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## Effects of dietary herb supplements on sheepmeat flavour

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### ABSTRACT

Sheepmeat flavour is characterised by distinctive species derived odours and flavour notes derived from the diet termed as 'pastoral' for pasture-based farming systems. An exploratory investigation was undertaken to determine if the flavour attributes of sheepmeat could be altered by short-term dosing of sheep with fresh or concentrated herbs. Twelve animals were dosed with 9 different fresh and/or concentrated herbs over 3 days. The animals were slaughtered, sub-sampled, and chemical analyses of levels of flavour compounds in the subcutaneous fat were performed along with sensory evaluation of the meat samples by a trained panel. From the sensory evaluation of the meat samples, the two animals that received the garlic powder supplement were described by the panellists as 'garlic', and these samples were significantly less intense in 'sheepmeat' (P=0.001) and 'sweet' (P=0.007) flavours and also had increased 'barnyard' (P=0.011) and 'foreign' (P<0.001) flavours. Subcutaneous fat skatole and indole levels for these animals were found to be significantly higher (P<0.001) compared to those grazing ryegrass. Other treatments were not significantly different in sensory evaluation. A garlic powder dose response trial was then carried out with 5 sheep receiving between 0 and 200 g/day of powder for two days. After slaughter, subcutaneous fat skatole levels were found to be elevated for animals receiving >50 g/day garlic powder. The results indicate that dosing sheep with garlic powder has a detrimental effect on the animal's ability to detoxify and remove skatole from the circulatory system, with consequent detrimental effects on the overall sensory quality of the meat. Thus a herbal dietary supplement to either mask undesirable flavours of sheep meat, or impart desirable flavours, is yet to be discovered.

**Keywords:** meat flavour; skatole; indole; metabolism; garlic; herb.

### INTRODUCTION

Sheepmeat flavour is characterised by distinctive species odours and also by 'pastoral' flavour characteristics of cooked meat from animals raised on pasture-based farming systems (Berry *et al.*, 1980; Melton, 1990; Bailey *et al.*, 1994). The species odours have been related to the presence of specific medium-length branched chain fatty acids (BCFA's) in storage fats (Wong *et al.*, 1975, Duncan *et al.*, 1978). Elevated levels of BCFA's are inversely correlated with consumer preference of Japanese and New Zealand consumers (Prescott *et al.*, 2001). The compound skatole (3-methylindole) in sheepmeat fat has been strongly linked to perceptions of 'barnyard' and 'animal' flavours and is characteristic of pasture feeding with levels typically elevated in the fat of pasture fed sheep (Young *et al.*, 1997; 2003). For some consumers more accustomed to the flavour of products from grain-finished animals, such as in the USA and Japan, the pastoral flavour has also been described by these consumers as 'off', 'animal-like', 'grassy' or 'barnyard' (Keen, 1998; Young *et al.*, 2003). The New Zealand pasture is relatively rich in protein compared to grain-based diets and it is the ruminal degradation of the tryptophan component of the protein that leads to

the formation of skatole and indole (Tavendale *et al.*, 2005), some of which accumulates in dairy (Lane *et al.*, 2002) and meat (Lane & Fraser, 1999) fats.

Prescott *et al.* (2001) suggested one possible strategy for improving the acceptability of sheepmeat flavour in Asian countries was to prepare value-added sheepmeat products, flavoured with herbs capable of suppressing, or perhaps complementing the existing sheepmeat odour/flavour. To improve consumer acceptance of unprocessed pasture raised sheepmeat it would also be useful to develop cost-effective feeding regimes that would modify or mask the 'pastoral' and 'sheepmeat' flavour background.

Anecdotally animals grazed on unimproved pastures containing herbs and shrubs have been described as having a different or improved flavour when compared to animals fed improved pasture. However, there is a lack of published scientific sensory evidence to back up these claims and a scientific trial measuring chemical indicators in fat failed to substantiate them (Fraser *et al.*, 2004). In this trial, rather than accumulating exogenous flavour compounds in the fat with higher levels of dosing of a herb slurry, the animals appeared to adapt metabolically by increasing the rate of excretion of these compounds.

