POTENITAL FORAGE RESOURCES AS ALTERNATIVES TO PARTIAL OR TOTAL SUBSTITUTION OF CORN SILAGE IN DAIRY CATTLE NUTRITION – *A REVIEW*

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SUMMARY

Corn silage is a common ingredient of dairy rations in most areas of the World, particularly in Europe and North America. The widespread use of corn silage implies that it has certain competitive advantages over other forages. However, currently there are some difficulties in corn cultivation (i.e., groundwater shortages, mycotoxin contamination), which have been forced dairy farmers to consider other optional forages. The safety yield of corn silage might be compromised in the future, if the expected climate change in Europe and Hungary will be characterized by the increase summer heat waves and the more extreme water course. Factors, such as competition for corn among livestock sectors, significant increase of corn for human consumption and industrial uses will eventually force farmers, producers, researchers and policy makers to find optional forages for corn silage in dairy farms. Therefore, it would be urgent to consider how crop production and feeding strategies can be adapted to this change in long term, taking into account the nutrient requirements of the high producing dairy cows. Therefore, finding and routine application of relevant optional forages is considered absolutely necessary to the success of future dairy operations. However, it could be difficult the total replacement of corn silage particularly for high producing dairy cows due to superior starch and energy content, digestibility and very good ensiling ability of corn. The purpose of this review is to summarize the literature focusing on the field crops (novel corn hybrids, sorghum forage, corn-sorghum mixtures, winter-type early harvested cereals, Italian ryegrass, winter cereal-legume mixtures, winter cereal-grass mixtures) which may be a viable option to corn silage in dairy nutrition.

ÖSSZEFOGLALÁS

Alemayehu, W. – Tóth T. – Orosz Sz. – Tóthi R.: A KUKORICASZILÁZS RÉSZLEGES VAGY TELJES HELYETTESÍTÉSÉNEK ALTERNATÍVÁI A TEJELŐ TEHENEK TAKARMÁNYOZÁSÁBAN ÚJ TÍPUSÚ TÖMEGTAKARMÁNYOK SEGÍTSÉGÉVEL (*IRODALMI ÁTTEKINTÉS*)

A kukoricaszilázs a tejelő tehenek takarmányadagjainak gyakori összetevője a világ legtöbb részén, különösen Európában és Észak-Amerikában. A kukoricaszilázs ilyen széles körben elterjedt alkalmazása azt jelenti, hogy bizonyos versenyelőnyökkel rendelkezik más tömegtakarmányokkal szemben. Mindazonáltal a silókukorica termesztésben jelentkező nehézségek miatt (pl. felszín alatti vízhiány, mikotoxin szennyeződés) a tejtermelőknek alternatív szántóföldi tömegtakarmányok használatának irányába kell fordulniuk. Lényeges ez főképp azért, mert a silókukorica termésbiztonsága a jövőben veszélybe kerülhet, ha a várható európai és magyarországi klímaváltozás a nyári hőhullámok gyarapodásával és a jelenleginél szélsőségesebb csapadékvíz eloszlással jár. További tényezők, mint például az állattenyésztési ágazatok kukorica felhasználása között kialakult versenyhelyzet, a kukorica étkezési és ipari célú felhasználásának jelentős növekedése, arra kényszerítik a gazdálkodókat, a termelőket, a kutatókat és a politikai döntéshozókat, hogy a kukoricaszilázs tejelő tehenek takarmányozásában felhasználható különböző alternatíváit megtalálják. Éppen ezért sürgető lenne megvizsgálni, hogy a növénytermesztési, az élelmiszeripari és a takarmányozási stratégiák hosszú távon hogyan alkalmazkodhatnak a változáshoz, figyelembe véve a nagy termelésű tehenek táplálóanyag szükségletét. A szóba jöhető alternatív tömegtakarmányok megtalálása és rutinszerű alkalmazása sürgős és elengedhetetlen fontosságú a jövőbeli tejtermelés magas színvonalon történő fenntarthatóságához. Ugyanakkor nehéz feladat lenne 100%-ban helyettesíteni a silókukorica szilázst, különösen nagy tejtermelésű tehenek esetében, mert kiváló keményítő- és energiatartalom jellemzi, jól emészthető és könnyen erjeszthető. Jelen irodalmi áttekintés fő célja azon szántóföldi tömegtakarmányok (új silókukorica hibridek, cirokfélék, kukorica-cirok keverékek, korai betakarítású gabonafélék, olaszperje, gabona-gabona, gabona-pillangós, gabona-fű keverékek) számbavétele és bemutatása, amelyek a kukorica-szilázs helyettesítői lehetnek a tejelő tehenek takarmányainak összeállítása során.

