MILK DEVELOPMENT COUNCIL

THE EFFECTS OF PROCESSED WHOLE CROP WHEAT, MAIZE SILAGE AND SUPPLEMENT TYPE ON THE PERFORMANCE OF DAIRY COWS

Project No. 01/T1/01

FINAL PROJECT REPORT

FORAGE PROCESSING OF WHOLE CROP WHEAT FOR MILK PRODUCTION

A two year study sponsored by the Milk Development Council and supported by the Maize Growers Association

Experimental work conducted 2000-2002

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June 2002

BACKGROUND

Whole crop cereals offer the potential of a high yielding crop, which is particularly beneficial for farms in the north and west of the country where alternative forages such as maize silage cannot be grown well. It has been well established that, compared with grass silage, the inclusion of urea-treated whole crop wheat in the diet of lactating dairy cows results in a significant increase in dry matter intake but has little effect on milk yield or composition. When compared with maize silage, yields are generally lower. Work has shown that the digestibility of fibre and particularly starch is depressed when cows are fed diets containing urea-treated whole crop wheat and it has been suggested that future work should focus on means of increasing the digestibility of starch and fibre fraction in this forage. Recently, a forage mill has been developed that allows the grains to be finely ground prior to ensiling. Whilst there is anecdotal evidence that the process is effective there is no experimental evidence to determine whether it results in an improvement in the efficiency of milk production.

An alternative means of increasing the nutritive value of urea-treated whole crop wheat is to increase the stubble height at harvest resulting in an increase in the ratio of grain to straw in the forage. Increasing the stubble height from 18 to 40cm for fermented whole crop wheat harvested at 450gDM/kg was shown to increase the metabolisabile energy content of the forage when determined in sheep although little work has been conducted in dairy cows. The use of sugar sources has also been suggested to improve animal performance and an effect would potentially be greatest in diets that contain a large amount of rapidly fermentable starch, such as those containing processed WCW.

Two experiments with dairy cows in early lactation were conducted.

In Year 1 the effects of processing (grinding) at harvest and stubble height on intake, milk yield and diet digestibility were determined.

In Year 2 the effects of carbohydrate supplement to processed, urea-treated whole crop wheat were determined and compared with cows fed maize silage.

The Final Report contains:

FARMER RECOMMENDATIONS

- When making urea-treated whole crop wheat (WCW) ensure that it is processed with a forage mill at harvest. This will increase the digestibility of the starch and eliminate whole grains passing through the cows.

- Processed, urea treated WCW results in a milk yield similar to that of a good quality maize silage. In areas of the country where maize can be grown well then WCW represents a viable alternative. In areas of the country where maize is marginal or cannot be grown successfully then WCW will result in milk yields similar to that if maize could be grown well.

- Compared with ground long straw WCW, feeding short ground WCW will decrease milk butterfat percentage (by around 0.5%), increase body condition score (by around 0.2 units) and results in the lowest forage cost (p/d).

- Supplement type to processed WCW can alter milk yield and composition although the response may be small and not significant.

- Costs of growing and harvesting urea-treated wheat are approximately £48/tDM which drops to around £35/tDM if arable aid payments are available. Head cutting (short straw) results in a cost of approximately £55/tDM which falls to around £38/tDM if area aid is available. These costs are comparable to maize silage (£/tDM).

Additional factors to consider:

- The effect of the processor means that there is now a much wider window within which to harvest WCW and it can be harvested between 55-80% dry matter (DM) but there may be advantages in terms of yield (tDM/ha) to leave it to at least 70% DM.

- Increasing the cutting height at harvest to provide a short straw (head cut) forage will increase starch levels and decrease fibre levels but reduces the yield of forage (tDM/ha) by around 20-25% (but will depend on the straw length and cut height).

- Whole crop cereals increase the flexibility of forage management, as the area of whole crop to be harvested does not have to be decided until after first cut grass silage has been made. The forage mill also allows the quality of the WCW to be modified (by altering cutting height) dependent on the quantity and quality of the first cut silage. If the quantity of first cut silage is high but the quality low then a shorter straw WCW can be made. If the quantity of first cut is low but the quality high then a longer straw WCW can be made.

- On farms that grow maize, processed WCW allows a high starch forage to be fed to early calved cows before the maize is harvested. This also enables the same clamp area to be used twice and therefore reduces capital costs.

YEAR 1: EXECUTIVE SUMMARY

This report describes year 1 of a 2 year study into the effects of processing (milling) whole crop wheat (WCW) at harvest and cutting height on milk production and diet digestibility in dairy cows.

Four dietary treatments were fed to 44 dairy cows for 14 weeks:

- Long straw WCW, unground (DM (g/kg), NDF & starch (g/kg DM) of 713, 425 and 369 respectively)
- Long straw WCW ground (DM (g/kg), NDF & starch (g/kg DM) of 653, 419 and 342 respectively)
- Short straw WCW unground (DM (g/kg), NDF & starch (g/kg DM) of 707, 331 and 417 respectively)
- Short straw WCW ground (DM (g/kg), NDF & starch (g/kg DM) of 709, 342 and 420 respectively)

The wheat was harvested at a height of 67cm and cut to leave a stubble height of either 18cm (long straw) or 37cm (short straw). The WCW forages were mixed with grass silage (DM of 232g/kgDM, crude protein of 120g/kg DM, ME of 10.9MJ/kg DM) in the ratio of 1:2 grass silage to WCW (DM basis) and all cows received 10.5kg of concentrates per day. Apparent digestibility was measured in 5 cows per treatment using chromic oxide as an indigestible marker.

Summary table for intake, milk yield and composition and digestibility

	Diets					Sign. Of main effects		
	Long straw Unground	Long straw Ground	Short straw Unground	Short straw Ground	s.e.d.	G	H	GxH
DM intake (kg/d)								
Concentrates	9.12	8.72	8.84	8.86	0.192	ns	ns	ns
Forage	14.09	12.97	13.32	12.03	0.834	*	0.08	ns
Total	23.21	21.65	22.16	20.83	0.983	*	0.10	ns
Milk yield	30.8	29.9	30.0	29.8	0.82	ns	ns	ns
Butterfat %	4.18	4.19	3.84	3.56	0.250	ns	*	ns
Protein %	3.44	3.46	3.33	3.30	0.111	ns	0.10	ns
Lactose %	4.61	4.54	4.64	4.62	0.059	ns	ns	ns
Liveweight (kg)	587	616	607	619	21.8	ns	ns	ns
Condition score	2.59	2.61	2.83	2.76	0.108	ns	*	ns
Digestibility (kg/kg)								
NDF	0.592	0.556	0.537	0.532	0.0458	ns	ns	ns
Starch	0.905	0.967	0.856	0.962	0.0174	***	0.05	ns

In conclusion the experiment has indicated that:

- Grinding significantly improved the apparent digestibility of starch but not fibre. Assuming the apparent digestibility of non-WCW starch to be constant at 0.964 then starch in unground WCW had an apparent digestibility of between 0.80and 0.87 and in ground WCW had a digestibility of 0.97.

- Cows responded to the greater nutritive value of short straw or ground forages by reducing intake.

- Milk yield (kg/d) was not significantly affected by grinding or cutting height

- Milk butterfat % was lowest and body condition score was highest in cows fed the short straw compared with the long straw treatments.

- A similar level of performance was obtained from a similar level of feed intake by feeding ground long straw WCW as feeding unground short straw WCW.

- Forage costs (including arable aid payments) were approximately £34.58/tDM for the long straw forages (LU and LG) and £37.86tDM for the short straw forages (SU and SG). Processing at harvest (LG and SG *vs.* LU and SU) resulted in a saving in total forage costs of between 4-8p/cow/d and feeding a short straw compared with a long straw WCW a further saving of between 0-3p/cow/day.

YEAR 2: EXECUTIVE SUMMARY

This report describes the 2nd year of a 2 year study to investigate means of improving the nutritive value of whole crop wheat (WCW) for dairy cows. The objectives of the current study were to determine the effects of carbohydrate supplement type to processed (milled) urea-treated whole crop wheat (WCW) and to compare WCW with maize silage on the intake and milk performance of dairy cows.

Four dietary treatments were fed to 44 dairy cows for 15 weeks:

- Maize: Maize silage (DM of 310g/kg; starch of 308g/kg DM and ME of 11.5MJ/kg DM) supplemented with 2kg/d of rolled wheat.
- W-WCW: WCW supplemented with 2kg/d of rolled wheat.
- L-WCW: WCW supplemented with 0.7kg/d of lactose and 1.3kg/d wheat
- M-WCW: WCW supplemented with 2kg/d of cane molasses

The WCW had a DM of 823g/kg, starch content of 350g/kg DM, crude protein content of 143g/kg DM and a pH of 8.0. The WCW forages were mixed with grass silage (DM of 356g/kg, crude protein of 123g/kg DM, ME of 11.5MJ/kg DM) in the ratio of 2:1 WCW to grass silage (DM basis) and all cows received 8.5kg/d of a standard concentrates resulting a total of 10.5kg of concentrates per day.

Summary table for intake, milk yield and composition

	Diets				s.e.d.	Significance
	Maize	W-WCW	L-WCW	M-WCW		
DM intake (kg/d)						
Concentrates	9.2	8.9	8.8	8.6	0.24	ns
Forage	10.7	13.3	12.2	14.6	0.68	***
Total	19.9	22.2	21.0	23.2	0.88	**
Milk yield	34.0	34.4	35.6	33.1	1.21	ns
Fat g/kg	37.7	34.3	34.3	38.4	2.20	ns
Protein g/kg	31.2	32.5	31.5	33.3	0.61	**
Fat yield (kg/d)	1.31	1.18	1.22	1.27	0.075	ns
Protein yield (kg/d)	1.07	1.13	1.11	1.10	0.040	ns
Condition score	2.53	2.71	2.60	2.50	0.16	Ns

In conclusion the experiment has indicated that:

- Milk yield (kg/d) was similar across all dietary treatments although it tended to be highest in cows fed WCW supplemented with lactose and lowest in WCW supplemented with molasses.

- Fat concentrations (g/kg) were low across all treatments but tended to be higher in the maize and molasses-WCW fed animals compared with the other two treatments although the effect was not significant.

- Milk protein concentration was significantly lower in cows offered the maize silage and lactose-WCW treatments than those fed the molasses-WCW treatment.

- There was no significant effect of treatment on milk component yield (kg/d).

- Daily DM intake (kg/d) was some 3.3kg/d greater in cows fed the molasses-WCW treatment than those fed the maize silage. Supplementing WCW with lactose resulted in a daily DMI that was not significantly different to maize silage.

- The production costs of processed, urea-treated whole crop wheat (£/tDM) was similar to that of maize silage.

FIRST YEAR REPORT

FORAGE PROCESSING OF WHOLE CROP WHEAT FOR MILK PRODUCTION

EFFECT OF FORAGE GRINDING AND CUTTING HEIGHT OF UREA TREATED WHOLE CROP WHEAT ON THE MILK PRODUCTION AND DIET DIGESTIBILITY IN DAIRY COWS

Experimental work conducted 2000-2001

Funded by the Milk Development Council with contributions from the Maize Growers Association

Project Team: Dr L.A. Sinclair, Miss. M. Jackson, Dr. R. Readman & Dr. J. Huntington

June 2001

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FARMER RECOMMENDATIONS

- When making urea-treated whole crop wheat (WCW) ensure that it is processed with a forage mill at harvest. This will increase the digestibility of the starch and eliminate whole grains passing through the cows.

- The effect of the processor means that there is now a much wider window within which to harvest WCW and it can be harvested between 55-80% dry matter (DM) but there may be advantages in terms of yield (tDM/ha) to leave it until at least 70% DM.

- Feeding processed whole crop wheat will not increase milk yield or significantly alter milk composition but will reduce forage requirements and therefore reduce feed costs (by between 4-8p/cow/d).

