A laboratory study of the composition and fermentation of various crop silages

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Grain sorghum, forage sorghum, sunflower and maize were ensiled on laboratory scale. Sunflowers, harvested at the milky seed stage of maturity, resulted in silage containing only 13,54% dry matter (DM). Maize, grain sorghum and forage sorghum silages, contained approximately 30% DM. Both maize and sunflower silage had an *in vitro* dry matter digestibility (IVDMD) of approximately 70%. Grain and forage sorghum silages had approximate IVDMD values of 60% and 53%, respectively. Sunflower silage was found to have the highest ($P < 0,01$) crude protein content (13,55%), followed by grain sorghum (9,42%), maize (8,23%) and forage sorghum (7,26%). The nitrogen (N) content of N-containing components was expressed as a percentage of total N content with the exceptions of crude protein and true protein which were expressed as a percentage of DM. Non-protein N content of the silages was found to be approximately 50%, with the exception of grain sorghum silage (56,16%). Acid detergent insoluble N content was highest ($P < 0,01$) in forage sorghum silage (16,61%). Acid detergent fibre content of forage sorghum and sunflower silages (38,6 and 35,2%, respectively) was appreciably higher than in maize and grain sorghum silages (29,5 and 32,9%, respectively). Both sorghums contained the least ($P < 0,01$) water soluble carbohydrates prior to ensiling. The amount of fermentation products was very high ($P < 0,01$) in sunflower silage (64, 77, 39 and 57% more lactic, butyric, acetic and total volatile fatty acids, respectively, than in maize silage). Ammonia N content was also highest ($P < 0,01$) in this silage. The analytical results of the plant matter and silages were statistically compared. Maize served as reference crop.

Graansorghum, voersorghum, sonneblom en mielies is op laboratoriumskaal ingekuil. Sonneblomme, geoes op die melkerige saadstadium van ontwikkeling, het 'n kuilvoer met 'n droëmateriaal (DM)-inhoud van slegs 13,54% gelewer. Mielie-, graansorghum- en voersorghumkuilvoer het ongeveer 30% DM bevat. Beide mielie- en sonneblomkuilvoer het 'n *in vitro* droëmateriaal verteerbaarheid (IVDMV) van ongeveer 70% gehad. Graan- en voersorghumkuilvoer het IVDMV van ongeveer 60% en 53%, onderskeidelik, gehad. Sonneblomkuilvoer het die hoogste ($P < 0,01$) ruproteïeninhoud (13,55%) gehad, gevolg deur graansorghum (9,42%), mielies (8,23%) en voersorghum (7,26%). Die stikstof (N)-inhoud van N-bevattende komponente is as persentasie van totale N-inhoud uitgedruk met die uitsondering van ruproteïen en ware proteïen wat as persentasie DM uitgedruk is. Nie-proteïen N-inhoud van die kuilvoere was ongeveer 50% met die uitsondering van graansorghumkuilvoer (56,16%). Suuronoplosbare N-inhoud was die hoogste ($P < 0,01$) in voersorghumkuilvoer (16,61%). Suuronoplosbare veselinhoud van voersorghum- en sonneblomkuilvoer (38,6 en 35,2%, onderskeidelik), was aansienlik hoër as in mielie- en graansorghumkuilvoer (29,5 en 32,9%, onderskeidelik). Beide sorghums het die laagste ($P < 0,01$) inhoud van wateroplosbare koolhidrate voor inkuiling, bevat. Die hoeveelheid fermentasieprodukte was baie hoog ($P < 0,01$) in sonneblomkuilvoer (64, 77, 39 en 57% meer melk-, botter- en asynsuur en totale vlugtige vetsure, onderskeidelik, as in mieliekuilvoer). Ammoniak N-inhoud was ook die hoogste ($P < 0,01$) in hierdie kuilvoer. Die analitiese resultate van die plantmateriaal en kuilvoere is statisties vergelyk. Mielies het as verwysingsgewas gedien.

Keywords: Chemical composition; fermentation; silage; sunflower; grain sorghum; forage sorghum.

