Comparison of three methods of packaging for the ageing/maturation of beef

(dry ageing, ageing in a permeable vacuum pack and standard vacuum packaging)

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Background

It is widely accepted that the maturation or ageing of beef improves its eating quality. There is no dispute that the higher value cuts improve in tenderness during the period post slaughter. Flavour also increases during ageing and there is an argument that "dry ageing" results in better flavour than "wet ageing." Although there is not a strong consensus in the published literature, some papers support this (eg Warren and Kastner (1992)).

Wet ageing is widely used in commercial beef production in England. This involves storage of the meat at chill temperatures (less than 3ºC) in vacuum packs, usually for 7 to 21 days.

Prior to the development of vacuum packaging, meat was dry-aged. Dry aging consists of placing unpackaged meat in a chill under controlled temperature, humidity and airflow. There is increasing interest in the use of dry ageing to produce a premium product because the beef flavour, in particular, is reputed to be superior to that of wet-aged beef. A comprehensive summary of the effects of dry ageing beef has been published by the National Cattlemen's Beef Association (National Cattlemen's Beef Association Center for Research and Knowledge Management, 2008).

The main disadvantage of dry ageing is the weight loss, as a result of two main factors: evaporative loss resulting in reduced water content of the meat (considered an important component of the improved quality) and discolouration/desiccation of externally exposed muscle resulting in the necessity of trimming.

Dry ageing is widely used in the US and there is interest in reducing the associated weight loss. Research has been undertaken at Kansas State University in collaboration with the Swedish University of Animal Sciences (Ahnstrom et al., 2006) to investigate the use of dry ageing in a bag that is highly permeable to water vapour. The aim is to facilitate the moisture loss associated with dry ageing but to reduce the overall weight loss. When aged for 21 days weight loss was reduced from 10.2 to 8.8%. Taste panel tests have demonstrated equivalent eating quality to dry ageing. Additional advantages of the system include reduced trimming loss (from 17.9 to 15.6%) and improved bacteriological quality.

There is clearly potential to gain the perceived quality advantages of dry-aged beef with reduced cost (through reduced weight loss).

Objective

To compare the weight loss and eating quality of beef sirloin subjected to traditional dry ageing, vacuum packaged ageing in a standard vacuum pouch and ageing in a permeable film.

Materials and Methods

Overview

The ageing was carried out in a commercial plant using sections of loin matured by the three methods. The weight losses (evaporative and trim losses) were assessed at the end of ageing. Loin sections were then transported to the University of Bristol for sensory analysis.

In total, both loins from 72 cattle were used for the trial with loins from opposite sides being allocated to different ageing treatments (details in Appendix 1). This resulted in a total of 144 loins for the trial.

Animal selection

Carcases were selected for the trial at slaughter and primals prepared the day after slaughter.

Selection was to the abattoir's normal criteria for standard dry aged product with the targets being:

1. fat class 4L to 5L
2. dark cutting carcases excluded

The characteristics of the selected cattle are described in the results section.

Loin sampling and maturation

Bone-in loins (hindquarter loins separated between the 10th and 11th ribs) from both sides of each selected carcase were taken at primal butchery.

Each loin was weighed (to the nearest 10 g), maximum fat depth measured over the eye muscle, and the loin allocated to one of the following treatments:

DRY	not packaged for maturation
VP-STD	vacuum packaged in standard vacuum pouch
VP-PERM	vacuum packaged in permeable film (Tublin™)

Thus there were 48 samples of each packaging type:

Treatment	Number of left loins	Number of right loins	Total
DRY	24	24	48
VP-STD	24	24	48
VP-PERM	24	24	48

Yield data are available for all 144 loins. On delivery to the University, however, loins from 3 carcases (6 loins) were missing and therefore the final numbers for sensory analysis were 46 of each treatment (a total of 138)

The loins were prepared for maturation as described below. Maturation took place for 21 days in the same chill for all treatments to ensure temperature conditions were as similar as possible.

Dry ageing
Loins were matured bone-in according to normal plant practice and placed on racks as normal.

Vacuum packaging - Standard
Loins were boned and the backstrap removed, but not trimmed, and vacuum packaged as normal. Trim was recovered from the bone and weighed for each loin. Following vacuum packaging, two loin sections of the same treatment were placed into a slotted plastic tray (supermarket-type storage tray).

Vacuum packaging - Permeable
Loins were boned and the backstrap removed, but not trimmed, and vacuum packaged as normal using Tublin™ bags on a normal vacuum machine. Trim was recovered from the bone and weighed for each loin. Following vacuum packaging in the Tublin™ bag, two loin sections of the same treatment were placed into a slotted plastic tray (supermarket-type storage tray).

<u>Sample preparation and transport</u>

Following the ageing time, samples of the loins were taken as follows for sensory panelling.

Dry ageing
Loins were boned and trimmed as normal. The weight of the trimmed loin and the weight of any usable trim was recorded. The anterior end (rib end) was trimmed to leave the cut surface of the eye muscle (*longissimus)* square to the surface of the loin. A piece of at least 60mm length was removed from the loin end. This was vacuum packed in a standard vacuum pack and then frozen.

Vacuum packaging - Standard
Loins were removed from the vacuum pack, dried with paper tissue, trimmed and the weight recorded. The anterior end (rib end) was trimmed to leave the cut surface of the eye muscle (*longissimus)* square to the surface of the loin. A piece of at least 60mm length was removed from the end. This was vacuum packed in a standard vacuum pack and then frozen.

Vacuum packaging - Permeable

Loins were removed from the vacuum pack, trimmed and the weight of the loin was recorded. The anterior end (rib end) was trimmed to leave the cut surface of the eye muscle (*longissimus)* square to the surface of the loin. A piece of at least 60mm length was removed from the end. This was vacuum packed in a standard vacuum pack and then frozen.

Loin pieces from all treatments were delivered frozen to the University of Bristol at Langford.

