Use of maize silage in beef cattle feeding during the finishing period

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ABSTRACT

The research investigated the use of maize silage (MS) in beef cattle diets during the finishing period by monitoring a sample of 406 commercial farms located in the Po Valley. Farms were selected in order to cover the most diverse rearing situations, in terms of farm size and cattle genotype, in which MS was fed to beef cattle during the finishing period. Each farm was visited to collect information about the feeding regimen and representative samples of total mixed ration (TMR) and MS were collected for chemical and physical analysis. Two specific classification factors of the farm population were created for statistical analysis of experimental data. The former considered the quantity of MS included in the TMR and the latter was based on the content of long particles of MS (>13 mm). Regardless of chop length, the quality of MS population was satisfactory both by a nutritional and a preservation standpoint, as indicated by the dry matter (DM) (350 ± 38 g/kg of fresh weight) and the high starch content (310 ± 28 g/kg DM) and lactic acid concentration (49 ± 12 g/kg DM). Physical analysis of MS samples showed a wide range of particle size, as result of the different chopping lengths during harvest. The average content of long particles retained by a 13-mm screen was 143 ± 73 g/kg of fresh weight. On average, MS accounted for 33.4% to the total dietary DM but a large standard deviation (11.4%) was observed across farms. The decision about the amount of MS to be included in the TMR has shown to be independent on both chemical composition and particle size of the roughage. In diets with a high quantity of MS the risk of occurrence of rumen acidosis due to the additional starch brought by this silage is balanced either by a significant reduction in the amount of other starch sources or by the higher NDF content and the coarser size of the dietary particles which should promote a prolonged rumination. The analysis of TMR particle size showed that in more than 30% of the farms MS was damaged during diet preparation with a loss of long particles. A logistic analysis demonstrated that the relative risk of MS damage was significantly increased either by a larger inclusion of the roughage in the TMR or by the use of silage with coarse particles.

Key words: Beef cattle, Maize silage, Finishing period, Nutrition.

RIASSUNTO
UTILIZZO DEL SILOMAIS NEL RAZIONAMENTO DEL BOVINO DA CARNE

La ricerca ha considerato il monitoraggio di un campione di 406 allevamenti intensivi di bovini da carne situati nella Pianura Padana che facevano uso del silomais nel proprio razionamento. Le aziende sono

state scelte in modo da rappresentare le più diverse tipologie di allevamento, in termini di dimensioni e tipi genetici. Ciascun allevamento è stato visitato per raccogliere informazioni sul piano alimentare e campioni rappresentativi di silomais e della dieta unifeed sono stati prelevati per essere sottoposti ad analisi chimiche e fisiche. L'analisi statistica dei dati ha considerato due tipologie di classificazione del campione aziendale: la prima basata sulla quantità di silomais presente nella razione e la seconda sul contenuto di particelle lunghe (> 13 mm) del silomais. Indipendentemente dalla lunghezza di trinciatura, la qualità della popolazione dei campioni di silomais è risultata soddisfacente sia dal punto di vista nutrizionale che dello stato di conservazione, come evidenziato dal contenuto di sostanza secca (350 ± 38 g/kg di prodotto fresco), dall'alto contenuto di amido (310 ± 28 g/kg SS) e dalla concentrazione di acido lattico (49 ± 12 g/kg SS). I campioni di silomais hanno mostrato una ampia variabilità nelle dimensioni delle particelle a seguito delle diverse lunghezze di trinciatura adottate in sede raccolta. Il contenuto medio di particelle lunghe è risultato di 143 ± 73 g/kg di prodotto fresco. L'analisi delle diete ha rivelato che in media il silomais rappresenta il 33,4% della sostanza secca totale della razione con un'ampia deviazione standard (11,4%). La quantità di silomais inserita nella miscelata è apparsa indipendente sia dalla composizione chimica che dalle dimensioni delle particelle dell'alimento. Nelle razioni a più alto contenuto di silomais, il rischio della manifestazione dell'acidosi ruminale dovuto al maggior apporto di amido da parte dell'alimento viene limitato dalla significativa riduzione della quantità di altre fonti amilacee presenti nella dieta, dal maggiore contenuto di NDF totale della razione e dall'aumento nella miscelata della percentuale di particelle in grado di stimolare una prolungata ruminazione. L'analisi della distribuzione delle particelle dell'unifeed ha mostrato che in più del 30% degli allevamenti il silomais ha subito una modifica della caratteristiche fisiche durante la preparazione della razione, con una parziale perdita di particelle lunghe. Un'analisi logistica ha permesso di evidenziare come il rischio di danneggiamento del silomais aumenti significativamente nel caso di una maggiore quota di inclusione dell'alimento nell'unifeed o dell'utilizzo di un insilato trinciato più grossolanamente.