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Introduction

Information regarding the suitability of grain and forage sorghum and sunflower as silage crops in South Africa is limited. At present maize is used, almost exclusively, as silage crop. A survey performed by the Resources Section of the Highveld Region (Jordaan, D.G., 1990, Department of Agricultural Development, Highveld Region, Potchefstroom, 2520; pers. comm.) found that approximately 1,955 million tonnes of maize silage were produced in this region during 1988/89. The only other crop referred to was forage sorghum (16 230 tonnes).

Many areas in the Highveld Region are regarded as marginal for maize cultivation due to soil type, low annual rainfall and intermittent seasonal droughts. According to Edwards, Harper, Henderson & Donaldson (1978) and Black, Ely, McCullough & Sudweeks (1980), sunflower and sorghum are more drought resistant than maize. Black *et al.* (1980) ascribed this to the lower water requirement and transpiration losses of the sorghums. Van Arkel (1978) stated that, under similar limited moisture conditions, sunflowers outyield maize in terms of dry matter (DM) production.

Sunflowers display a higher cold tolerance than maize and also have an appreciably shorter growing season (McGuffey & Schingoethe, 1980; Harper, Donaldson, Henderson & Edwards, 1981; Thomas, Sneddon, Roffler & Murray, 1982). This reduces the risk of cultivation of this crop, particularly since it is harvested well before seed harvest maturity. Sunflowers may be planted later in the season for silage in the event of late spring rains.

The suitability of a crop for ensiling is established by comparing some of its chemical parameters with standardized chemical parameters. The comparison of sorghum and sunflower with maize is, however, very relevant in terms of:

(a) Nutritional value and animal performance, which is well documented in South Africa.

(b) Replacement of maize silage by silage from crops under investigation.

The National Pasture Strategy calls for the establishment of alternative feed sources to prevent over-exploitation of the natural veld resource. Alternatively, stock numbers must be reduced to prevent further deterioration of the natural resource. Veld pasture should be primarily used by breeder herds. During the period 1985 to 1989, the RSA imported between 35,5 and 46,1 thousand tonnes of red meat annually (Abstract of Agricultural Statistics, 1990). Stock destined for slaughter can be finished using intensive feeding strategies. Silage forms an integral part of intensive rations and can be used to over-winter breeder stock.

Owen, Kuiken & Webster (1962) found that both forage and grain sorghum consistently produced higher DM yields than maize. Hinds, Bolsen, Brethour, Milliken & Hoover (1985) stated that forage sorghum, receiving less fertilizer and water than maize, produced comparable DM yields. Sunflower was found to be as productive as maize within a shorter growing season (Sheaffer, McNemar & Clark, 1977). Average herbage yields per hectare obtained over the past few years at the Highveld Region Research Facility were 15, 18 to 20, and 20 to 25 tonnes for maize, grain sorghum and forage sorghum, respectively. Sunflower yields are dependent on planting density but regular yields of 15 to 18 tonnes per hectare are obtainable.

During seasons in which rainfall is high, forage sorghum produced the highest yield (23–30 t/ha), whilst maize and grain sorghum had comparable yields (18–22 t/ha). Yield reduction was less obvious in the sorghums during the drier years (Schutte, A.R., 1989, Department of Agricultural Development, Highveld Region, Potchefstroom 2520; pers. comm.). The ideal DM contents for ensiling maize, grain sorghum and forage sorghum are 33 to 35%, 30 to 33%, and 28 to 30%, respectively (Vermaak, L.M., 1989, Department of Agricultural Development, Highveld Region, Potchefstroom 2520; pers. comm.).

The utilization of cash crops in the form of silage will provide more stability to the farming enterprise. In fact the reconstruction of agriculture has become a main issue in the Highveld Region due to the losses realized on maize exports.

Silage production can be expanded should sorghum and/or sunflower prove to be suitable silage crops. Silage can then be produced in the drier areas of the Highveld and relieve much of the pressure placed on the natural resources to get slaughter animals into a marketable condition.

With this in mind, this trial was designed to compare the chemical composition and fermentation characteristics of maize (MA), grain sorghum (GS), forage sorghum (FS) and sunflower (SF) with one another. Maize served as a reference crop, as it is known to be suitable for ensiling.