INTRODUCTION

Dairy farmers in many parts of the world rely on corn silage as a source of digestible fibre and readily fermentable energy for their cattle (*Adesogan*, 2006). However climate change, which is currently characterized by increased atmospheric CO_2, rising temperature, and altered pattern of precipitation, is affecting corn production for silage making. Corn silage production is particularly affected by shortage of water, agronomic practices and environmental factors (including heat, moisture, and soil type). Farmers face several climatic challenges that can complicate corn silage production, including temperatures that reduce the rate of photosynthesis (*Crafts-Brandner and Salvucci*, 2002), and reduction in potential yields due to faster crop life-cycles. For instance in Hungary according to a study of *Kálmán and Rajki* (2015), on an average of the year, the acreage devoted to silage corn production (80-90,000 ha/year) is usually enough to meet the needs of feeding the cattle population (818,000). However at the same time, in extremely hot and dry years, the corn reacts very sensitively to the actual weather condition in Hungary. They further noted that the climate in Hungary has become more arid with extremities due to global climate change during the past decades. In Hungary, the arable crops are mostly not irrigated, therefore the yield reduction as a consequence of drought cannot be estimated in advance which currently affecting dairy farming. Rising temperature and shifting precipitation patterns will also alter the ability to meet crop water requirements, water availability, crop productivity, and costs of water access across the agricultural landscape (*Getachew et al.,* 2016). Climatic factors cause not only loss of silage corn production but also other factors which aggravates crop failure as a whole. In this regard *Kucharek and Raid* (2005) and *Samapundo et al.* (2005) reported that climatic conditions are conducive for proliferation of many bacterial and fungal pathogens which cause stalk rot, smut, leaf blight and rust, and predispose to growth of mycotoxin producing fungi (*Fusarium*, *Aspergillus*, *Penicillium*). In addition to affecting crop growth and disease incidence, previous studies also showed that these climatic factors have adverse effects on silage fermentation and aerobic stability (*Dewar et al.,* 1963; *Muck,* 1987; Garcia *et al.,* 1989 and *McDonald et al.,* 1991). For instance, rainfall at harvest can increase proteolysis in the silo (*McDonald et al.,* 1991) and effluent production (*Fransen and Strubi,* 1998) thereby reducing dry matter recovery. According to *Ashbell et al.* (2002) and *Weinberg et al.* (2001) ensiling at high temperatures reduces lactic acid concentration, aerobic stability and increases pH and dry matter losses. In the last years, difficulties occurring in corn cultivation (i.e., groundwater shortages, mycotoxin contamination) have been forced dairy farmers to consider alternative silages. Mainly, because the yield safety of corn silage will be compromised in the future if the expected climate changes in Hungary will be characterized by the increase of summer heat waves and the more extreme water course. Therefore it would be urgent to consider how crop production and feeding strategies can be adapted to this change in long term, taking into account the needs of the high producing dairy cows. Based on this finding acceptable other forages which replace corn silage will be a critical point for the success of future dairy operations if corn production is still decline, particularly in Europe. In this regard attempts has been done so far, however attaining forage species which are cheap, locally available and acceptable by farmers, adapted to climatic stress and of course equivalent with corn silage in terms of nutritional value, biomass yield, digestibility and improve milk production would be difficult. The situation will get worse if that forage is intended to replace whole corn silage particularly for high producing dairy cows. The main objective of this review is to assess potential of different crop silages for partial or total replacement of corn silage in dairy cattle nutrition.

The importance of corn silage in dairy cow nutrition

Corn silage is a major dietary component for dairy cows in most parts of the world particularly in USA and Europe with average feeding rates of 2.7 and 4.1 tonne dry matter (DM) per cow per year, respectively (*Kleinmans et al.,* 2016). The widespread use of corn silage implies that it has certain competitive advantages over other feedstuffs. This means over the long term, diets with corn silage must result in higher income over feed costs than do diets that include less commonly used feeds (*McCuaghey et al.,* 2002). Corn silage produces more digestible energy per acre than other forages; therefore corn silage is included in ruminant rations primarily as a source of energy. According to *Swift* (2004) the starch in corn grain accounts for approximately 45% of the energy value, and microbial digestion of cellulose and hemicellulose (NDF fraction) in the rumen contributes a further 25% to the energy value of corn silage. The remaining 30% of energy comes from sugars, pectin, organic acids, crude protein and ether extract. There is a substantial body of evidence from studies with lactating dairy cows that increasing digestibility, increased milk yield, milk protein concentration and higher yields of fat plus protein could be observed. According to *Keady and Hanrahan* (2013) the mean daily response for each 1 percentage unit increase in silage dry matter digestibility (DMD) is plus 0.33 kg milk production. The fibre digestibility of the stove and digestibility of starch in grain as well as the ratio of stove to grain explain the nutritional value of corn silage. Maturity at harvest has the greatest influence on NDF digestibility. NDF digestibility in corn silage declines approximately 10.0 percentage units between the ½ milk-line to advanced black layer stages of maturity. Because corn silage has a high grain content, it is important that it also have adequate effective fibre to obtain successful utilization of the silage. Adequate physically effective NDF (peNDF, as the fraction of NDF that stimulated chewing and contributed to a ruminal digesta mat) in dairy cow diets is essential for good rumen function that results in proper digestion of the diet and maintenance of animal health and milk fat production. Because corn silage is often chopped finely or processed through rollers, its peNDF is typically 85% of amylase-treated neutral detergent fiber (aNDF), but this can vary from 70 to 95%. The recommendation for peNDF in dairy rations is about 21% of dry matter, but this fibre requirement probably increases with increasing non-fibre carbohydrates (NFC) in the ration. The starch content of corn silage is mainly affected by stage of maturity of the plant at harvest (*Johnson et al.,* 1999). The advancing maturity of the corn crop during the grain-filling period increases the content of starch (*Phipps et al.,* 2000) but its digestibility can decrease as kernels becomes harder, drier, and more vitreous (*Keady,* 2016).

