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ADAPTIVE FORAGE STRATEGY IN CENTRAL EUROPE

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ABSTRACT

Climate change has become even more pronounced in dry continental Central Europe. Intense, high-sugar grasses (Lolium multiflorum, Festulolium-type grass hybrids) and whole-crop winter cereals such as rye (Secale cereale) cut in early spring minimise weather risk. Early spring harvesting allows double cropping having many environmental benefits for dairy farms. This offers a promising opportunity to mitigate climate change risks and minimise maize yield losses. Early cut whole-crop cereals and intensive grasses can therefore be part of a new forage strategy. The use of novel crop rotation systems such as maize and whole-crop rye, maize or brown midrib (BMR) sorghum and intensive grasses has proven to be very effective in the reduction of climate change-induced yield losses in arid continental areas. Hungary has been developing this strategy since 2008. Now, a 10-year Near Infrared (NIR) database is available on the fundamental forages of the new climate change strategy. The authors aimed to describe the nutritional value of the early cut whole crop rye (Secale cereale) and intensive high sugar grass (Lolium multiflorum, Festulolium-type grass hybrids) silages based on 10-years NIR-database (dry matter, crude protein, soluble protein, crude ash, sugar, fiber fractions, nitrate, organic matter digestibility, NDF-digestibility).

ÖSSZEFOGLALÁS

A száraz kontinentális Közép-Európában az éghajlatváltozás egyre hangsúlyosabbá válik. Az intenzív, szántóföldi termesztésű fűfélék (Lolium multiflorum, Festulolium típusú fűhibridek) és a kora tavasszal betakarított gabonafélék, például a rozs (Secale cereale) minimalizálják az időjárás okozta kockázatot. A kora tavaszi betakarítás lehetővé teszi a kettős termesztést, mely számos környezeti előnnyel jár a tejtermelő gazdaságok számára. Ez ígéretes lehetőséget kínál az éghajlatváltozás kockázatainak mérséklésére és a kukorica termésveszteségének minimalizálására is. Az újszerű vetésforgórendszerek, mint például a silókukorica és a korai betakarítású rozs, a silókukorica vagy a BMR-cirok és az intenzív fűfélék használata igen hatékonynak bizonyult az éghajlatváltozás okozta termésveszteségek csökkentésében a száraz kontinentális területeken. Magyarország 2008 óta fejleszti ezt a stratégiát. Mostanra egy 10 éves NIR-adatbázis áll rendelkezésre az új stratégia alapvető tömegtakarmány-növényeiről. A szerzők célja a korán betakarított rozsból és intenzív termesztésű fűfélékből készült szilázsok táplálóértékének leírása volt a 10 éves NIR-adatbázis alapján (szárazanyag, nyersfehérje, oldható fehérje, nyershamu, cukor, rostfrakciók, nitrát, szervesanyag-emészthetőség, NDF-emészthetőség).

INTRODUCTION

In dry continental Central Europe, climate change has become more pronounced: heat stress, drought and their combinations are more frequent during the summers. Therefore corn production is expected to be difficult due to the variable yields and quality in many European countries (Orosz and Balogh, 2013). Moreover, these extremely dry and hot weather conditions increase the incidence of Aspergillus spp. infections and aflatoxin contamination in corn. A new forage strategy could solve partially this problem. Intensive high–sugar grasses (*Lolium multiflorum*, Festulolium type grass hybrids) and whole-crop winter cereals such as rye (*Secale cereale*) and triticale (x *Triticosecale*), or blends of these forages cut in early spring are minimizing the weather risk and increasing the stability of the forage bank with +5–15 ton DM/ha yields for first cut (Orosz et al, 2014, 2018, 2019; Alemayehu et al, 2020; Auerbach and Theobald, 2020). The intensive grass term is based on the fact that these grasses are grown on arable (good conditions), usually as 1-year-old winter forages and rotated after the 1st or 2nd mowing. Early spring harvesting allows double cropping. Dual-crop combinations such as winter whole crop rye and corn, winter whole crop triticale and corn, high sugar grass and BMR sorghum, can increase on-farm forage production and provide a range of environmental benefits to dairy farms (Ketterings et al, 2015; Ranck et al, 2019). Winter cover crops prevent soil erosion, deflation and nitrogen leakage from September to April (8 months) and give good weed suppression. Whole-crop cereals are recommended to be harvested in the boot stage due to their high fibre digestibility and nutritive value for high-milking dairy cows in intensive systems (Orosz et al, 2014, 2018, 2019; Alemayehu et al, 2020). Better digestibility of neutral detergent fibre has a beneficial effect on dry matter intake in dairy cows (Oba and Allen, 1999).