Parole chiave: *Bovino da carne, Silomais, Finissaggio, Alimentazione.*

Introduction

Under intensive rearing systems, the diets for finishing beef cattle are generally offered as total mixed rations (TMR), rich in concentrate feedstuffs and starch sources, to promote the maximum daily gain. However, the inclusion of roughage in the diet is necessary to maintain normal ruminant function (Campbell *et al.*, 1992). Among forage sources there has been a growing interest towards maize silage (MS) because of its high starch content and the quality of the fibrous portion (Allen *et al.*, 1996). Maize silage is considered a good roughage source for the finishing phase of fattening bulls since it requires a moderate energy and protein supplementation to meet the nutrient requirements of the animals (Browne *et al.*, 1998). As compared with pasture or grass silage, the most common forages used for beef cattle feeding across Europe, MS is an alternative that allows a higher ratio of animals grown per hectare of farm land (Abdelhadi *et al.*, 2005). When properly produced and stored, this roughage is easy to handle and is highly palatable to cattle (Atwood *et al.*, 2001). Moreover, the nutritional quality of MS is more stable than pasture, the quality of which varies consistently with the change of seasons (Allen *et al.*, 1996), or grass silage, because of its wide range of botanical and chemical composition (Steen *et al.*, 1998). A recent study has also demonstrated that the progressive substitution of grass silage with maize silage has the potential to reduce the time required to finish beef cattle with no apparent detrimental effects on meat quality (Juniper *et al.*, 2005). Despite the increased use of MS by beef farmers, there is still a lack of scientif-

ic information on how MS should be handled when comprising part of beef cattle diets. Therefore the present study monitored the current use of MS in a large sample of intensive beef farms. The aim of the research was to evaluate the MS quality and to compare the chemical composition and physical properties of finishing TMR which differed for the quantity of MS or for the use of MS with different particle size.

Material and methods

Location and time of the study

The study was undertaken on a sample of 406 commercial beef farms located in the Po Valley, the main area for beef production in Italy with more than 2 million heads finished per year (Cozzi and Ragno, 2003). The period of data collection lasted from January to July 2005 and only MS harvested in the year 2004 were considered.

Farm selection

The study considered a wide sample of farms in order to cover more diverse rearing situations in terms of farm size and cattle genotype in which MS was fed to beef cattle. All fattening units housed a minimum of 40 animals above 400 kg live weight in multiple pens indoors. The cattle population of the entire farm sample was 233,664 heads and its distribution is described in Figure 1 where the selected farms are grouped in 4 classes according to their size, measured as number of cattle per farm. Only 15.6% of the total cattle population was raised in farms with less than 331 animals per unit, while more than 60% of the animals were fattened in the biggest farms.

As cattle genotype was concerned, the majority of cattle were of French pure breeds (Charolaise 35%; Limousine 16%) or French Crossbreds (35%). The remaining

14% of cattle were dual-purpose breeds or crosses between beef bulls and dairy cows. A majority of cattle were imported from France while the percentage of animals native to Italy accounted for less than 5% of the total population.

