Particle size distribution of forages and mixed rations, and their relationship with ration variability and performance of UK dairy herds

Table 1. Herd and feeding characteristics on 50 UK dairy herds.

	Mean	SD	Min	Max	Median
Herd size (n)	354	343.9	75	2220	277
Cows in milk (n)	310	282.3	67	1770	240
Milk yield (kg/cow/year)	9199	1583.2	6000	12500	9200
Milk fat (g/kg)	41.0	0.36	36.2	57.0	40.0
Milk protein (g/kg)	32.9	0.21	29.3	41.0	32.8
ECM yield (kg/cow/year)[1]	10011	1434.9	7248	13209	9891
Frequency of fresh feed delivery (n/d)	1.3	0.46	1	2	1.0
Frequency of feed push up (n/d)[2]	4.7	3.19	1	16	4.0
Frequency of refusals removal (n/wk)	4.4	2.75	0.25	7	5.5
Feed space per cow (m/cow)	0.56	0.098	0.30	0.76	0.61
Length of feed mixing (min/mix)	19	10.2	5	60	15
No. of chews/bolus	66	9.81	44	105	66

[1]Energy corrected milk.

[2]Herds feeding into a trough (n = 20) have been excluded.

Table 2. Mean chemical (g/kg DM ± SD) and physical characteristics (%DM ± SD) of grass (n = 50) and maize silage (n = 34) on 50 dairy herds.

	Grass silage			Maize silage				
Chemical composition	Mean	Min	Max	Mean	Min	Max	SED	*P* value
Dry matter (g/kg)	273 ± 46.1	205	390	300 ± 55.8	219	420	11.2	0.022
Organic matter	899 ± 20.0	854	945	961 ± 7.1	942	974	3.6	< 0.001
Ash	101 ± 20.0	55	146	39 ± 7.1	26	58	3.6	< 0.001
Crude protein	136 ± 26.0	81	184	82 ± 9.3	56	98	4.7	< 0.001
Neutral detergent fibre	492 ± 75.0	362	702	427 ± 74.1	276	559	16.8	< 0.001
Acid detergent fibre	331 ± 41.9	242	459	267 ± 44.8	176	347	9.7	< 0.001
Physical composition								
Fractions (mm)[1]								
>60	2.1 ± 5.12[a]	0	31.8	-	-	-	ND	ND
44-60	23.1 ± 13.38[c]	0	53.5	-	-	-	ND	ND
26.9-44	51.6 ± 14.01[d]	5.9	77.2	-	-	-	ND	ND
19-26.9	3.5 ± 3.29[a]	0.7	20.5	6.9 ± 4.55[a]	2.0	22.8	0.75	< 0.001
8-19	15.8 ± 10.01[b]	0.8	39.8	73.2 ± 8.75[d]	37.7	84.1	2.02	< 0.001
4-8	2.4 ± 1.44[a]	0.6	6.9	13.1 ± 5.02[c]	7.7	33.1	0.77	< 0.001
<4	1.6 ± 1.35[a]	0.1	6.0	6.8 ± 4.14[a]	1.4	18.8	0.64	< 0.001
$pef_{>4mm}$ (%)[2]	98 ± 1.5	93	100	93 ± 4.1	81	99	0.6	< 0.001
$peNDF_{>4mm}$ (%)	48 ± 7.0	36	66	40 ± 7.7	24	54	1.7	< 0.001
$pef_{>8mm}$ (%)[3]	96 ± 3.1	86	100	80 ± 8.0	48	90	1.3	< 0.001
$peNDF_{>8mm}$ (%)	47 ± 6.7	35	62	34 ± 7.7	19	48	1.6	< 0.001
X_m[4]	42.6 ± 5.63	17.5	53.9	10.6 ± 1.21	7.4	13.6	0.98	< 0.001

DM = dry matter, SD = standard deviation, SED = standard error of difference

[1]Grass silage was separated into 7 fractions; >60, 44-60, 26.9-44, 19-26.9, 8-19, 4-8 and <4 mm. Maize silage was separated into 4 fractions; >19, 8-19, 4-8 and <4 mm.

[a,b,c,d]Within each forage, different superscripts between fractions indicate a significant ($P < 0.05$) difference.

[2]Physical effective factor; % proportion of particles >4 mm.

[3]Physical effective factor; % proportion of particles >8 mm.

[4]Geometric mean particle size.

Table 3. Mean chemical composition and physical characteristics of mixed rations (MR) on 50 herds.

	Fresh basis	DM basis		
Forage (kg/cow/d)	40.5	12.2		
Concentrate (kg/cow/d)[1]	11.7	9.5		
Forage to concentrate ratio (F:C)[1]	77:23	57:43		
Grass to maize silage ratio (GS:MS)[2]	50:50	48:52		
Composition (g/kg DM ± SD)[1]	Mean	Min	Max	Median
Dry matter (g/kg)	373 ± 78.6	213	544	380
Organic matter	920 ± 11.5	883	944	922
Ash	80 ± 11.5	56	117	78
Crude protein	160 ± 18.9	116	205	162
Ether extract	28 ± 8.2	11	40	30
Starch	138 ± 44.1	63	237	139
Neutral detergent fibre	391 ± 59.3	290	507	381
Acid detergent fibre	249 ± 42.6	173	329	245
Physical composition (%DM ± SD)				
Fractions (mm)[3]				
>60	0.1 ± 0.29	0	1.4	0
44-60	7.3 ± 9.27	0	32.8	2.4
26.9-44	26.0 ± 15.10	1.6	75.9	24.7
19-26.9	4.4 ± 3.38	0.9	21.8	3.7
8-19	34.9 ± 13.31	3.5	67.8	34.9
4-8	11.8 ± 5.58	0.9	29.6	10.9
<4	15.5 ± 9.72	0.4	37.4	14.9
$pef_{>4mm}$ (%)[4]	85 ± 9.6	63	100	85
$peNDF_{>4mm}$ (%)	33 ± 6.8	22	47	33
$pef_{>8mm}$ (%)[5]	73 ± 12.9	44	99	70
$peNDF_{>8mm}$ (%)	29 ± 7.3	16	43	28
X_m[6]	19.5 ± 12.09	6.2	44.9	13.3