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With the aim of pre-empting such metabolic adaptation by the animals we have carried out an exploratory investigation of the effects of short term dosing with fresh or concentrated herbs on the flavour attributes of sheepmeat from lambs raised on pasture. A wide range of herb supplements were screened to discover promising effects for further investigation. Individual lambs were dosed with fresh or concentrated herbs, and responses of a sensory panel and indicators of 'pastoral' flavour were measured. Based on unexpected results from the initial dosing trial, a follow up trial was conducted dosing with different amounts of garlic powder.

## MATERIALS AND METHODS

### Animals and Sampling

#### Trial 1

Fourteen Romney cross ram lambs with a mean live weight of approximately 40 kg were selected from a single mob grazed on standard New Zealand perennial ryegrass based pasture at Aorangi Research Farm, Awahuri. The animals were brought into the yards once a day for 3 consecutive days (10:00am, 12-14 March 2001), orally drenched with their appropriate treatment (see Table 1 for treatments) and then returned to pasture. The powdered herb supplements given were made fresh daily by mixing with water (100-200 mL) prior to dosing. Following the final dosing the animals were transferred to the abattoir (Richmonds, Oringi, Hawkes Bay) and slaughtered the next day (15 March 2001) giving carcass weights of approximately 16 kg. The carcasses were chilled and hung at 4°C for a further 24 hours and then sampled and stored at -20°C until analysis. A single shoulder and strip loin sample was collected from each animal for sensory

evaluation, together with flap fat for measuring indole and skatole concentrations.

#### Trial 2

Five Romney cross ram lambs selected from the same overall group of animals that the above trial animals were grazed on a standard New Zealand perennial ryegrass based pasture. The animals were brought in once a day for 2 consecutive days (10.00am, 2-3 July 2001) for dosing with either 0, 10 g, 20 g, 50 g, or 100 g of garlic powder mixed with water to a thin paste and orally drenched. The animals were returned to pasture after dosing each day. Following the final dosing the animals were transferred to an abattoir (Richmonds, Oringi, Hawkes Bay) and slaughtered the next day (4 July 2001). The carcasses were chilled and hung at 4°C for a further 24 hours and then flap fat was sampled for chemical analysis and stored at -20°C until analysis. No sensory analysis was done on these samples.

### Sensory analysis method

#### Sample Preparation

Individual animal samples were thawed, trimmed of excess fat, diced and minced (shoulder and strip loin mixed together) producing a mince comprising approximately 85% lean to 15% fat. The samples were re-frozen at -20°C until required for assessment within one week of mincing. The samples were thawed at 4°C for 24 hours and then cooked individually in stainless steel pots, with lids, in a double boiler to an internal temperature of 75-80°C. Mince samples were stirred regularly to ensure even cooking. The cooking time for each sample was approximately 20 minutes. Cooked samples were then placed into individual polycarbonate jars with caps and held in a bain-marie at 80°C until presented to the panellists.

**Table 1:** Number of animals, herb treatment, daily dose amounts, and treatment groups for statistical analysis for trial 1. DW = dry weight. FW = fresh weight.

Animals	Treatment	Daily dose	Treatment group
2	Control (Pasture)		Control
1	Garlic powder 2X	140 g DW	Garlic
1	Garlic powder 1X	70 g DW	Garlic
2	Fresh garlic bulb	70 g FW	Herb other
2	Citrus juice concentrate	1.5 L	Herb other
1	Ginger powder	166 g DW	Herb other
1	Ginger + Coriander powder	83 g DW ginger, 83 g DW coriander	Herb other
1	Curry powder	166g DW	Herb other
1	Curry + Fennel powder	83 g DW curry, 83 g DW fennel	Herb other
1	Celery seed powder	166 g DW	Herb other
1	Celery seed + Mint powder	83 g DW celery, 83 g DW mint	Herb other