The feeding value of corn silage is mainly determined by intake and digestibility of silage (*Huhtanen et al.,* 2002). There are no negative implication for corn silage digestibility and intake, except some reports (*Charmley,* 2001; *Neto et al.,* 2009) which are suggested that ensiling process reduces the feeding value and digestibility of corn silages. Rations containing only corn silage as forage may limit the intake and production due to excess rapidly fermentable starch, low effective fibre, and/or slow rates of fibre digestion (*Neto et al.,* 2009). Prolonged ensiling period increases digestibility of starch. A recent study *Weakley* (2016) reported that during storage, the digestibility of the starch will increase as the ensiled time increases. Typically, starch digestibility increases over the next 90 to 180 days, and by 180 days the digestibility will usually reach a plateau. On average, starch digestibility can increase 15 percentage units during this time. The upsurge in digestibility occurs because of the breakdown of prolamin proteins that protect the starch granules from microbial degradation. Proteolytic enzymes in the silage pile break down the prolamins holding the starch together during ensiling. This process allows for easier access to starch granules for microbial degradation in the rumen. On the other hand protein degradability is also higher in the silage than the original green forage. According to *González et al.* (2007), it is generally accepted that proteins from silages have a higher efficient degradability than those of their original green forages as a consequence of the previous degradative actions of the ensiling microflora.

Effect of climate change on the production and quality of corn silage

Despite tremendous improvements in technology and crop yield potential, crop production remains highly dependent on climate, because solar radiation, temperature, and precipitation are the main drivers of crop growth. Plant diseases and pest infestations, as well as the supply of and demand for irrigation water are also influenced by climate (*Tigchelaar et al.*, 2018). According to the report of United States Department of Agriculture, Foreign Agricultural Service (*USDA*, 2018) the area, yield and production of corn reduced or at least maintained constant for the last three years particularly in the EU and USA (*Table 1*). This could be attributed to the climate change which is expected to bring warmer weather, changes to rainfall patterns, and increased frequency of extreme weather.

Results of a recent study revealed that climate change will increase the risk of corn crop failures across the world's biggest corn-growing regions (*Tigchelaar et al.*, 2018). According to this report much of the world's corn goes into feeding livestock and making biofuels. In United States the mean total maize production is projected to decline by 18% under 2 °C of global warming and by 46% with 4 °C of warming (*Table* 2).

Table 1.

Area, yield and production of corn from 2015/16-2017/18

Item (1)	Production year (2)			
	2015/16	2016/17	2017/18	
			January	February
Area (million hectare) (3) World (4)	181.01	185.68	184.59	184.43
EU	9.25	8.65	8.47	8.47
USA	32.68	35.11	33.47	33.47
Yield (metric tons per hectare) (5)				
World (4)	5.38	5.79	5.66	5.65
EU	6.35	7.18	7.10	7.10
USA	10.57	10.96	11.08	11.08
Production (millions metric tons) (6)				
World (4)	973.45	1075.97	1044.56	1041.73
EU	58.75	61.45	60.09	60.09
USA	345.51	384.78	370.96	370.96

Source/ Forrás: USDA / Foreign agricultural service, office of global analysis (February, 2018)

1. táblázat A kukorica termőterülete, hektáronkénti hozama és termésmennyisége 2015/16 és 2017/18 között

megnevezés (1); termőév (2); termőterület, millió hektár (3); világ (4); hektáronkénti hozam, millió tonna/ha (5); termésmennyiség, millió tonna (6)

Table 2.

Predicted changes in total production in the top-four maize producing countries in response to a 2°C and 4°C warming (*Tigchelaar et al.,* 2018)

Country (1)	**2C° warming (2)**	**4C° warming (3)**
USA	-17.8%	-46.5%
China (4)	-10.4%	-27.4%
Brazil (5)	-7.9%	-19.4%
Argentina (6)	-11.6%	-28.5%

2. táblázat A összes kukoricatermés előrelátható változása 2°C illetve 4°C hőmérséklet emelkedés hatására a négy fő kukoricatermelő országban

ország (1); 2°C melegedés (2); 4°C melegedés (3); Kína (4); Brazília (5); Argentína (6)

Rainfall at harvest and high temperature during ensiling adversely affect the fermentation and quality of corn silage. Hot and humid conditions that occur during the corn growing season is responsible for production loss of corn for silage making (*Adesogan*, 2006). Corn silage producers in hot and humid regions need to adhere strictly to excellent silage making practices to overcome the adverse effects of moisture and temperature on corn silage production. Corn silages grown in hot and humid areas should be harvested at 34 % DM to optimize

DM yield, nutritive value, fermentation quality and reduce fungal counts. Higher stay-green rankings in corn hybrids resulted in greater moisture and crude protein (CP) concentrations and less *in vitro* dry matter digestibility (IVDMD) and starch concentrations (*Arriola et al.,* 2005). Corn silage producers in hot and humid regions need to avoid harvesting corn in wet weather, and ensure that excellent silage management practices are followed to overcome these climatic challenges to quality silage production. In addition to climate change, factors like high demand of corn for different purposes; like other livestock feeds, particularly pig and poultry, raw material for most food, bioethanol/beverage and biogas industries and even for human consumption decrease the availability of corn for silage making for high producing dairy cows.