Material and methods

Plant matter, with the exception of sunflowers, which were specifically planted for this trial, was harvested from fields which had been cultivated for silage production . All crops were planted on a Westleigh (Series 13) type soil (depth 30–35 cm) which is regarded as a marginal soil in the western parts of the Highveld Region. Random selection of 120 plants from each crop supplied sufficient plant material for the execution of the trial. The herbage was immediately cut into 2-cm pieces, thoroughly mixed and ensiled. Twelve 1 000-g samples of fresh herbage were taken from each crop. Six of these samples were dried in a ventilation oven (105°C) to constant mass for DM determination. The remaining six samples were dried at 65°C for 48 h, ground through a 1-mm sieve and then analysed in duplicate.

Harvesting took place at the recommended stages of maturity. Maize at the hard dough–early dent stage (Groenewald & Boyazoglu, 1980), GS at the early dough stage (Black *et al.*, 1980), FS at the early to medium dough stage (Owen & Kuhlman, 1967) and SF at the milky seed stage (Edwards *et al.*, 1978).

Approximately 700 to 1 000 g of plant matter was tightly compressed into 1-*l* preserve jars using a wooden spatula. The jars were immediately sealed by means of a metal screw-top lid fitted with a rubber gasket, thereby ensuring an anaerobic environment. Twelve replicates of each crop were ensiled in this way and later analysed in duplicate.

Fermentation characteristics were measured after ensilage periods of 48 h and 10 weeks. Characteristics determined were pH (wet glass electrode), ammonia-nitrogen (NH_3-N) (adaptation of Clare & Stevenson, 1963), lactic acid (LA) (Barker & Summerson, 1941), total volatile fatty acids (TVFA), (Fenner & Elliot, 1963) and individual fatty acids (Clancy, Wangsness & Baumgardt, 1977). According to Groenewald & Boyazoglu (1980), lactic acid production continues in MA silage for three weeks after ensiling. A further three weeks is then allowed for the stabilization of the silage, which entails the cessation of bacterial activity and the preservation of nutrients through the action of lactic acid. As it is not known how long stabilization takes in the other crops, it was decided to allow ample time and thus the period of 10 weeks was chosen. Once an ensiled crop has stabilized, chemical composition and fermentation characteristics do not alter.

Dry matter of the silage was determined by means of oven drying, during which volatile fatty acids are lost. Dry matter obtained in this way underestimates the value by between 0,2 and 1,0%, the latter being reached in very wet silage. Dewar & McDonald (1961) proposed the toluene distillation method which is, however, time consuming and dependent on an arbitrarily chosen correction factor.

Chemical analyses were performed on the plant matter prior to ensiling and on the silage after an ensiling period of 10 weeks. Chemical components determined included crude protein (CP) and true protein (TP) (Clare & Stevenson, 1963), non-protein nitrogen (NPN) (by difference CP – TP = NPN), acid detergent fibre (ADF) (Van Soest, 1963), acid detergent insoluble nitrogen (ADF-N) (Clare & Stevenson, 1963) and water soluble carbohydrates (WSC) (Shannon, 1972). The N-content of the N-containing components was expressed as percentage of total N with the exception of TP and CP which were expressed on a DM basis. *In vitro* dry matter digestibility (IVDMD) was determined by the method described by Tilley & Terry (1963) as adapted by Engels & Van der Merwe (1967).

The trial consisted of a completely randomized design (Little & Hills, 1978) on which a one-way analysis of variance was performed. Variation was measured by means of F-test and least significant difference (LSD) procedures

(Snedecor & Cochran, 1980). Only LSD values are presented in the statistical tables.

Results and discussion

Lactic acid is the prime preservative in silage produced mainly by the bacterial catabolism of WSC and organic acids. For this reason, crops suitable for ensilage should contain between 6 and 8% WSC on a DM basis (Whittenbury, McDonald & Bryan-Jones, 1967). A silage with a pH in the range of 3,8 to 4,2 is considered well preserved (McDonald, Edwards & Greenhalg, 1973; Van der Merwe, 1980). A further criterion of well-preserved silage is an LA content between 8 and 12% of DM (McDonald *et al.*, 1973; Jackson, 1974; Van der Merwe, 1980). According to Haigh (1987), pH and LA content alone are not reliable indicators of silage preservation as they are extensively influenced by DM content. As an alternative, Haigh (1987) suggests that NH_3-N content as percentage of total N is a more reliable index of fermentation. Well-preserved silage should contain less than 10% of the total N in the form of NH_3-N. Silages containing excessive levels of NH_3-N have been subjected to less efficient fermentation. This results in a slower pH decline which is detrimental to preservation.