- Increasing the cutting height at harvest to provide a short straw (head cut) forage will increase starch levels and decrease fibre levels but reduces the yield of forage (tDM/ha) by around 20-25% (but will depend on the straw length and cut height).

- Compared with ground long straw WCW, feeding short ground WCW will decrease milk butterfat percentage (by around 0.5%), increase body condition score (by around 0.2 units) and results in the lowest forage cost (p/d).

- Costs of growing and harvesting urea-treated wheat are approximately £48/tDM which drops to around £35/tDM if arable aid payments are available. Head cutting (short straw) results in a cost of approximately £55/tDM which falls to around £38/tDM if area aid is available.

1. INTRODUCTION AND OBJECTIVES

It is now well established that, compared with grass silage, the inclusion of urea-treated whole crop wheat in the diet of lactating dairy cows results in a significant increase in dry matter intake (DMI) but has little effect on milk yield (Abdalla *et al.* 1999, Hameleers *et al.* 1998, Leaver and Hill, 1992, Leaver and Hill, 1995, Phipps *et al.* 1998, Sutton *et al.* 1997, 1998). Leaver and Hill (1992) suggested that the discrepancy between energy intake and milk output could be attributed to a low efficiency of conversion of ME into milk energy. However, Sutton *et al.* (1997) demonstrated that the digestibility of fibre and particularly starch was depressed in cows fed diets containing urea-treated whole crop wheat. Subsequent energy balance studies confirmed that urea-treated whole crop wheat had low digestibility and that the metabolisable energy content of the forage was low at between 7.8 and 8.1MJ/kg DM (Sutton *et al.* 1998). This reduction in digestibility was shown to be due to a reduced digestion in the rumen and an increased rumen outflow rate of undigested fibre and starch resulting in over 50% of the dietary starch flowing to the duodenum (Abdalla *et al.* 1999). It was suggested by Sutton *et al.* (1998) that future work should focus on means of increasing the digestibility of starch and fibre fraction of urea-treated whole crop wheat. Recently, a forage mill has been developed that allows the grains to be finely ground prior to ensiling. Whilst there is anecdotal evidence that the process is effective there is no experimental evidence to determine whether it results in an improvement in the efficiency of milk production.

An alternative means of increasing the nutritive value of urea-treated whole crop wheat is to increase the stubble height at harvest resulting in an increase in the ratio of grain to straw in the forage. Work conducted by Weller *et al.* (1995) reported that increasing the cutting height of whole crop wheat harvested from 10 to 40cm stubble height resulted in a reduction in DM yield of approximately 25% but an increase in calculated ME from 10.6 to 11.2MJ/kg for the short and long stubble height respectively. Increasing the stubble height from 18 to 40cm for fermented whole crop wheat harvested at 450g/kg was shown to increase the metabolisabile energy content of the forage determined in sheep from 10.5 to 11.0MJ/kg DM (Wilkinson and Sinclair 1999). However, this increase in energy content was not translated into an increased milk yield and it was concluded that increasing the stubble height had little effect on less mature crops and that the greatest effects of cutting height would potentially be with more mature forages (Sinclair and Wilkinson 1999).

1.1. Objectives:

The objectives of the current work were therefore to examine the effects of cutting height and grinding at harvest on intake, milk production and digestibility in dairy cows.

2. GENERAL MATERIALS AND METHODS

2.1. Forage Production

A commercial crop of winter wheat (c.v. Equinox) was grown on a sandy loam soil following potatoes. The crop was sown on 19th October 1999 at a target seed rate of 150kg/ha. The seed was dressed with fludioxnil. The crop received 155kg N/ha applied as a split dressing: 45kgN/ha on 17/03/00 at GS 22 and a further 110kg N/ha applied on 1/5/00 at GS 32. An aphicide spray (cypermethrin) and manganese were applied on 17/03/00 at GS 22. The fungicide programme consisted of a two spray programme: kresoxim methyl and fluquinconazole + prochloraz was applied on 02/05/00 at GS 32, followed by azoxystrobin and epoxiconazole + fenpropimorph applied on 30/05/00 at GS 51. Weed control consisted of isoproturon + trifluralin and isoproturon + diflufenican applied on 17/03/00 at GS22 followed by mecoprop-p and bromoxynil applied on 02/05/00 at GS32. The crop received a growth regulator (chlormequat) at GS32.

Prior to harvest the field was sub-divided into 3 blocks each of 4 plots. Treatments were allocated randomly to plots in each block to ensure that a representative area of the field was harvested for each of the four forage treatments. The crop was harvested on 14/08/00 using a Claas forage harvester fitted with a grain processor and a combine header. The height of the crop prior to harvest was 66.6cm (+/- 5.18cm) and was harvested at one of two heights: long straw (L): stubble height of 17.8cm (+/- 2.79cm) or short straw (S) stubble height of 37.3cm (+/-4.46cm) and either unground (U) or ground (G) at harvest. This resulted in four forage treatments:

Long straw unground:	LU
Long straw ground:	LG
Short straw unground:	SU
Short straw ground:	SG

Prior to ensiling, the urea additive “Home “N” Dry” (Dugdales, Clitheroe, Lancs) was applied at the rate of 35kg/tonne fresh weight. This was achieved by spreading out each load onto concrete, adding the required amount of “Home “N” Dry” by hand and then mixing with a buck rake. The material was then transferred to one of four concrete walled, roofed silage clamps of 9m length x 5m width, rolled and consolidated to a height of approximately 2m and sheeted immediately.

3. EFFECTS OF A FORAGE MILL AND CUTTING HEIGHT ON THE PERFORMANCE OF AND DIET DIGESTIBILITY IN DAIRY COWS FED UREA-TREATED WHOLE CROP WHEAT

3.1. Animals

Forty four Holstein-Friesian dairy cows (8 primaparous and 36 multiparous) that were on average 62 days into lactation were used. Based on recordings taken when the cows were in week 8 of lactation the cows were blocked according to parity (prima or multi), calving date, milk yield, condition score, milk composition, and liveweight and allocated to one of the four dietary treatments. The trial began at the end of October 2000 and all animals remained on trial for 14 weeks.

3.2. Housing

All cows were housed within the same area of an open span building in cantilever and super comfort cubicles fitted with pasture mats. The cubicles were scraped out twice daily, bedded twice weekly with sawdust and limed weekly. All cows had continuous access to water.

3.3. Diets

There were four dietary treatments:

Treatment

LU: long straw unground
LG: long straw ground
SU: short straw unground
SG: short straw ground

The whole crop was mixed with grass silage in the ratio of 1:2 grass silage:whole crop wheat on a dry matter basis. All animals received 8.5kg/d of a standard dairy concentrate (Table 1) which was fed in three meals through out of parlour feeders. The feeders were calibrated twice weekly. All cows also received 2kg/d of rapeseed meal which was mixed and fed with the forage mixture.

3.4. Experimental routine

The forages and rapeseed meal were mixed and fed daily at approximately 08.00h using a Keenan Compact feeder mixer wagon which was calibrated to +/- 1kg. Sufficient feed was provided daily such that each group received 1.05 of *ad libitum* intake. Each of the forage mixtures were fed through six Insentec Roughage Intake (RIC: Marknesse, Holland) feeders resulting in 24 RIC feeders in total. The feeders electronically recorded the weight of the feedbin to within 0.1kg and cows were permitted access to the appropriate RIC by the use of collar transponders. The intake data was downloaded daily and transferred into an Excel spreadsheet prior to analysis. Refusals were collected twice weekly on a Tuesday and a Friday.

Forage samples were taken twice weekly. One sample was oven dried at 100°C and the ratio of grass silage to whole crop wheat adjusted to maintain a ratio of 1:2 respectively on a dry matter basis. The other sample was frozen at –20°C prior to bulking and subsequent analysis.

Cows were milked twice daily at approximately 6.30am and 4.30pm through a Westfalia 24x24 direct to line parlour. Milk yield was recorded daily and a milk sample taken on a Monday pm and Tuesday am milking for subsequent analysis of butterfat, protein and lactose. Cows were weighed and condition scored weekly after the evening milking on each Wednesday. Blood samples were taken by venepuncture from the tail vein from a subsample of 6 cows per treatment when cows were in their 9^{th} 12^{th}, 17^{th} and 22^{nd} week of lacatation. Blood samples were taken at 11am into vacutainer tubes containing either potassium oxalate or lithium heparin as an anti-coagulant. Samples were centrifuged immediately and the plasma stored at –80°C prior to subsequent analysis.

Diet apparent digestibility was measured in five cows per treatment when they were in their 21st week of lactation using chromic oxide as an indigestible marker. The chromic oxide was mixed with the dairy concentrates and fed through the out of parlour feeders for a period of 14 days to provide a daily intake of 42.67g of chromic oxide. During the final 7 days of marker administration faecal grab samples were taken from each cow at 09.00 and 18.00h. To determine the diurnal variation in marker excretion faecal grab samples were also taken during the final two days of marker administration at 03.00, 06.00, 09.00, 12.00, 15.00, 18.00, 21.00, and 00.00h. Approximately 100g of faeces was taken at each sampling time and stored at –20°C prior to subsequent analysis.

3.5 <u>Chemical analysis</u>

Weekly forage and concentrate samples were bulked within each month and a sub-sample analysed by wet chemistry by NRM laboratories, Berkshire. Milk samples were analysed weekly on a Dairylab double beam infra red spectrophotometer. Blood samples were analysed using a Bayer Technicon RA 1000 auto-analyser. Feed and faecal samples were analysed for marker concentration using a Smith-Hjelte atomic absorption spectrophotometer.

3.6. <u>Statistical analysis</u>

Milk yield parameters, liveweight, condition score and blood parameters were evaluated by analysis of variance as a 2 x 2 factorial design with main effects of straw length (long (L) *vs.* short (S)) and grinding (ground (G) *vs.* unground (U)) and the interaction (GxH) between straw length and grinding. Milk yield (kg/d) in the week prior to blocking or liveweight was used, when appropriate, as a co-variate. Significance levels were denoted as $P<0.05$ = *, $P<0.01$ = **, $P<0.001$ ***. Values of <0.10 are stated in the tables.

4. RESULTS

The estimated yield (tDM/ha) for the long straw WCW forages (LU and LG) and short straw (SU and SG) were 15.78 and 12.64tDM/ha respectively. The yield of grain from an area of the field left unharvested and combined when ripe was 10.5t/ha with a specific weight of 74.3kg/hl.

4.1 Forage analysis

The chemical composition of the grass silage and the four WCW forages is presented in Table 2. The four whole crop wheat forages had similar dry matter contents at approximately 700g/kg except for treatment LG which was lower at 653g/kg. By contrast treatment LG had the highest crude protein content at 146g/kg DM whilst SG had a lower value at 134g/kg DM. The grass silage had the lowest crude protein concentration at 120g/kg DM. The two long straw WCW forages had a concentration of NDF and ADF approximately 25% greater than the two short straw forages (mean values for NDF were 422 and 336 and for ADF were 258 and 198g/kg DM for treatments LU and LG *vs.* SU and SG respectively). Similarly, the long straw forages (LU and LG) had a lower concentration of starch at approximately 355g/kg DM compared with a mean value of 420g/kg DM for short straw treatments (SU and SG). The grass silage had an average ME content of 10.9MJ/kg DM although the pH was low at pH 3.73. The concentrate had an ME value of 13.4MJ/kg DM, a crude protein content of 200g/kg DM whilst the sum of sugars and starch was 341g/kg DM (Table 3).