Diet info and sample collection

Each farm was visited to collect information about the feeding regimen of the finishing cattle. The composition of the TMR offered to animals was recorded and, due to the variety of feedstuff in diets of the whole farm sample, each ingredient was associated to one of the following 7 feed categories to simplify the analysis of the diet composition (as fed):
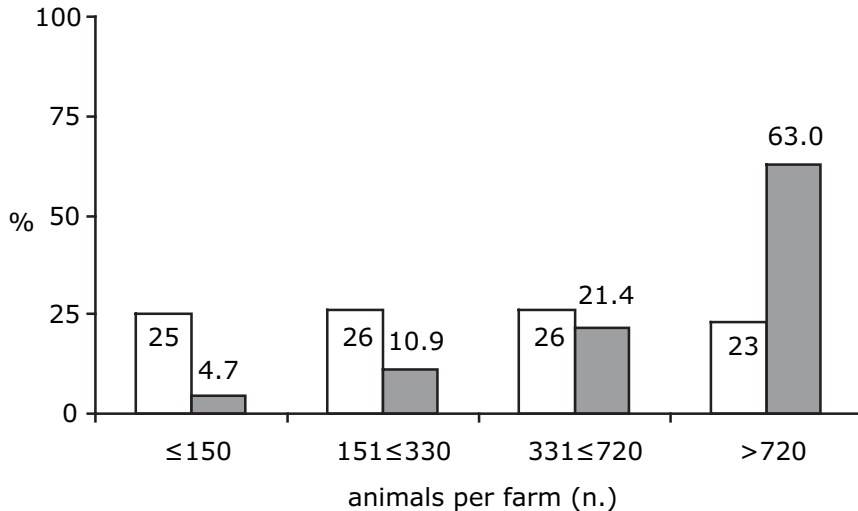- maize silage;
- maize ear silage;
- cereal grains and meals;
- dried sugar beet pulps and other fibrous concentrates;
- long fibre roughages (i.e. hay, straw);
- protein sources (i.e. soybean meal, corn gluten feed, protein-vitamin-mineral premixes) with crude protein > 150 g/kg of dry matter (DM);
- molasses and vegetal fats.

In each farm, a representative sample of TMR and MS were collected for subsequent chemical and physical analysis. The TMR sample was taken from the manger of one pen at time of feeding to avoid any selection by the animals. The sample of MS was collected directly from the silo.

Chemical and physical analysis

All samples of TMR and MS were chemically analysed for dry matter (DM), crude protein, ether extract, ash and starch according to AOAC (1990). The analysis of neutral detergent fibre (NDF) and acid detergent fibre of the same samples was conducted according to Van Soest *et al.*, (1991) and the content of non-fibrous car-

Figure 1.   Partition of the farms sample according to the number of cattle raised per single farm (□) and distribution of the cattle population in percentage within classes (■).

bohydrates was calculated as 100 – (crude protein + ether extract + ash + NDF). Maize silage pH was measured with a glass electrode on squeezed juice taken from the fresh sample. Silage volatile fatty acids and lactic acid content were measured by high performance liquid chromatography according to Canale *et al.*, (1984). Silage ammonia nitrogen was measured with a specific ion-selective electrode.

The particle size distribution of TMR and MS samples was determined using a mechanical siever derived from the Penn State Forage Particle Separator (Nasco, Fort Atkinson, WI, USA). The instrument had four screens with hole sizes of 19, 13, 8 and 4 mm, respectively, and a bottom pan. Samples were separated into five fractions following the procedure of Lammers *et al.*, (1996). Each fraction was then weighed and divided by total sample weight to calculate the percentage of the five fractions of parti-cles. The amount of long particles of TMR and MS samples were then calculated by

summing the percentages of particles retained by the 13mm and the 19mm sieves.

Maize silage damage during diet preparation
The mechanical equipment used to han-dle the forages after the harvest may reduce their particle size. In the case of MS, the silo unloaders and TMR mixers often grind and churn the forage particles caus-ing a loss of the roughage long particles (Lammers *et al.*, 1996). A simple mathe-matical method was developed in order to verify the occurrence of any damage to silage particles. For each farm, the percent-age of long particles (19 mm + 13 mm) of MS, measured by mechanical sieving, was multiplied by the amount of silage included in the TMR to obtain the fresh weight of long particles of MS which should be found in that ration. This value was then expressed as percentage dividing it by the total TMR fresh weight and the result rep-resented the minimum acceptable value

(A). If the percentage of long particles actually measured by the mechanical sieving of the TMR sample of the same farm (B) was below this minimum acceptable value (B< A), a loss of MS long particles had certainly occurred.