The change in climatic condition particularly temperature and precipitation does not only affect the corn production but also quality of corn silage. According to a recent report by *Phibro Animal Health Corporation* (Sep 18, 2018), the effects of hurricanes and flooding can take their toll in corn crop harvesting, producing heavy rains that could delay harvest and force farmers to keep their silage corn in the field for a longer period of time. Delayed harvest may lead to altered DM content of the forage, which could lead to mould growth and stalk and ear rot; both of which may increase the opportunity for mycotoxin contamination. According to *David and Gary* (*2018*) report cited in the 2018 *American Phytopathological Society* (APS) report, FAO has estimated that 25% of the world's crops are affected by mycotoxins each year, with annual losses of around 1 billion metric tons of foods and food products. Climate change is conducive for the reproduction and proliferation of invasive pests and insects. The recent outbreak (2016) in Africa of the fall armyworm (*Spodoptera frugiperda*)/ the American armyworm, is an example of climate change effect (*Saliou and Sevgan,* 2018). The pest, an alien from the Americas (widely distributed in Eastern and Central North America, and in South America), was first reported in Africa in 2016 (*Saliou and Sevgan,* 2018). The outbreak started in São Tomé and Príncipe islands and Nigeria, and just two years spread to over 38 African countries. Cereal farmers across Sub-Saharan Africa are experiencing heavy losses due to the devastation by this invasive pest. In Africa it has caused huge losses to staple cereals, especially corn and sorghum, affecting food security and trade. According to recent a report (May 7, 2018), damage to corn alone is estimated to be between 2.5 to 6.2 billion US$ per year (*Saliou and Sevgan,* 2018).

Replacement of corn silage with different crop silages

The use of new silo corn hybrids

The development of corn hybrids plays an important part in the worldwide success of corn silage, and the choice of suitable hybrid is the most important factor for profitable silage production. Plant breeders have made considerable advances in achieving earlier maturing maize varieties that are more reliable for a specific area (*Dewhurst,* 2013). The main criteria for selecting a hybrid variety are yield, precocity, and resistance to disease, pests and lodging (*Delmotte,* 2010). Stalk characteristics are usually modified with the aim of increasing the digestibility of the fibre in corn silage. Grain characteristics can be altered through modifications in nutrient or starch composition (*Ferraretto et al.,* 2015). Commonly there are two types of corn hybrids use in dairy cattle nutrition; these are the brown mid rib (bmr) and leafy (lfy) silo corn hybrids. According to *Grant and Contanch* (2012) and *Kung* (2011), nutrient composition of bmr corn hybrid silage is generally similar to the conventional hybrids with two important differences; the bmr is lower in lignin and has a significantly higher *in vitro* NDF digestibility. The *in vitro* fibre digestibility was greater in bmr corn silage than a conventional hybrid, DM intake of cows was greater with the bmr, but total tract digestion of the fibre did not differ between the hybrids. However, NDF digestibility did not increase because higher feed intake decreases the amount of time available for its microbial degradation (*Martin et al.,* 2008). There are also hybrids with high fibre digestibility, such as waxy and stay-green types, which are rarely known. Waxy types have been used for silage but with inconsistent results (*Roth and Heinrich,* 2001). Some hybrids called "stay-green" maintain leafiness and have a slower DM accumulation in the grain (*Arriola et al.,* 2012). Some hybrids intended for grain production have high yield and better degradability of DM and fibre, and thus also suitable for forage production. According to *Dwyer et al.* (1998) and *Shaver* (1983), corn silage produced from lfy hybrids is characterized by more leaves above the ear and, in some cases, higher grain moisture content or softer kernel texture. Lfy types have yields similar to those of grain types, but have softer kernels that dry more slowly. Such varieties may contain less starch and more fibre. Some lfy types were bred for silage production, while others have a faster drying rate, which requires for grain production (*Roth and Heinrich,* 2001). Corn hybrids traditionally have been selected for grain yield, but also for production of both grain and whole-plant corn silage (*Bal et al.,* 2000). However, hybrids selected for high grain yield may not be the highest yielding for whole plant corn silage (WPCS) (*Coors et al.,* 1994). Although differences in fibre concentrations and *in vitro* digestibility of WPCS produced from hybrids selected using conventional grain breeding strategies have been reported (*Hunt et al.,* 1992). Feeding trials using corn hybrid silages to evaluate animal performance are limited. *Hunt et al.* (1993) and *Barriere et al.* (1995) reported improved weight gain and feed efficiency in beef steers, and DMI and milk yield in dairy cow, respectively, due to hybrid-related improvements in WPCS nutritive value. As reported by *Bal et al.* (2000) intake, digestion and milk production of dairy cows were not affected by corn hybrids. There are minimal benefits the feeding of leafy or low-fibre corn silage hybrids. Feeding bmr corn silage in a high-forage diet increased milk fat percentage and milk yield as compared to conventional corn silage diet (*Bal et al.,* 2000).