MATERIAL AND METHODS

Routine laboratory samples derived from large-scale farms in Hungary (early cut whole crop rye silage n = 1379; intensive grass silage n = 910) between 2013–2022. Results based on routine laboratory NIR analyses (Livestock Performance Testing Ltd, Hungary). Dry matter yield, crude nutrient content, fibre fractions (amylase treated NDF on organic matter basis – aNDFom, acid detergent fibre – ADF, acid detergent lignin –ADL), organic matter digestibility detected during 48 hours incubation time in vitro (OMd_{48}), amylase treated and ash corrected NDF rumen degradability with 48 hours incubation time in vitro ($NDFd_{48}$) are given based on the spectra determined by Q-Interline Quant FT-NIR analyser. Samples were dried at 70 °C and ground according to the Guidelines of Samplinq® system (Eurofines Agro, Wageningen, The Netherlands). The EG guideline L54 2009/152 was applied for the determination of moisture content (dry matter determination). Spectra were determined according to the guidelines of NEN-EN-ISO 12099 (Q-Interline Quant FT-NIR analyser, ISO 12099:2010 guidelines for the application of near-infrared spectrometry). Data (Table 1–4) are expressed as mean ± standard deviation (SD). GraphPad InStat 3.05 software (GraphPad Software, San Diego, CA, USA) was used for the statistical evaluation. Data were analyzed by one-way ANOVA and Tukey-Kramer multiple comparison post hoc test ($p < 0.05$).

RESULTS AND DISCUSSION

The variability in nutrient content and digestibility of early-cut whole-crop rye silage is shown in Table 1–2. Data reported are for 2013–2022, based on NIR analysis of 1379 farm samples. The dry matter content averaged 291 g/kg (range of averages over 10 years: 269–320 g/kg DM), combined with an ash content of 106 g/kg (92–119 g/kg). The ideal ash content would be a maximum of 80 g/kg. The measured dry matter and ash content increase the risk for harmful Clostridial fermentation and protein breakdown. Crude protein content averaged 137 g/kg DM (range of averages over 10 years: 130–145 g/kg DM). This is an extreme weakness of our technology, we should achieve an average of at least 150 g/kg DM in the future. It is mainly related to soil quality, forecrops, quantity and distribution of N-fertilisation. Nitrate content averaged 3.5 g/kg DM (range of averages over the 10 years: 2.4–5.6 g/kg DM.) Recommended nitrate content in forages: max. 3 g/kg DM; nitrate in total mix ratio(TMR) max. 5 g/kg DM). The challenge is therefore to achieve both higher protein and lower nitrate content.

Table 1 Nutrient content of early-cut whole-crop rye silage harvested in the period 2013–2022 based on g per 1000 g dry matter (NIR database, n = 1379)