4.2. Milk production, composition and condition score

Data was excluded from the analyses for cow 45 (treatment LU) due to mastitis, cow 41 (treatment SG) due to inconsistent use of the out of parlour feeders and cow 202 (treatment SG) due to ill health unrelated to the dietary treatment. Milk production and composition, liveweight and condition scores are presented in Table 4 and Figures 1-5. There were no significant differences in average or weekly milk yield between cows fed any of the dietary treatments (Table 4 and Figure 1). By contrast the average milk butterfat percentage was significantly lower in cows fed the short straw treatments (mean value of 3.70%) compared with those fed the long straw treatments (mean value of 4.18%). Although not significant most of this effect could be attributed to cows fed the short straw, ground forage (SG) which had the lowest average butterfat percentage at 3.56%. The difference in milk butterfat percentage between animals fed the long and short strawed WCW forages occurred within three weeks of the cows going on to trial and continued throughout the period of the trial (Figure 2). The reduction in milk butterfat precentage was also translated into a significantly lower butterfat yield in cows fed the short straw WCW forages ($P<0.01$; Table 4). Milk protein percentage also tended to be lower in cows fed the short straw WCW forages (SU and SG; $P=0.10$) although most of this effect could be attributed to the lower milk protein percentages of these cows when allocated to treatments with little change during the trial period (Figure 3). Average liveweight was not significantly affected by treatment and increased gradually over the trial period (Figure 4). By contrast, body condition score was significantly higher in cows fed the short straw forages (SU and SG; mean value of 2.80) compared with those fed the long straw forages (LU and LG; mean value of 2.60; $p<0.05$). This change occurred rapidly with an effect of straw length being evident after 2 weeks on trial with the difference continuing to develop until the end of the experimental period.

4.3. Intake

The intake of concentrates, forage and total dry matter intake (DMI) is presented in Table 5 and daily forage dry matter intakes in Figure 6. The intake of concentrates through the out of parlour feeders was similar for cows fed any of the forage treatments at approximately 7.1kg DM/d (Table 5). Animals offered the long straw, unground forage treatment (LU) had the highest total DMI of concentrates (out of parlour plus rapeseed meal) at 9.12kg/d with animals fed any of the other three treatments having a similar intake at approximately 8.80kg DM/d. Intake of total forage (grass silage and WCW) was higher in cows fed long straw treatments (LU and LG) compared with those offered short straw (SU and SG: P<0.05) and higher in animals fed unground WCW (LU and SU) compared with those offered ground (LG and SG: P<0.05). Animals fed treatment LU had the highest forage intake of 14.09kg DM/d, approximately 2.4kg DM/d higher than cows fed treatment SG with animals fed forage treatments LG and SU having similar and intermediate forage intakes at approximately 13.1kg DM/d. Similarly, total dry matter intake was greatest in cows fed treatment LU at 23.21kgDM/d and lowest in animals fed treatment SG at 20.83kgDM/d (P<0.05). The total dry matter intake of the long, unground forage (LU) of 23.21kgDM/d compares with a value of 22.5kgDM/d reported Phipps *et al.* (1998) in cows fed urea-treated whole crop wheat that were producing a similar milk yield and offered a similar amount of concentrates to that reported here. Forage dry matter intakes were lowest during the first week of the trial in cows fed any of the dietary treatments (Figure 6). For cows fed treatments LG and SU highest forage intakes were recorded during week 11 of lactation whilst cows fed LU had their highest intake during week 15 of lactation. By contrast, cows fed treatment SG had a similar forage intake over the whole of the treatment period.

4.4 <u>Blood analysis</u>

Mean blood metabolite concentrations over the period of the trial are presented in Table 6. There was a tendency for cows fed the long straw treatments (LU and LG) to have lower plasma urea concentrations than those offered the short straw treatments (SU and SG; P=0.08). Plasma glucose concentrations were significantly higher in animals fed the short straw compared with the long straw treatments (mean values of 3.34 and 3.51 for treatments LU and LG *vs.* SU and SG respectively; P<0.05). By contrast, plasma ∃-hydroxybutyrate (BHB) was significantly lower in animals fed the short straw treatments whilst there was a trend for cows fed the short, straw, ground treatment to have the lowest concentrations of BHB at 0.67mmol/l. There was no significant effect of dietary treatment on plasma non-esterified fatty acid (NEFA) concentrations.

4.5 <u>Diet Digestibility</u>

Intakes, faecal output and digestibility of organic matter, NDF and starch are presented in Table 7. The high organic matter intakes reflected the dry matter intakes in the production experiment. Cows fed treatment SG had the lowest intake of OM (19.50kg/d) whilst those fed LG and SU had similar intakes (mean value of 21.44kg/d). However, cows fed treatment LU had similar organic matter intakes to those fed LG and SU. There was a significant interaction between cutting height and grinding on faecal organic matter output with cows fed SU having the highest faecal OM output (8.67kg/d) whilst those fed SG had the lowest (6.99kg/d; P<0.05). There were no significant effects of treatment on organic matter digestibility (kg OM digested/kg OM intake) with an overall mean value of 0.626. The intake of NDF was significantly higher in cows fed the long compared with the short straw WCW diets (mean values of 8.92 and 7.88kg/d for cows fed LU and LG *vs.* SU and SG; P<0.05). There a trend for cows to have a lower digestibility of fibre when fed the short straw treatments (SU and SG) compared with the long straw treatments (LU and LG) although this effect was not statistically significant.

Starch intake (kg/d) was similar on all treatments although tended to be higher in cows fed the short straw (SU and SG) compared with the long straw treatments (LU and LG; P=0.08). Faecal output of starch (kg/d) was significantly affected by treatment. Output was significantly lower in cows fed ground compared with unground WCW (mean values of 0.17 and 0.63kg/d for cows fed LG and SG *vs.* LU and SU; P<0.001) and for cows fed long straw compared with short straw (mean values of 0.31 and 0.49kg/d for cows fed LU and LG *vs.* SU and SG; P<0.05). There was a trend for an interaction between straw length and grinding (P=0.05) with cows fed treatment SU having the highest faecal output of all treatments at 0.80kg/d. Grinding WCW at harvest significantly increased the digestibility of starch (kg digested/kg intake). The mean digestibility of ground WCW (LG and SG) was 0.965 and for unground material (LU and SU) was 0.880. There was also a trend for long straw WCW (LU and LG) to have a higher starch digestibility than short straw WCW (SU and SG; P=0.05).

Assuming a constant apparent digestibility of concentrate starch at 0.964 (Sutton *et al.* 1998) and that the starch in the grass silage and rapeseed meal also had an apparent digestibility of starch of 0.964 then an estimate can be made of the digestibility of the starch in the whole crop wheat forages. This results in a starch apparent digestibility of 0.87, 0.97, 0.80 and 0.96 for forages LU, LG, SU and SG respectively (s.e.d. 0.027; $P<0.001$). The unground digestibilities compare with values of between 0.80 and 0.90 reported by Sutton *et al.* (1998).

4.6 Forage costs

The cost of growing, harvesting and storing the crops (£/ha) is presented in Table 8. Seed, establishment and storage costs were the same for all four treatments. Differences in the additive cost reflect the respective yields (tDM/ha) and the dry matter contents of the forages as the Home N'Dry was applied at 35kg/tonne on a fresh weight basis. This resulted in the greatest additive cost for the long straw ground forage (£265.15/ha) and the lowest for the short straw ground (£195.62). A standard rental value was applied to all the forage treatments. This resulted in the greatest cost of £776.55/ha for the long straw ground WCW and the lowest of £698.02/ha for the short straw unground WCW.

When converted to a £/tDM basis (Table 9) the costs of the two long straw forages were approximately £48.34/t DM and the short straw treatments were £55.04/tDM. These costs reduced to approximately £34.58/tDM for the long straw forages and £37.86/t DM for the short straw forages. Assuming a cost of grass silage of £76.44/tDM (Sinclair & Wilkinson: MDC Whole Crop Wheat for Milk Production Report 2) and that arable aid payments are available equates to a saving due to grinding of between 4-8p/day with no significant effect on milk yield or composition (Table 10). A further saving of 0-3p/cow/day can be made by feeding short straw compared with long straw WCW although milk butterfat levels will decrease and body condition score increase.

4.7. <u>Conclusions:</u>

- Increasing the cutting height at harvest to leave a 37cm stubble (short straw) *vs.* an 18cm stubble (long straw) increased the starch concentration from approximately 355g/kg DM to 420g/kg DM whilst decreasing the fibre (NDF) content from approximately 420g/kg DM to 340g/kg DM.

- Grinding of WCW at harvest significantly increased the digestibility of starch but not fibre. This resulted in a calculated digestibility of starch in the forage to be 0.87 in the long, unground WCW (LU), 0.97 in the long ground WCW (LG), 0.80 in the short unground WCW (SU) and 0.96 in the short ground WCW (SG).

- Cows fed the ground treatments (LG and SG) had lower dry matter intakes than those fed the unground treatments (LU and SU) whilst increasing the cutting height (SU and SG) also decreased DMI compared with the long straw treatments (LU and LG). This resulted in cows fed treatment SG having a forage DMI of 2.4kgDM/d less than those offered LU.

- There was no significant effect of either increasing the cutting height or grinding at harvest on milk production with a mean yield of 30kg/d over the trial period.

- Cows fed the short straw treatments (SU and SG) had significantly lower butterfat percentages and higher body condition scores than those fed the long straw treatments (LU and LG)

- Plasma ∃-hydroxybutyrate concentrations were lower and glucose concentrations higher in cows fed the short straw compared with the long straw treatments with those fed diet SG having the lowest concentration of plasma ∃-hydroxybutyrate at 0.67mmol/l.

- Forage costs were approximately £48/tDM for the long straw forages (LU and LG) and £55/tDM for the short straw forages (SU and SG). If arable area payment is available then these costs are reduced to approximately £35/tDM for the long straw forages and £38/tDM for the short straw forages.

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Table 1. Ingredient composition of the concentrate

	kg/t
Wheat	265
Rapeseed meal	100
Sugarbeet pulp	181
Palm kernel extract	75
Maize	31
Soyabean meal	125
Sunflower meal	69
Molasses	77
Oil	23
Megalac	30
Minerals and vitamins	24

Table 2. Chemical composition of grass silage and whole crop wheat forages

	Grass silage	Long straw Unground	Long straw Ground	Short straw Unground	Short straw Ground
Dry matter %	232	713	653	707	709
Crude protein (g/kg DM)	120	137	146	140	134
Ash (g/kg DM)	87.8	42.4	48.4	44.1	45.6
Ammonia-N as % total N	10	17	23	17	20
PH	3.73	7.6	7.5	7.4	7.9
D-value (% DM)	68.1	72.2	66.7	75.4	74.3
ME (MJ/kg DM)	10.9	10.8	10.3	11.2	11.1
WSC (g/kg DM)	18.1	16.8	14.8	16.3	19.8
ND Fibre (g/kg DM)	609	425	419	331	342
AD Fibre (g/kg DM)	360	264	251	197	199
Oil (g/kg DM)	34.4	17.6	19.2	17.7	19.3
Starch (g/kg DM)	23.3	369	342	417	420

Table 3. Chemical composition of the concentrate

	Dairy concentrate
Dry matter %	871
Crude protein (g/kg DM)	200
Ash (g/kg DM)	86.6
Oil (g/kg DM)	69.9
NCDG (% DM)	83.4
ME (MJ/kg DM)	13.4
WSC (g/kg DM)	117.7
ND Fibre (g/kg DM)	238
Starch (g/kg DM)	223

Table 4. Average milk yield, composition, liveweight and condition score of cows fed whole crop wheat either ground or unground at harvest and at one of two straw lengths.

	Diets					Sign. of main effects		
	Long straw Unground	Long straw Ground	Short straw Unground	Short straw Ground	s.e.d.	G	H	GxH
Milk yield	30.8	29.9	30.0	29.8	0.82	ns	ns	ns
Butterfat %	4.18	4.19	3.84	3.56	0.250	ns	*	ns
Protein %	3.44	3.46	3.33	3.30	0.111	ns	0.10	ns
Lactose %	4.61	4.54	4.64	4.62	0.059	ns	ns	ns
Butterfat yield (kg/d)	1.28	1.24	1.16	1.07	0.071	ns	**	ns
Protein yield (kg/d)	1.05	1.02	1.01	0.99	0.034	ns	ns	ns
Lactose yield (kg/d)	1.42	1.34	1.40	1.40	0.062	ns	ns	ns
Liveweight (kg)	587	616	607	619	21.8	ns	ns	ns
Condition score	2.59	2.61	2.83	2.76	0.108	ns	*	ns

Table 5. Average intakes of concentrates and forage for cows fed whole crop wheat either ground or unground at harvest and at one of two straw lengths.