Use of sorghum silage

Sorghum has been grown as a silage crop for many years. In general, under conditions of high temperature and moisture stress, the forage sorghums have given higher yields than corn (*Rusche,* 2015). Forage sorghum types range from sudangrass to traditional grain sorghum (*Neto et al.,* 2009). In addition, forage sorghums can be bmr or photoperiod sensitive. The type and variety that best utilized will depend on its end use. For silage production, forage sorghums rather than sudangrass or sorghum-sudangrass hybrids are the best choice. Forage sorghums silage typically has lower energy values than corn silage but their crude protein contents are similar (*Table 3*). *Grant and Stock* (1994) reported that, forage sorghum silage has less energy value because of a lower percentage of grain-to-forage, a higher undigested ratio of the grain, and lower digestibility of stalk. When compared to sorghum-sudangrass, forage sorghum silage is higher in energy and lower in protein. Other limitation to sorghum silage fed to cattle is the digestibility is generally less than that of corn, because corn has less lignin and more grain content. The higher lignin content and lower degradability of sorghum silage can result in less fibre digestion, lower DM intake and less milk produced in dairy cow (*Cattani et al*., 2017). However, bmr sorghum contains less lignin and offers higher digestibility. In this regard *Oliver et al.* (2004) reported that the total tract NDF digestibility of bmr6 and bmr18 variety is 54.4% and 47.9%, respectively. According to the same author the total tract DM digestibility of bmr6 and bmr18 is 62.9% and 69.1% respectively. Many of the bmr varieties, as well as some of the non-bmr varieties, have consistently had an *in-vitro* true digestibility (IVTD) value equal or greater 80.7 % DM (*McCollum et al.*, 2005) than that of corn. An important point is the variation among the varieties within each type. Utilization of sorghum forage as a total replacement for corn silage in dairy cow diets is possible. Bmr hybrids likely offer the greatest advantage to lactating dairy cattle due to the increased fibre digestibility. Results of the study of *Colombini et al.* (2010) indicated that, although the rate of NDF degradability of bmr sorghum forage is faster, the effective rumen degradability of NDF in bmr sorghum forage is equal to corn silage. In a study that compared sorghum varieties and corn, total tract digestibility of starch in wild type, bmr6, bmr18, and corn silages were 85.7%, 82.3%, 79.7%, and 91.7 %, respectively (*Oliver et al.,* 2004). Development of new cultivars that are more forage than grain types have higher yielding in digestible DM shows promise for the future of sorghum forages. However, the potential for sorghum silage in the diets of high producing dairy cows has not been adequately studied, therefore additional research is needed in this area to fully address how these forages can be utilized in lactating dairy diets.

Use of corn-sorghum mixed silage

Although the yield potential of corn grown for silage is high, it is also sensitive to environmental stress. Dry conditions during any stage of corn growth can significantly reduce corn silage yields. In contrast to corn, forage sorghum possesses a much higher level of drought tolerance and water use efficiency (*Grant and Stock*, 1994; *Getachew et al.*, 2016). Planting mixtures of corn and forage sorghum may reduce the risk of low yields during years with below average rainfall and above average temperatures. There are two, often applied, farming techniques to plant mixed cropping: either two rows of maize or two rows of sorghum side by side or corn and sorghum planted in the same row upon each other (*Kálmán and Rajki,* 2015). Making mixed silage from corn and sorghum 1:1, corn increases the energy value of the silage blend and ensures the appropriate feed value for dairy cows. However, mixed silage has slightly lower dry matter and energy values than corn silage alone. Although, digestibility study report on corn and sorghum mixture silage is rare.

Use of winter cereal silages

Whole crop cereals for silage making are an exciting area of potential integration of the cropping and dairy industries. Research reports are not frequent on the potential of winter cereals for silage making, particularly in Europe. This could be attributed to the long tradition of using winter cereals as green forage, haylage as well as wrapped haylage. However, there are some reports (*Table 4*) in Hungary LPT Ltd. NIR Laboratory database (April 2013 – August 2017) compiled by *Orosz et al.* (2017), revealed the potential of early harvested winter cereal silages (boot-early heading, heading and milky dough stage). According to this report, at milky-dough stage, cereal silages have higher DM and lower fibre fraction content than its heading stage. However, NDF digestibility at this stage is lower than heading stage, but OM digestibility generally better for both stages. As compared to the corn silage (*Table 3*), cereal silage at both milky–dough and heading stages has lower DM and relatively higher fibre fractions (NDF, ADF and ADL). On the other hand the *NRC* (2001) nutritional composition table (*Table 3*) reported that cereal silages have lower NE_l and higher fibre fraction (NDF and ADF) than corn silage. However, the dry matter content is comparable with corn silage, but the crude protein content is higher than corn silage.

Digestibility reports are also not so frequent, particularly for whole total tract DM, NDF and ADF digestibility. *Lyons et al.* (2016) suggested that winter cereals, such as cereal rye and triticale, grown as double crops in corn silage rotations in the Northeast United States have the potential to increase on-farm forage production as well as provide many environmental, economic and nutritional benefits to dairy farms. The author further noted that winter cereals can provide a significant amount of additional, nutritious forage without greatly interfering with corn silage production. Winter wheat, winter triticale, and winter rye can be planted in autumn to produce good yields of high quality forage in the following spring. Rye will grow and mature the quickest in the spring and must be managed to avoid over ripening. Wheat and winter triticale are easier to manage in spring because they mature later and more slowly than rye. Forage quality of winter cereals (winter wheat, winter triticale, and winter rye) will be excellent if harvested in the vegetative to boot stage of growth in the spring, with yields of 5 to 7 t DM/ha, depending on harvest stage. It fares well in years with extreme weather, such as in 2016, when a severe drought impacted corn silage throughout New York State (*Lyons et al.*, 2016). Work is ongoing to determine specific planting dates, harvest times, and fertilizer recommendations for winter cereal crops to ensure successful implementation of these rotations. However, very recently by using double cropping of winter rye for extra forage, farmers are looking for extra forage can plant winter rye following the harvest of many crops, particularly corn silage (*Bagg,* 2005).

Table 3.