Year of harvest	Sample number	Dry matter	Crude protein	Crude fat	Crude fiber	Ash	Total sugar	Nitrate	Soluble protein
2013	70	294^{abc}	132^{abc}	32^{a}	327^{f}	104^{abc}	19^{a}	5.6^{d}	103^{ab}
2014	144	271^{a}	132^{ab}	34^{a}	313^{e}	98^{ab}	37^{b}	3.4^{b}	105^{ab}
2015	166	313^{c}	132^{ab}	32^{a}	300^{d}	99^{ab}	52^{c}	3.2^{b}	104^{a}
2016	141	288^{ad}	140^{abc}	36^{c}	289^{bc}	113^{cd}	33^{b}	2.7^{ab}	110^{abc}
2017	137	297^{bc}	139^{abc}	36^{c}	275^{b}	119^{d}	40^{b}	3.9^{c}	114^{b}
2018	137	300^{be}	140^{abc}	35^{be}	303^{d}	119^{d}	28^{ab}	4.2^{c}	113^{abc}
2019	126	288^{ab}	144^{bc}	35^{be}	280^{b}	114^{cd}	33^{ab}	4.6^{c}	119^{c}
2020	132	320^{c}	145^{c}	36^{c}	250^{a}	94^{a}	56^{c}	3.4^{b}	118^{c}
2021	151	276^{ab}	133^{ab}	35^{be}	280^{d}	92^{a}	37^{b}	2.6^{ab}	112^{abc}
2022	175	269^{ab}	130^{a}	34^{a}	302^{d}	107^{b}	30^{ab}	2.4^{a}	111^{abc}
2013-2022	1379	291^{b}	137^{abc}	35^{b}	291^{c}	106^{a}	39^{b}	3.5^{c}	111^{bc}

a,b The different letter signs in the columns indicate significant differences in the mean values ($p < 0.05$)

Table 2 Fiber fractions, organic matter and fiber digestibility, net energy content of early-cut wlohe-crop rye silage harvested in the period 2013–2022 based on 1000 g dry matter (NIR database, n = 1379)

Year of harvest	Sample number	aNDFom[1]	ADF[2]	ADL[3]	NDFd$_{48}$[4]	dNDF$_{48}$[5]	OMd$_{48}$[6]	Nel[7]
		g	g	g	%NDF	g	%	MJ
2013	70	607^{f}	363^{d}	32^{d}	63^{ab}	380^{e}	69.2^{a}	5.43^{a}
2014	144	578^{e}	349^{d}	29^{c}	66^{bc}	376^{e}	71.7^{b}	5.57^{ab}
2015	166	560de	329^{c}	25^{b}	66^{c}	368de	72.2^{c}	5.66^{b}
2016	141	535^{bc}	317^{bc}	25^{b}	68^{c}	357^{c}	71.9^{bc}	5.70^{b}
2017	137	516^{bc}	304^{b}	26^{b}	67^{c}	340^{b}	72.1^{bc}	5.64^{b}
2018	137	554^{d}	334^{c}	29^{c}	66^{bc}	362^{cd}	70.2^{ab}	5.53^{ab}
2019	126	529^{bc}	305^{b}	27^{c}	66^{bc}	344^{b}	71.0^{ab}	5.65^{b}
2020	132	488^{a}	268^{a}	21^{a}	67^{c}	324^{a}	73.4^{c}	5.93^{d}
2021	151	532^{bc}	307^{b}	24^{b}	65^{bc}	342^{b}	72.1^{bc}	5.82^{c}
2022	175	562de	331^{c}	26^{b}	62^{a}	347^{bc}	70.6^{ab}	5.57^{ab}
2013–2022	1379	544^{c}	319^{c}	26^{b}	66^{bc}	353^{c}	71.6^{b}	5.66^{b}

[1]aNDFom - amylase treated and ash corrected NDF; [2] ADF – acid detergent fibre; [3]ADL – acid detergent lignin; [4]NDF$_{48}$ – degradability of NDF (48 hours *in vitro* incubation); [5]dNDF$_{48}$ - rumen degradable (amylase treated and ash corrected) NDF (48 hours *in vitro* incubation); [6]OMd$_{48}$ - organic matter digestibility (48 hours *in vitro* incubation); [7] Nel – Net energy for lactation; *abc* Means in the same column with different letters differ statistically ($p < 0.05$)