### **Training and familiarisation**

Twelve panellists (New Zealanders) experienced in assessing sheepmeat attributes were selected for this trial comprising nine newly selected and trained panel members and three panellists who had participated in this type of work previously. The panellists attended four one-hour training/familiarisation sessions. Panellists were seated at a round-table under red lights to mask any visual differences between samples. The panel was firstly retrained in sheepmeat and barnyard flavours. Following this the panellists were then presented with samples from each of the 14 animals of trial 1 to evaluate and discuss differences.

For the attribute of sheepmeat a range of sheepmeat flavours was presented to the panellists in increasing intensity. Lamb that had been soaked in water for 24 hours was presented as 'weak' sheepmeat flavour, followed by normal lamb and, finally, mutton as an extreme sheepmeat flavour. To remind panellists of barnyard flavours, samples of lamb mince with added levels of skatole were presented in increasing intensity; normal lamb then lamb + skatole at 80 ng/g and 240 ng/g. In all instances the samples were presented many times to allow panellists to re-familiarise themselves with the typical flavours associated with each attribute.

Development of the assessment form was then carried out using samples from trial 1 to introduce the flavours expected during the formal assessments and to develop the attribute lexicon. So as to not influence the panellists or direct them to taste for herb flavour, panellists were not told of the types of diets fed to the sheep. Samples were presented singularly and discussion was encouraged during tasting to generate attributes.

At the second and subsequent training/familiarisation sessions a mock form was used (developed by the panel during the first session) to refine the questionnaire and further define the attributes measured. Standard attributes of sheepmeat and barnyard were assessed, along with other attributes panellists determined as being important. If any apparent herbal or other flavours

were present then these would be included as an attribute to be assessed. The panellists subsequently decided by consensus on the attributes to be assessed, the definitions for each attribute and the technique to be used for assessment (Table 2).

During training, panellists found no noticeable herbal or other flavours other than a garlic flavour in some samples. This flavour was not considered important enough to be measured as a separate attribute as the flavour did not occur in all samples, rather it was agreed to score it as other/foreign flavour when perceived.

### **Sensory evaluation**

Panellists were seated in individual, ventilated, odour-free booths, under red lights. Samples were presented one at a time and panellists each received a different sample order within and between sessions to balance for order and carry-over effects across panellists. Panellists received filtered water, heated to 55°C to remove any fat residue from the mouth and unsalted crackers to cleanse the palate between samples. There was no discussion between panellists at anytime during the trial and panellists were unaware of the exact sample treatments and order of presentation. For each of the seven sessions, which was within a week of mincing, six samples were assessed comprising one replicate of six different treatments selected at random from the 14 animals, so that each animal was tested three times over the seven sessions.

Samples were evaluated for sheepmeat, barnyard, sweet, and other/foreign flavours using a scale where 0 = none and 10 = intense. Any comments relating to the sample were also recorded. Each attribute (flavour) was assessed for intensity within the first 3-4 chews of the sample.

### **Analytical method**

Concentrations of indole and skatole in subcutaneous fat (ng/g fat) were measured by simultaneous distillation-extraction and gas chromatography mass spectrometry (Lane & Fraser, 1999).

**Table 2:** Definitions of attributes used for sensory evaluation of trial 1 mince samples.

<b>Attribute</b>	<b>Definition</b>
Sheepmeat	Intensity of typical sheepmeat flavours
Barnyard	Intensity of barnyard flavours such as sweaty, musty, animal, manure, dung, and stale hay
Sweetness	Intensity of typical natural lamb sweetness (not artificial)
Other/Foreign	Intensity of flavours that are not expected with sheepmeat, such as garlic, peppery, herbal, and storage-related.