Energy and nutrient composition of corn and other crop silages (*NRC*, 2001)

Item (1)	Energy and nutrient composition (2)							
Silage type (3)	NE_l MJ/kg (4)	DM (%) (5)	CP (%) (6)	EE (%) (7)	NDF (%) (8)	ADF (%) (9)	ADL (%) (10)	Ash (%) (11)
Corn silage (12)	6.57	35.1	8.8	3.2	45	28.1	2.6	4.3
Grass silage (13)	4.56	36.2	16.8	2.4	58.2	35.2	6.6	8.7
Italian ryegrass silage (14)	4.37	36.5	12.8	3.1	60.7	40.3	6.9	8.1
Sorghum silage (15)	4.35	28.8	9.1	2.9	60.7	38.7	6.5	7.5
Barley silage (16)	4.89	35.5	12.0	3.5	56.3	34.5	5.6	7.5
Oat silage (17)	4.52	34.6	12.9	3.4	60.6	38.9	5.5	9.8
Triticale silage (18)	4.60	32	13.8	3.8	59.7	39.6	5.8	9.7
Wheat silage (19)	4.52	33.3	12.0	3.2	59.9	37.6	5.8	8.6

3. táblázat A kukoricaszilázs és és egyéb erjesztett tömegtakarmányok energia- és táplálóanyag tartalma (NRC, 2001)

megnevezés (1); energia és táplálóanyag tartalom (2); szilázs típus (3); tejtermelési nettó energia (4); szárazanyag (5); nyersfehérje (6); nyerszsír (7); neutrális detergens rost (8); savdetergens rost (9); savdetergens lignin (10); nyershamu (11); silókukorica szilázs (12); fűszilázs (13); olaszperje szilázs (14); cirokszilázs (15); árpaszilázs (16); zabszilázs (17); tritikálészilázs (18); búzaszilázs (19)

Use of Italian ryegrass silage

Italian ryegrass *(Lolium multiflorum Lam., var. italicum)* evolved in the Mediterranean region, and in northern Italy, its cultivation as forage for livestock dates back as far as the 12th century (*Baldinger et al.,* 2013). Both fresh and preserved Italian ryegrass is frequently used as forage for dairy cows and known for its high energy value and highly digestible fibre (*Tamburini et al.,* 1995). Plant breeders have developed perennial ryegrass cultivars with an elevated concentration of water soluble carbohydrates (WSC, also known as high sugar grasses) relative to conventional cultivars (*Turner et al.,* 2006). This breeding has focused on increasing the accumulation of high molecular weight storage sugars (i.e. fructans), particularly in leaf blades rather than sheath bases (*Pavis et al.,* 2001). It is proposed that perennial ryegrass with high WSC may improve the balance and synchrony of the nitrogen and energy supply to the rumen (*Miller et al.,* 2001). The CP and net energy content of new varieties of Italian ryegrass (e.g. the perennial Bahial hybrid, the one-year Suxyl variety) are high (175-179 g/kg DM and 6.25- 6.28 MJ/kg DM) (*Lehel et al.,* 2011). High energy concentration due to good nutrient digestibility can be explained by relatively low lignin content of the grass hybrid silage (ADL: 20 and 27 g/kg DM) (*Lehel et al.,* 2011). Reports about its positive effects on the forage intake of dairy cows are frequent (*Bernard et al.,* 2002; *Baldinger et al.,* 2011) and some researchers even report better feed efficiency than when feeding corn silage (*Cooke et* *al.,* 2008). The sugar content of Italian ryegrass is good as compared to other grass silage provided that it is harvested in the early stages of harvesting. In this regard, *Baldinger et al.* (2013) reported that Italian ryegrass which is harvested at second cut had significantly higher (71.87 %) sugar content than corn silage. However, as the cutting day prolonged, such as the third cut the variation is not significant among them. According to *Burke et al.* (2007), *Kliem et al.,* (2008) and *Keady et al.* (2008) if perennial ryegrass silage replaced with corn silage, it have shown that increasing inclusion of corn silage positively affects the DM intake, milk yield, and milk protein content, while milk fat concentration is either not affected or decreased. Reports on digestibility and degradability on replacing corn silage with Italian ryegrass are not frequent. However, *Bernand et al.* (2002) reported that apparent DM digestibility declined linearly; whereas CP digestibility increased linearly as Italian ryegrass silage replaced with corn silage. They further noted that apparent digestibility of NDF and ADF was the highest for the diets in which ryegrass or corn silages provided all of the forage, resulting in a quadratic response. Their result on linear increments in apparent digestibility of CP is supported by other reports (*González et al.,* 2007, 2009). The reason for this could be the fact that proteins from silages have a more efficient digestibility than those of their original green forages. This idea is also supported by *González et al.* (2007), who had an opinion that higher digestibility values are consequence of the previous degradative actions of the ensiling microorganisms. On the other hand, *Narasimaluhi et al.* (1984), reported that apparent digestibility of DM, NDF and ADF of Italian ryegrass is 63.6%, 57.3% and 64.1%, respectively. According to the *NRC* (2001) (*Table 3*) and *Jacobs et al.* (2009) CP content of Italian ryegrass silage is 12.8% and 12.5% respectively, which is higher as compared to other grass and cereals, even corn silage.