Eating quality assessment

Samples were transported to the University of Bristol for sensory analysis. Sensory analysis was carried out by a 10-person trained taste panel. The sample was defrosted overnight at 4ºC and then cut into steaks 20 mm thick. Steaks were grilled to an internal temperature of 74ºC (measured by a thermocouple probe) after which all fat and connective tissue was trimmed and the muscle cut into blocks 2 cm^3. The blocks were wrapped in pre-labelled foils and placed in a heated incubator. The samples were then given to the assessors in an order chosen by computer. They were panelled by the trained panel and assessed for tenderness, juiciness, beef flavour, abnormal flavour and overall acceptability on a 1-8 scale.

Results

Characteristics of selected carcases

The cattle selected came from a wide range of breeds as shown in Table 1.

Table 1. Breeds of cattle selected for trial from declaration on passport

Breed	Number of carcases
Aberdeen Angus	2
Aberdeen Angus X	4
Belgian Blue X	5
Blond X	1
Charolais	1
Charolais X	14
Galloway	1
Gelbvieh	1
Gelbvieh X	1
Hereford X	10
Limousin	2
Limousin X	20
Montbeliarde X	3
Simmental X	3
South Devon X	3
Welsh Black X	1

The carcase characteristics are summarised in Table 2.

Table 2. Carcase characteristics

	Mean	Minimum	Maximum
Age at slaughter (d)	796.2	437	966
Carcase Weight (kg)	328.4	289.2	373.1
Conformation class		O-	R
Fat class		3	5L

It should be noted that the experimental design (pairwise comparisons within carcase) removes any effect of carcase from the ageing comparisons.

Chiller temperature

Over 6 weeks of the trial a data logger was used to record temperatures in the chiller used for maturation. The mean temperature was 2.2ºC and the range 0.0 to 7.6ºC. The higher temperatures were recorded in the first few days of the trial when the chiller appeared to be operating ineffectively.

Visual observations

Loin sections in the permeable vacuum pouches were held in plastic trays with slots in the bottom. Discolouration occurred of the areas that were exposed to the air. The darkening is what would be expected of a dry ageing treatment as the surface dries and oxidation occurs. Where this contrasts with the colour of meat in the pouch in contact with the tray it gives a rather undesirable appearance (picture 1). An informal trial at EBLEX's Winterhill House facilities found that use of wire racks (as recommended by the Tublin™ manufacturers) resulted in much more even colour (picture 2). This will also result in more even evaporative loss and, presumably, eating quality.

Picture 1. Uneven colouration of meat from permeable packaging

Picture 2. Even colour achieved on wire racks

Weight loss and yield

Table 2 shows the yields and weight losses from the three packaging types. It is clear that weight loss, from both trimming and evaporation, is highest from the dry aged product, and in this case the majority of the trim is not usable.

Table 2. Yield and weight losses from different packaging treatments (least squares means)

	DRY	VP-PERM	VP-STD	significance
Trimmed aged loin %	54.4	57.1	61.1	***
Usable trim %	0.1	5.5	5.5	***
Usable yield %	54.5	62.6	66.5	***
Evaporative loss %	6.9	3.1	0.6	***
Waste trim %	7.5	8.4	6.3	***

Trimmed loin % yield = final yield of trimmed loin compared with bone-in primal loin at start
Usable yield % = trimmed loin yield and usable trim combined
Waste trim includes trim both before and after maturation but not tissue attached to the bone for the dry-aged product.

Sensory panel results

Due to the timing of the trial, the sensory panelling was separated by the summer break. This meant that the panel composition varied between two phases of the panelling. The University of Bristol undertook an analysis for the two phases separately and for the two phases combined using only common panellists. This analysis is shown in Appendix 2. The balanced design, however, with every treatment equally represented within each panel session means that it is possible to analyse the data across all panel sessions combined. The results of this analysis are presented in table 2.

Table 2. Sensory panel results overall analysis (least squares means by analysis of variance)

	DRY	VP-PERM	VP-STD	significance	approx. LSD
Texture	4.87	4.79	4.86	ns	!
Juiciness	5.16	5.23	5.11	ns	!
Beef Flavour	4.69	4.59	4.74	ns	!
Abnormal Flavour	2.76	2.97	2.53	***	0.18
Flavour Liking	5.01	4.84	5.23	**	0.18
Overall Liking	4.91	4.70	5.04	**	0.18

There were no significant differences in texture, juiciness or beef flavour. Small but statistically significant differences in abnormal flavour resulted in differences in flavour liking and overall liking, with the standard vacuum pack having the lowest abnormal flavour score and the highest liking scores. Interestingly, the permeable vacuum pack resulted in the highest abnormal flavour and lowest liking scores.

Discussion and Conclusions

The results would suggest that there is no advantage to dry ageing and that the permeable bags lead to more abnormal flavours. The permeability of the bags in unusual in that they allow the escape of moisture. Usually the permeability in plastic packaging has to do with gaseous exchange. One assumes that if moisture can permeate then oxygen can flow backwards and forwards either freely or dissolved in the moisture that is permeating the bag. This could lead to oxidation and some of the abnormal odours found.

It is clear that the dry ageing (whether in air or in a permeable bag) resulted in a different flavour from standard vacuum pack ageing. This was perceived as abnormal flavour by the Bristol panel but it is likely that this is the flavour desired by those who prefer dry aged meat.

While the Bristol panel found the flavour of dry aged beef less agreeable than that of vacuum packed beef, there was no significant difference in flavour liking between that of dry aged and aged in the semi-permeable bag. In addition, the semi-permeable bag resulted in a significant improvement in meat yield and a halving of evaporative loss when compared to dry aged although vacuum packing improved this still further.

The ageing of meat in permeable packaging resulted in a marked improvement in yield, although standard vacuum packaging improves this further. The flavour developed was similar to that from traditional dry aging, which was not liked by the University of Bristol sensory panel.