### Statistical analysis

Data from trial 1 were statistically analysed using a General Linear Model (Minitab version 14.20) to test for significant treatment differences between the 3 sub-groupings of the treatments (shown in Table 1). A Gompertz curve for garlic powder dosing effects on skatole concentration in the adipose tissue from both trials 1 and 2 (Figure 2) was generated using Genstat version 9.1.0.150.

## RESULTS

### Trial 1

Garlic powder had a major effect on both panellists' sensory responses and chemical analysis results while for all the other samples, sensory and chemical analytical data were similar to the controls. Ten of the twelve panellists described meat from the two garlic powder dosed animals as having a strong 'garlic' note, and the concentrations of skatole and indole in the sheepmeat fat were also much higher in the animals dosed garlic powder. The samples from the remaining animals were similar for all attributes measured, with moderate sheepmeat flavours, low barnyard and sweet flavours and no apparent foreign flavours and skatole and indole levels similar to the controls. The sensory and chemical analysis results are summarised in Figure 1, with the data pooled into groups as listed in Table 1.

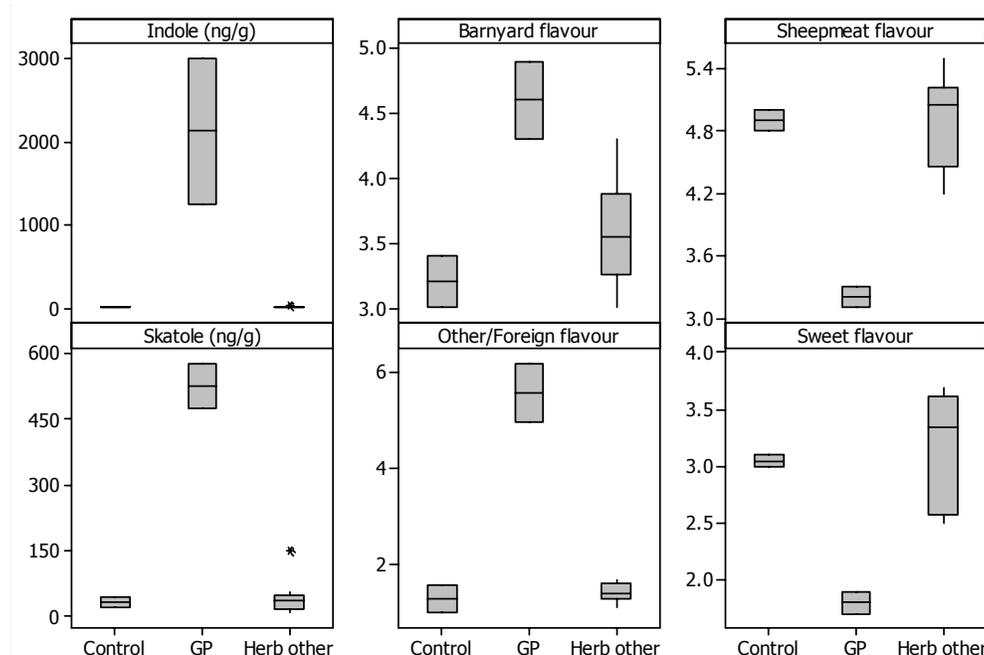
Post-facto statistical analysis showed that the

garlic powder dosed animal samples had significantly less sheepmeat ( $P=0.001$ ) and sweet flavours ( $P=0.007$ ) but increased barnyard ( $P=0.011$ ) and intense foreign flavours ( $P<0.001$ ) and significantly higher skatole and indole in the fat ( $P<0.001$ ) than the other animals.

