain length. Three long chain lactones, one of which was unidentified were similarly associated with slow-grown lambs.

Volatiles related to sheepmeat, animal and rancid odours

Odorous volatiles that were consistently associated with three key attributes in each of the three components were identified by inspection of correlation circles for components 1, 2 and 3 (Table 3).

FIGURE 3: The circle of correlation (components 2 and 3) for 244 volatiles and 11 odour attributes. The attributes are named; non-obvious abbreviations are POULtry, SHEEPmeat, LIVer, ANIMal, RANCid and CABbage. The volatiles labelled are 4-methyl-substituted or similar fatty acids with around 10 carbon atoms (●), alkyl-substituted fatty acids with fewer carbon atoms (○), long chain lactones (Δ), short chain lactones or hydroxy acids (Δ), 4-methylphenol (■), other phenols (□), benzenethiol (+) or 3-methylindole (◆). All other classes are represented by the small dots.

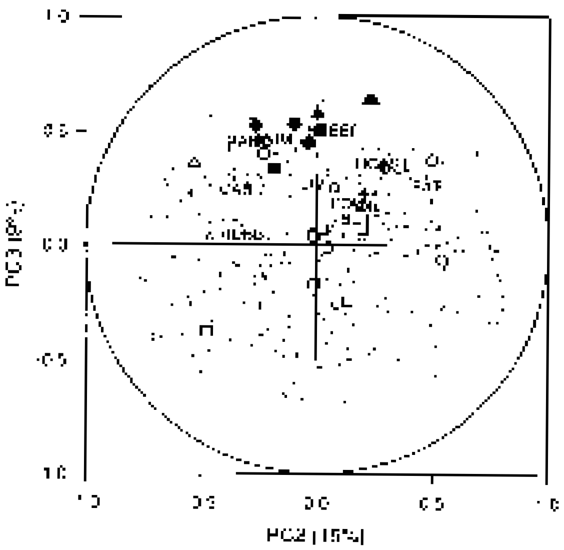


TABLE 3: Volatiles statistically associated with three attributes in principal component analysis.

Attribute	Associated volatiles[1]
Sheepmeat odour	Tetrachloroethene
	2-Methylpyrazine
	Unknown (branch alkane?)
	3-Ethyl-1,4-hexadiene
	A dichlorobenzene
	4-Methyloctanoic acid
	4-Methylnonanoic.acid
	Unidentified branch chain acid
	5-Hydroxydecanoic lactone
	5-Hydroxydodecanoic lactone
	Tetradecanoic acid
	Unidentified lactone (99-71-114...)
Animal odour	Dimethyldisulphide
	4-Methylphenol
	4-Methylnonanoic.acid
	Unknown (124-111-41-55)
	3-Methylindole
	A methylalkane
Rancid odour	3-Methylindole
	1-Pentadecene
	1-Hexadecene

[1] Within an attribute volatiles are arranged in order of increasing Kovat number.

Volatiles such as chlorinated compounds, alkenes and alkanes can be confidently dismissed because their odours are not reminiscent of sheepmeat. Descriptions of 2-methylpyrazine's odour include 'meaty', 'nutty', 'chocolate', 'green', and it occurs widely in odour profiles. It can be confidently excluded as a sheepmeat-specific odour. A similar argument applies to the lactones, which have 'peachy' and 'coconutty' notes. The fact that phenolics and sulphur compounds are not associated with sheepmeat odour means they too can be excluded as causal agents, although as with all these 'dismissals', interactions are possible, even probable. Branch chain fatty acids emerge the clear winner.

3-Methylindole - also known as skatole - was a clear winner in the animal odour category. It is distinctly 'faecal' in odour and showed the highest correlation coefficient, r = 0.53 (P < 0.001), in the entire study, and its strict association with a pastoral diet suggests that its presence of may be an inevitable consequence of the the way New Zealand produces lamb. The biological origins of 3-methylindole in sheepmeat and beef are planned for future study. 4-Methylphenol may have related origins, namely from amino acids in the diet (Ha & Lindsay, 1991).

The classic odours associated with rancidity are aldehydes like hexanal, but is clear from Table 3 that these are not affected by treatment. Therefore, panellists were interpreting another odour(s) as 'rancid'. Of the three contenders, 3-methylindole was probably the villain.