Appendix 1. Allocation of loins to treatment

Carcase number	Left loin	Right loin
01	DRY	VP-STD
02	DRY	VP-PERM
03	VP-STD	DRY
04	VP-STD	VP-PERM
05	VP-PERM	DRY
06	VP-PERM	VP-STD
07	DRY	VP-STD
08	DRY	VP-PERM
09	VP-STD	DRY
10	VP-STD	VP-PERM
11	VP-PERM	DRY
12	VP-PERM	VP-STD
13	DRY	VP-STD
14	DRY	VP-PERM
15	VP-STD	DRY
16	VP-STD	VP-PERM
17	VP-PERM	DRY
18	VP-PERM	VP-STD
19	DRY	VP-STD
20	DRY	VP-PERM
21	VP-STD	DRY
22	VP-STD	VP-PERM
23	VP-PERM	DRY
24	VP-PERM	VP-STD
25	DRY	VP-STD
26	DRY	VP-PERM
27	VP-STD	DRY
28	VP-STD	VP-PERM
29	VP-PERM	DRY
30	VP-PERM	VP-STD
31	DRY	VP-STD
32	DRY	VP-PERM
33	VP-STD	DRY
34	VP-STD	VP-PERM
35	VP-PERM	DRY

Carcase number	Left loin	Right loin
36	VP-PERM	VP-STD
37	DRY	VP-STD
38	DRY	VP-PERM
39	VP-STD	DRY
40	VP-STD	VP-PERM
41	VP-PERM	DRY
42	VP-PERM	VP-STD
43	DRY	VP-STD
44	DRY	VP-PERM
45	VP-STD	DRY
46	VP-STD	VP-PERM
47	VP-PERM	DRY
48	VP-PERM	VP-STD
49	DRY	VP-STD
50	DRY	VP-PERM
51	VP-STD	DRY
52	VP-STD	VP-PERM
53	VP-PERM	DRY
54	VP-PERM	VP-STD
55	DRY	VP-STD
56	DRY	VP-PERM
57	VP-STD	DRY
58	VP-STD	VP-PERM
59	VP-PERM	DRY
60	VP-PERM	VP-STD
61	DRY	VP-STD
62	DRY	VP-PERM
63	VP-STD	DRY
64	VP-STD	VP-PERM
65	VP-PERM	DRY
66	VP-PERM	VP-STD
67	DRY	VP-STD
68	DRY	VP-PERM
69	VP-STD	DRY
70	VP-STD	VP-PERM
71	VP-PERM	DRY
72	VP-PERM	VP-STD

Appendix 2. University of Bristol sensory panel analysis

	Numbers with higher numerical scores for:		
	Dry aged	VP-Perm	Equal
Tenderness	10	12	1
Juiciness	10	11	2
Beef Flavour	10	10	3
Abnormal flavour	8	15	0
Flavour liking	11	11	1
Overall liking	14	7	2

	Dry aged	VP-Std	Equal
Tenderness	10	12	1
Juiciness	9	11	3
Beef Flavour	9	13	1
Abnormal flavour	14	9	0
Flavour liking	7	15	1
Overall liking	10	13	0

	VP-Std	VP-Perm	Equal
Tenderness	10	11	2
Juiciness	7	14	2
Beef Flavour	13	9	1
Abnormal flavour	3	19	1
Flavour liking	17	2	4
Overall liking	13	6	4

Table 1, Part 1.

Influence of Treatment on the eating quality of Grilled beef loin steaks.

Values are the means derived from analysis of variance with Treatment and assessor as factors with 11 replications, 8 point scale used throughout.

	Treatment					
	DRY	VP-PERM	vr	Probability	sig	lsd
Attributes						
Tenderness	4.56	4.75	1.02	0.315	ns	!
Juiciness	4.90	5.16	2.84	0.094	ns	!
Beef Flavour	4.66	4.47	1.02	0.315	ns	!
Abnormal Flavour	3.23	3.23	0	0.997	ns	!
Hedonic						
Flavour Liking	4.76	4.80	0.02	0.877	ns	!
Overall Liking	4.61	4.64	0.02	0.882	ns	!
	DRY	VP-STD	vr	Probability	sig	lsd
Tenderness	4.61	4.64	0	0.967	ns	!
Juiciness	5.10	5.07	0.06	0.803	ns	!
Beef Flavour	4.83	4.89	0.19	0.665	ns	!
Abnormal Flavour	2.78	2.57	1.13	0.289	ns	!
Hedonic						
Flavour Liking	5.18	5.28	0.31	0.576	ns	!
Overall Liking	5.03	5.10	0.14	0.712	ns	!
	VP-STD	VP-PERM	vr	Probability	sig	lsd
Tenderness	5.06	4.74	4.58	0.034	*	0.30
Juiciness	5.17	5.28	0.85	0.358	ns	!
Beef Flavour	4.64	4.43	1.56	0.213	ns	!
Abnormal Flavour	2.87	3.62	16.25	<0.001	***	0.37
Hedonic						
Flavour Liking	5.23	4.58	11.77	<0.001	***	0.38
Overall Liking	5.10	4.42	13.43	<0.001	***	0.37

Table 2, Part 2.

Influence of Treatment on the eating quality of Grilled beef loin steaks.