Haigh (1987) stated that NH_3-N is indicative of protein degradation and therefore, an indication of unfavourable fermentation processes and poor preservation. Whittenbury *et al.*, (1967) stated that as much as 50 to 60% of the TP fraction is degraded during ensiling, resulting in higher NPN levels in the silage as compared to the herbage. The NPN is nevertheless still available to the animal. Nitrogen bound to the ADF fraction is indigestible and decreases the amount of CP available to the animal (Goering, Gordon, Hemken, Waldo, Van Soest & Smith, 1972).

Laboratory scale silos enable the examination of a wider range of crops and an increased number of replicates at vastly reduced expenses. Wilson & Wilkins (1972) and El Hag, Vetter, Kenealy & Smith (1982) ensiled 100 g and 250 g samples in test tubes and glass jars, respectively. Both authors found that laboratory silos closely simulated the processes in large silos. Results obtained from both large and small silos were comparable.

The chemical composition and IVDMD of the different herbages and silages are presented in Tables 1 and 2. Fermentation characteristics are presented in Tables 3 and 4.

Grain sorghum herbage and silage compared favourably with MA in terms of chemical composition (Tables 1 and 2). Contents of CP ($P < 0,01$), TP ($P<0,05$), ADF ($P < 0,05$) and ADF-N ($P < 0,01$) were higher in GS herbage. Both IVDMD and WSC content were lower ($P < 0,01$) in GS herbage. Values for TP and ADF-N were no longer different in the respective silages. The increase in NPN was larger in GS (approximately 23% units) than in MA (approximately 20% units) resulting in a significant difference in the silages. Foreign research regarding GS, determined CP contents lower or equal to those of the current study (Reames, Stallcup & Thurman, 1961; Owen *et al.*, 1962; Garret & Worker, 1965; Browning & Lusk, 1966 & 1967; Johnson, DeFaria & McClure, 1971; Smith, Bolsen, Pope & Hoover, 1986). Dry matter digestibilities cited were generally 3 to 4% units lower than the values presented in Tables 1 and 2 (Ramsey, Lusk & Miles, 1961; Reames *et al.*, 1961; Fox, Klosterman, Newland & Johnson, 1970).

The low WSC content of the GS herbage is ascribed to the stage of maturity of the grain. Johnson *et al.* (1971) state that WSC content decreased from 15% during the milk stage to 4% during the dough stage due to the translocation of nutrients for starch production. Later ensiling may, therefore, lead to low lactic acid production and poor preservation due to a lack of WSC (Whittenbury *et al.*, 1967).

Adewakun & Felix (1986) found that, despite differences in chemical composition and IVDMD, GS and MA silages, supplemented with soybean meal, supported similar average

Table 1 The dry matter content, *in vitro* dry matter digestibility and chemical composition of maize, grain sorghum, forage sorghum and sunflower herbage

Chemical component		Crop MA[2] 1	GS[3] 2	FS[4] 3	SF[5] 4	Significance[1]	Least significant difference $P < 0,05$	$P < 0,01$
Dry matter (DM)	(%)	27,39	30,23	29,91	12,54			
In vitro dry matter digestibility	(%)	74,88	61,43	54,48	70,19	1>2,3,4** 4>2,3** 2>3**	1,65	2,24
Crude protein	(% DM)	8,38	9,16	6,95	13,57	1,2,4>3** 4>1,2** 2>1**	0,27	0,36
True protein	(% DM)	5,69	6,06	4,64	7,12	4>1,2,3** 1,2>3** 2>1*	0,28	0,38
Acid detergent fibre	(% DM)	31,05	33,40	38,02	37,31	1,2<3,4** 1<2**	1,78	2,43
Water soluble carbohydrates	(% DM)	12,13	6,36	6,35	10,20	1>2,3,4** 2,3<4**	1,13	1,54
Acid detergent insoluble nitrogen	(% of Total N)	11,30	14,50	24,08	20,43	3>1,2,4** 4>1,2** 2>1**	2,06	2,81
Non-protein nitrogen	(% of Total N)	32,68	33,40	33,23	48,11	4>1,2,3**	2,91	3,97