Implications for New Zealand lamb production

With a slaughter age around 90 days, as occurs in New Zealand, the panel data collectively show that an enhanced sheepmeat odour/flavour is probably an inevitable consequence of our pastoral production system. This has major implications for discerning markets. The same conclusion applies to animal and rancid odour/flavours. Lamb weight had no significant effect.

From the volatiles analysis, it is clear that the branch chain fatty acids are responsible for the sheepmeat specific odour, but other compounds, notably 3-methylindole, undoubtedly contribute. The net result is that around a slaughter age of 90 days, a pasture-fed lamb will be slightly 'sheepier', and more 'animal' than a corn/wheat fed lamb.

If pasture feeding continues to 200 days, the attributes 'sheepmeat', 'animal' and 'rancid' are all much worse, irrespective of carcass weight. Whether these are age or puberty effects (Table 1) is not known, although there is evidence that ram lambs have a higher branch chain fatty acid content (Busboom *et al.*, 1981). Because the the New Zealand lamb system is increasingly geared to entire animals, the experiment comparing castrates and rams at 200 days must now be performed.

Experiment 2: Effects of pH

Table 4 shows the intensity score means and levels of statistical significance between each pH group. The panellists found that overall odour and flavour decreased significantly as pH increased. The change was significant between each of the three pH groups (P<0.05) but was most obvious between the Low and High pH groups (P < 0.001). Panellists could not detect a change in sheepmeat odour between any of the groups, but did detect a decrease in sheepmeat flavour between the Low and High and the Medium and High groups (P < 0.01). A smaller but still significant decrease (P < 0.05) in foreign odour was observed between the Low and High pH groups only. There was no significant difference in foreign flavour between any of the groups. This is in contrast to findings of Dutson *et al.,* (1981) and Fjelkner-Modig and Ruderus (1983) who found an increase in negative or off-flavours in high pH meat.

The observation by the sensory panel that overall flavour decreased with increasing pH agrees with similar work on beef (Dransfield, 1981; Fjelkner-Modig and Ruderus, 1983) and pigs (Buscailhon *et al.*, 1994).

The most significant descriptors from panellists' comments of odours and flavours are shown graphically in Figures 4a and 4b.

The frequency of Bland/Flat/Low and Stale/Musty flavour descriptors, considered as undesirable attributes of cooked meat, increased greatly as pH increased. This can be clearly seen in the "Radar" plot of Figure 4a. At the same time, Strong, Beefy, Meaty and Sweet flavours, considered as desirable attributes, decreased. The "Radar" plot of odours also shows a general movement of emphasis from desirable descriptors to undesirable descriptors as pH increased.

Gas chromatography/mass spectrometry analysis

Inn this dynamic headspace analysis, thermal desorption of Tenax-TA traps eluted more than 325 compounds that were recorded as total ion chromatogram peaks by GC/MS for each sample.

Twenty-eight compounds have so far been identified as decreasing significantly (P<0.05) between each sample group as pH increased (Table 5). Of this group of compounds, 11 were identified as aldehydes, eight as alcohols, one an alkane, one a fatty acid and seven are as yet unidentified.

In addition, 11 compounds (one ketone, five alkanes and five unknowns) decreased in concentration from the Low to Medium pH group, four compounds (three alcohols and one

TABLE 4: Mean intensity scores for three pH groups.

	Low (pH 5.66)	Medium (pH 6.26)	High (pH 6.81)	Low vs. Medium	Low vs. High	Medium vs. High
Overall odour	51.10	44.83	39.78	*	***	*
Overall flavour	50.25	41.71	27.01	*	***	**
Sheepmeat odour	28.53	26.85	25.92	NS	NS	NS
Sheepmeat flavour	38.06	34.83	21.67	NS	**	**
Foreign odour	21.87	19.56	16.63	NS	*	NS
Foreign flavour	13.36	14.77	15.95	NS	NS	NS

NS, not significant (P>0.05); *P < 0.05; **P < 0.01;***P < 0.001

FIGURE 4A: Radar plot of the frequency of sensory panellistsí descriptors of flavours of cooked sheepmeat of Low, Medium and High ultimate pH.