Values are the means derived from analysis of variance with Treatment and assessor as factors with 12 replications

	Treatment					
	DRY	VP-PERM	vr	Probability	sig	lsd
Attributes						
Tenderness	4.87	5.01	1.98	0.160	ns	!
Juiciness	5.22	5.27	0.42	0.516	ns	!
Beef Flavour	4.71	4.62	1.36	0.244	ns	!
Abnormal Flavour	2.48	2.74	6.86	0.009	**	0.20
Hedonic						
Flavour Liking	5.12	4.85	6.68	0.010	**	0.21
Overall Liking	5.00	4.79	4.68	0.031	*	0.20
	DRY	VP-STD	vr	Probability	sig	lsd
Tenderness	4.93	4.78	2.34	0.127	ns	!
Juiciness	5.26	5.09	5.32	0.022	*	0.15
Beef Flavour	4.73	4.63	2.11	0.147	ns	!
Abnormal Flavour	2.45	2.49	0.26	0.613	ns	!
Hedonic						
Flavour Liking	5.17	5.10	0.51	0.476	ns	!
Overall Liking	5.06	4.87	4.50	0.034	*	0.18
	VP-STD	VP-PERM	vr	Probability	sig	lsd
Tenderness	4.80	5.06	7.45	0.007	**	0.19
Juiciness	5.07	5.27	6.58	0.011	*	0.16
Beef Flavour	4.62	4.59	0.16	0.693	ns	!
Abnormal Flavour	2.47	2.73	7.13	0.008	**	0.20
Hedonic						
Flavour Liking	5.11	4.85	6.89	0.009	**	0.20
Overall Liking	4.88	4.79	0.82	0.365	ns	!

Table 3. Part 1 and Part 2 Combined
NB. Not all panellists were common to the two halves of the study (Pre- and post- summer break) so data was only combined for common panellists. Hence, mean values are not the means of those in Tables 1 and 2.

Influence of Treatment on the eating quality of Grilled beef loin steaks.
Values are the means derived from analysis of variance with Treatment and assessor as factors with 23 replications

	Treatment					
	DRY	VP-PERM	vr	Probability	sig	lsd
Attributes						
Tenderness	5.13	5.06	0.42	0.517	ns	!
Juiciness	5.15	5.24	0.84	0.360	ns	!
Beef Flavour	5.10	5.08	0.04	0.841	ns	!
Abnormal Flavour	2.57	2.64	0.39	0.530	ns	!
Hedonic						
Flavour Liking	5.42	5.30	0.78	0.377	ns	!
Overall Liking	5.33	5.13	2.31	0.130	ns	!
	DRY	VP-STD	vr	Probability	sig	lsd
Tenderness	4.90	4.90	0	0.956	ns	!
Juiciness	5.07	5.09	0.06	0.805	ns	!
Beef Flavour	4.92	5.01	0.93	0.335	ns	!
Abnormal Flavour	2.74	2.59	1.77	0.184	ns	!
Hedonic						
Flavour Liking	5.24	5.36	1.01	0.315	ns	!
Overall Liking	5.09	5.13	0.12	0.728	ns	!
	VP-STD	VP-PERM	vr	Probability	sig	lsd
Tenderness	5.26	5.01	5.31	0.022	*	0.21
Juiciness	5.11	5.22	1.49	0.224	ns	!
Beef Flavour	4.97	4.88	0.82	0.367	ns	!
Abnormal Flavour	2.61	3.09	14.34	<0.001	***	0.25
Hedonic						
Flavour Liking	5.43	4.92	14.22	<0.001	***	0.27
Overall Liking	5.29	4.78	15.08	<0.001	***	0.26

Appendix 3. Values for individual animals within a pairing

Influence of Dry vs Vp-Perm on the eating quality of Grilled beef loin steaks for within individual animal comparison. Values are the means derived from analysis of variance with Treatment and assessor as factors.

Animal		DRY	VP-PERM	vr	Probability	sig	lsd
	Tenderness						
2		5.11	4.78	0.31	0.5943	ns	!
5		5.50	4.75	2.03	0.1970	ns	!
8		3.38	3.13	0.37	0.5630	ns	!
11		5.00	5.13	0.18	0.6845	ns	!
14		4.88	5.13	0.64	0.4512	ns	!
17		5.13	4.75	0.66	0.4423	ns	!
20		3.44	3.67	0.31	0.5943	ns	!
23		4.89	5.78	19.69	0.0022	**	0.46
26		5.30	5.30	0	>0.9999	ns	!
29		4.63	4.13	1.75	0.2275	ns	!
32		5.50	5.75	0.47	0.5165	ns	!
35		5.20	5.40	0.15	0.7052	ns	!
38		3.70	3.30	1.16	0.3092	ns	!
41		5.60	5.40	0.38	0.5554	ns	!
44		4.90	4.80	0.05	0.8321	ns	!
47		5.78	5.78	0	>0.9999	ns	!
50		4.67	4.44	0.37	0.5588	ns	!
53		5.80	5.10	4.37	0.0662	ns	!
56		5.50	5.70	0.23	0.6424	ns	!
59		4.70	4.90	0.26	0.6193	ns	!
65		5.10	4.20	3.49	0.0947	ns	!
68		5.10	4.80	1.98	0.1934	ns	!
71		5.00	5.10	0.13	0.7263	ns	!
	Juiciness						
2		5.33	5.33	0	>0.9999	ns	!
5		5.88	4.88	14.00	0.0072	**	0.63
8		4.50	5.00	1.75	0.2275	ns	!
11		5.00	5.38	0.80	0.4015	ns	!
14		4.25	4.88	2.78	0.1395	ns	!
17		5.13	5.00	0.07	0.8018	ns	!
20		4.11	4.00	0.18	0.6811	ns	!
23		5.78	5.11	5.33	0.0497	*	0.67
26		5.10	5.40	0.57	0.4679	ns	!
29		5.13	5.63	2.33	0.1705	ns	!
32		4.88	5.50	5.65	0.0492	*	0.62
35		5.00	5.40	0.59	0.4620	ns	!
38		4.40	5.00	3.86	0.0811	ns	!
41		5.30	5.30	0	>0.9999	ns	!
44		4.50	4.60	0.08	0.7804	ns	!
47		5.56	5.89	2.00	0.1950	ns	!
50		5.11	4.89	0.37	0.5588	ns	!
53		5.40	5.20	0.26	0.6193	ns	!
56		6.60	5.90	7.23	0.0248	*	0.59
59		5.20	4.90	1.00	0.3434	ns	!
65		5.50	5.30	0.38	0.5554	ns	!
68		5.70	5.20	1.80	0.2126	ns	!
71		5.30	5.40	0.13	0.7263	ns	!

