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THE FEEDING VALUE ASSESSMENT OF FORAGE FROM SOME C-4 GRASS SPECIES IN DIFFERENT PHASES OF VEGETATION. PART II. *MISCANTHUS SACCHARIFLORUS* (MAXIM.) HACK.

ABSTRACT

Chemical composition of forage from silver banner grass, *Miscanthus saccharifloru*s (Maxim.) Hack. was determined in different phases of vegetation. Plants were grown in Botanical Garden of PBAI in Bydgoszcz and analysis were done in Department of Animal Nutrition and Feed Management Economy, Faculty of Animal Breeding and Biology of University of Technology and Agriculture in Bydgoszcz. Along with plant growth and development, significant changes of some components were observed. Crude protein content in dry matter at the beginning of earing and flowering phase was significantly lower as compared to vegetative phase. As opposite to above, structural carbohydrates contents (crude fiber, neutral detergent fiber, acid detergent fiber) were significantly higher during beginning of heading and flowering phase. Statistically significant increase of water soluble carbohydrates content in forage dry matter was noted at the beginning of flowering as compared to earlier phases. Tested species ensiled easy at all vegetative phases. The quality of silage was good or very good, excluding silage with addition of chemical inoculants (MIII). Silage during oxygenic phase was stable. Our results suggest possible forage use of *Miscanthus* biomass.

Key words: aerobic stability, *Miscanthus sacchariflorus*, chemical composition, quality, silage stage of vegetation

INTRODUCTION

Grass species from C-4 carbon fixation group (like *Miscanthus sacchariflorus*) are natural element of Southeast Asian flora. Such grasses can be used as a forage for animals (Ogura *et al.*, 1999; Ogura *et al.*, 2001). In Japan, cattle prefer *Miscanthus* and it is controlled in fields by allowing cattle to graze beginning in June. Heavy grazing is a known method in Japan for con-

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trolling *Miscanthus*. It is perennial and rhizomatous species. Tall reed or cane-like plants grow up to 150-250 cm (Watson and Dallwitz, 1992).

Miscanthus sacchariflorus was introduced in Europe many years ago mainly for its decorative value and in Poland and Germany it was tested for energetic (Majtkowski and Majtkowska, 1998; Lewandowski *et al.*, 2000) and forage purposes (Lewandowski *et al.*, 2000). The efficiency of water, nitrogen and other components are higher for C-4 grasses then for C-3 grass species (Nalborczyk, 1996). It is therefore possible that *Miscanthus sacchariflorus* could be an alternative forage source in regions of high water deficit during vegetation.

The aim of above work was to determine the chemical composition and ensilage ability of *Miscanthus sacchariflorus* grown in climatic conditions of Poland during different phases of development as well as quality and oxygenic stability of silage.

MATERIALS AND METHODS

Plants were planted at spring 1998 on the lessives soil in distance of 0.15 – 0.20 m between plants (0.25 m between rows). Total area of *Miscanthus* plantation was ca. 55 m^2. No additional treatments (fertilization, watering etc.) were used. During three consecutive years (2003, 2004, 2005) forage was collected at following phases of development:

— vegetative phase (VS) – at 78 (±7) days of vegetation (days starting from 1st April),

— beginning of earing (BE) – at 150 (±8) days of vegetation,

— beginning of flowering (BF) – at 167 (± 4) days of vegetation.

Details of weather conditions during experiment were described by Piłat *et al.* (2007).

Green forage was collected randomly from 3 points on plantation, each point of 1 m^2. Forage was cut by hand collector ca. 3 cm above ground. Further analysis were performed in Department of Animal Nutrition and Feed Management Economy, Technical and Agricultural University in Bydgoszcz.