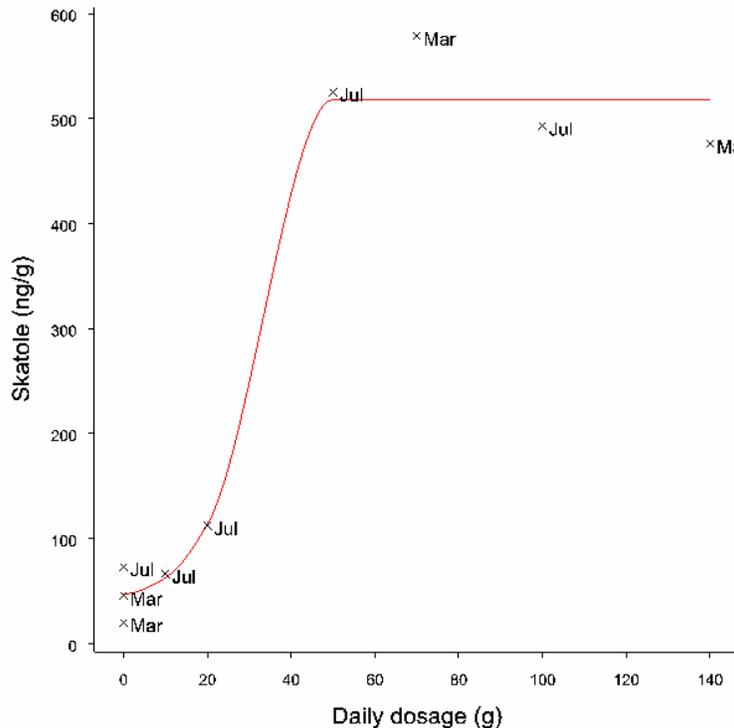
### Trial 2

The 10 g per day garlic powder dosing level did not increase the skatole concentration (66 ng/g fat) above the background level (0 g per day, 73 ng/g fat). There was a small increase at the 20 g per day dosing level (112 ng/g fat), but a large increase was observed with skatole concentrations for the 50 g and 100 g per day (525 and 493 ng/g fat respectively). The dosed animal data is consistent with skatole concentrations for the garlic powder dosed animals from trial 1. The skatole concentrations in the background sample (0 g per day, 73 ng/g fat) is higher than in the two background control samples from trial 1 (20 and 45 ng/g fat), but this variation in concentration is not unusual compared to individual animal variation observed in other studies (Lane & Fraser, 1999; Young *et al.*, 2003). The dosing of garlic powder at levels of 50 g per day or greater dramatically increased the concentrations of skatole in the subcutaneous fat in both trials (Figure 2). The best fit for the combined data for skatole subcutaneous fat concentration data of animals dosed garlic powder was a Gompertz curve, which accounted for 97.4% of the variation.

**Figure 1:** Boxplots from trial 1 showing indole and skatole subcutaneous fat concentrations (ng/g) and mean scores of the four sensory attributes assessed in intensity (0=none, 10=intense) vs. assigned treatment groups (Pasture (Control), Garlic powder (GP), Herb other).



**Figure 2:** Concentration of skatole (ng/g) in subcutaneous fat vs. daily dosage of garlic powder (g) from both trials (March and July). The curve is fitted to the equation [subcutaneous fat skatole] =  $a + c \cdot \text{EXP}(-\text{EXP}(-b \cdot (\text{daily dose of garlic powder} - m)))$  and accounts for 97.4% of the variance.



## DISCUSSION

As the control animals used were from the same original mob as the dosed animals and grazing the same pasture as those dosed with herbs, it was hypothesised that any effect of herbs would either mask or mediate the 'sheepy' and pasture background flavour observed in the control sheep. Except in the use of garlic powder, using short term dosing of a range of herbs we were unable to effect any significant change to panellist perceptions of sheepmeat flavour in lambs, or in concentrations of two compounds (indole and skatole) contributing to pastoral flavour. This may have been due to the levels of the herb supplements given being too low to cause any effect, although 70 g DW of garlic powder was enough to cause a significant effect and all the other herb treatments except for fresh garlic and citrus juice received more than 70 g DW. The characteristic flavour compounds of these herbal treatments may be modified by the microbial fermentation process within the rumen, or may not accumulate appreciably in the meat as we have found that animals may increase their metabolism and excretion of ingested exogenous compounds (Fraser *et al.*, 2004), although this is unlikely to be