	Diets					Sign. of main effects		
	Long straw Unground	Long straw Ground	Short straw Unground	Short straw Ground	s.e.d.	G	H	GxH
Dairy concentrates	7.23	7.10	7.03	7.08	0.094	ns	ns	ns
Total concentrates	9.12	8.72	8.84	8.86	0.192	ns	ns	ns
Grass silage	4.80	4.33	4.33	3.92	0.268	*	*	ns
WCW	9.28	8.64	9.00	8.11	0.570	*	ns	ns
Total Forage	14.09	12.97	13.32	12.03	0.834	*	0.08	ns
Total DMI	23.21	21.65	22.16	20.83	0.983	*	0.10	ns

Table 6. Average plasma concentrations of urea, glucose, ∃-hydroxybutyrate (BHB) and non-esterified fatty acids (NEFA) during the trial for cows fed whole crop wheat either ground or unground at harvest and at one of two straw lengths.

	Diets					Sign. of main effects		
	Long straw Unground	Long straw Ground	Short straw Unground	Short straw Ground	s.e.d.	G	H	GxH
Urea (mmol/l)	5.78	6.02	5.52	6.23	0.359	0.08	ns	ns
Glucose (mmol/l)	3.36	3.32	3.50	3.53	0.093	ns	*	ns
BHB (mmol/l)	0.90	0.97	0.82	0.67	0.083	ns	**	0.09
NEFA (:mol/l)	0.282	0.274	0.294	0.283	0.0097	ns	ns	ns

Table 7. Intake, faecal output (kg/d) and apparent digestibility (kg/kg) of organic matter, fibre and starch for cows fed whole crop wheat either ground or unground at harvest and at one of two straw lengths

	Diets					Sign. of main effects		
	Long straw Unground	Long straw Ground	Short straw Unground	Short straw Ground	s.e.d.	G	H	GxH
Organic matter								
Intake	21.58	21.32	21.57	19.50	1.235	ns	ns	ns
Faecal output	7.73	7.88	8.67	6.99	0.532	0.07	ns	*
Digestibility	0.640	0.627	0.600	0.638	0.0325	ns	ns	ns
NDF								
Intake	9.02	8.81	8.27	7.49	0.590	ns	*	ns
Faecal output	3.65	3.86	3.82	3.45	0.255	ns	ns	ns
Digestibility	0.592	0.556	0.537	0.532	0.0458	ns	ns	ns
Starch								
Intake	4.78	4.79	5.48	4.87	0.291	ns	0.08	ns
Faecal output	0.46	0.16	0.80	0.18	0.103	***	*	0.05
Digestibility	0.905	0.967	0.856	0.962	0.0174	***	0.05	ns

Table 8. Forage costs (£/ha) for whole crop wheat either ground or unground at harvest and at one of two straw lengths

	Long straw Unground	Long straw Ground	Short straw Unground	Short straw Ground
Seed	35.10	35.10	35.10	35.10
Establishment	88	88	88	88
Fertiliser	37	37	37	37
Slurry/FYM	-	-	-	-
Sprays	101.80	101.80	101.80	101.80
Harvesting	122.50	127.50	113.50	118.50
Additive	242.84	265.15	196.17	195.62
Rent	122	122	122	122
Total A	749.24	776.55	693.57	698.02
Area Payment	217.27	217.27	217.27	217.27
Total B	531.97	559.28	476.30	480.75

Assumptions: Grinding cost @ £5/ha
Home N'Dry applied @ 35kg/t and costing £313.50/tonne
Rental cost for wheat from ABC costings (2000)

Table 9. Forage costs (£/tDM) for whole crop wheat either ground or unground at harvest and at one of two straw lengths

	Long straw Unground	Long straw Ground	Short straw Unground	Short straw Ground
Total A	47.48	49.21	54.87	55.22
Total B	33.71	35.44	37.68	38.03

Table 10. Total forage costs (grass silage + WCW; p/d) for treatments of whole crop wheat either ground or unground at harvest and at one of two straw lengths

	Long straw Unground	Long straw Ground	Short straw Unground	Short straw Ground
Without AAP				
*Grass silage	36.7	33.1	33.1	30.0
WCW	44.1	42.5	49.4	44.8
Total forage costs	80.8	75.6	82.5	74.8
With AAP				
Grass silage	36.7	33.1	33.1	30.0
WCW	31.3	30.6	33.9	30.8
Total forage costs	68.0	63.7	67.8	60.8

*Assuming a cost for grass silage of £76.44 (see text for details).

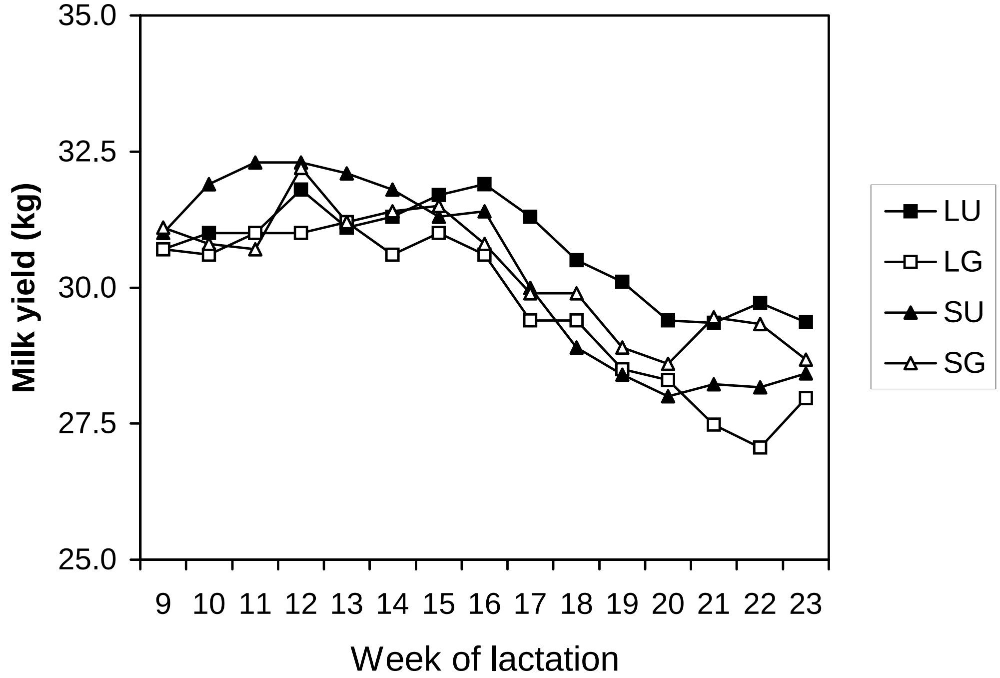

Figure 1. Effect of cutting height (long straw (L) or short straw (S)) or forage processing at harvest (Unground (U) or ground (G)) on milk yield in dairy cows

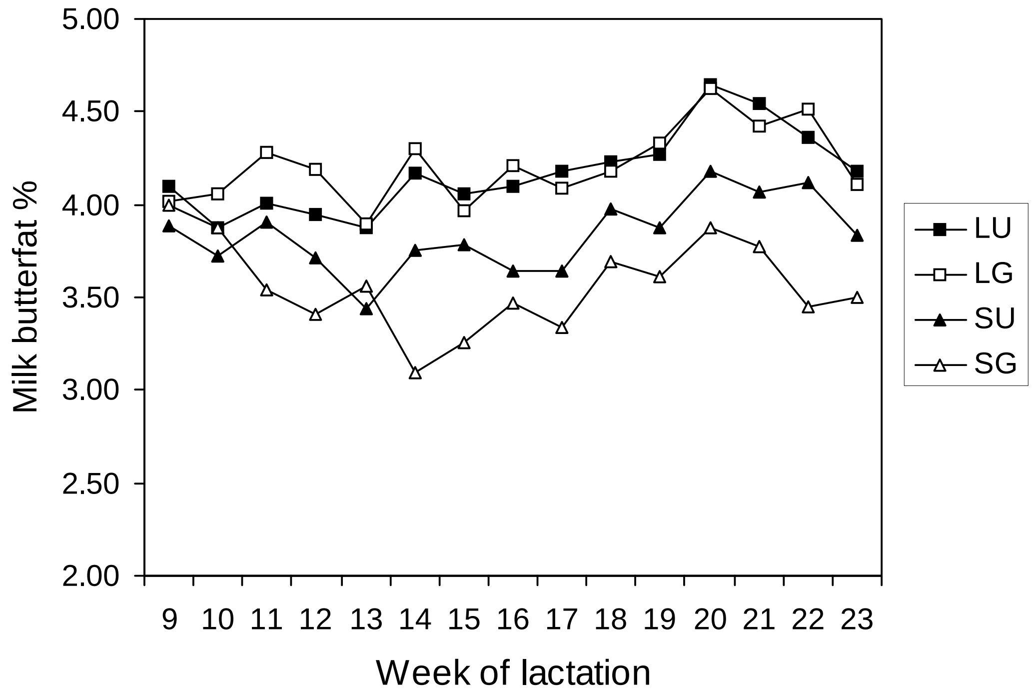

Figure 2. Effect of cutting height (long straw (L) or short straw (S)) or forage processing at harvest (Unground (U) or ground (G)) on milk butterfat % in dairy cows

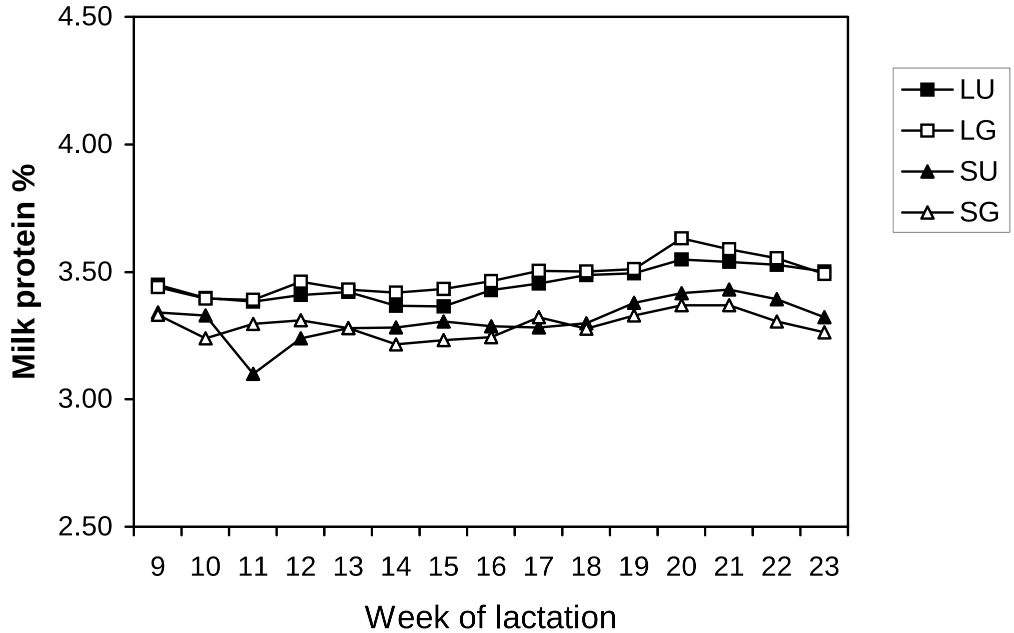

Figure 3. Effect of cutting height (long straw (L) or short straw (S)) or forage processing at harvest (Unground (U) or ground (G)) on milk protein percentage in dairy cows