[1] Significance ** Highly significant $P < 0,01$
* Significant $P < 0,05$
[2] MA – Maize
[3] GS – Grain sorghum
[4] FS – Forage sorghum
[5] SF – Sunflower

Table 2 The dry matter content, *in vitro* dry matter digestibility and chemical composition of maize, grain sorghum, forage sorghum and sunflower silage

Chemical component		MA[2] 1	GS[3] 2	FS[4] 3	SF[5] 4	Significance[1]	Least significant difference $P < 0,05$	$P < 0,01$
Dry matter (DM)	(%)	28,62	31,50	30,35	13,51			
In vitro dry matter digestibility	(%)	72,94	60,18	53,26	70,83	1,4>2,3** 3<2,3**	2,17	2,96
Crude protein	(% DM)	8,23	9,42	7,26	13,55	1,2,4>3** 1,2<4** 1<2**	0,43	0,58
True protein	(% DM)	4,03	4,12	3,68	6,59	1,2,3<4** 1,2>3**	0,13	0,17
Acid detergent fibre	(% DM)	29,49	32,88	38,58	35,20	1,2,4<3** 2,4>1** 4>2*	1,81	2,47
Water soluble carbohydrates	(% DM)	5,76	2,46	1,95	3,58	2,3,4<1** 3<4** 2<4*	1,06	1,45
Acid detergent insoluble nitrogen	(% of Total N)	9,38	9,38	16,61	11,77	1,2,4<3** 1,2<4**	0,42	0,57
Non-protein nitrogen	(% of Total N)	52,72	56,16	49,20	51,01	2>3,4** 2>1* 3<1*	3,30	4,50

[1] Significance ** Highly significant $P < 0,01$
* Significant $P < 0,05$
[2] MA – Maize
[3] GS – Grain sorghum
[4] FS – Forage sorghum
[5] SF – Sunflower

daily gains, feed efficiency and DM intakes in growing beef steers.

Fourty-eight hours after ensiling, there were no differences ($P > 0,05$) in pH, LA and NH_3-N contents of MA and GS silages (Table 3). On completion of the 10 week ensilage period, however, the pH and NH_3-N content of MA was lower ($P < 0,01$) than that of GS (Table 4). The low pH (4,14) of GS silage, combined with the presence of residual WSC (Table 2), shows that the herbage contained sufficient WSC to effectively preserve the silage. The LA content of the two silages did not differ significantly ($P > 0,05$), despite a significant difference in pH. The LA content was below the recommended minimum of 8% in both silages, but both were well preserved in terms of recommended pH values. The criterion of an NH_3-N content below 10% in well-preserved silage (Haigh, 1987), suggests that preservation was less efficient in GS than in MA. The higher levels of NPN (Table 2) and NH_3-N (Table 4) suggest that protein degradation was more extensive in GS silage. Reames *et al.* (1961) and Johnson *et al.* (1971) reported well-preserved GS silages with pH values between 3,72 and 4,20.

Forage sorghum herbage and silage did not compare favourably with the MA equivalents (Tables 1 and 2). Both CP and TP were lowest ($P < 0,01$) in FS combined with the highest ($P < 0,01$) ADF-N content. The IVDMD was lower ($P < 0,01$) for FS herbage and silage than the MA equivalents. The low IVDMD of FS silage is associated with a high ($P < 0,01$) ADF content in the same crop. The content of WSC was similarly low in both FS and GS.