a major factor with short-term dosing. The data shows that with short-term feeding of garlic powder it is possible to increase of the undesirable 'barnyard' flavour. The majority of the sensory panel were able to accurately describe a garlic note in the garlic powder dosed animals. This garlic note was not detected in the animals fed fresh garlic, suggesting that the garlic powder may be either a more concentrated source of garlic flavour related compounds, or contain a different profile of compounds. As fresh garlic contains approximately 65% water (Velisek *et al.*, 1997), the fresh garlic diet was equivalent to only *ca.* 24.5 g of garlic powder, and no effect on skatole concentrations was observed for the animals with garlic powder at the 20 g dosing level in trial 2.

This increase in undesirable flavours and subcutaneous fat skatole and indole concentrations resulting from dosing sheep with garlic powder may be due to effects on animal liver metabolism. It is unlikely that the levels of skatole and indole measured could have been generated from skatole and indole precursors in the garlic powder. The slope of the dose response curve suggested that sheep could tolerate a certain amount of garlic powder per day, but once this level was exceeded excess skatole and indole remained in circulation

to be deposited in the subcutaneous fat. This may be due to effects of garlic powder components on skatole and indole metabolism in the sheep. Investigations of circulating skatole and indole concentrations in sheep have shown that the majority of skatole and indole absorbed from the rumen is metabolised in the liver (Roy *et al.*, 2004). Earlier studies of taints in milk from dairy cows grazing pastures containing *Lepidium* species demonstrated that these were due to high levels of skatole resulting from impaired liver skatole metabolism (Conochie, 1953). Similarly skatole levels have been found to be elevated in dairy cows with impaired liver function due to facial eczema (FE) (Fraser *et al.*, 2006).

Adverse effects on the flavour of sheepmeat from animals with FE liver damage have also been reported (Kirton *et al.*, 1979). There was no evident liver damage reported when the animals in these trials were slaughtered and liver function tests were not carried out. It is highly unlikely that FE was the cause of high fat skatole concentrations in only the animals receiving high levels of garlic powder in both trials. However garlic derived compounds may have had more specific effects on skatole and indole metabolism in the liver. Sulphur compounds derived from fresh garlic homogenates have been shown to inhibit the P450 enzyme CYP2E1 in rats (Yang *et al.*, 2001) and this enzyme has been shown to be involved in the hepatic metabolism of skatole in pigs (Babol *et al.*, 1998). Thus there may be specific inhibition of this key liver enzyme by components in garlic powder when dosing levels exceeded 50 g per day.

The data from trial one shows a herbal dietary supplement to either mask undesirable flavours of sheep meat, or impart desirable flavours, is yet to be discovered. However the effects observed with garlic powder draw further attention to the importance of maintaining efficient liver metabolism in avoiding adverse effects on sheepmeat flavour.