The low ADL content, the main advantage of the early whole–crop rye silage, averaged 26 g/kg (range of averages over 10 years: 21–32 g/kg DM). The low lignin (ADL) content resulted in an average NDFd$_{48}$ value of 66% (range of averages over 10 years: 62–68% NDFd$_{48}$). But there is still room for improvement. The dNDF$_{48}$ content averaged 353 g/kg (range of averages over 10 years: 324–380 g/kg DM). This is one of the most important parameters for high-milking dairy cows, especially during the summer (fermentable organic matter source in the rumen and main substrate for milk fat synthesis). The digestible fibre content of early-cut whole-crop rye silages is higher by 60% compared to the corn silage (2020 corn silage: 218 g/kg DM dNDF$_{48}$, n = 411).

Nutrient content and digestibility of early-cut intensive grass silages (Lolium multiflorum, Festulolium-type grass hybrids) are shown in Table 3 and Table 4. Data reported are for the period 2013–2022, based on NIR analysis of 910 farm samples.

Table 3 Nutrient content of early-cut intensive grass silage harvested in the period 2013–2022, based on g per 1000 g dry matter (NIR database, n = 910)

Year of harvest	Sample number	Dry matter	Crude protein	Crude fat	Crude fiber	Ash	Total sugar	Nitrate	Soluble protein
2013	74	344 ^{ab}	145	34 ^{ab}	290 ^{d}	117 ^{ab}	47 ^{ab}	4.9 ^{ab}	106
2014	100	322 ^{ab}	142	35 ^{bc}	277 ^{cd}	113 ^{ab}	57 ^{bc}	4.1 ^{ab}	90
2015	70	346 ^{ab}	132	33 ^{ab}	267 ^{bc}	112 ^{ab}	77 ^{d}	3.9 ^{ab}	89
2016	82	336 ^{ab}	144	34 ^{ab}	260 ^{ab}	116 ^{ab}	64 ^{bc}	4.4 ^{ab}	94
2017	54	358 ^{ab}	136	32 ^{a}	269 ^{bc}	117 ^{ab}	73 ^{cd}	4.5 ^{ab}	90
2018	102	358 ^{b}	147	36 ^{bc}	281 ^{cd}	124 ^{b}	46 ^{ab}	5.1 ^{b}	95
2019	91	314 ^{a}	143	34 ^{ab}	280 ^{cd}	124 ^{b}	38 ^{a}	4.8 ^{ab}	93
2020	112	355 ^{b}	148	34 ^{ab}	262 ^{ab}	109 ^{a}	72 ^{cd}	4.0 ^{ab}	97
2021	113	349 ^{ab}	146	35 ^{bc}	252 ^{a}	118 ^{ab}	62 ^{bc}	3.5 ^{a}	97
2022	112	323 ^{ab}	144	37 ^{c}	270 ^{bc}	113 ^{ab}	52 ^{abc}	4.1 ^{ab}	96
2013-2022	910	340 ^{ab}	143	34 ^{b}	271 ^{bc}	116 ^{ab}	59 ^{bc}	4.3 ^{ab}	95

a,b The different letter signs in the columns indicate significant differences in the mean values ($p < 0.05$)

The average dry matter content of the intensive grass silages was 340 g/kg (range of average values: 314–358 g/kg). This average value is optimal from the fermentation point of view. The crude protein content of intensive grass silages was 143 g/kg DM between 2013 and 2022 (average values range from 132 to 148 g/kg DM). However, we cannot be satisfied with the 10-year average value measured, because Italian ryegrass and *Festulolium* can achieve much higher values. Since *Italian ryegrass* and *Festulolium* are often cut at the same time as alfalfa, the dominance of alfalfa may cause late mowing of intensive grasses and consequently low protein content. The aNDFom content (Table 4) averaged 499 g/kg DM (range of averages: 479–525 g/kg DM). The average value of ADF was 302 g/kg DM (range: 281–325 g/kg DM). The lignin content is critical because it determines the digestibility of the cell wall and also the digestibility of the nutrients inside the cell (cell wall effect). The average ADL content was 25 g/kg DM (range of average values: 23–31 g/kg DM).