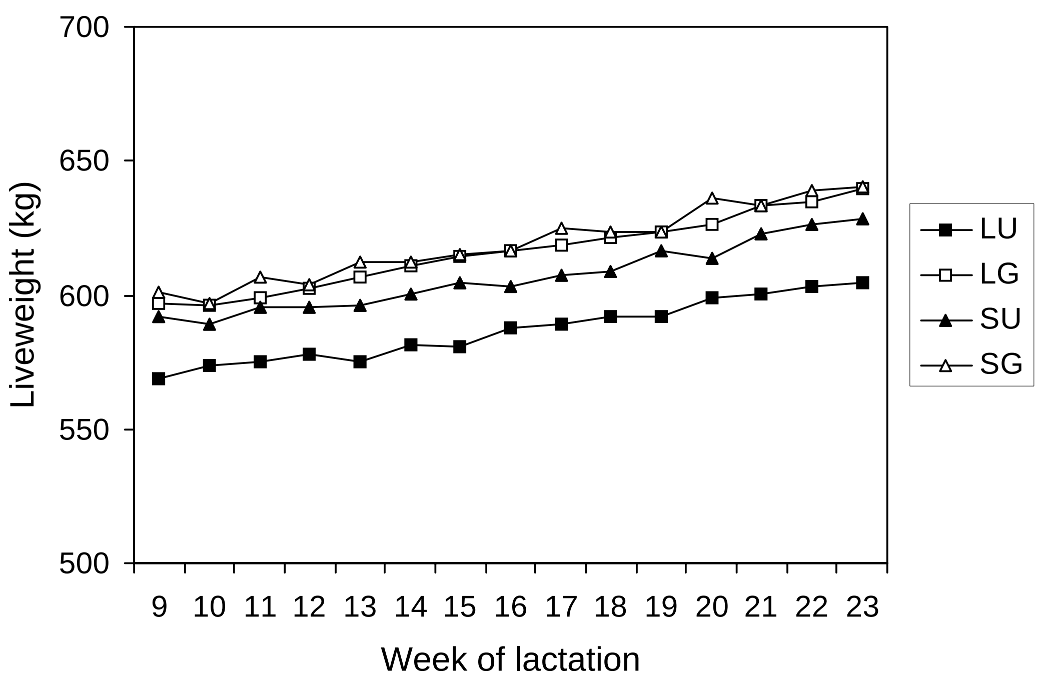

Figure 4. Effect of cutting height (long straw (L) or short straw (S)) or forage processing at harvest (Unground (U) or ground (G)) on body liveweight in dairy cows

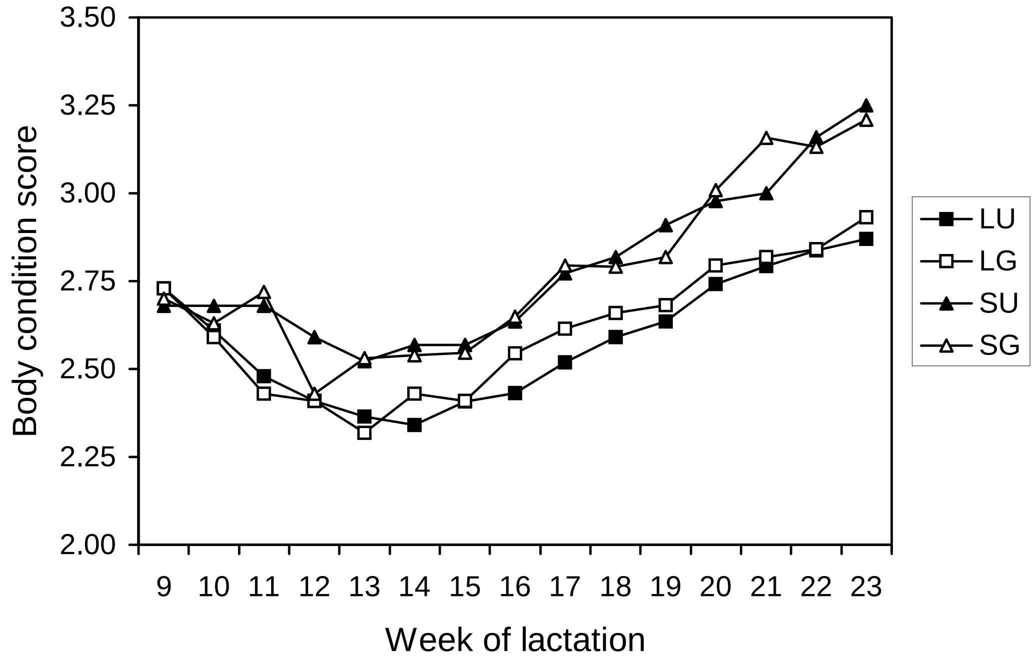

Figure 5. Effect of cutting height (long straw (L) or short straw (S)) or forage processing at harvest (Unground (U) or ground (G)) on body condition score in dairy cows

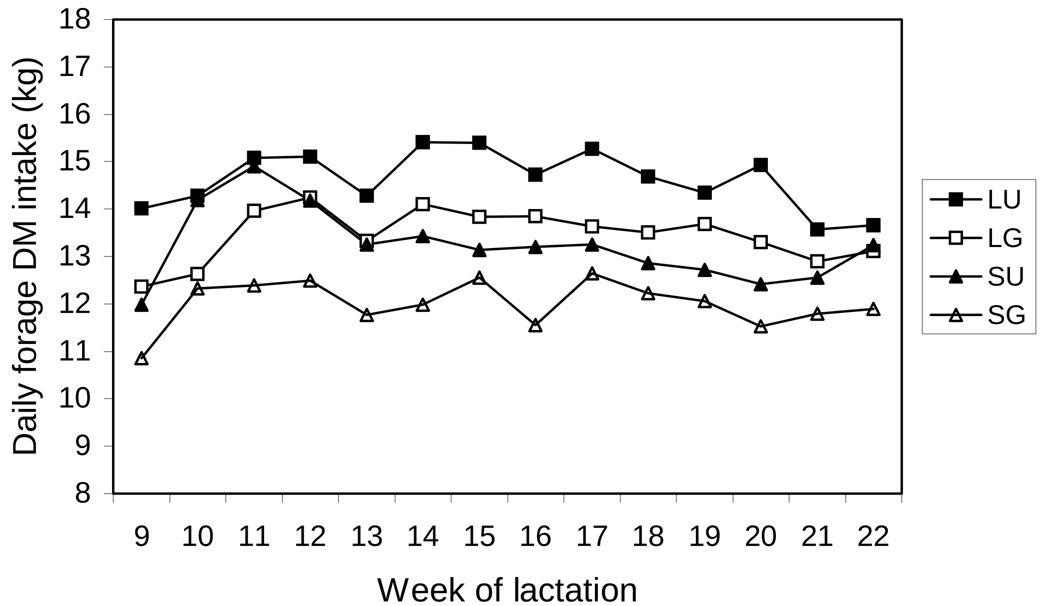

Figure 6. Effect of cutting height (long straw (L) or short straw (S)) or forage processing at harvest (Unground (U) or ground (G)) on average daily forage dry matter intake (kg) in dairy cows

APPENDIX 1

Table 1a. Individual analysis of the concentrates

	Weeks 1-4	Weeks 5-8	Weeks 9-12	Weeks 13-16
Dry matter %	886	872	865	862
Crude protein (g/kg DM)	198	196	210	194
Ash (g/kg DM)	84.4	85.2	85.9	90.7
Oil (g/kg DM)	67.9	67	69.8	74.9
NCDG (% DM)	83.9	82.6	83.4	83.5
ME (MJ/kg DM)	13.4	13.2	13.4	13.6
WSC (g/kg DM)	117.4	112.5	115.6	125.3
ND Fibre (g/kg DM)	244	239	247	220
Starch (g/kg DM)	233	231	207	220

Table 1b. Individual analysis reports on the grass silage

	Weeks 1-4	Weeks 5-9	Weeks 9-12	Weeks 13-16
Dry matter %	234	217	233	245
Crude protein (g/kg DM)	127	115	104	135
Ash (g/kg DM)	89.4	91.0	84.1	86.7
Ammonia-N as % total N	13	9	10	8
pH	3.95	3.60	3.64	3.73
D-value (% DM)	64.6	67.4	71.2	69.1
ME (MJ/kg DM)	10.3	10.8	11.3	11.1
WSC (g/kg DM)	10.7	10.7	15.0	36.0
ND Fibre	661	604	587	585
AD Fibre	364	349	362	363
Oil (g/kg DM)	30.7	32.1	35.9	38.7
Starch	46	23	12	12
Ethanol (g/kg DM)	19	29	25	14
Fermentation acids (g/kg DM)				
Acetic	26	25	25	18
Propionic	4.4	<1.0	<1.0	<1.0
Butyric	2.4	<2.0	<1.0	<1.0

Table 1c. Individual analysis reports on the long unground (LU) WCW

	Weeks 1-4	Weeks 5-9	Weeks 9-12	Weeks 13-16
Dry matter %	697	723	734	697
Crude protein (g/kg DM)	129	131	130	137
Ash (g/kg DM)	44.0	40.4	41.0	44.3
Ammonia-N as % total N	18	15	17	18
pH	8.4	7.2	7.2	7.5
D-value (% DM)	73.8	74.7	71.2	69.1
ME (MJ/kg DM)	11.0	11.1	10.7	10.5
WSC (g/kg DM)	17.0	16.0	17.0	17.0
ND Fibre	395	409	448	446
AD Fibre	245	237	265	308
Oil (g/kg DM)	17.2	19.2	17.2	16.8
Starch	397	429	380	332

Table 1d. Individual analysis reports on the long ground (LG) WCW

	Weeks 1-4	Weeks 5-9	Weeks 9-12	Weeks 13-16
Dry matter %	652	637	659	662
Crude protein (g/kg DM)	153	150	157	137
Ash (g/kg DM)	48.5	58.7	43.3	43.0
Ammonia-N as % total N	25	29	23	23
pH	5.6	7.6	7.7	7.5
D-value (% DM)	68.0	66.1	65.6	67.0
ME (MJ/kg DM)	10.4	10.2	10.2	10.3
WSC (g/kg DM)	18.0	14.0	14.0	13.0
ND Fibre	422	407	418	430
AD Fibre	243	247	265	250
Oil (g/kg DM)	20.0	17.6	21.2	18.0
Starch	332	326	332	337

Table 1e. Individual analysis reports on the short unground (SU) WCW

	Weeks 1-4	Weeks 5-9	Weeks 9-12	Weeks 13-16
Dry matter %	679	719	703	727
Crude protein (g/kg DM)	120	142	161	136
Ash (g/kg DM)	43.2	41.7	45.1	46.4
Ammonia-N as % total N	20	17	17	15
pH	7.0	7.4	7.8	7.54
D-value (% DM)	77.6	76.1	73.6	74.4
ME (MJ/kg DM)	11.4	11.2	11.0	11.1
WSC (g/kg DM)	15.0	16.0	18.0	16.0
ND Fibre	305	307	354	358
AD Fibre	179	187	218	204
Oil (g/kg DM)	20.8	17.2	19.2	13.6
Starch	435	451	375	408

Table 1f. Individual analysis reports on the short ground (SG) WCW

	Weeks 1-4	Weeks 5-9	Weeks 9-12	Weeks 13-16
Dry matter %	659	712	732	734
Crude protein (g/kg DM)	147	142	122	124
Ash (g/kg DM)	46.2	43.9	48.6	43.8
Ammonia-N as % total N	20	14	17	28
pH	7.0	8.3	8.2	8.1
D-value (% DM)	75.1	75.0	74.5	72.5
ME (MJ/kg DM)	11.1	11.1	11.1	10.9
WSC (g/kg DM)	26.0	22.0	16.0	15.0
ND Fibre	301	334	354	377
AD Fibre	175	200	200	221
Oil (g/kg DM)	19.2	22.0	18.0	18.0
Starch	435	397	446	402

SECOND YEAR REPORT

FORAGE PROCESSING OF WHOLE CROP WHEAT FOR MILK PRODUCTION

THE EFFECTS OF PROCESSED WHOLE CROP WHEAT, MAIZE SILAGE AND SUPPLEMENT TYPE TO WHOLE CROP WHEAT ON THE PERFORMANCE OF DAIRY COWS

Experimental work conducted 2001-2002

Funded by the Milk Development Council with contributions from the Maize Growers Association

Project Team: Dr L.A. Sinclair, Miss. M. Jackson, Dr. R. Readman & Dr. J. Huntington

May 2002

CONTENTS

FARMER RECOMMENDATIONS

- Processed, urea treated WCW results in a milk yield similar to that of a good quality maize silage. In areas of the country where maize can be grown well then WCW represents a viable alternative. In areas of the country where maize is marginal or cannot be grown successfully then WCW will result in milk yields similar to that if maize could be grown well.