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#### REFERENCES

- Babol, J.; Squires, E.J.; Lundstrom, K. 1998: Hepatic metabolism of skatole in pigs by cytochrome P450E1. *Journal of Animal Science* **76**: 822-828.
- Bailey, M.E.; Suzuki, J.; Fermanado, L.N.; Swartz, H.A.; Purchas, R.W. 1994: Influence of finishing diets on lamb flavour. *In*: Ho, C.-T.; Hartman, T.G. ed. Lipids in food flavours. Washington DC, American Chemical Society. Pp. 170-185.
- Berry, B.W.; Maga, J.A.; Calkins, C.R.; Wells, J.E.; Carpenter, Z.L.; Cross, H.R. 1980: Flavour profile analysis of cooked beef loin steaks. *Journal of Food Science* **45**: 1113-1121.
- Duncan, W.R.H.; Garton, G.A. 1978: Differences in the proportion of branched chain fatty acids in subcutaneous triacylglycerols of barley-fed ruminants. *British Journal of Nutrition* **40**: 29-33.
- Conochie, J. 1953: Indole and skatole in the milk of the ruminant feeding on *lepidium* spp. *Australian Journal of Experimental Biological and Medical Science* **31**: 373-384.
- Fraser, K.; Lane, G.A.; Schreurs, N.M.; Tavendale, M.H.; Keogh, R.G.; Kirk, M.R.; McNabb, W.C. 2004: Formation and excretion of phenol flavour compounds in sheep. *Proceedings of the New Zealand Society of Animal Production* **64**: 203-207.
- Fraser, K.; Lane, G.A.; Morris, C.A.; Cullen, N.G. 2006: Effects of facial eczema on indole flavour compounds in dairy cows. *Proceedings of the New Zealand Society of Animal Production* **66**: 315-319.
- Keen, A.R. 1998: Flavour compounds and their origin in dairy products. *Chemistry in New Zealand*, September/October issue: 5-13.
- Kirton, A.H.; Campbell, A.G.; Payne, E.; Woods, E.G. 1979: Facial eczema and the palatability of meat from lambs. *New Zealand Journal of Agricultural Research* **22**: 399-403.
- Lane, G.A.; Fraser, K. 1999: A comparison of phenol and indole flavour compounds in the fat, and of phenols in the urine of cattle fed pasture or grain. *New Zealand Journal of Agricultural Research* **42**: 289-296.
- Lane, G.A.; Fraser, K.; Kolver, E.S.; Rowan, D.D.; Allen, J.M.; Mills, O.E.; Abraham, A.S.; Olney, S.D. 2002: Effect of a total mixed ration diet on the concentration of amino acid-derived volatiles in milk. *Proceedings of the New Zealand Society of Animal Production* **62**: 242-245.
- Melton, S.L. 1990: Effects of feeds on flavour of red meat, a review. *Journal of Animal Science* **68**: 4421-4435.
- Prescott, J; Young, O.A.; O'Neill, L. 2001: The impact of variations in flavour compounds on meat acceptability: a comparison of Japanese and New Zealand consumers. *Food Quality and Preference* **12**: 257-264.
- Roy, N.C.; Fraser, K.; Lane, G.A.; Sinclair, B.R.; McNabb, W.C. 2004: Polyethylene glycol increases intestinal absorption and hepatic uptake of indole and skatole in sheep fed sulla. *Journal of Animal and Feed Sciences* **13** (Supplement 1): 339-342.
- Tavendale, M.T.; Lane, G.A.; Schreurs, N.M.; Fraser, K.; Meagher, L.P. 2005: The effects of condensed tannins from *Dorycnium rectum* on skatole and indole ruminal biogenesis for grazing sheep. *Australian Journal of Agricultural Research* **56**: 1331-1337.
- Velisek, J.; Kubec, R; Davidek, J. 1997: Chemical composition and classification of culinary and pharmaceutical garlic-based products. *Zeitschrift für*

- Lebensmitteluntersuchung und -Forschung A* 204 (2): 161-164.
- Wong, E.; Johnson, C.B.; Nixon, L.N. 1975: The contribution of 4-methyloctanoic (hircinoic) acid to mutton and goat meat flavour. *New Zealand Journal of Agricultural Research* **18**: 261-266.
- Yang, C.S.; Chhabra, S.K.; Hong, J.Y.; Smith, T.J. 2001: Mechanisms of inhibition of chemical toxicity and carcinogenesis by diallyl sulphide and related compounds from garlic. *Journal of Nutrition* **131**: 1041S-1045S.
- Young, O.A.; Berdague, J.L.; Viallon, C.; Rousset-Akrim, S.; Theriez, M. 1997: Fat-borne volatiles and sheepmeat odour. *Meat Science* **45**: 183-200.
- Young, O.A.; Lane, G.A.; Priolo, A.; Fraser, K. 2003: Pastoral and species flavour in lambs raised on pasture, lucerne or maize. *Journal of the Science of Food and Agriculture* **83**: 93-104.