The results presented by Black *et al.* (1980) correspond closely to the results obtained in this study. Owen *et al.* (1962), Webster (1963) and Axe & Bolsen (1984) report CP values ranging from 8,64 to 14,40% in FS silages. In con-

Table 3 The pH and fermentation characteristics of maize, grain sorghum, forage sorghum and sunflower silage ensiled for 48 h

Fermentation characteristics		MA[2] 1	GS[3] 2	FS[4] 3	SF[5] 4	Significance[1]	Least significant difference $P < 0,05$	$P < 0,01$
pH		4,43	4,52	4,61	5,59	1,2,3<4** 1<3**	0,13	0,17
Lactic acid	(% DM)[6]	2,10	2,21	1,83	2,62	1,2,3<4** 3<2** 3<1*	0,24	0,37
Ammonia nitrogen	(% of Total N)	15,56	16,90	18,08	15,63	1,4<3**	1,64	2,24

[1] Significance ** Highly significant $P < 0,01$
* Significant $P < 0,05$
[2] MA – Maize
[3] GS – Grain sorghum
[4] FS – Forage sorghum
[5] SF – Sunflower
[6] DM – Dry matter

Table 4 The pH and fermentation characteristics of maize, grain sorghum, forage sorghum and sunflower silage ensiled for 10 weeks

Fermentation characteristics		Crop MA[2] 1	GS[3] 2	FS[4] 3	SF[5] 4	Significance[1]	Least significant difference $P<0,05$	$P<0,01$
pH		3,92	4,14	4,24	4,18	1,2,4<3** 1<2,4** 2<4*	0,04	0,05
Lactic acid	(% DM)[6]	7,32	7,10	6,75	20,24	1,2,3<4** 3<1*	0,51	0,70
Butyric acid	(% DM)	0,042	0,051	0,061	0,183	1,2,3<4**	0,025	0,033
Acetic acid	(% DM)	1,09	0,99	1,09	1,78	1,2,3<4**	0,22	0,30
Total volatile fatty acids	(% DM)	1,85	1,84	1,85	4,30	1,2,3<4**	0,42	0,57
Ammonia nitrogen	(% of Total N)	9,68	12,19	11,89	18,13	1,2,3<4** 1<2,3**	0,73	0,99

[1] Significance ** Highly significant $P<0,01$
* Significant $P<0,05$

[2] MA – Maize

[3] GS – Grain sorghum

[4] FS – Forage sorghum

[5] SF – Sunflower

[6] DM – Dry matter

trast, the CP content of FS harvested at the hard dough stage was as low as 4,7% (Wright & Shaw, 1926, Owen & Webster, 1963). Garret & Worker (1965) and Choe, Moon & Ko (1986) reported CP contents of 5,9 and 6,4 in FS silage, respectively.

After 48 hours the pH and NH_3-N content of ensiled FS was higher ($P<0,01$) than MA. In fact, FS silage had the highest NH_3-N content (Table 3) and the lowest LA content.

At the completion of the ensilage period (10 weeks), the pH was highest (4,24) in the FS silage ($P<0,01$). According to the limits expressed by McDonald *et al.* (1973), the possibility exists that FS was not sufficiently preserved. According to TVFA and individual fatty acid content (Table 4) preservation was satisfactory and compared well with the contents of MA. A high level of butyric acid is indicative of spoilage but was not in evidence here. Reames *et al.* (1961) and Black *et al.* (1980) reported pH values of 3,53 and 4,50 in FS silage. The ammonia-nitrogen content was slightly above 10% of total N (Haigh, 1987) which indicates a slightly less efficient LA fermentation. The LA content was low ($P<0,05$) in FS silage (6,75%). Black *et al.* (1980) recorded LA contents of 20,7% in FS silage with a pH of 3,53 and a DM content of 27,4%. It is questionable whether a silage with this composition would be acceptable to animals due to the acidity.

Sunflower herbage and silage contained only about 40% of the DM content of the other silages. It was therefore to be expected that it would react differently during ensilage. The content of CP and of NPN (Table 1) was highest ($P<0,01$) in sunflower herbage. The change in NPN level during ensiling was much lower in this silage than in the others (approximately 3% units *vs* approximately 20% units in the other silages). It appears that sufficient NPN was available to the bacteria during fermentation without further degradation of protein. A high ($P<0,01$) content of ADF is combined with a high ADF-N content in SF herbage but the latter was markedly lower in the silage. It appears that the ADF fraction in SF herbage is partially susceptible to the microbiological processes in silage. Both the ADF and ADF-N contents decreased during ensiling. The IVDMD of SF silage is comparable to that of MA silage.