Statistical analysis

Two specific classification factors of the farm population were created to allow the statistical analysis of the experimental data. The former factor classified the farms according to the amount of MS included in the TMR (Figure 2). Mean and standard deviation (SD) of the distribution obtained for this classification factor were used to assign each farm to one of the three following classes:

'Low' which included all samples with a value below the mean value minus 0.5*SD;

'High' which included all samples with a value above the mean value plus 0.5*SD and

'Middle' which considered the remaining samples of the population located between the 'Low' and 'High' classes.

A similar procedure was adopted for the latter classification factor which was based on the content of long particles of the MS (Figure 3) and the three resulting classes were named as 'Short', 'Long' and 'Mid,' respectively. All the experimental data were submitted to analysis of variance within the GLM procedure of SAS (1990) and the statistical model considered the effects of the class of MS in the diet, the class of long particles content of MS and the relative interactions. Two separate logistic analyses were performed within PROC LOGISTIC of SAS (1990) to calculate the odds ratio estimates for the occurrence of MS damage during the TMR preparation. The first one considered the risk of MS damage due to the use of an increasing amount of the roughage in the diet, while the second tested the risk due to the use of MS with a different content of long particles.

Results

The overall average inclusion of MS in the diet was 7.79 kg of fresh weight but there was a wide variation among farms with a SD of 2.45 kg. As shown in Figure 2, 8 kg of MS fresh weight was the amount fed by the largest number of farms (20% of the total farm sample) followed by 10 kg (14%) and 6 kg (12%) and these three different values closely reflected the three classes of silage inclusion in the TMR used in the statistical processing of the data (Table 1). The results of the partition of the

Table 1. Classification of the farm population according to the amount of maize silage[1] included in the diet for finishing beef cattle.

		Class of maize silage inclusion in the diet		
		Low	Middle	High
Farms	n.	130	172	104
Mean quantity		5.1	7.9	10.9
Minimum		1.0	7.0	9.5
Maximum		6.5	9.0	17.9

[1] kg of fresh weight, unless otherwise stated.

Figure 2.   Distribution of the farm population according to amount of maize silage included in the diet for finishing beef cattle.
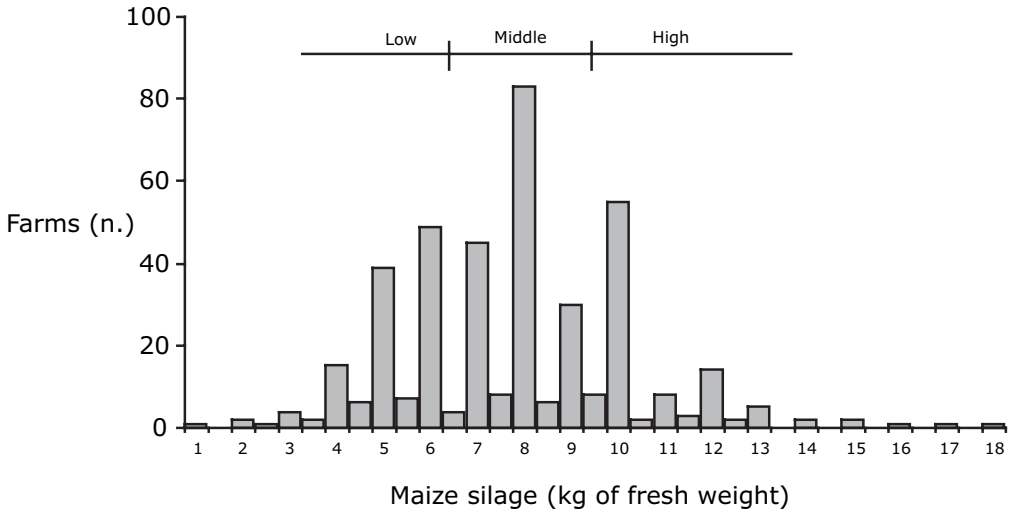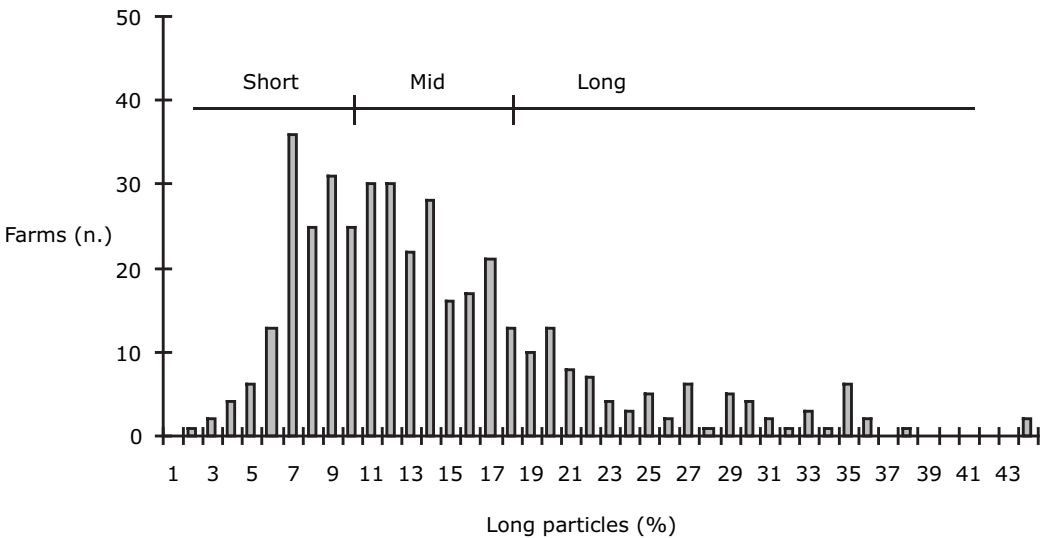