Winter cereal-cereal mixtures as alternatives to corn silage

Because of their more adaptable to early sowing due to higher tolerance of dry conditions, winter cereals can provide feed earlier than annual grasses, such as *Lolium italicum* (*Geren,* 2014). Cereals are also better suited to single-cut silage-making, whereas annual grasses require multiple cuts or grazing to be fully utilized. The small grain forages if harvested at the proper stage of development, can make a suitable feed for dairy cattle (*Bagg,* 2005). According to *Geren* (2014) it is possible to produce an average of 10.9 t DM/ha yield with an average of 9.2% crude protein content at mid-dough stage in regions with Mediterranean-type climates. It was also concluded that *Avena sativa* should be preferred for high biomass yield and should be cut at the beginning of mid-dough maturity stages for higher quality silage. *Bagg* (2005) also reported that, rye which can be used to make silage, haylage or wrapped baleage, must be harvested for silage making in the boot or vegetative state before seed head development. That means wilting to 30 to 40% dry matter before ensiling. It also noted that it is recommended to harvest rye no later than at early boot stage (before heading) in order to maintain good palatability, intake and nutritive value. At this stage, yields are about 5 t DM/ha. After rye forage is cut it should be wilted and then made into silage in the tower, bunk, pile or bag silos. However, triticale

Nutrient content and digestibility of different winter-type whole crop cereal silages and mixed silages

	Sample no. (1)	DM (2)	Crude Protein (3)
		g/kg	g/kg DM
Rye silage (in boot-early heading) (8)	599	293	135
Triticale silage (in heading) (9)	18	306	107
Triticale silage (milky-dough stage) (10)	44	356	81
Oat silage (in heading) (11)	14	323	110
Oat silage (milky-dough stage) (12)	9	326	99
Barley silage (in heading) (13)	15	317	133
Barley silage (milky-dough stage) (14)	48	343	92
Wheat silage (in heading) (15)	9	282	121
Wheat silage (milky-dough stage) (16)	25	365	92
Oat and pea mixed silage (milky-dough stage) (17)	25	294	130
Wheat and pea mixed silage (milky-dough stage) (18)	35	232	159
Barley and pea mixed silage (milky-dough stage) (19)	29	218	148
Triticale and pea mixed silage (milky-dough stage) (20)	35	333	125

[1]NDF digestibility (*in vitro*, 48 hours incubation) (21), [2]digestible NDF (*in vitro*, 48 hours incubation) (22), [3]organic matter digestibility (*in vitro*, 48 hours incubation) (23)

4. táblázat Tömegtakarmányok táplálóanyag-tartalma és emészthetősége (ÁT Kft. NIR adatbázisa alapján, 2013. április-2017. augusztus, Orosz és mtsai, 2017)

mintaszám (1); szárazanyag (2); nyersfehérje (3); nyersrost (4); nyershamu (5); cukor (6); keményítő (7); rozsszilázs (kalászhányás) (8); tritikálészilázs (kalászhányás) (9); tritikálészilázs (szemérésben) (10), zabszilázs (kalászhányás) (11); zabszilázs (szemérésben) (12); árpaszilázs (kalászhányás) (13); árpaszilázs (szemérésben) (14); búzaszilázs (kalászhányás) (15); búzaszilázs (szemérésben) (16); zabos borsó szilázs (17); búzás borsó szilázs (kalászhányás) (18); árpás borsó szilázs (kalászhányás) (19); tritikálé és borsó szilázs (kalászhányás) (20); NDF emészthetőség (*in vitro*, 48 óra inkubálás) (21); emészthető NDF (*in vitro*, 48 óra inkubálás) (22); szervesanyag emészthetőség *(in vitro*, 48 óra inkubálás) (23)

can be harvested at the soft dough stage which allows for direct cutting without wilting, a benefit during wet spring weather. To meet the nutritional requirements, large proportions of grains are included in dairy cow rations (*Krieg et al.,* 2017).

Silage of winter cereal-legume mixtures

Feeding mixed silages of cereals and legumes to ruminants is an established practice in many parts of the world. Compared to grass alone, grass-legume or cereal-legume intercrops are more productive on DM basis and can give higher DM intakes. The other advantages of such mixes also tend to have higher CP contents and therefore their utilization can reduce the requirement for protein supplements in livestock rations, including dairy cow. Intercropping the addition

Table 4.

in Hungary (LPT Ltd. NIR Laboratory, NIR-database, April 2013 - August 2017 (*Orosz et al.*, 2017)

Crude Fiber (4)	Ash (5)	NDF	ADF	ADL	$NDFd_{48}$[1] (21)	$dNDF_{48}$[2] (22)	Sugar (6)	Starch (7)	OMd_{48}[3] (23)
					%	g/kg DM			%
300	106	558	331	27	66	365	39	-	72
320	82	583	352	29	59	339	64	-	66
280	69	521	327	35	47	254	59	118	64
291	154	535	324	31	60	315	31	-	68
298	101	553	320	39	51	270	36	40	64
304	127	551	328	30	60	327	35	-	67
265	77	503	297	30	49	240	49	122	66
310	131	565	325	36	58	313	20	-	66
264	82	502	305	34	46	236	47	122	65
280	126	504	317	35	58	277	36	52	68
281	101	532	317	34	53	275	41	32	69
249	87	498	250	30	53	227	37	102	70
303	87	543	345	41	52	279	46	64	66

of peas to barley or other small grains including oat or triticale grown for forage does not necessarily improve yield, although it can increase yields from 0-0.5 tonnes DM per acre. The main reason for including peas is the positive effect on protein content and palatability of the resulting ensiled forage. Harvest timing of barley/pea forage also has a large impact on yield and quality. Timing of harvest is usually determined by the developmental stage of the oats or other small grain, which normally makes up most of the tonnage (*Isleib,* 2016).