After drying, amount of following components and coefficients were determined according the same procedures as given by Piłat *et al* (2007): dry matter (DM), organic matter (OM), crude protein (CP), crude fat (CT), crude fiber (CF), nitrogen-free extracts (NFE), structural carbohydrates: neutral detergent fiber (NDF) and acid detergent fiber (ADF), hemicelluloses (HEM), water soluble carbohydrates (WSC), buffer capacity of forage (BC) and forage fermentation coefficient (VK). Forage with supplements (Table 1) was ensiled (3 replications per one supplement) and further analyzed in the same way as in Piłat *et al.* (2007).

Table 1

Ensilage supplements used in above experiment

Supplement	Main components of supplement
Without supplement (M I)	—
Chemical supplement (M II)	Formic acid 55% Formate ammonium 24% Propionic acid 5% Other organic acids 2% Water 14%, colouring substance E150d
Microbiological supplement (M III)	Lactic acid bacteria - min. 10×10^9 CFU per g of substance
Microbiological - enzymatic supplement (M IV)	Micobiological part: lactic acid bacteria - min. 6.7×10^9 CFU/g Enzymatic part: cellulase - min. 43000HEC/g

Obtained data were analyzed with SAS® statistical package (SAS Institute, 2004 a, b). Tukey's Honestly Significant Differences (HSD) test was used for testing the significance of unplanned pairwise comparisons between means.

RESULTS

Dry matter contents of *Miscanthus* forage during vegetative phase reached 23.2% (Table 2). Further plant development yielded in increase of dry matter from 34.7% (before earing) to 44% (during beginning of flowering). Forage consisted of 12% of crude protein (CP) and during plant growth significant decrease ($p<0.05$) was observed to ca. 6.0% at the beginning of earing and at the beginning of flowering. CP content during vegetative phase was similar to values noted for *Dactylis glomerata* (10.90%) by Yahaya *et al.* (2001). Average CP content in *Phleum pratense* forage dry matter ranged from 9.45% (at first cut) to 16.12% at second cut (Łyszczarz *et al.* 1998). Similar values were also noted for *Festuca pratensis*, where CP content ranged from 12 to 15% of forage dry matter (Filipek and Kasperczyk, 1992).

Crude fiber content during vegetative phase equals 29.89% of *Miscanthus* forage dry matter and significantly ($p<0.05$) increased during further plant development. The highest value was noted at the beginning of earing (38.29%) and lower values at the beginning of flowering (35.81%).

Nitrogen-free extracts content during vegetative phase reached 48.8% (Table 2) and during further development slightly increased from 50.15% at beginning of earing to 52.39% at the beginning of flowering. No significant difference was noted between above values. Neutral detergent fiber (NDF) content during vegetative phase (64.89%) was significantly lower ($p<0.05$) than at the beginning of earing (71.42%) and beginning of flowering (71.01%). Similar relation was noted for acid detergent fraction (ADF), where during vegetative phase it reached 31.11% of forage dry matter and significantly ($p<0.05$) increased during further development.

Table 2

Chemical composition of *Miscanthus sacchariflorus* forage during different phases of vegetation

Trait measured	Phase of vegetation:		
	VS	BE	BF
DM [%]	23.19	34.78	43.96
Contents in dry matter			
OM *	93.01	95.83	95.61
CP	11.99 [a]	5.98 [b]	5.93 [b]
CT	2.33	1.41	1.48
CF	29.89 [a]	38.29 [b]	35.81 [b]
NFE	48.8	50.15	52.39
NDF	64.89 [a]	71.42 [b]	71.01 [b]
ADF	32.11 [a]	41.99 [b]	40.32 [b]
HEM	32.78	29.43	30.69
WSC	7.97 [a]	7.55 [a]	9.80 [b]
BC (g $C_3H_6O_3$ × 100 g DM^{-1})	4.69	2.9	2.86
WSC/BC	1.84	2.62	3.42
VK	41.22	55.71	71.28

* - explanation of symbols see in text
Values in rows marked with different letters differ significantly a, b,....p<0,05
Otherwise, means in rows are not statistically different

No significant difference was noted for hemicellulose (HEM) content. It ranged from 32.78% of forage dry matter at vegetative phase to 30.69% at the beginning of flowering. Yahaya and co-authors (2001) noted lower level of NDF (55.8%) and HEM (23.7%) in dry matter of *Dactylis glomerata*. On the other hand, ADF content at the vegetative phase was similar for *Dactylis glomerata* and *Miscanthus* (Yahaya *et al.* 2001).