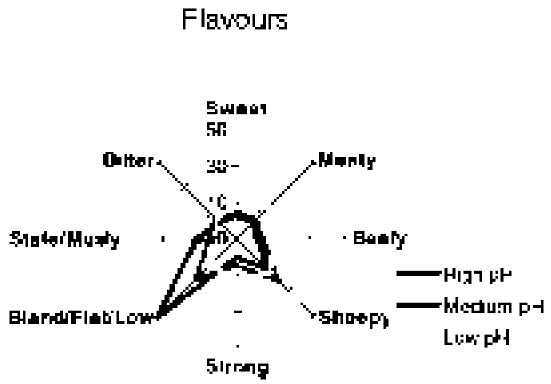
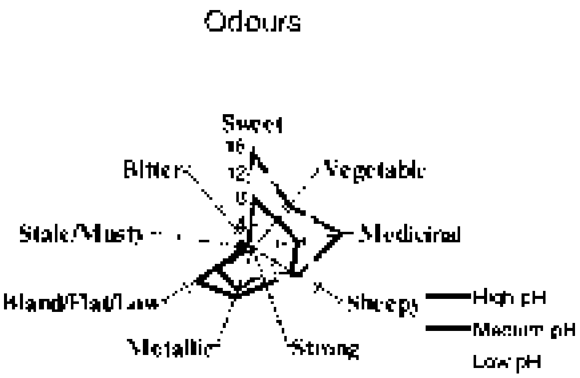


FIGURE 4B: Radar plot of the frequency of sensory panellistsí descriptors of flavour of cooked sheepmeat of Low, Medium and High ultimate pH.



fatty acid) decreased from the Medium to High group and six compounds (one ketone, one acid, one furan and three unknowns) decreased from the Low to High pH group.

Most interestingly, no compounds showed a statistically significant increase in concentration with increasing pH between any of the treatment groups. This is inconsistent with panellists' observations that the frequency of undesirable odour descriptors increased as pH increased. Reasons for this difference may be that purge and trap GC/MS technique lacks the sensitivity to detect odours that may be in the part per billion concentration range but are still above the perceivable threshold of panellists. Alternatively, favourable odours notes present in low pH meat may mask the less desirable odour notes and only when the masking odours are reduced, due to an increase in meat pH, do the undesirable odours dominate.

Changes in the concentration of volatile compounds detected by GC/MS reflect the sensory panellists' perceptions and are consistent with biochemical changes expected to occur in the muscle *post-rigor*. Proteolysis and lipolysis operate more favourably at lower pH (Buscailhon *et al.,* 1994). These pathways produce the vital precursors required for generation of odour and flavour compounds produced during cooking. Most of the volatile compounds identified by GC/MS (Tables 5) that decreased as pH increased are generated from the oxidation of lipid-derived fatty acids at cooking temperatures. Many have distinct odours, such as the French Fry aroma associated with 2,4-decadienals and the Green or Grassy aroma attributed to hexanal, as well as playing a major role in the Maillard reaction (Reineccius, 1994). The aldehydes 2,4-decadienal, (E,E), 2,4-decadienal, nonanal and 2-undecenal, which were more prominent in low pH samples, were identified by Gasser and Grosch (1990) as being highly significant contributors to the odour of meat broths. More recently, Madruga and Mottram (1995) observed increases in a number of volatile heterocyclic compounds, also thought to contribute to meaty flavour, as they titrated meat from pH 5.6 to 4.0 before cooking. They also found that the total number of volatile compounds increased as the pH decreased.

Current work is concentrating on the effects of manipulating high ultimate pH meat to lower its pH level and studying changes in volatile compounds and precursor compounds that are responsible for odour and flavour changes at high ultimate pH.

TABLE 5: Mean Log10 transformed peak areas of compounds that decreased significantly ($P<0.05$) from Low to Medium and Medium to High pH groups. Numbers in parentheses refer to the principal ions observed, in decreasing order of intensity.