[1]Includes the concentrates offered in the parlour.
[2]Ratio of GS to MS in 34 herds, where both silages were fed.
[3]Rations were separated into 7 fractions; >60, 44-60, 26.9-44, 19-26.9, 8-19, 4-8 and <4 mm; SED = 2.72 and $P < 0.001$.
[4]Physical effective factor; % proportion of particles >4 mm.
[5]Physical effective factor; % proportion of particles >8 mm.
[6]Geometric mean particle size.

Table 4. Particle size distribution of mixed rations (0hMR) at feed out containing grass silage (16) and mixtures of grass and maize silage (34) on 50 herds.

	Particle size distribution (%DM)			
Fractions[1] (mm)	GS	GS+MS	SED	*P* value
>60	0.1	0.1	0.08	0.55
44-60	10.6	5.7	2.75	0.08
26.9-44	34.6	22.0	4.25	< 0.01
19-26.9	3.5	4.8	1.01	0.22
8-19	26.4	39.0	3.65	< 0.01
4-8	10.2	12.6	1.67	0.15
<4	14.6	15.9	2.97	0.68
X_m[2]	23.1	17.8	3.63	0.15

GS = grass silage, GS+MS= mixture of grass and maize silage, SED = standard error of difference

[1]Rations were separated into seven fractions; >60, 44-60, 26.9-44, 19-26.9, 8-19, 4-8 and <4 mm.

[2]Geomatic mean particle size.

Table 5. Within farm standard deviation (SD) and coefficient of variation (CV) of particle fractions of mixed ration at 5 points along feed face on 50 dairy herds.

Fractions[1]		Standard deviation[3]			CV (%)[4]		
(mm)	Mean[2]	Mean ± SD	Min	Max	Mean ± SD	Min	Max
>26.9	33.4	2.9 ± 2.28	0.1	10.8	13.7 ± 13.25	0.1	10.8
19-26.9	4.4	0.7 ± 1.16	0.1	7.7	15.0 ± 12.56	0.1	7.7
8-19	34.9	2.1 ± 1.60	0.0	7.9	7.3 ± 8.09	0.0	7.9
4-8	11.8	0.7 ± 0.53	0.1	2.9	6.4 ± 4.59	0.1	2.9
<4	15.5	1.1 ± 1.26	0.1	5.9	8.0 ± 7.43	0.1	5.9

[1]Ration was separated into five fractions; >26.9, 19-26.9, 8-19, 4-8 and <4 mm.
[2]Average particle size distribution of MR on 50 herds.
[3]SD of each fraction at 5 sampling points at each farm.
[4]CV = (SD of each fraction at 5 sampling points at each farm/ average value of each fraction) × 100.

Table 6. Group level sorting[1] (% ± SD) on 50 dairy herds.

Fractions[2] (mm)	Sorting		
	0-4h	4-24h[3]	0-24h[3]
>26.9	115 ± 59.5	158 ± 98.8	165 ± 113.0
19-26.9	101 ± 10.6	117 ± 47.8	106 ± 9.0
8-19	99 ± 28.0	92 ± 39.1	89 ± 32.4
4-8	99 ± 25.7	85 ± 32.5	83 ± 36.5
<4	103 ± 52.8	96 ± 143.7	93 ± 83.6

[1]Sorting was calculated for each fraction by dividing the proportion (DM basis) at 0hMR by the corresponding proportion at 4hMR and RefMR, and presented as a percentage. A sorting value of 100% indicated no sorting, <100% indicated preferential consumption, and >100% indicated selective refusal.
[2]Rations were separated into 5 fractions; >26.9, 19-26.9, 8-19, 4-8 and <4 mm.
[3]24h sorting activity was calculated across 33 herds, where refusals were available.

Table 7. Comparative particle size distribution of mixed rations (n = 50), grass silage (n = 50) and maize silage (n = 34) analysed by fresh and dry shaking on 50 dairy herds.

Sample	Fractions[1] (mm)	% Dry matter		SED	*P* value
		Fresh	Dry		
Grass silage	>26.9	78.7	45.7	3.15	< 0.001
	19-26.9	2.7	2.9	0.38	0.75
	8-19	14.3	34.4	2.16	< 0.001
	4-8	2.6	10.1	0.63	< 0.001
	<4	1.7	6.9	0.57	< 0.001
Maize silage	>19	6.9	4.3	0.87	0.004
	8-19	73.2	52.6	2.37	< 0.001
	4-8	13.1	28.8	1.53	< 0.001
	<4	6.8	14.3	1.28	< 0.001
Mixed ration	>26.9	32.8	16.2	4.08	< 0.001
	19-26.9	4.4	3.5	0.54	0.10
	8-19	35.6	38.0	2.58	0.35
	4-8	12.2	21.2	1.25	< 0.001
	<4	15.0	21.1	1.88	0.002

[1]MR and GS were separated into 5 fractions; >26.9, 19-26.9, 8-19, 4-8 and <4 mm. MS was separated into 4 fractions; >19, 8-19, 4-8 and <4 mm.