Structural carbohydrates content was lower for corn forage as compared to *Miscanthus*. At the early dent phase 55.6% of NDF, 35.4% of ADF and 20.20% of HEM were noted in corn forage dry matter (Filya 2004). According to Filipek and Kasperczyk (1992) forage dry matter of *Festuca pratensis* consist of 62.32% of NDF and 34.82% of ADF.

Water soluble carbohydrates (WSC) level was variable during vegetation. It was lower during vegetative phase and beginning of earing (7.97% and 7.50% of forage dry matter, respectively). Further, while plants reached flowering phase, WSC significantly increased up to 9.80% of forage dry matter. It was similar to values for other forage grass species, where WSC contents ranged from 6.37% to 8.53% of forage dry matter (Janicki and Piłat 1998). Higher values were given by Podkówka (2001) from 9.35% for *Phleum pratense* to 9.79% for *Lolium perenne* first-cut forage dry matter and by Yahaya *et al.*

(2001) for *Dactylis glomerata* – 9.5%. Rather high value was also noted for corn - 11% of WSC in forage dry matter (Meeske and Bason 1998).

Buffer capacity (BC) of *Miscanthus* forage was strongly related to growing phase and reached the highest value at the vegetative phase – 4.69 g of lactic acid / 100g of dry matter. Further, it dropped to 2.90 g of lactic acid per 100 g of dry matter during earing and flowering phases. Differences between above values were not significant. Values noted for *Miscanthus* forage were lower then for other forage grasses and similar for corn. According to Janicki and Piłat (1998) BC of forage grasses ranged from 6.12 to 6.35 g of lactic acid per100 g of dry matter and of corn forage - from 2.54 to 2.92 g of lactic acid per100 g of dry matter.

Water soluble carbohydrates to buffer capacity quotient (WSC/BC) for *Miscanthus* forage was different in different phases. During vegetative phase it was similar to values given by Podkówka (2001), where in dry matter of forage from first cut of *Festulolium* it was 1.84. Janicki and Piłat (1998) suggested that WSC/BC may vary from 1.00 to 1.37 for grasses. Along with plants growth, WSC/BC linearly increased from 2.62 (beginning of earing) to 3.42 (beginning of flowering). It is opposite to results given by Podkówka (2001), where during experiments on ensilage ability of common pasture grasses (*Phelum pratense, Lolium perenne* and *Festulolium*) decrease of WSC/BC was observed during plant development. It changed from 1.91 for first cut, 1.37 for second cut and 1.23 for third cut of *Lolium perenne.*

Forage fermentation coefficient (VK) also increased linearly during plant growth and development – from 41.22 at the vegetative phase to more than 71 at flowering. It is claimed that VK higher than 35 ensure correct fermentation (Weissbach 1998).

Dry matter content of silages ranged from 24.25 (control silage, M I) to 26.15% (silage with M II) and CP content ranged from 10.09% (silage with M III) to 11.07% (M II) (Table 3). Above differences were not significant. Content of CP in silages made from *Miscanthus* forage was similar to values obtained by Yahaya *et al.* (2001) for corn silage – CP = 10.9% of dry matter. Filya (2004) noted that CP content ranged from 5.8% to 8.0% in corn silages at different stages of maturity. Similar values of CP (8%) for corn silages were also reported by Anil *et al.* (2000).