Harvesting at the boot stage of the barley results in higher protein content and improved digestibility this is most desirable if the forage is fed to dairy cattle. Expressed on a DM basis barley has 7.5-18% CP (*Mustafa et al.,* 2000). These authors investigated degradability of nutrient of pea and barley silages in cannulated dairy cows. Pea silage had lower content of NDF, ADF, and starch but higher CP than barley silage (mid dough stage). Pea silage has higher effective ruminal degradability of DM than that of barley silage (mid dough stage). The rate of degradation and effective ruminal degradability of NDF was intermediate for pea silage and lowest for barley silage. According to *Orosz, et al.* (2017) cereal and legume mixed silage (e.g. wheat and pea, barley and pea, triticale and pea) at its milky-dough stage has lower DM and higher fibre fraction. However the CP content, NDF and OM digestibility is higher than cereal silage alone at the same stage (*Table 4*).

Due to their high protein content, the EU has promoted the production of field peas (*Pisum sativum*). *Mustafa and Seguim* (2004) studied on *in vitro* dry matter and NDF digestibility of silages made from whole crop-pea (*Pisum sativum* L.), pea-wheat (*Triticum aestivum* L.), pea-barley (*Hordeum vulgare* L.) and pea-oat (*Avena sativa* L.) mixtures harvested at 8 weeks and 10 weeks after seeding. Forty-five days after ensiling, all forages were well ensiled as indicated by low pH, water soluble carbohydrate and high lactic acid concentration. They further noted that regardless of forage type, CP and *in vitro* NDF digestibility were higher, while starch and ADL content were lower in 8 weeks than 10 weeks harvesting. The *in vitro* DMD of whole pea silage was higher than that of the three pea and cereal mixture silages in 8 weeks but was only higher than that of pea barley in week 10 harvest. For the pea and cereal mixtures, IVDMD was higher for pea-oat than pea-barley and pea-wheat in week 8 and was higher for pea-barley than pea-wheat in week 10. They concluded that silage from pea monoculture had similar forage yields and a generally higher nutritive value than silages from pea–cereal mixtures.

Silage of winter cereal-grass mixtures

Dairy operators are increasing the winter cereal content in the rations they feed to lactating dairy cows (*Stevens et al.,* 2004). These winter cereals, sometimes referred to as small-grain forages, include barley, wheat and oats, either individually or mixed. Vetch and peas are sometimes included in the mixtures to enhance protein content. Other small grains that have received attention include rye and triticale. Whole-crop winter cereals such as wheat, barley or triticale offer high quality forage in regions where maize silage is limited by growing season or out of season frosts. Reports suggest that whole crop cereal silages improve feed intake, feed nutrient concentration and milk yield of dairy cows (*Stevens et al.,* 2004). The use of Italian ryegrass and winter cereal mixtures such as wheat, winter barley, triticale and oats will improve the quality of silage made of them due to the high sugar content of the Italian ryegrass and the combined higher water soluble carbohydrate content of the winter cereal. Higher sugar and soluble carbohydrate contents in the forages mean best quality silage made of them due to rapid and sufficient fermentation. Cereal silage can be used successfully in lactation rations if harvested at an early maturity. But for further understanding of digestibility, as well as degradability of winter cereals and Italian ryegrass mix, requires intensive study in the future.

CONCLUSIONS AND SUGGESTIONS

Replacing whole corn silage with other silages particularly for high producing dairy cows could be difficult task due to superior starch as well as energy content, higher organic matter digestibility, high milk production of cows after feeding corn silage and best silage making ability of corn. However, finding and robust application of acceptable other silages to replace corn silage is still critical issue to the success of future dairy operations in Europe as corn production still decline due to climate change and competition among the sectors still exists. Nowadays difficulties occurring in corn cultivation (i.e., groundwater shortages, mycotoxin contamination) have been forced dairy farmers to consider alternative silages. Mainly because the yield safety of corn silage will be compromised in the future if the expected climate change will be characterized by the increase of summer heat waves and the more extreme water course. Therefore, it would be urgent to consider how crop production and feeding strategies can be adapted to this change in long term, taking into account the needs of the high producing lactating cows. Options like using new forage corn hybrids, new irrigation systems (such as sprinkler and drip water) in areas where shortage of water, partial replacement/changes of corn silage preparation in the diet (using whole dwarf and brown mid rib sorghum, corn plus sorghum silage mixes, winter-type early harvested cereals like rye and triticale, intensive annual and perennial grasses, winter-type cereal plus legume mixtures (barley plus pea, wheat plus pea and triticale plus pea) and winter-type cereals plus grass mixtures (wheat, oats, triticale and winter barley plus e.g. Italian ryegrass) are among the potential ones. Although very recently because of its highest sugar content and comparable digestibility with corn as compared to other grass species, the use of Italian ryegrass has been an emerging potential for replacing corn silage and researchers give more attention to the use of this grass species. However, Italian ryegrass has low starch content as compared to corn and it needs to combine with other starch rich forage species such as cereals silage. Due to long tradition of farmers using corn silage particularly in Europe and other advantages of corn silages, replacing corn with other silage crops could not be an easy task even best forage species is found in the future. Therefore different extension approaches should be implemented for the adoption of new feed and feeding system by the farmers before disseminating the new technology.

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