		DRY	VP-PERM	vr	Probability	sig	lsd
	Beef Flavour						
2		4.00	3.56	0.70	0.4260	ns	!
5		5.63	5.25	0.80	0.4015	ns	!
8		4.38	4.88	3.50	0.1036	ns	!
11		5.75	4.25	6.30	0.0404	*	1.41
14		3.63	4.00	0.80	0.4015	ns	!
17		4.50	5.25	0.84	0.3899	ns	!
20		4.22	4.33	0.10	0.7599	ns	!
23		5.00	4.56	1.73	0.2249	ns	!
26		5.30	5.20	0.18	0.6783	ns	!
29		5.00	4.13	1.23	0.3042	ns	!
32		4.13	4.38	0.13	0.7318	ns	!
35		4.70	5.30	1.59	0.2393	ns	!
38		4.60	4.80	0.47	0.5086	ns	!
41		5.20	5.00	0.38	0.5554	ns	!
44		4.80	4.90	0.18	0.6783	ns	!
47		5.00	5.00	0	>0.9999	ns	!
50		4.67	4.22	1.39	0.2721	ns	!
53		4.70	4.80	0.10	0.7577	ns	!
56		4.80	4.80	0	>0.9999	ns	!
59		4.90	4.30	3.86	0.0811	ns	!
65		4.80	4.90	0.13	0.7263	ns	!
68		5.10	4.70	0.88	0.3732	ns	!
71		4.50	4.50	0	>0.9999	ns	!
	Abnormal Flavour						
2		3.56	3.44	0.31	0.5943	ns	!
5		2.88	3.00	0.03	0.8619	ns	!
8		3.00	2.50	1.75	0.2275	ns	!
11		2.13	3.13	1.33	0.2861	ns	!
14		4.25	3.38	1.23	0.3042	ns	!
17		2.88	3.13	0.08	0.7849	ns	!
20		4.33	3.22	5.97	0.0404	*	1.05
23		3.44	3.56	0.06	0.8131	ns	!
26		2.20	2.40	1.00	0.3434	ns	!
29		3.00	3.13	0.13	0.7318	ns	!
32		2.88	3.00	0.01	0.9108	ns	!
35		2.40	2.00	0.88	0.3732	ns	!
38		2.70	2.90	0.23	0.6424	ns	!
41		2.10	2.80	2.74	0.1323	ns	!
44		2.20	2.00	1.00	0.3434	ns	!
47		2.00	2.67	2.00	0.1950	ns	!
50		2.67	3.00	0.31	0.5943	ns	!
53		2.40	2.90	0.92	0.3629	ns	!
56		2.40	3.20	2.67	0.1369	ns	!
59		1.90	2.90	5.63	0.0418	*	0.95
65		2.20	1.90	0.67	0.4344	ns	!
68		2.50	2.70	0.18	0.6783	ns	!
71		2.70	2.40	1.98	0.1934	ns	!

Hedonic Attributes		DRY	VP-PERM	vr	Probability	sig	lsd
	Flavour Liking						
2		4.00	4.56	5.26	0.0509	ns	!
5		5.25	5.25	0	>0.9999	ns	!
8		5.00	5.50	2.33	0.1705	ns	!
11		5.50	4.50	1.47	0.2641	ns	!
14		3.63	4.63	1.87	0.2141	ns	!
17		5.00	4.88	0.02	0.9031	ns	!
20		3.89	4.67	2.23	0.1739	ns	!
23		5.11	4.67	0.78	0.4028	ns	!
26		5.80	5.50	1.98	0.1934	ns	!
29		5.13	4.63	0.78	0.4071	ns	!
32		4.75	5.00	0.10	0.7627	ns	!
35		5.20	6.10	4.31	0.0676	ns	!
38		4.60	5.20	1.59	0.2393	ns	!
41		5.70	5.30	1.16	0.3092	ns	!
44		5.40	5.40	0	>0.9999	ns	!
47		5.67	5.11	0.85	0.3842	ns	!
50		5.00	4.78	0.18	0.6811	ns	!
53		5.40	4.40	5.00	0.0522	ns	!
56		5.10	4.40	1.69	0.2259	ns	!
59		5.40	4.50	4.31	0.0676	ns	!
65		5.50	5.60	0.08	0.7804	ns	!
68		5.50	5.10	1.00	0.3434	ns	!
71		4.80	5.00	0.47	0.5086	ns	!
	Overall Liking						
2		3.89	4.44	3.57	0.0955	ns	!
5		5.38	5.13	0.18	0.6845	ns	!
8		4.25	4.75	1.75	0.2275	ns	!
11		5.50	4.38	2.16	0.1855	ns	!
14		3.63	4.63	1.87	0.2141	ns	!
17		5.00	5.00	0	>0.9999	ns	!
20		3.78	4.33	2.70	0.1388	ns	!
23		5.00	4.78	0.20	0.6646	ns	!
26		5.70	5.60	0.18	0.6783	ns	!
29		4.88	3.88	4.00	0.0856	ns	!
32		4.75	5.00	0.10	0.7627	ns	!
35		5.00	5.00	0	>0.9999	ns	!
38		5.50	5.10	1.71	0.2229	ns	!
41		5.50	5.20	0.80	0.3938	ns	!
44		5.40	4.30	6.44	0.0318	*	0.98
47		5.10	4.50	1.23	0.2967	ns	!
50		5.20	4.50	2.44	0.1530	ns	!
53		4.78	4.56	0.20	0.6646	ns	!
56		5.67	5.11	1.10	0.3251	ns	!
59		5.20	5.00	0.23	0.6424	ns	!
65		5.00	5.90	2.93	0.1212	ns	!
68		4.50	4.90	0.55	0.4790	ns	!
71		5.70	5.30	1.71	0.2229	ns	!