Edwards *et al.* (1978) ensiled SF at the milky seed stage, which resulted in silage with 12,6% DM, 13,1% CP and an IVDMD of 67,6%. These results correlate closely with the results presented in Table 2. A number of authors reported CP values between 10,3 and 13,2% and ADF values between 33,0 and 37,0 (McGuffey & Schingoethe, 1980; Schingoethe, Skyberg & Rook, 1980; Harper *et al.*, 1981; Thomas *et al.*, 1982). A number of researchers, working with dairy and beef cattle, found that supplemented SF and MA silages gave similar results in terms of milk production, average daily gain and feed efficiency (Vandersall & Lanari, 1973; Vandersall, 1976; Schingoethe *et al.*, 1980; Kercher, Jackson & Smith, 1983; Kercher, Smith & Jackson, 1985).

In terms of fermentation, SF silage reacted somewhat differently to the other silages due to its high moisture content. After 48 h (Table 3), SF silage had a pH of 5,59 despite having the highest ($P<0,01$) LA content. The high moisture content tends to dilute the acids, thereby raising requirements to reduce pH. Despite the high pH the NH3-N content of the SF silage did not differ ($P>0,05$) from that of MA silage at this stage of fermentation.

After 10 weeks (Table 4), the pH of SF silage was higher ($P<0,01$) than that of MA, but it was sufficiently low (4,18) to be effectively preserved. Sunflower silage contained the highest ($P<0,01$) levels of all determined fatty acids. The high level of LA and the presence of residual WSC (Table 2) show that fermentation was predominantly favourable. The increased levels of the other fatty acids are the result of a slow pH decline (Table 3), which allows bacteria, other than lactic acid producing bacteria, to remain active for a longer period of time. The NH_3-N content of SF silage was also the highest ($P<0,01$), resulting from more extensive N catabolism. Despite the difference in fermentation, the SF silage was well preserved and of a high nutritional quality based on chemical parameters.

Other researchers reported pH values between 3,86 and 4,46 in SF silage (Edwards *et al.*, 1978; Schingoethe *et al.*, 1980). Edwards *et al.* (1978) and Harper *et al.* (1981) recorded LA contents of 10,5 and 12,5 in SF silages with DM contents of 12,6 and 14,3%, respectively. These results were obtained in large scale silos where leaching of LA may have occurred. Schingoethe *et al.* (1980) reported an LA content of only 5,9% in SF silage with a 32,4% DM content. It appears that SF silage, ensiled at a similar DM content as is indicated for MA, might not preserve satisfactorily.

Conclusions

In this trial, the silage that was most efficiently preserved was MA. Of the initial WSC content, 52% was utilized during ensilage, whilst between 62 and 70% was utilized in the other crops. the lowest pH was attained by maize silage despite this limited use of WSC which is indicative of more efficient preservation.

Based on chemical parameters, GS silage was found to be nutritionally comparable to MA silage, with the exception of a lower IVDMD. The silage was well preserved and reacted to ensilage in much the same way as MA. Grain sorghum is definitely worth considering as an alternative silage crop where the cultivation of MA is a risk. Grain sorghum has the potential to play an important role in animal nutrition in the form of silage.

The combination of a low CP content and high ADF-N content in FS silage makes protein supplementation a prerequisite in this feed. The high ADF content and low IVDMD makes FS a medium to low quality roughage which could possibly be used in maintenance rations or as a source of fibre in high concentrate finishing rations. The silage did not preserve as efficiently as MA or GS. Ensiling both FS and GS removes the danger of prussic acid poisoning and preserves the feed for winter utilization.

Sunflower silage compared most favourably with MA silage in terms of nutritional quality. The high CP content and IVDMD makes this silage a good alternative to MA. A problem arises, however, with the high moisture content which, by itself, causes excessive rumen fill, restricting DM intake. The high levels of fatty acids raise the question of palatability and acceptability which may also restrict DM intake. Nutrient losses through leaching could also occur in large-scale silos. This is, however, not reported by researchers. Drainage in large silos would be important to remove effluent arising from the wet silage.

These results are all laboratory-based. Feeding trials would be required to test the animal response to the various silages. This trial indicates that all the crops examined could form an alternative feed source provided the animal response is satisfactory.

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