Crude fiber contents in silages with different supplements were similar and ranged from 35.77% (M II) to 36.69% (M I). Neutral detergent fiber (NDF) contents ranged from 59.43% (M II) to 60.85% (M I). Different silage supplements had no significant effect on crude fiber and NDF contents in dry matter of tested silages.

Silages with chemical supplement (M II) had significantly lower ($p<0.05$) level of ADF as compared to silages with microbiological supplement (M II). Anil *et al.* (2000) reported lower level of NDF (46.9%) and ADF (21.7%) in dry matter of corn silage than in *Miscanthus*. Silage supplements had no effect

on hemicellulose and nitrogen free extracts contents in dry matter of silage made from *Miscanthus* (Table 3).

Table 3

Chemical composition of silages from *Miscanthus sacchariflorus* with different supplements

Supplement	DM [%]	Content in dry matter [%]							
		OM	CP	CT	CF	NDF	ADF	HEM	NFE
Green forage									
—	25.54	93.39	11.97	2.56	34.38	63.24	33.05	30.19	44.48
Silages									
MI	24.25	92.02	10.86	3.25	36.96	60.85	36.6 ab	24.25	40.95
MII	26.15	91.66	11.70	2.50	35.77	59.43	35.23 b	24.20	41.69
MIII	25.74	91.77	10.09	2.76	36.80	60.68	37.65 a	23.02	42.12
MIV	25.39	91.48	10.92	2.50	36.07	60.15	36.67 ab	23.49	41.99

Values in the same columns marked with different letters differ significantly a,b, ab - $p<0,05$.
Otherwise, means in columns are not statistically different

Acidities of silages (pH) were similar for all supplements and ranged from 4.34 (M I) to 4.55 (M III) (Table 4). Silages with microbiological supplement (M III) had significantly higher ($p<0.01$) contents of ammonia than silage without supplement.

Table 4

Quality of silages from *Miscanthus sacchariflorus* forage with different supplements

Supplement	pH	$N\text{-}NH_3$	Acid content [%]			Flieg-Zimmer evaluation	
			Lactic	Acetic	Butyric	Scores	Quality
MI	4.54	0.0210 ^{b}	1.46	0.77	0.03	77	Good
MII	4.34	0.0231 ^{ab}	1.53	0.76	0.00	79	Good
MIII	4.55	0.0742 ^{a}	1.11	0.60	0.03	57	Satisfactory
MIV	4.53	0.0492 ^{ab}	1.43	0.62	0.02	82	Very good

Values in the same columns marked with different letters differ significantly a,b, ab - $p<0,01$.
Otherwise, means in columns are not statistically different

Silage supplements had no significant effect on ensilage profile and silages had similar level of volatile fatty acids. Lactic acid content ranges from 1.11% (M III) to 1.46% (MI), acetic acid content ranges from 0.60% (M III) to 0.77% (MI). Silage with chemical supplement (M II) was free from butyric acid and in other silages only traces of this acid were found (Table 4). Meeske and Basson (1998) reported lower lactic acid content in corn silage with microbiological supplement as compared to silage without supplement.

Silage evaluation, according to Flieg-Zimmer scale gave range of quality from very good (silage with M IV), good (control silage and M II) and satisfactory (silage with M III).

Silages were stable during oxidative test (Fig. 1) and supplements had no effect on theirs stability. However, during initial 5 days of incubation temperature increase was higher in silage without supplement (0.27°C per a day) and slowest for silage with chemical supplement (0.03°C per day). It was proved by Pahlow and Weissbach (1999) that chemical supplements resulted in silage stability to 3 days, while microbiological supplements to more than 7 days. Silages without supplements were stable only for 1.5 day.