Influence of Dry vs Vp-Std on the eating quality of Grilled beef loin steaks for within individual animal comparison. Values are the means derived from analysis of variance with Treatment and assessor as factors

Animal		DRY	VP-STD	vr	Probability	sig	lsd
	Tenderness						
1		5.67	5.22	1.39	0.2721	ns	!
4		4.63	4.88	1.00	0.3506	ns	!
7		4.88	5.00	0.10	0.7627	ns	!
10		4.38	4.50	0.30	0.5983	ns	!
13		4.63	4.50	0.18	0.6845	ns	!
16		3.75	4.25	3.50	0.1036	ns	!
19		4.88	4.88	0	>0.9999	ns	!
22		5.00	4.56	1.39	0.2721	ns	!
25		5.60	5.50	0.05	0.8227	ns	!
28		4.00	4.63	3.72	0.0950	ns	!
31		3.38	3.13	0.64	0.4512	ns	!
34		5.00	5.20	0.20	0.6618	ns	!
37		5.10	4.90	0.20	0.6618	ns	!
40		5.80	5.70	0.13	0.7263	ns	!
43		5.00	5.10	0.10	0.7577	ns	!
46		4.56	4.00	0.69	0.4304	ns	!
49		4.33	4.56	1.00	0.3466	ns	!
52		4.00	4.20	0.31	0.5911	ns	!
55		4.00	4.40	0.71	0.4226	ns	!
58		5.10	5.90	4.97	0.0528	ns	!
64		4.10	3.40	2.19	0.1727	ns	!
67		4.70	4.90	0.23	0.6424	ns	!
70		4.50	4.30	0.38	0.5554	ns	!
	Juiciness						
1		4.89	5.33	1.39	0.2721	ns	!
4		5.13	5.25	0.30	0.5983	ns	!
7		5.50	6.00	0.54	0.4869	ns	!
10		4.88	4.88	0	>0.9999	ns	!
13		5.00	5.38	2.03	0.1970	ns	!
16		5.00	4.50	1.17	0.3159	ns	!
19		5.25	5.00	0.47	0.5165	ns	!
22		5.33	5.00	0.80	0.3972	ns	!
25		5.30	5.60	0.57	0.4679	ns	!
28		4.88	4.25	5.65	0.0492	*	0.62
31		4.38	4.38	0	>0.9999	ns	!
34		5.20	5.70	5.00	0.0522	ns	!
37		5.10	5.70	1.98	0.1934	ns	!
40		5.00	5.20	0.64	0.4433	ns	!
43		5.20	4.70	5.00	0.0522	ns	!
46		4.78	5.00	0.26	0.6224	ns	!
49		5.33	5.33	0	>0.9999	ns	!
52		5.20	5.10	0.18	0.6783	ns	!
55		5.00	4.60	1.71	0.2229	ns	!
58		5.20	5.80	7.36	0.0239	*	0.50
64		5.30	4.30	5.62	0.0418	*	0.90
67		5.40	5.50	0.10	0.7577	ns	!
70		5.10	4.60	1.55	0.2443	ns	!

		DRY	VP-STD	vr	Probability	sig	lsd
	Beef Flavour						
1		4.44	4.78	0.44	0.5237	ns	!
4		5.00	4.38	0.44	0.5290	ns	!
7		5.13	5.25	0.30	0.5983	ns	!
10		5.50	5.13	0.66	0.4423	ns	!
13		3.88	4.88	4.00	0.0856	ns	!
16		4.25	4.75	0.88	0.3807	ns	!
19		5.63	4.75	8.79	0.0209	*	0.70
22		4.67	4.67	0	>0.9999	ns	!
25		4.70	5.30	1.76	0.2172	ns	!
28		5.38	4.25	4.20	0.0796	ns	!
31		4.38	5.25	2.05	0.1949	ns	!
34		4.80	4.50	0.57	0.4679	ns	!
37		4.50	5.00	1.00	0.3434	ns	!
40		4.60	4.50	0.13	0.7263	ns	!
43		4.40	4.60	1.00	0.3434	ns	!
46		4.60	4.50	0.08	0.7804	ns	!
49		4.20	4.40	0.47	0.5086	ns	!
52		4.33	4.89	10.00	0.0133	*	0.41
55		4.78	4.56	0.47	0.5121	ns	!
58		5.20	4.80	3.27	0.1039	ns	!
64		4.40	4.60	0.47	0.5086	ns	!
67		4.80	4.90	0.05	0.8321	ns	!
70		5.00	5.20	0.38	0.5554	ns	!
	Abnormal Flavour						
1		3.00	3.33	0.31	0.5943	ns	!
4		1.88	2.63	1.15	0.3200	ns	!
7		2.63	2.13	2.33	0.1705	ns	!
10		1.63	2.38	2.33	0.1705	ns	!
13		3.38	2.13	5.00	0.0604	ns	!
16		3.25	2.13	1.82	0.2190	ns	!
19		2.00	2.75	4.20	0.0796	ns	!
22		2.67	3.11	3.37	0.1038	ns	!
25		2.90	2.00	2.52	0.1467	ns	!
28		1.88	2.88	2.00	0.2002	ns	!
31		3.75	2.50	1.16	0.3174	ns	!
34		2.30	2.10	0.31	0.5911	ns	!
37		2.10	2.70	1.76	0.2172	ns	!
40		2.50	2.90	1.38	0.2695	ns	!
43		2.20	2.40	0.64	0.4433	ns	!
46		2.56	2.22	2.00	0.195	ns	!
49		2.67	2.44	0.47	0.5121	ns	!
52		3.00	2.80	0.47	0.5086	ns	!
55		2.70	2.40	1.00	0.3434	ns	!
58		2.80	2.40	1.71	0.2229	ns	!
64		2.70	2.30	1.71	0.2229	ns	!
67		2.60	2.20	0.51	0.4945	ns	!
70		3.10	2.50	2.25	0.1679	ns	!