Figure 3.   Distribution of the farm population according to the percentage of long particles of maize silage.

farms sample according to the content of long particles of MS are reported in Table 2. On average the content of long particles was 143 g/kg of silage fresh weight with a SD of 73 g/kg. The Short class included all the farms in which the content of MS long

Table 2. Classification of the farm population according to the content of long particles of maize silage[1].

		Class of maize silage long particles		
		Short	Mid	Long
Farms	n.	149	166	91
Mean content		79	140	251
Minimum		22	107	179
Maximum		106	178	443

[1] g/kg of fresh weight, unless otherwise stated.

particles resulted below 107g/kg of MS fresh weight while in Long class the minimum percentage of long particles was 179 g/kg of fresh weight.

Maize silage chemical composition and particle size

Chemical composition and fermentation profile of MS samples are shown in Table 3. All these variables were not affected either by the different level of inclusion of MS or by its content of long particles. Consistent with the chemical composition, the particle size distribution of MS did not change according to its rate in the diet (Table 4). The partition of the silage particles among the different sieves showed on average that 50% of the particles were retained by the 8 mm sieve. This fraction of particles as well as the one retained by the 4 mm sieve and that of the bottom pan were significantly reduced by a progressive increase in the content of the longer particles of the silage (Table 4).

Diet formulation and analysis

As shown in Table 5, the inclusion of increasing amounts of MS had a significant impact on the feed composition of the TMR for finishing beef cattle. In comparison with the Low class of diets in which there was a moderate inclusion of MS, the average

increase of 2.7 kg of MS as fed in the Middle class significantly reduced the amounts of cereals and fibrous concentrates. A further increase in the amount of MS in the High class diets lowered either some of the energy sources included in the TMR such as maize ear silage and fibrous concentrates or the long fibre roughages. On the contrary, the use of MS with a different particle size had no effect on either the feed composition of the TMR, nor on the content of long fibre roughages (Table 5).

As expected, the inclusion of increasing amounts of a wet roughage like MS progressively lowered the DM content of the TMR (Table 5). Within DM, starch content was similar across the 3 classes of MS inclusion, whereas there was a progressive increase in the fibrous content of the TMR from Low to High diets.

The chemical composition of the TMR was very similar across the three classes obtained when considering the content of long particles of the silage (Table 5).

The results of the physical analysis of the TMR samples are reported in Table 6. The inclusion of increasing amount of MS in the diet had no effect on the percentage of long particles of the TMR, while it resulted in a significant increase of the particles retained by both the 8 mm and the 4 mm screens lowering the percentage of feed

Table 3. Change in chemical composition and fermentation profile of maize silage (g/kg dry matter basis, unless otherwise stated) due to the class of inclusion of the roughage in diets for beef cattle and to the class of long particles content of the feed.