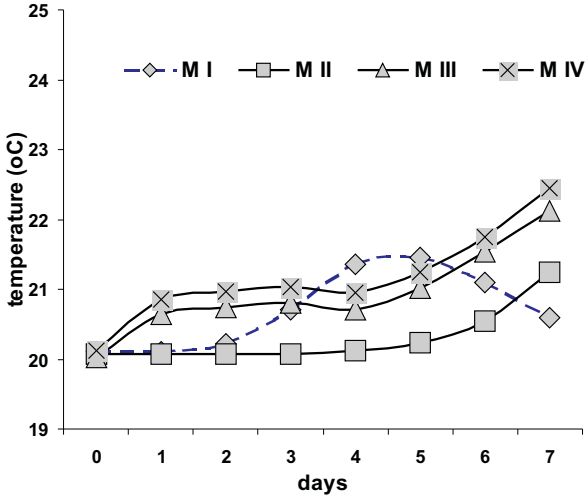

Fig. 1. Average age temperatures of silages during incubations period (ambient temperature 20°C ± 1°C)

In Tokayashi *et al.* 1999 (after Zastawny and Jaśniewicz 2000) experiments on *Dactylis glomerata* silage, temperature raised slowly up to 7 days of incubation. Temperature in silages from other grasses raised at the second day over the temperature of surrounding environment (30°C) (Ostrowski *et al.* 1992). Moreover, temperature in silages from pre-dried forage raised slower than in silages from fresh forage. It has been also proved by Pflaum (2003) that silages stored in anaerobic conditions were much more stable, even without supplements. Microbiological supplement had no effect on silages stability while chemical supplement increased stability and microbiological – chemical had medium activity. Better activity of supplements, especially with *Lactobacillus buchneri*, is connected with the time of silage storage. Silage containers should be opened 2 – 3 months after silage was prepared.

CONCLUSIONS

The value of water soluble carbohydrates to buffer capacity quotient of *Miscanthus sacchariflorus* forage during different phases of vegetation indicated the right course of fermentation of ensiled material.

High water soluble carbohydrates content in *Miscanthus* forage dry matter indicated the possibility to ensile during later phases of vegetation.

The ensiling suitability of *Miscanthus* is similar to common C-3 forage grasses, therefore biomass from examined species could be also suitable as source for animal feeding.

REFERENCES

Anil L., Park J., Phipps R.H. 2000. The potential of forage maize intercrops in ruminant nutrition. Animal Feed Science and Technology 86: 157-164.

Collective work.1991. Ćwiczenia z żywienia zwierząt i paszoznawstwa. AR Kraków, ss.240.

Filipek J., Kasperczyk M. 1992. Wartość pastewna kostrzewy łąkowej, kupkówki pospolitej, tymotki łąkowej i życicy wielokwiatowej. Zeszyty Naukowe AR Kraków 265, Rolnictwo 30: 173-181.

Filya I. 2004. Nutritive value and aerobic stability of whole crop maize silage harvested at four stage of maturity. Animal Feed Science and Technology 116: 141-150.

Janicki B., Piłat J. 1998. Wpływ różnych dodatków do zakiszania na wartość pH kiszonek sporządzonych z traw i motylkowatych oraz kukurydzy o zróżnicowanej zawartości suchej masy. Zeszyty Problemowe Postępów Nauk Rolniczych 462: 403-408.

Lewandowski I., Clifton-Brown J.C., Scurlock J. M. O., Huisman W. 2000. *Miscanthus*: European experience with a novel energy crop. Biomass and Bioenergy 19: 209-227.

Łyszczarz R., Podkówka Z., Dembek R., Kochanowska-Bukowska Z., Dorszewski P., Sikorra J., Zimmer-Grajewska M.. 1998. Ocena wartości gospodarczej polskich odmian życicy trwałej. Zeszyty Problemowe Postępów Nauk Rolniczych 462: 67-74.

Majtkowski W., Majtkowska G. 1998. Introdukcja pozaeuropejskich gatunków traw na tereny parkowe i zdegradowane. Biuletyn Ogrodów Botanicznych, Muzeów i Zbiorów 7: 117-122.