		DRY	VP-STD	vr	Probability	sig	lsd
	Flavour Liking						
1		4.67	4.67	0	>0.9999	ns	!
4		5.75	4.75	2.80	0.1382	ns	!
7		5.13	6.00	6.24	0.0412	*	0.83
10		5.88	5.13	2.70	0.1419	ns	!
13		4.25	5.38	2.85	0.1353	ns	!
16		4.50	5.38	1.87	0.2133	ns	!
19		5.88	5.00	14.91	0.0062	**	0.54
22		5.78	5.33	6.40	0.0353	*	0.41
25		5.10	5.80	2.74	0.1323	ns	!
28		5.88	4.88	5.60	0.0499	*	1.00
31		4.13	5.25	1.58	0.2492	ns	!
34		4.70	4.90	0.26	0.6193	ns	!
37		5.00	5.60	1.00	0.3434	ns	!
40		5.00	5.00	0	>0.9999	ns	!
43		4.60	5.10	3.46	0.0957	ns	!
46		4.80	5.00	0.23	0.6424	ns	!
49		4.30	4.60	0.80	0.3938	ns	!
52		5.22	5.56	1.00	0.3466	ns	!
55		5.11	5.33	0.31	0.5943	ns	!
58		5.70	5.30	1.71	0.2229	ns	!
64		5.00	5.10	0.13	0.7263	ns	!
67		5.20	4.80	0.64	0.4433	ns	!
70		5.60	6.10	2.65	0.1382	ns	!
	Overall Liking						
1		4.56	4.67	0.03	0.8771	ns	!
4		5.88	4.88	2.00	0.2002	ns	!
7		5.13	5.75	2.78	0.1395	ns	!
10		5.63	5.00	2.22	0.1803	ns	!
13		4.00	5.25	3.43	0.1064	ns	!
16		4.25	5.25	2.33	0.1705	ns	!
19		5.63	4.88	5.73	0.0479	*	0.74
22		5.78	5.11	8.00	0.0222	*	0.54
25		5.10	5.60	1.36	0.2729	ns	!
28		5.63	4.63	7.00	0.0331	*	0.89
31		3.88	4.63	1.15	0.3200	ns	!
34		5.60	6.00	1.71	0.2229	ns	!
37		5.20	4.80	0.88	0.3732	ns	!
40		5.10	5.20	0.13	0.7263	ns	!
43		5.70	5.20	3.46	0.0957	ns	!
46		5.00	4.78	0.31	0.5943	ns	!
49		5.00	5.22	0.47	0.5121	ns	!
52		3.80	4.40	5.06	0.0510	ns	!
55		4.40	4.70	0.50	0.4961	ns	!
58		4.60	5.20	3.12	0.1114	ns	!
64		4.80	4.30	1.80	0.2126	ns	!
67		4.80	5.50	2.19	0.1727	ns	!
70		4.40	4.30	0.06	0.8114	ns	!

Influence of Vp-Std vs Vp-Perm on the eating quality of Grilled beef loin steaks for within individual animal comparison. Values are the means derived from analysis of variance with Treatment and assessor as factors

		VP-STD	VP-PERM	vr	Probability	sig	lsd
	Tenderness						
3		4.78	5.00	0.16	0.6953	ns	!
6		5.75	4.38	27.32	0.0012	**	0.62
9		6.25	5.25	14.00	0.0072	**	0.63
12		5.25	5.00	1.00	0.3506	ns	!
15		4.50	4.50	0	>0.9999	ns	!
18		4.75	4.50	0.64	0.4512	ns	!
21		5.56	5.33	1.00	0.3466	ns	!
24		3.90	4.00	0.03	0.8723	ns	!
27		4.40	4.70	0.17	0.6911	ns	!
30		5.50	5.13	0.80	0.4015	ns	!
33		5.13	4.88	0.37	0.5630	ns	!
36		5.80	5.10	2.19	0.1727	ns	!
39		4.70	4.70	0	>0.9999	ns	
42		4.70	5.20	1.55	0.2443	ns	!
45		4.22	5.22	2.57	0.1475	ns	!
48		4.44	4.22	0.23	0.6454	ns	!
51		3.89	4.56	0.94	0.3604	ns	!
54		5.50	5.80	1.00	0.3434	ns	!
57		5.20	5.70	2.14	0.1773	ns	!
60		5.10	5.30	0.20	0.6618	ns	!
66		5.00	5.40	2.25	0.1679	ns	!
69		5.30	5.40	0.06	0.8114	ns	!
72		4.90	4.20	5.44	0.0445	*	0.68
	Juiciness						
3		5.33	5.56	0.64	0.4468	ns	!
6		5.38	5.63	0.30	0.5983	ns	!
9		5.75	5.50	0.37	0.5630	ns	!
12		4.63	5.25	11.67	0.0112	*	0.43
15		4.75	5.00	0.15	0.7110	ns	!
18		5.13	5.25	0.13	0.7318	ns	!
21		5.44	5.89	3.37	0.1038	ns	!
24		4.70	4.70	0	>0.9999	ns	!
27		5.40	5.50	0.08	0.7804	ns	!
30		4.75	5.25	2.33	0.1705	ns	!
33		5.50	5.00	1.40	0.2753	ns	!
36		4.50	4.70	0.64	0.4433	ns	!
39		5.20	5.20	0	>0.9999	ns	!
42		5.40	5.70	0.80	0.3938	ns	!
45		4.20	5.10	3.49	0.0947	ns	!
48		5.60	5.50	0.31	0.5911	ns	!
51		5.10	4.90	0.47	0.5086	ns	!
54		5.00	5.67	16.00	0.0039	**	0.38
57		5.56	5.33	0.37	0.5588	ns	!
60		5.50	5.20	1.00	0.3434	ns	!
66		5.40	5.90	2.14	0.1773	ns	!
69		4.89	5.33	3.37	0.1038	ns	!
72		5.40	5.10	0.45	0.5203	ns	!