	Maize silage									
	Class of inclusion in the diet (I)			Class of long particles (LP)			SE	Significance (P)		
	Low	Middle	High	Short	Mid	Long		I	LP	I*LP
Chemical composition:										
Dry matter (g/kg fresh weight)	352	350	344	352	348	346	3.8	ns	ns	ns
Ash	40	41	41	40	41	41	0.4	ns	ns	ns
Crude protein	75	77	76	76	76	75	0.5	ns	ns	ns
NDF	440	442	446	441	444	443	2.5	ns	ns	ns
ADF	250	251	255	250	253	253	1.9	ns	ns	ns
NFC	409	406	402	408	404	405	2.8	ns	ns	ns
Starch	314	308	306	312	307	308	2.8	ns	ns	ns
Fermentation profile:										
pH (units)	3.8	3.8	3.8	3.8	3.8	3.8	0.1	ns	ns	ns
Lactic acid	48	50	49	48	49	49	1.2	ns	ns	ns
Acetic acid	24	26	26	25	25	25	0.8	ns	ns	ns
Propionic acid	6.4	6.5	6.7	6.5	6.6	6.8	0.2	ns	ns	ns
Butyric acid	0.7	0.7	0.7	0.7	0.7	0.7	<0.1	ns	ns	ns
Ethanol	6.2	5.9	5.6	6.0	5.9	5.8	0.2	ns	ns	ns
Ammonia N (g/kg total N)	67	68	67	68	68	66	1.1	ns	ns	ns

NDF: neutral detergent fibre; ADF: acid detergent fibre; NFC: non-fibrous carbohydrates.
ns: not significant.

Table 4. Change in particle size distribution of maize silage (g/kg of fresh weight) due to the class of inclusion of the roughage in diets for beef cattle and to the class of long particles content of the feed.

	Maize silage									
	Class of inclusion in the diet (I)			Class of long particles (LP)			SE	Significance (P<)		
	Low	Middle	High	Short	Mid	Long		I	LP	I*LP
Particle size distribution:										
Particles retained by a sieve of 19 mm	34	38	40	17^y	35^x	61^w	22	ns	0.001	ns
Particles retained by a sieve of 13 mm	125	121	115	62^y	105^x	194^w	34	ns	0.001	ns
Particles retained by a sieve of 8 mm	500	495	502	507^w	507^w	482^x	72	ns	0.02	ns
Particles retained by a sieve of 4 mm	238	243	242	300^w	250^x	174^y	53	ns	0.001	ns
Particles on the bottom pan	103	104	101	114^w	103^x	90^y	33	ns	0.001	ns

Within a row and class, means with different letters (w,x,y) differ for the reported threshold of significance; ns: not significant.

material recovered in the bottom pan. When the class of silage long particles was considered, there was a significant increase in the percentage of TMR particles retained by the 19, 13 and 8 mm screens in diets using a Mid silage in comparison to the Short silage. The diets made with the Long silage showed a further increase in the particles retained by the 13 and 8 mm screens to the detriment of the ones accumulating on the 4 mm screen. No effect of silage long particles was observed on the percentage of TMR particles recovered on the bottom pan of the instrument (Table 6).

Maize silage damage during diet preparation

The proposed procedure to assess the maize silage damage during the preparation of the TMR demonstrated the loss of MS long particles in 32% of the samples. Considering the different class of MS inclusion in the diet, the percentage of damaged diets was 23% for the Low class and it was increased up to 31% in the Middle one. However, the logistic analysis reported in Table 7 showed that the risk of silage damage was similar between the two classes. In the case of the High class the estimated percentage of damaged TMR (42%) almost doubled that of the Low class and the relative risk set by the logistic analysis was 2.44 time higher. When diets were analysed according to the class of silage long particles (Table 7), a loss of MS long particles was observed in only 12% of the Short class samples. The percentage of damaged diets increased to 30 and 67% for the Mid and Long classes, respectively. The logistic analysis showed that the relative risk of long

Table 5. Effects of the class of inclusion in the diet and of the class of long particles of maize silage on feed (kg of fresh weight) and chemical composition (g/kg of dry matter, unless otherwise stated) of total mixed rations for beef cattle.