- Supplement type to processed WCW can alter milk yield and composition although the response may be small and not significant:

  - Molasses maintains protein percentage although milk yield tends to be lower and there is no significant difference in component yield (kg/d) to other carbohydrate sources.

  - Lactose tends to increase milk yield (kg/d) although not significantly.

  - Wheat as a supplement tends to partition food energy towards body fat

- Processed and urea treated WCW can produce a forage with a similar cost to maize silage (£/tDM).

1. INTRODUCTION AND OBJECTIVES

There has been increasing interest in dairy units being able to produce more of their energy and protein feed requirements on farm. Whole crop cereals offer the potential of a high yielding crop, which is particularly beneficial for farms in the north and west of the country where alternative forages such as maize silage cannot be grown well. Whilst it has been established that whole crop wheat (WCW), either fermented or urea treated, has high intake characteristics, the digestible energy value of the forage is low due predominately to a poor digestibility of the starch component (Sutton *et al.* 1998; Wilkinson and Sinclair 1999). Resultant milk yields have therefore been disappointing and significantly lower than that of a maize silage/grass silage mixture (Phipps *et al.* 1995). Recent research at Harper Adams University College (Sinclair *et al.* 2001; Jackson *et al.* 2002) has demonstrated that the use of a forage mill that processes and grinds the grain at harvest improved the digestibility of the starch component in urea-treated WCW from approximately 840 to 970g/kg. Cows fed a mixture of grass silage and processed WCW responded to the improved nutritive value by decreasing their intakes with a resultant improvement in the efficiency of forage use with a similar milk yield (kg/d).

The use of sugar sources such as sucrose have been shown to improve the efficiency of microbial protein synthesis and been suggested to improve animal performance (Chamberlain *et al.* 1993; Kim *et al.*1999). Other sugar supplements such as lactose have been shown to reduce protozoal numbers, improve microbial efficiency and result in a more stable rumen pH (Hussain and Miller 1999), an effect that would potentially be most beneficial in diets that contain a large amount rapidly fermentable starch such as those containing processed WCW.

1.1. Objectives:

To compare processed, urea treated whole crop with maize silage and to examine the effects of carbohydrate supplementation of whole crop wheat on the intake, milk production and composition and liveweight change in dairy cows.

2. GENERAL MATERIALS AND METHODS

2.1. Forage Production

2.1.1. *Whole crop wheat*

A commercial crop of winter wheat (c.v. Equinox) was grown on a sandy loam soil following a three-year grass ley. The crop was sown on 26th November 2000 using fludioxinil treated seed at a target seed rate of 175 kg/ha. Soil analysis for phosphate & potash indicated P and K indices of 4 and 1 respectively and 160 kg/ha of K_2O was applied as muriate of potash on 18/02/01. Nitrogen was applied at the rate of 136 kg N/ha as a split dressing: 50 kg N/ha on 18/02/01 (GS 21) and 86 kg N/ha on 18/04/01 (GS 30/31). An early application of growth regulator (trinexapac ethyl) was applied on 20/03/01 to encourage root development and tillering.

Disease control consisted of a two spray fungicide programme: kresoxim methyl + fenpropimorph applied on 5/5/01 (GS 31) and kresoxim methyl + fenpropimorph and fluquinconazole + prochloraz applied on 30/05/01 (GS 39). Weed control consisted of isoproturon + diflufenican applied on 20/03/01 to control annual meadow grass and annual broad leafed weeds followed by fluroxypyr and metasulfuron urea applied on 30/05/01 to control late spring germinators. One third of the field was sprayed with fenoxaprop-P- ethyl to control wild oats. The crop was sprayed with cypermethrin against aphids on 20/03/01 and received routine manganese sprays. The crop was harvested on 17th August 2001 using a self propelled forage harvester fitted with a forage mill and ensiled in a concrete walled, roof clamp. Volac Home n'Dry was applied at the rate of 40kg/tonne fresh weight as a preservative and the clamp double sheeted.

2.1.2. *Maize silage*

The maize variety Nancis was grown on a sandy loam soil following winter wheat. The crop was drilled on 25th May 2001 at a seed rate of 110,000 seeds per hectare at 12 cm spacing and 76cm row width. On 6 June 2001 the crop was sprayed with Atrazine and was harvested on 15th October 2001 using a self propelled forage harvester fitted with a corn cracker and ensiled in a concrete walled, roofed clamp.

2.1.3. *Grass silage*

The grass silage was made from a predominately ryegrass sward. It was cut and left to wilt for approximately 36 hours and ensiled on 23rd May 2001 into a concrete walled clamp.

3. THE EFFECTS OF PROCESSED WHOLE CROP WHEAT, MAIZE SILAGE AND SUPPLEMENT TYPE TO WHOLE CROP WHEAT ON THE PERFORMANCE OF DAIRY COWS

3.1. Animals

Forty four Holstein-Friesian dairy cows (8 primaparous and 36 multiparous) that were on average 55 days into lactation were used. Based on recordings taken when the cows were in week 7 of lactation the cows were blocked according to parity (prima or multi), calving date, milk yield, condition score, milk composition, and liveweight and allocated to one of the four dietary treatments. The experiment began at the end of October 2001 and all animals remained on trial for 15 weeks.

3.2. Housing

All cows were housed within the same area of an open span building in cantilever and super comfort cubicles fitted with pasture mats. The cubicles were scraped out twice daily, bedded twice weekly with sawdust and limed weekly. All cows had continuous access to water.

3.3. Diets

There were four dietary treatments:

Treatment:

Maize:	Maize silage + conventional concentrates + 2kg/d rolled wheat
W-WCW:	Processed WCW + conventional concentrates + 2kg/d rolled wheat
L-WCW:	Processed WCW + conventional concentrates + 0.7kg/d lactose +1.3kg/d rolled wheat
M-WCW:	Processed WCW + conventional concentrates + 2kg/d cane molasses

The WCW and maize silages were mixed with the grass silage in the ratio of 2:1on a DM basis. In all treatments the cows received 6.5kg/cow/day of a standard concentrate (Table 1). The concentrate was formulated to be similar in composition to that used in the previous experiment (Sinclair *et al.* 2001) but with the wheat component removed. The standard concentrate was fed through out of parlour feeders and 2kg/cow/day of rapeseed meal was mixed and fed with the forage component. In addition cows on treatments Maize and W-WCW received 2kg/cow/day of rolled wheat which was also fed along with the forage mixture. In treatment L-WCW approximately 0.7kg/cow/day of the wheat was replaced with lactose (Suga-Lac, Trouw Nutrition, Cheshire, UK) whilst in treatment M-WCW all the wheat was replaced with an equivalent amount of cane molasses (DM basis; SVG Intermol, Merseyside, UK). In addition, sufficient urea was added to treatment Maize (approximately 140g urea /cow/day) and fed with the forage mixture to ensure a similar amount of crude protein in the maize and WCW forages. Therefore all four treatments received approximately 10.5kg of concentrates/cow/day.

3.4. Experimental routine

The forages and concentrates were mixed and fed once daily at approximately 0900h using a Keenan Compact mixer wagon which was calibrated to +/-1kg. Sufficient feed was provided daily such that each group received 1.05 of *ad libitum* intake. Each of the forage mixtures were fed through six Insentec Roughage Intake (RIC: Marknesse, Holland) feeders resulting in 24 RIC feeders in total. The feeders recorded electronically the weight of the feed bin to within 0.1kg and cows were permitted access to the appropriate RIC by the use of collar transponders. The intake data was downloaded daily and transferred into an Excel spreadsheet prior to analysis. Refusals were collected three times weekly on a Monday, Wednesday and Friday.

Forage samples were taken twice weekly. One sample was oven dried at 100°C and the ratio of grass silage to whole crop wheat or maize silage adjusted to maintain a ratio of 1:2 respectively on a dry matter basis. The other sample was frozen at –20°C prior to bulking and subsequent analysis.

The cows were milked three times daily through a 24x24 direct to line herringbone parlour at approximately 06.30, 15.30 and 22.00h. Milk yield was recorded daily with weekly samples taken for subsequent analysis of fat, protein and lactose. The cows were weighed and condition scored after the evening milking on the Wednesday during week 7 of lactation and then every week. Blood samples were taken by venepuncture at 10.30h from a sub-sample of 6 cows per treatment when the they were in their 7th, 10th, 15th and 20th week of lactation (weeks 0, 3, 8 and 13 of the experiment).

3.5. Chemical analysis

Weekly forage and concentrate samples were bulked within each month and a sub-sample analysed by a wet chemistry (NRM Laboratories, Berkshire). Milk samples were analysed weekly on a Dairylab double beam infra red spectrophotometer. Blood samples were analysed for pH, urea, beta-hydroxybutyrate (ß-HB), glucose and non-esterified fatty acids (NEFA) on a Bayer Technicon RA 1000 auto-analyser.

3.6. Statistical analysis

Milk yield parameters, liveweight, condition score and blood parameters were evaluated by analysis of variance as a randomised block design using the performance in the week prior to blocking as a co-variate where appropriate.

4. RESULTS

4.1. Feed analysis

The chemical analysis of the concentrate and three forages is presented in Table 2. The grass silage had a high dry matter content (356g/kg), a low crude protein (122g/kg DM) but a high metabolisable energy (ME) content (11.5MJ/kg DM). Soluble carbohydrate levels were also high in the grass silage at 98g/kg DM. The processed, urea treated whole crop wheat had the highest DM content of all three forages (823g/kg), had the highest starch and protein contents (350 and 143g/kg DM respectively) and the highest pH (pH 8.0). The maize silage had the lowest dry matter content of the three forages at 310g/kg DM but a relatively high starch content at 308g/kg DM and had a high ME value (11.5MJ/kg DM). By contrast, the crude protein content of the maize silage was the lowest of all three forages at 76g/kg DM. The concentrate had an ME value of 13.5MJ/kg DM and a crude protein content of 249g/kg DM.

4.2. Milk production, composition, liveweight and condition score

One cow (4217: M-WCW) was removed from the experiment during week 17 of lactation for reasons unrelated to the dietary treatments and her data was excluded from the statistical analyses. In addition, cows 645 (W-WCW) and 166 (L-WCW) were removed from the data set due to recurring mastitis. Therefore the data from 41 cows were analysed. Milk production and composition, liveweight and condition scores are presented in Table 4 and Figures 1-4. Average milk yield over the experimental period was 34.2kg/d. While cows fed the WCW supplemented with lactose (L-WCW) had the highest milk yield throughout the experimental period at 35.6kg/d (Table 4; Figure 1), some 2.5kg/d more than those fed the molasses supplemented WCW (M-WCW), this difference was not statistically significant. Similarly, whilst there was a trend for cows offered the maize and M-WCW treatments to have higher milk fat contents (g/kg) than those offered the WCW supplemented with wheat (W-WCW) or lactose (L-WCW) the difference was not significant (Figure 2). Cows fed the molasses supplemented WCW (M-WCW) had the highest milk protein content ($P<0.01$) at 33.3g/kg followed in turn by W-WCW, L-WCW with those offered the maize silage treatment having the lowest value at 31.2g/kg. There was however, no significant effect of treatment on fat or protein yield (kg/d) or on average or weekly liveweight or condition score.