		VP-STD	VP-PERM	vr	Probability	sig	lsd
	Beef Flavour						
3		3.89	4.56	5.33	0.0497	*	0.67
6		5.13	4.50	1.84	0.2168	ns	!
9		4.63	4.75	0.13	0.7318	ns	!
12		4.88	4.50	4.20	0.0796	ns	!
15		4.38	4.75	0.25	0.6344	ns	!
18		4.50	4.63	0.04	0.8505	ns	!
21		5.67	4.44	3.02	0.1202	ns	!
24		4.40	3.70	2.19	0.1727	ns	!
27		4.30	4.30	0	>0.9999	ns	!
30		4.75	4.38	2.03	0.1970	ns	!
33		4.63	4.25	0.66	0.4423	ns	!
36		4.80	5.20	1.38	0.2695	ns	!
39		5.10	4.30	7.58	0.0224	*	0.66
42		4.70	5.40	3.64	0.0886	ns	!
45		5.11	5.11	0	>0.9999	ns	!
48		5.00	4.67	0.67	0.4379	ns	!
51		4.11	4.78	1.60	0.2415	ns	!
54		4.10	3.90	0.38	0.5554	ns	!
57		4.10	3.00	5.21	0.0484	*	1.09
60		4.60	4.40	0.31	0.5911	ns	!
66		4.70	4.40	0.67	0.4344	ns	!
69		4.70	5.00	0.67	0.4344	ns	!
72		4.50	4.20	0.67	0.4344	ns	!
	Abnormal Flavour						
3		3.22	3.44	0.18	0.6811	ns	!
6		2.75	3.75	1.75	0.2275	ns	!
9		2.75	4.38	10.66	0.0138	*	1.18
12		2.25	2.50	0.64	0.4512	ns	!
15		2.50	3.25	1.07	0.3358	ns	!
18		3.13	3.13	0	>0.9999	ns	!
21		2.33	3.78	4.39	0.0695	ns	!
24		2.70	4.00	7.57	0.0224	*	1.07
27		3.20	3.70	0.85	0.3809	ns	!
30		3.13	4.00	14.91	0.0062	**	0.54
33		2.75	3.50	1.80	0.2216	ns	!
36		2.20	2.30	0.31	0.5911	ns	!
39		2.20	2.50	1.33	0.2789	ns	!
42		2.60	2.20	1.38	0.2695	ns	!
45		2.22	2.44	0.64	0.4468	ns	!
48		2.89	3.00	0.04	0.8487	ns	!
51		2.89	3.22	0.24	0.6406	ns	!
54		3.10	2.70	1.16	0.3092	ns	!
57		3.10	5.20	8.84	0.0156	*	1.60
60		2.40	2.60	0.23	0.6424	ns	!
66		2.00	2.60	1.33	0.2789	ns	!
69		2.40	2.30	0.08	0.7804	ns	!
72		2.30	2.90	3.86	0.0811	ns	!

		VP-STD	VP-PERM	vr	Probability	sig	lsd
	Flavour Liking						
3		4.33	4.67	0.50	0.4996	ns	!
6		5.63	5.13	1.00	0.3506	ns	!
9		5.38	4.00	4.84	0.0637	ns	!
12		5.13	5.13	0	>0.9999	ns	!
15		5.38	4.75	0.85	0.3884	ns	!
18		4.75	4.63	0.03	0.8786	ns	!
21		5.89	4.33	5.76	0.0431	*	1.49
24		4.80	3.70	8.44	0.0174	*	0.86
27		5.10	4.60	0.79	0.3974	ns	!
30		5.63	4.38	5.65	0.0492	*	1.24
33		5.38	4.50	1.60	0.2470	ns	!
36		4.90	4.40	1.80	0.2126	ns	!
39		5.10	5.20	0.13	0.7263	ns	!
42		5.50	5.30	0.18	0.6783	ns	!
45		5.30	4.90	0.71	0.4226	ns	!
48		4.20	2.50	18.45	0.002	**	0.90
51		4.50	4.40	0.07	0.7976	ns	!
54		4.67	4.56	0.02	0.8916	ns	!
57		5.33	4.56	1.38	0.2738	ns	!
60		5.22	5.11	0.06	0.8131	ns	!
66		5.40	5.40	0	>0.9999	ns	!
69		5.40	5.40	0	>0.9999	ns	!
72		5.70	5.70	0	>0.9999	ns	!
	Overall Liking						
3		4.33	4.44	0.06	0.8131	ns	!
6		5.63	5.00	1.58	0.2495	ns	!
9		5.38	3.75	8.27	0.0238	*	1.34
12		4.88	5.00	0.18	0.6845	ns	!
15		5.25	4.75	0.47	0.5165	ns	!
18		4.63	4.63	0	>0.9999	ns	!
21		6.00	4.33	7.69	0.0242	*	1.39
24		4.60	3.80	7.58	0.0224	*	0.66
27		4.80	4.00	7.58	0.0224	*	0.66
30		5.38	4.25	3.75	0.0938	ns	!
33		5.00	4.13	2.05	0.1949	ns	!
36		5.70	5.60	0.13	0.7263	ns	!
39		5.20	5.20	0	>0.9999	ns	!
42		5.00	5.40	2.25	0.1679	ns	!
45		4.78	5.11	0.67	0.4379	ns	!
48		4.89	4.56	0.40	0.5447	ns	!
51		4.33	4.33	0	>0.9999	ns	!
54		4.50	4.50	0	>0.9999	ns	!
57		4.10	2.50	18.58	0.002	**	0.84
60		4.80	4.90	0.06	0.8114	ns	!
66		5.50	5.30	0.20	0.6618	ns	!
69		5.10	5.30	0.64	0.4433	ns	!
72		4.70	4.20	2.65	0.1382	ns	!

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