	Maize silage									
	Class of inclusion in the diet (I)			Class of long particles (LP)			SE	Significance (P<)		
	Low	Middle	High	Short	Mid	Long		I	LP	I*LP
Feed categories:										
Maize silage	5.17^y	7.90^x	11.28^w	8.07	8.08	8.21	1.06	0.001	ns	ns
Maize ear silage	1.13^w	0.91^w	0.57^x	0.87	0.77	0.98	1.45	0.05	ns	ns
Cereals meals and grains	2.71^w	2.38^x	2.43^x	2.50	2.53	2.50	1.31	0.05	ns	ns
Fibrous concentrates	1.00^w	0.77^x	0.52^y	0.78	0.75	0.76	0.72	0.001	ns	ns
Long fibre roughages	0.78^w	0.71^{wx}	0.65^x	0.75	0.75	0.65	0.37	0.07	ns	ns
Protein sources	2.18	2.17	2.28	2.33	2.16	2.15	1.04	ns	ns	ns
Molasses and vegetal fats	0.08	0.09	0.01	0.08	0.07	0.03	0.31	ns	ns	ns
Chemical composition:										
Dry matter (g/kg of fresh weight)	591^w	550^x	500^y	552	551	540	7.2	0.001	ns	ns
Ash	54	53	53	53	54	53	0.7	ns	ns	ns
Crude protein	130^w	129^w	127^x	128	127	130	1.0	0.05	ns	ns
Ether extract	35	34	33	34	33	34	0.8	ns	ns	ns
NDF	307^y	316^x	331^w	316	324	314	4.9	0.001	ns	ns
ADF	154^x	158^x	169^w	158	164	159	5.0	0.001	ns	ns
NFC	474^w	469^w	457^x	469	462	469	3.2	0.01	ns	ns
Starch	322	323	316	322	315	323	2.9	ns	ns	ns

NDF: neutral detergent fibre; ADF: acid detergent fibre; NFC: non-fibrous carbohydrates.
Within a row and class, means with different letters (w,x,y) differ for the reported threshold of significance; ns: not significant.

Table 6. Effects of the class of inclusion in the diet and of the class of long particles of maize silage on particle size distribution (g/kg of fresh weight) of total mixed rations for beef cattle.

	Maize silage									
	Class of inclusion in the diet (I)			Class of long particles (LP)			SE	Significance (P<)		
	Low	Middle	High	Short	Mid	Long		I	LP	I*LP
Particle size distribution:										
Particles retained by a sieve of 19 mm	35	37	38	32^x	42^w	37^w	28	ns	0.01	ns
Particles retained by a sieve of 13 mm	60	60	57	50^y	59^x	68^w	31	ns	0.001	ns
Particles retained by a sieve of 8 mm	178^y	196^x	245^w	185^y	205^x	233^w	67	0.001	0.001	ns
Particles retained by a sieve of 4 mm	203^y	220^x	237^w	247^w	227^x	187^y	64	0.003	0.001	ns
Particles on the bottom pan	523^w	483^x	422^y	487	466	475	96	0.001	ns	ns

Within a row and class, means with different letters (w,x,y) differ for the reported threshold of significance; ns: not significant.

particles damage was increased 3.1 and 14.8 times, respectively, when the Mid and the Long class diets were compared with the Short class ones.

Discussion

The study considered a large number of beef cattle farms in which MS was included in the TMR fed during the finishing period. The amount of inclusion of the roughage in the diet showed a wide variation across farms but on average MS represented 33.4% of the total DM. Maize silage was the main constituent of the dietary DM in 194 farms (48% of the total sample) and in these diets the contribution of MS as percentage of the total DM increased up to 40.3%.

According to Allen *et al.*, (1996), the high starch content and the quality of the fibrous portion are the main reasons for the large inclusion of MS in beef cattle diets. These nutritional properties offer the potential to lower the amount of energy concentrates given during the finishing period or to reduce the duration of the finishing period itself (Juniper *et al.*, 2005). The chemical characteristics of MS have shown to affect its intake by beef cattle (Wilkinson *et al.*, 1978), therefore MS quality is a key factor when aiming at a large inclusion of the roughage into a finishing TMR. With this in mind, the average quality of MS samples analysed in the present study was satisfactory as indicated by the DM and starch content and by the satisfactory fermentation

Table 7.   Logistic analysis of the relative risk of occurrence of maize silage damage during total mixed ration preparation.