4.3. Dry matter intake

The intake of concentrates, forages and total dry matter intake (DMI) is presented in Table 4. The intake of the standard concentrate was similar for cows offered any of the dietary treatments at approximately 5.5kg DM/d. Cows offered the maize silage treatment had the highest total DMI (9.2kg/d) of concentrates (standard concentrate + rapeseed meal + straight feeds) although this value also included the additional urea on this treatment. Cows on the other dietary treatments had similar total concentrate intakes at approximately 8.8kg DM/d. Intake of forage (grass silage + maize silage or WCW) was highest ($P<0.001$) in cows offered the molasses supplemented WCW (M-WCW) at 14.6kg DM/d followed by those offered W-WCW and L-WCW at 13.3 and 12.2kg DM/d respectively. The lowest forage intake was recorded in cows offered the maize silage treatment at 10.7kg DM/d. Similarly, total DMI was highest in cows fed the molasses supplemented WCW at 23.2kg DM/d, some 3.3kgDM/d more than the lowest intake on the maize silage treatment at 19.9kg DM/d ($P<0.01$).

4.4. Blood metabolites

Mean blood metabolite concentrations over the experimental period are presented in Table 5. There was a trend for glucose concentrations (mmol/l) to be lowest in cows fed the maize silage and highest in the WCW supplemented with lactose (L-WCW) although the difference was not significant. There was also no significant effect of treatment on plasma ß-hydroxybutyrate concentrations. In contrast, plasma non-esterified fatty acid (NEFA) levels were highest in cows fed the WCW supplemented with molasses ($P<0.05$). These results reflected the lower and higher body condition scores recorded for cows on each of these treatments respectively. Plasma urea concentrations (mmol/l) were significantly lower in cows fed the M-WCW than any of the other dietary treatments which had a similar plasma urea concentration at approximately 5.81mmol/l. This difference was observed throughout the experimental period (Figure 5).

4.5. Forage costs

Forage costs (£/ha) for the whole crop wheat and maize forages are presented in Table 6. The major differences in the forage costs were the greater seed cost for the maize (£38.50 for the WCW and £117.61 for the maize) and the greater fertilizer and spray cost for the WCW (combined cost of £196.69 for the WCW and £24.91 for the maize). In addition, the additive cost was greater for the WCW resulting in a total cost/ha of £800.78/ha which reduced to £577.46/ha if arable aid payments (AAP) are included. The corresponding costs for the maize were £482.52 which reduced to £419.87 if AAP are included.

The forage costs (£/tDM) based on the actual forage costs and expressed at a range of potential yields are presented in Table 7. At the same yield the cost of maize (£/tDM) was approximately £25/tDM less than WCW although this difference dropped to approximately £12/tDM if AAP are included. However, as the WCW had urea which resulted in a higher crude protein content, the costings have been re-calculated in Table 8 assuming that feed grade urea was added (at feeding) to the maize silage to produce a forage with a similar crude protein content. The difference in cost between the two forages at the same yield is now reduced to approximately £19/tDM or £7/tDM if AAP are included. Alternatively, to produce a forage at a similar cost (£/tDM) then urea+urease treated whole crop wheat would need to yield approximately 3tDM/ha more than maize silage.

4.6. Supplement costs

The cost of the carbohydrate supplements to the whole crop wheat are presented in Table 9. The lowest daily cost was from feeding 2kg/d of rolled wheat (18p/d) and the highest from feeding molasses (48p/d). Feeding 0.7kg/d of lactose cost 21p/d with a combined lactose + wheat cost of 33p/d. To cover the cost of feeding molasses or lactose above that of feeding wheat would require an increase in milk yield of approximately 1.8 and 0.9kg/d respectively (assuming a milk price of 17p/kg).

4.7. CONCLUSIONS

- Milk yield (kg/d) was similar across all dietary treatments although it tended to be highest in cows fed WCW supplemented with lactose and lowest in WCW supplemented with molasses.

- Fat concentrations (g/kg) were low across all treatments but tended to be higher in the maize and molasses-WCW fed animals compared with the other two treatments although the effect was not significant.

- Milk protein concentration was significantly lower in cows offered the maize silage and lactose-WCW treatments than those fed the molasses-WCW treatment.

- There was no significant effect of treatment on milk component yield (kg/d).

- Daily DM intake (kg/d) was some 3.3kg/d greater in cows fed the molasses-WCW treatment than those fed the maize silage. Supplementing WCW with lactose resulted in a daily DMI that was not significantly different to maize silage.

- The cost of processed and urea treated WCW was similar to that of maize silage when balanced for their differences in crude protein content..

- To cover the cost of feeding molasses or lactose above that of feeding wheat would require an increase in milk yield of approximately 1.8 and 0.9kg/d respectively (assuming a milk price of 17p/kg).

Table 1. Ingredient composition of the concentrate

	kg/t
Sugarbeet pulp	220
Rapeseed meal	190
Palm kernel extract	185
Sunflower meal	130
Soyabean meal	110
Molasses	75
Fat	42
Limestone	5
Calcined magnesite	10
Di-calcium phosphate	7
Salt	5
Minerals and vitamins	21

Table 2. Chemical composition of the forages and concentrate

	Grass silage	Whole crop wheat	Maize silage	Concentrate
Dry matter g/kg	356	823	310	892
Crude protein (g/kg DM)	122	143	76	249
Ash (g/kg DM)	73	33	39	114
Ammonia-N as % total N	8.6	31.5	3.3	nd
pH	4.5	8.0	4.2	nd
ME (MJ/kg DM)	11.5	nd	11.5	13.5
WSC (g/kg DM)	98	7	16	116
ND Fibre (g/kg DM)	509	410	442	286
AD Fibre (g/kg DM)	nd	237	nd	nd
Starch (g/kg DM)	nd	350	308	62
Volatile fatty acids				
Lactic	73	nd	82	nd
Acetic	41	nd	26	nd
Propionic	--	nd	---	nd
Butyric	10	nd	1.3	nd
Ethanol	20	--	0	nd

nd = not determined

Table 3. Average milk yield, composition, liveweight and condition score of cows fed maize silage supplemented with wheat or whole crop wheat (WCW) supplemented with wheat (W), lactose (L) or molasses (M)

	Diets				s.e.d.	Significance
	Maize	W-WCW	L-WCW	M-WCW		
Milk yield kg/d	34.0	34.4	35.6	33.1	1.21	NS
Fat g/kg	37.7	34.3	34.3	38.4	2.20	NS
Protein g/kg	31.2	32.5	31.5	33.3	0.61	**
Lactose g/kg	45.5	45.6	46.3	46.3	0.53	NS
Fat yield kg/d	1.31	1.18	1.22	1.27	0.075	NS
Protein yield kg/d	1.07	1.13	1.11	1.10	0.040	NS
Lactose yield kg/d	1.54	1.57	1.65	1.53	0.057	NS
Liveweight kg	585	613	585	606	21.6	NS
Condition score	2.53	2.71	2.60	2.50	0.16	NS

Table 4. Average intakes (kg DM/d) of concentrates and forage for cows fed maize silage supplemented with wheat or whole crop wheat (WCW) supplemented with wheat (W), lactose (L) or molasses (M)

	Diets				s.e.d.	Significance
	Maize	W-WCW	L-WCW	M-WCW		
Dairy concentrates	5.5	5.4	5.5	5.4	0.097	NS
Total concentrates	9.2	8.9	8.8	8.6	0.24	NS
Grass silage	3.6	4.4	4.0	4.7	0.25	***
Test forage	7.1	8.9	8.2	9.5	0.51	***
Total Forage	10.7	13.3	12.2	14.6	0.68	***
Total DMI	19.9	22.2	21.0	23.2	0.88	**

Table 5. Average plasma concentrations of glucose, ß-hydroxybutyrate (ß-HB), non esterified fatty acids (NEFA), urea and pH in cows fed maize silage supplemented with wheat or whole crop wheat (WCW) supplemented with wheat (W), lactose (L) or molasses (M)

	Diets				s.e.d.	Significance
	Maize	W-WCW	L-WCW	M-WCW		
Glucose (mmol/l)	3.47	3.54	3.68	3.59	0.117	NS
ß-HB (mmol/l)	0.59	0.55	0.58	0.60	0.034	NS
NEFA (mmol/l)	0.33	0.32	0.38	0.42	0.029	*
Urea (mmol/l)	5.76	5.87	5.81	5.06	0.260	*
Ph	7.73	7.72	7.72	7.72	0.014	NS

Table 6. Forage costs (£/ha) for whole crop wheat and maize silage recorded in 2001

	Wheat	Maize
Seed	38.5	117.61
Establishment	88	88
Fertiliser	79.39	
Slurry/FYM	---	21
Sprays	117.27	3.91
Harvesting	115	130
[a]Additive	195.94	---
Rent	122	122
Total A	**756.1**	**482.52**
Area payment	223.32	62.65
Total B	**532.78**	**419.87**

[a]Home n' Dry cost at £313.5/t

Table 7. Forage costs (£/tDM) at different potential yields for wheat and maize forages based on the costings recorded in 2001

Yield (tDM/ha)	[a]WCW	Maize
9	---	54 (47)
10	---	48 (42)
11	---	44 (38)
12	62.4 (43.7) [a]	40 (35)
13	58.8 (41.6)	37 (32)
14	55.7 (39.7)	35 (30)
15	53.0 (38.1)	32 (28)
16	50.7 (36.7)	---
17	48.6 (35.5)	---
18	46.8 (34.4)	---

[a]Assuming a cost for Home n'Dry of £313.50 and an application rate of 40kg/tonne
[b]With arable aid payments

Table 8. Forage costs (£/tDM) at different potential yields for wheat and maize forages based on the costings recorded in 2001 and balanced with feed grade urea to the same crude protein content

Yield (tDM/ha)	[a] WCW	[b]Maize
9	---	59 (52)
10	---	54 (47)
11	---	49 (44)
12	62.4 (43.7) [a]	46 (40)
13	58.8 (41.6)	43 (38)
14	55.7 (39.7)	40 (35)
15	53.0 (38.1)	38 (33)
16	50.7 (36.7)	---
17	48.6 (35.5)	---
18	46.8 (34.4)	---

[a]Assuming a cost for Home n'Dry of £313.50/t and an application rate of 40kg/tonne fresh weight
[b]Assuming a cost of feed grade urea to be £225/tonne
[c]With arable aid payments

Table 9. Relative costs of supplements to WCW used

	£/t	Cost (p/d) as fed	Cost (p/d) total
Wheat (rolled)	90	18	18
Molasses (cane)	220	50	48
Lactose (dried:25kg bags)	304	21	33[a]