Table 4 Fiber fractions, organic matter digestibility, net energy content and relative forage quality (RFQ) of early-cut intensive grass silage harvested in the period 2013–2022 based on 1000 g dry matter (NIR database, n = 910)

Year of harvest	Sample number	aNDFom[1]	ADF	ADL	$NDFd_{48}$[2]	$dNDF_{48}$[3]	OMd_{48}[4]	RFQ[5]	NEl
		g	g	g	%NDF	g	%	-	MJ
2013	74	525^{c}	325^{d}	31^{c}	63^{a}	327^{ab}	71^{a}	169^{b}	5.88^{a}
2014	100	508^{bc}	311^{cd}	27^{b}	65^{ab}	327^{ab}	73^{ab}	157^{ab}	6.19^{b}
2015	70	494^{ab}	294^{ab}	24^{ab}	65^{abc}	317^{ab}	73^{b}	163^{abcd}	6.17^{b}
2016	82	479^{a}	290^{ab}	23^{ab}	68^{bc}	321^{ab}	75^{bc}	175^{cd}	6.21^{b}
2017	54	491^{ab}	301^{bc}	27^{b}	63^{a}	311^{a}	73^{ab}	157^{abc}	6.17^{b}
2018	102	509^{bc}	315^{cd}	26^{b}	65^{abc}	331^{b}	73^{b}	156^{ab}	6.14^{b}
2019	91	514^{bc}	316^{cd}	27^{b}	64^{a}	325^{ab}	72^{ab}	151^{a}	6.19^{b}
2020	112	489^{ab}	290^{ab}	25^{b}	66^{abc}	317^{ab}	74^{b}	169^{b}	6.40^{c}
2021	113	474^{a}	281^{a}	22^{a}	68^{c}	319^{ab}	76^{c}	173^{d}	6.53^{c}
2022	112	504^{bc}	298^{b}	24^{ab}	65^{ab}	323^{ab}	74^{bc}	159^{abc}	6.32^{b}
2013-2022	910	499^{b}	302^{cd}	25^{b}	65^{ab}	322^{ab}	73^{b}	163^{abc}	6.22^{b}

[1]$aNDFomd_{48}$ = amylase treated and ash corrected NDF rumen degradability (48 hours *in vitro* incubation); [2]$NDFd_{48}$ - rumen degradable (amylase treated and ash corrected) NDF (48 hours *in vitro* incubation); [3]$dNDF_{48}$ - rumen degradable (amylase treated and ash corrected) NDF (48 hours *in vitro* incubation); [4]OMd_{48} - organic matter digestibility (48 hours *in vitro* incubation); [5] relative forage quality; [abc] Means in the same column with different letters differ statistically ($p < 0.05$)

The measured data indicate that ADL content is extremely low in intensive grass silages so the negative effect on fiber and organic matter digestibility is minimal. It can be seen that between 2013 and 2022, the 48-hour fiber digestibility ($NDFd_{48}$) was 65% (Table 5). The target value for $NDFd_{48}$ is above 70%. So, it is a challenge for the future.

Digestible fiber ($dNDF_{48}$) averaged 322 g/kg DM, which is twice the value of alfalfa silages (2013–2022 alfalfa silage: 166 g/kg DM $dNDF_{48}$, n = 3043, unpublished). The digestible fiber content of intensive grass silages is similar to the digestible fiber content of rye silage cut in the boot stage. Therefore, intensive grass silages are potentially excellent sources of digestible fiber in the dairy cow diet, especially during the summer.

CONCLUSIONS

The advantage of winter cereals grown from autumn to early spring is that they can be grown during periods of increased rainfall while avoiding the adverse effects of heat stress and drought. This offers a promising opportunity to mitigate climate change risks and minimise corn yield losses. Additionally, early-cut whole-crop rye silage and intensive grass silage with high fibre digestibility and digestible fibre content can maintain the dry matter intake of dairy cows, especially during the summer ("heat stress forages").

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