	Log_{10} peak area			
Kovat's Index	Low pH	Medium pH	High pH	Compound name
672	5.133	4.803	4.623	2-butenal, (E)
702	6.269	5.852	5.503	1-penten-3-ol
715	6.757	6.493	6.371	pentanal
762	5.502	5.237	5.002	unknown (55,83,84,41)
772	6.443	6.087	5.890	unknown 774 (42,55,41,70)
774	5.570	5.075	4.747	2-penten-1-ol
800	6.261	5.988	5.690	unknown (59,80)
852	5.415	5.088	4.923	2-hexenal, (E)
867	6.070	5.724	5.489	unknown (56,55,43,69)
963	6.367	5.973	5.730	benzaldehyde
980	6.522	6.035	5.685	7-octen-4-ol (or 1-octen-3-ol)
1004	6.254	5.886	5.762	octanal
1012	5.710	5.442	5.271	2,4-heptadienal, (EE)
1003	5.051	4.813	4.650	benzenemethanol (benzyl alcohol)
1058	5.905	5.465	5.259	2-octenal, (E)
1063	5.529	5.135	4.699	heptanoic acid
1065	5.867	5.367	5.000	2-octenol
1068	5.936	5.640	5.480	1-octanol
1077	5.144	4.872	4.751	unknown (68,71)
1103	6.733	6.338	6.248	nonanal
1112	5.197	4.928	4.745	benzene ethanol (2-phenylethanol)
1217	5.348	5.179	5.053	unknown (43,88,99,144)
1265	5.970	5.462	5.257	2-decenal, (E)
1302	5.340	4.746	4.511	2,4 decadienal, (E,E)
1306	5.399	5.085	4.919	tridecane
1330	5.609	4.994	4.683	2,4 decadienal
1379	5.731	5.135	4.889	2-undecenal
1536	5.104	4.903	4.703	unknown (124,137,55,180)

Concluding Remarks

This work has shown that the weight to which lambs are grown has no significant effect on sheep meat flavour and odour but significant effects are observed due to the animal's growth rate, age, diet and possibly its sex. Overall flavour and odour intensity was much lower in corn/wheat fed animals compared to pasture fed animals slaughtered at 90 days. From the marketing view point, grain fed lambs about 90 days old are preferred for markets requiring milder flavoured meat whereas slow grown older animals (200 days) fed on pasture suit markets desiring more stronger flavoured sheepmeat.

Results from this work also supports the argument that an increase in meat ultimate pH, even to moderate levels, significantly alters the quality and quantity of odours and flavours of the cooked meat. This provides strong support for those who seek to control the variability and reduce the incidence of pre-slaughter stress induced high ultimate pH meat produced in New Zealand.

With due consideration to animal age, diet and control of pre-slaughter stress the New Zealand meat industry can produce consistent high quality sheepmeat tailored to specific discerning markets.

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Processing for meat quality

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ABSTRACT

The factors which constitute quality of meat will vary according to its end use. In this sense, quality can be defined as 'fitness for purpose' and, to the extent that the purposes to which meat is used is highly variable, the properties of meat need to be controlled accordingly.

The quality of high value table meat required by the consumer can be defined in terms of tenderness, colour, juiciness and flavour. However, the processor has the facility to tailor his process to account for other important variables: these would include whether the product is chilled or frozen, the time interval before it reaches its intended destination and the packaging system used to get it there, whether the product needs a long shelf life for retail distribution or is intended for the HRI trade, and, of vital importance, the economic implications of the whole process. In many cases the processor needs to find the best compromise between conflicting requirements, and the equation needs to account for these background events which are not visible to the end user.

This paper discusses how processing can be used to modify the properties of meat so as to produce the 'best fitness for purpose' to the end user. A comparison is made between two extremes of processing conditions: slow chilling combined with electrical stimulation versus rapid chilling without stimulation. The outcome in terms of tenderness, water binding, colour and hygiene are compared.

INTRODUCTION

The concept of quality is a complex one. The intention here is to assess quality in terms of "fitness for purpose": in other words, to define and measure quality as the difference between the true performance of a product and the expectation of its performance.

Such a definition avoids problems associated with absolute measurement of meat quality, but it does place the onus on the industry to understand the expectations associated with meat and its various products. While expectations involve some degree of flexibility, modified particularly by price, there will always be a minimum requirement: the expectations associated with buying a Corolla are not identical to those of a BMW, but in either case, you expect transport. Absolute requirements will relate primarily to safety, appearance, eating experience (particularly tenderness, but also flavour and juiciness) and consistency.

Identifying these expectations is only part of the challenge. The expectations of the end users is the most visible purpose for which the product must be fit, rather like the visible 10% of the proverbial iceberg. The invisible 90% for which a product must be fit relate to the circumstances of the particular food chain which leads to the end user; meat products can be handled and stored