Meeske R., Basson H.M. 1998. The effect of a lactic acid bacterial inoculant on maize silage. Animal Feed Science and Technology 70: 239-247.

Nalborczyk E. 1996. Nowe rośliny uprawne i perspektywy ich wykorzystania. W: Praca zbiorowa. Nowe rośliny uprawne na cele spożywcze, przemysłowe i jako odnawialne źródła energii. SGGW Warszawa: 5 - 20.

Ogura S., Kosako T., Hayashi Y., Dohi H. 1999. Effect of eating mastication on *in vitro* ruminal degradability of *Zoysia japonica, Miscanthus sinensis* and *Dactylis glomerata*. Grassland Science 45 (1): 92 - 94.

Ogura S., Kosako T., Hayashi Y., Dohi H. 2001. Is sacco ruminal degradation characteristics of chemical components in fresh *Zoysia japonica* and *Miscanthus sinensis* growing japanese native pasture. Asian-Aust.J.Anim.Sci.14, 1: 41 - 47.

Ostrowski R., Daczewska M., Podkówka W. 1992. Zmiany składu chemicznego i straty suchej masy w różnych kiszonkach podczas ich wtórnej fermentacji. Roczniki Naukowe Zootechniki 2: 201 - 209.

Pahlow G., Weissbach F. 1999. New aspects of evaluation and application of silage additives. Contributions of Grassland and Forage Research to the Development of Systems of Sustainable Land Use, Landbauforschung Völkenrode, Wissenschaftliche Mitteilungen der Bundesforschungsanstalt für Landwirtschaft (FAL), Sonderheft 206: 141 - 158.

Pflaum J. 2003. The influence of additives and storage time on the aerobic stability of maize silage. Proceedings – Plenary papers, 11th International Symposium "Forage Conservation", 9th-11th September 2003, Nitra, Slovak Republic.

Piłat J., Majtkowski W., Majtkowska G., Żurek G., Mikołajczak J., Buko M. 2007. The feeding value assessment of forage from few C-4 grass species in different phases of vegetation. Part I. *Andropogon gerardii* Vitman. Plant Breeding and Seed Science, (in press)

Podkówka L. 2001. Wartość pokarmowa oraz ocena przydatnosci do zakiszania zielonek z *Phelum pratense, Lolium perenne* i *Festulolium*. Rozprawa doktorska, ATR Bydgoszcz, ss.88.

SAS Institute Inc. 2004 a. SAS 9.1 Companion for Windows. Cary, NC, USA, SAS Publishing, SAS Institute Inc.

SAS Institute Inc. 2004 b. SAS/STAT 9.1 User's Guide. Cary, NC, USA, SAS Publishing, SAS Institute Inc.

Watson, L., and M. J. Dallwitz. 1992. Grass Genera of the World: Descriptions, ilustrations, identification, and information retrieval; including synonyms, morphology, anatomy, physiology, phytochemistry,

cytology, classification, pathogens, world and local distribution, and references. http://biodiversity.uno.edu/delta/. version: 18th August 1999.
Weissbach F. 1998. Bestimmung der Pufferkapzität, Materiały Institut für Grünland und Futterpflanzenforschung FAL Braunschweig, ss.3.
Weissbach F. 1998. Über der Einfluss von verschiedenen kräutern in aufwuchs extensiv genutzter wiesen auf den gärungsverlauf bei der bereitung von grassilagen. Zeszyty Problemowe Postępów Nauk Rolniczych 462: 297-313.
Yahaya M.S, Kimura A., Harai J., Nguyen H.V., Kawai M., Takahashi J., Matsuoka S. 2001. Effect of lenght of ensiling on silo degradation and digestibility of structure carbohydrates of lucerne and orchardgrass, Animal Feed Science and Technology 92: 141-148.
Zastawny J., Jaśniewicz P. 2000. Jakość i stabilność kiszonek. Przegląd Hodowlany 4: 20 - 25.