Effect	Point estimate	95 % Wald confidence limits	
Class of silage inclusion in the diet:			
Middle *vs* Low	1.57	0.93	2.63
High *vs* Low	2.44	1.39	4.30
Class of silage long particles:			
Mid *vs* Short	3.14	1.73	5.68
Long *vs* Short	14.80	7.66	28.59

profile with a predominant lactic acid fermentation and a modest content of ammonia nitrogen (McDonald *et al.*, 1991). It is of particular interest to note that the silage quality did not decline with a coarser chopping of the plant. This result should direct the farmers towards the increase in the chopping length which should maximise the amount of silage particles capable of stimulating chewing (Mertens, 1997). In a recent study carried out by Cozzi *et al.*, (2005) with finishing Limousin bulls, the animals fed a coarsely chopped MS (chop length = 19 mm) as the sole roughage source of the TMR showed similar growth performance and a prolonged rumination time per unit of DM intake than the control bulls fed a diet made of conventional MS (chop length = 9 mm) and straw.

Data about the feed and chemical composition of the TMR recorded in the present study showed how beef farmers who are using large quantities of MS in the finishing diet are aware of the high amount of starch brought by the roughage and, in order to prevent the occurrence of rumen acidosis, they lower the quantity of other starch sources such as maize ear silage and cereals. Also in this regard, it must be noted that feeding diets with high quantities of MS should provide further prevention of rumen acidosis through the increase of

dietary NDF and acid detergent fibre (Rebhun, 1995).

The physical analysis of the MS samples collected in the farms showed a wide range of the roughage particle size as the result of different chopping lengths adopted during the harvest of the crop. However, the amount of inclusion of MS in the TMR has shown to be absolutely unaltered by the content of long particles of the roughage. The practical consequence of this decision is that even in diets made with the coarsest class of MS there was not any reduction in the amount of straw or other long fibre roughages. A clear explanation for this decision came from the analysis of TMR particle size, which showed that for more than 30% of samples there was a loss of MS long particles during diet preparation. The relative risk of this loss has shown to be increased either by a large inclusion of MS in the TMR or by the use of silage with coarser particles. Several strategies should be recommended to prevent MS long particles losses during TMR preparation. The roughage should be carefully loaded into the mixing wagon avoiding any potential grinding during this process. The use of silage cutters is likely to increase the risk of particles damages and at this regard it must be noticed that this device was operating in 95% of the farms in which the finishing diet showed a loss of MS

structure. In the case of the farms in which TMR was undamaged, the use of silage cutter was reduced down to 88%. A further guideline to minimize the loss of the long particles brought by MS regards the order of feedstuffs load in to the mixing wagon during the TMR preparation. Maize silage should be the last feedstuffs to be loaded and its mixing time should be the minimum required to allow the proper amalgamation with the other ingredients of the TMR. In the present study, 28% of the farms in which the diet showed a loss of MS long particles did not follow this recommendation.

The prevention of MS long particles from the mechanical damage during the TMR preparation could avoid the current inclusion of straw or other long fibre roughages required to increase the physical effectiveness of the dietary particles (Mertens, 1997). In this way, the energy density of the diet should be increased with a likely positive outcome by the animals during the finishing period.

Conclusions

Data from a large sample of intensive beef farms have shown the good nutritional quality and the satisfactory fermentative pattern of MS, which makes this roughage an interesting forage base for finishing cattle diets. The decision about the amount of MS to be included in the TMR was shown to be independent with respect to both chemical composition and particle size of the roughage. The risk of a greater occurrence of rumen acidosis in diets with a large inclusion of MS has shown that it can be controlled either by balancing the additional starch brought by the roughage with a significant reduction in the amount of other starch sources or by the increase of the NDF content and the coarser size of the dietary particles which should promote a prolonged rumination.

A more careful handling of MS during the TMR preparation could reduce the damage and the consequent loss of its long particles, which at the moment imposes the inclusion of straw or other long fibre roughages in the TMR for rumination purpose. By increasing the energy density of the TMR, this strategy should lead to improved growth performance of beef cattle during the finishing period.

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