[a] Includes lactose + wheat costs

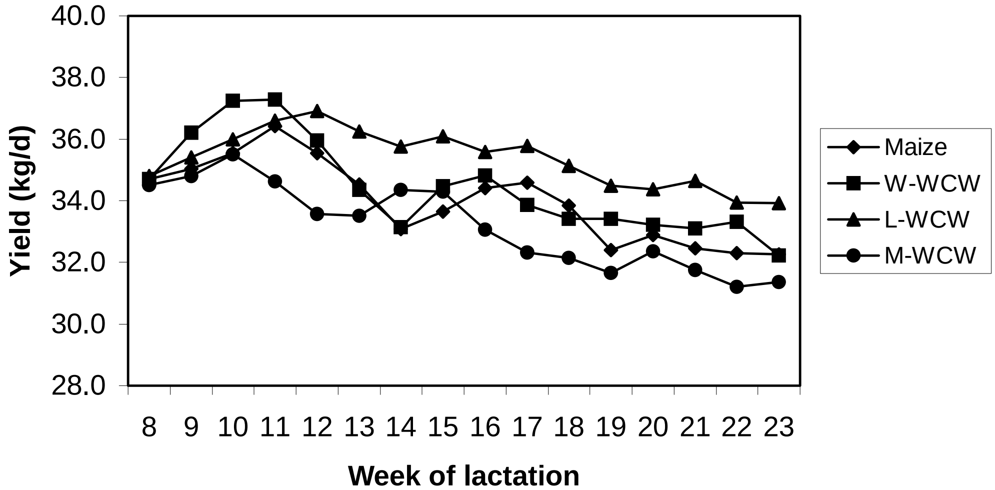

Figure 1. Weekly milk yield (kg/d) of cows fed maize silage supplemented with wheat or whole crop wheat (WCW) supplemented with wheat (W), Lactose (L) or molasses (M)

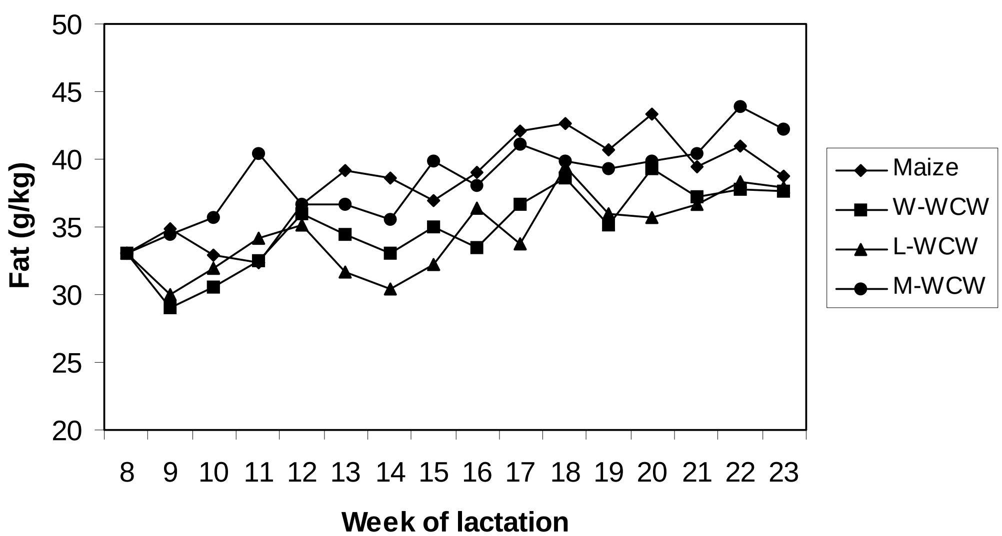

Figure 2. Weekly milk fat content (g/kg) of cows fed maize silage supplemented with wheat or whole crop wheat (WCW) supplemented with wheat (W), Lactose (L) or molasses (M)

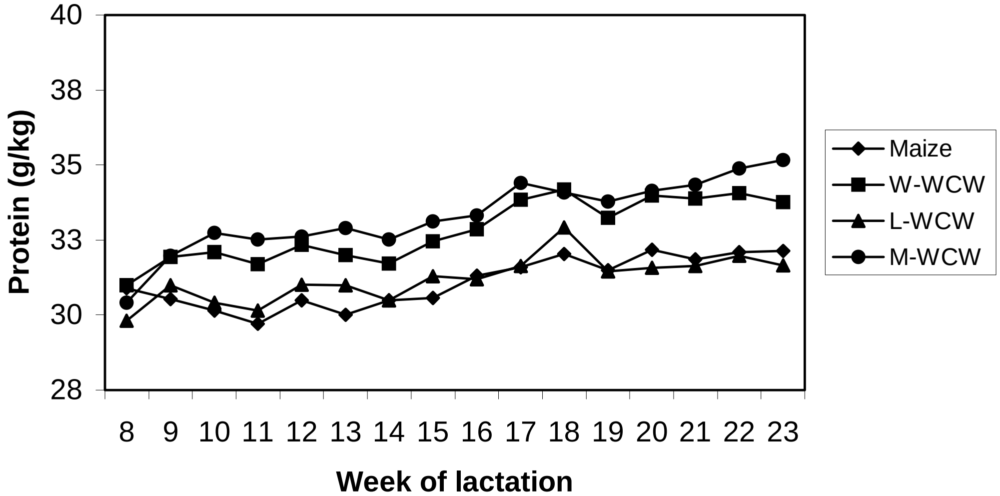

Figure 3. Weekly milk protein content (g/kg) of cows fed maize silage supplemented with wheat or whole crop wheat (WCW) supplemented with wheat (W), Lactose (L) or molasses (M)

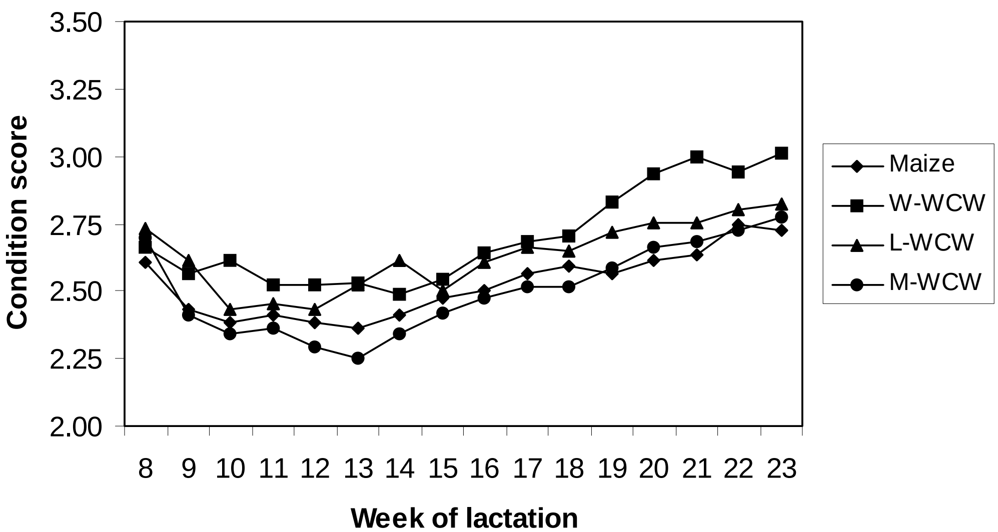

Figure 4. Weekly condition score of cows fed maize silage supplemented with wheat or whole crop wheat (WCW) supplemented with wheat (W), Lactose (L) or molasses (M)

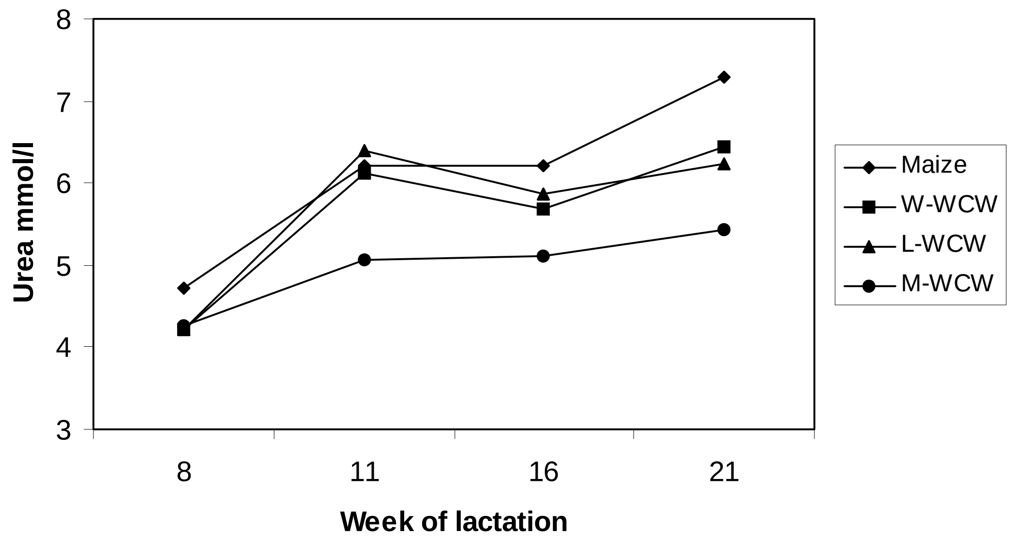

Figure 5. Weekly plasma urea concentrations in cows fed maize silage supplemented with wheat or whole crop wheat (WCW) supplemented with wheat (W), Lactose (L) or molasses (M)

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APPENDIX 1

Table 1a. Individual analysis of the concentrates

	Weeks 1-4	Weeks 5-8	Weeks 9-12	Weeks 13-16
Dry matter g/kg	899.0	893.0	893.0	884.0
Crude protein (g/kg DM)	245.8	252.0	254.2	245.5
Ash (g/kg DM)	113.9	114.1	117.0	109.3
Oil (g/kg DM)	89.4	95.6	92.9	94.8
NCDG (% DM)	80.2	80.5	79.6	79.9
ME (MJ/kg DM)	13.5	13.5	13.5	13.5
WSC (g/kg DM)	120.8	121.6	107.6	114.1
ND Fibre (g/kg DM)	267.0	278.8	291.2	307.7
Starch (g/kg DM)	66.7	60.5	60.5	61.1

Table 1b. Individual analysis of the grass silage

	Weeks 1-4	Weeks 5-9	Weeks 9-12	Weeks 13-16
Corrected dry matter g/kg	365	365	344	351
Crude protein (g/kg DM)	122	111	125	130
Ash (g/kg DM)	83	65	79	65
Ammonia-N as % total N	8.6	5.8	8.6	11.5
pH	4.4	4.4	4.6	5
D-value (% DM)	70	73	72	72
ME (MJ/kg DM)	11.2	11.6	11.6	11.5
WSC (g/kg DM)	87	86	114	105
ND Fibre	510	518	480	528
Ethanol (g/kg DM)	7	5	23	46
Fermentation acids (g/kg DM)				
Lactic	88	64	79	62
Acetic	48	34	50	32
Propionic	<0.1	<0.1	<0.1	<0.1
Butyric	14	8	8	7

Table 1c. Individual analysis of the processed WCW

	Weeks 1-4	Weeks 5-9	Weeks 9-12	Weeks 13-16
Dry matter g/kg	814	816	824	839
Crude protein (g/kg DM)	181	135	117	140
Ash (g/kg DM)	33.7	33.6	32.1	33.3
Ammonia-N as % total N	32	33	31	30
pH	8.3	7.1	8.4	8.1
WSC (g/kg DM)	5	5	5	12
ND Fibre	431	414	424	372
AD Fibre	239	249	255	206
Starch	332	332	348	386

Table 1d. Individual analysis of the maize silage

	Weeks 1-4	Weeks 5-9	Weeks 9-12	Weeks 13-16
Dry matter g/kg	270	298	319	355
Crude protein (g/kg DM)	81	76	76	71
Ash (g/kg DM)	45	31	37	42
Ammonia-N as % total N	1.3	2.4	3.1	6.2
pH	4.1	4	4	4.6
D-value (g/kg DM)	759	773	741	716
ME (MJ/kg DM)	11.7	11.9	11.4	11.1
WSC (g/kg DM)	18	5	27	13
ND Fibre	463	449	419	438
Starch	273	308	328	324
Ethanol	<0.1	<0.1	<0.1	<0.1
Fermentation acids (g/kg DM)				
Lactic	80	91	81	75
Acetic	23	31	29	21
Propionic	<0.1	<0.1	<0.1	<0.1
Butyric	<0.1	<0.1	<0.1	5